CARTOGRAPHIC DESIGN ASPECTS OF MEDIUM- AND SMALL-SCALE SPACE IMAGE MAPS – WITH SPECIFIC REFERENCE TO LIBYA

BY

HASIN MOHAMMED RAMMALI

VOLUME I

A Thesis Submitted for the Degree of Doctor of Philosophy (Ph. D.)

In

Cartography, Digital Mapping and Remote Sensing

In the Faculty of Science at the University of Glasgow

Topographic Science, September 2000

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" This thesis is the sole work of the candidate and has not been accepted in any previous application for a degree. Quotations are distinguished by quotation marks and all sources are acknowledged. "

The signature of the candidate:

Topographic Science, September 2000

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ABSTRACT

This dissertation covers the cartographic design aspects of medium- and small-scale space image maps with specific reference to Libya. The huge areas of desert and semi-arid terrain in Libya are difficult to represent or depict cartographically in an adequate manner using conventional line mapping techniques. By contrast, space image maps based on remotely sensed satellite imagery offer the possibility of much improved representation of the terrain features that are present in such areas – especially at small-scales where large areas can be accommodated within a single sheet. In spite of the perceived advantages of these cartographic products, very little basic research into their design has taken place. This dissertation attempts to rectify this shortcoming.

After an initial review of the status of mapping in Libya and the cartographic requirements for medium- and small-scale topographic line and image maps, a detailed investigation concerning both the high resolution space photographic sensors and the high resolution spaceborne scanner systems and their topographic mapping potential has been conducted and the results discussed at some length. This investigation also includes the suitability – based on specific criteria – of these space photos and images for use in topographic mapping in Libya. From the investigation, it was evident that, at least for now, the space imageries acquired from Landsat-7; SPOT Pan and IRS-1C/1D are the most suitable for the mapping of Libya. SPOT and IRS are of especial importance, since enhanced versions of these satellites will be launched in the near future.

A detailed review and systematic analysis have also been carried out to evaluate the cartographic design aspects of existing space photo and image maps published by different organisations world-wide. These image map products have been produced at a wide variety of scales ranging from 1:50,000 to 1:1,000,000, have been made for different purposes, and cover different areas in the world. They show the quite different cartographic strategies and solutions that have been devised and adopted for these space image maps. The lack of standardization and the variety of cartographic solutions that have been devised for these image maps stand in stark contrast to the comparative standardization of conventional line maps at these scales. The poor design of many of the products is also obvious.

Prior to the author's experimental work on the cartographic design of space image maps, digital image processing techniques have been devised and applied to match and merge adjacent overlapped images to produce a seamless mosaic of a high geometric and radiometric quality suitable for mapping. Other relevant activities such as the planning of the content and the actual acquisition of the information – required for the production of space image maps at 1:50,000 and 1:250,000 scales within the Libyan context – have also been carried out. The specification of the map content at each scale has been defined and specified. Besides which, a detailed methodology for the production of space image maps using image processing techniques has been established and used successfully.

Space image maps of arid and semi-arid areas do have their own special problems in terms of their cartographic design. To solve these problems, an extensive series of design experiments have been carried out in a highly structured and systematic manner in an attempt to reach a good balance between the natural space image and the symbols and names that need to be added to give a superior final product. All of these aspects are discussed in some detail with specific reference to the design and production of experimental space image maps at both 1:50,000 and 1:250,000 scales for the Misratah area in Libya. These are prototypes for a new national space image map series that has been proposed to cover the whole of Libya as a replacement for the existing national series produced from Landsat MSS imagery 20 years ago. Both experimental space image maps have been evaluated by a group of users and have been well accepted – especially that at 1:250,000 scale. The results of these tests are provided in some detail. The results of the successful efforts to design and produce these experimental space image maps will lead to a proposal for their adoption for the national map coverage of Libya.

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CHAPTER 1: INTRODUCTION

1.1 Introduction

At the present time, every country in the world faces an increasing demand for maps and geo-referenced data, both in quantity and having a quality to satisfy the various different requirements of society. These include the monitoring of the environment and management of natural resources; and the development of land for agriculture, forestry and most other human activities. In particular, for many users, the measurement, study, management and conservation of the Earth's resources have become an urgent challenge, alongside the exploitation of these resources to satisfy the continuously increasing demands of the world's human population. Topographic maps form the basis for the provision of geographic information on the environment and to act as a tool for sustainable development. Indeed many human activities are or should be based on accurate and readily available topographic maps. Furthermore these maps need to be continuously updated, because of the fast and dynamic changes taking place both of the physical terrain and in its man-made (cultural) features.

In practice, the importance of basic topographic mapping of a whole country at the scales 1:50,000, 1:100,000 and 1:250,000 for the efficient administration, economic development and defence requirements of every country is beyond question. Indeed the demands for accurate maps giving national coverage over the scale range of 1:50,000, 1:100,000 and 1:250,000 are increasing daily. This need occurs particularly in certain developing countries where adequate mapping has not yet been completed. The most unfortunate aspect of topographic mapping in these developing countries is that the coverage at these basic scales increases very slowly. Furthermore, even where the coverage has been completed, the rate of change taking place in many parts of these countries occurs at a higher speed than the rate of map revision. This means that a great percentage of the maps that have been produced are of limited value because of inadequate map revision. Consequently, in many cases, the actual map coverage does not represent the real mapping situation, since the task to be undertaken by the mapping community also involves continuous map revision, especially with regard to the planimetry shown by the maps. Indeed, for many countries, the revision of the existing maps is now the major task confronting national mapping organisations. In some cases, they may be so out-of-date that they need to be replaced by new maps.

The current status of world mapping reveals that much needs to be done to complete even the basic mapping coverage, especially in the developing countries, some of which still do not have any substantial coverage of basic medium-scale topographic maps. This results from various factors mostly relating to their poor economic condition and chronic political and military conflicts. However sometimes the problem is the vast area of an individual country, much of which may comprise desert, dense forest or mountainous terrain and which is inaccessible and either uninhabited or sparsely inhabited. The huge areas of desert in Africa are a good example of this situation. Almost invariably, Africa is quoted as the most poorly mapped continent, followed by South America. While the situation in the highly developed countries is far better, even there, the pace of development in many areas has resulted in the existing topographic maps becoming out-of-date. Thus the need for up-to-date maps becomes a necessity.

Among the available solutions that are being investigated to satisfy such needs, especially in Africa, is to try and make efficient use of space images for cartographic purposes. Indeed, the need for topographic mapping in Africa to be carried out using space imagery has received a great deal of attention, both in the scientific literature and at a political level – though up till now, the actual use of space image data has been quite low. Nevertheless to help remedy the situation and increase the speed of mapping and map revision at medium- and small-scales, it seems that one way of accomplishing this is to utilize the capabilities of modern digital image processing technology in conjunction with the appropriate space imagery. However, from the topographic mapping point of view, this will need to be confined to those space sensors capable of acquiring image data of comparatively high ground resolution. As will be seen later, even then, while there are quite a number of space sensors available, they have differing characteristics and attributes. These need to be critically assessed and evaluated with regard to their suitability for the mapping task.

1.2 Mapping in Libya

Taking the specific case of Libya (which is the author's home), most of the land is pure desert and gives special problems to the map-maker. The basic national map coverage is at

1:250,000 scale produced as a very simple and rather crude image map series from Landsat MSS images by the Earth Satellite Corporation in the United States of America in the late 1970s and early 1980s. The more detailed 1:50,000 scale coverage (which is a conventional line map series) is confined to the narrow band of populated and developed land lying between latitudes 28°N and 32°N, adjacent to the Mediterranean Sea. Thus, only about 40% of the country has been covered at that scale, so the completion of the coverage of the country at 1:50,000 scale would require a very substantial number of additional sheets. However, given the comparative lack of detail on the ground, this cannot be justified. Those areas that have not yet been mapped at a medium scale are mostly remote areas with very little population and have very limited economic value. Furthermore, both the 1:250,000 and 1:50,000 scale series were completed many years ago and are now completely out-of-date. Thus the main concerns of its national mapping organisation, the Surveying Department of Libya (SDL), are how to revise or replace the old image map and topographic line map series at these scales and how to put in place mechanisms that will ensure the continuous revision of these series. A secondary task is that of achieving new coverage at 1:25,000 scale for the more developed areas of the country. Also there is a need for the re-mapping of certain areas to a higher standard. For all of these different topographic mapping activities, the possibilities of undertaking the required tasks using space mapping techniques is a matter of great current interest in Libya.

Huge changes in the country's landscape have been taken place since the discovery of oil and gas deposits in the late 1960s. Currently Libya is the biggest oil and gas producer in North Africa and the production of oil and gas has had a great impact on the economic situation of the country. The industry is very active and generates about 95% of the country's revenue. As a result of this activity, the infrastructure (comprising roads, oil pipelines, gas pipelines, etc.) is quite extensive in the north-western and north-eastern parts of the country. Indeed, this good economic condition has also enabled the country to undertake large and important projects for improved communication and transportation and for the development of agriculture, water resources, etc. Furthermore, many previously nomadic tribes in the central parts of the country have become agriculturists and have become permanently settled in large villages, thereby extensively changing the landscapes shown in the old topographic maps covering these areas. The results of all of these development activities form important terrain elements that require mapping and need to be depicted on topographic maps – which is not the case at the present time.

Notwithstanding the economic growth of the country, the national mapping authority of Libya does not operate in ideal circumstances. Indeed the conditions under which it conducts its operations are not dissimilar to those found in other developing countries. The number of well-trained and skilful personnel is limited, which is holding back the internal production of maps. So most of the country's mapping activities have been carried out abroad by foreign mapping organisations and companies from Europe and the USA. Furthermore, since Libya is a huge country and most of the terrain is an untouched physical landscape with few man-made features, the production of medium- and small-scale conventional topographic line maps using aerial photography is time consuming, costly and, in the end, it is often inadequate and not suitable for representing certain types of area features (e.g. sand dunes, swamps, mountains, forests, etc.). Indeed, the progress of map production and revision using conventional methods is much too slow having regard to the demands of users for up-to-date topographic information. Thus, a great deal of attention needs to be paid to this particular problem. A thorough investigation into the matter of whether space images can be used effectively for topographic mapping and map revision in Libya is therefore timely – since, if the result was a positive one, it would not be too difficult for the national mapping organisation, i.e. the Surveying Department of Libya, to acquire the capability to do so in terms of equipment and trained personnel. Thus the project described in this dissertation has been carried out primarily with a view to investigating and producing a solution to the present problem of having a very deficient national map coverage of Libya.

1.3 Justification for the Research Study in the Context of the Future National Mapping Programme for Libya

The main reasons underlying the decision for the author and his organisation to carry out this research project are:

- Generally speaking, space imagery has been considered as a solution for world-wide mapping problems for some time. Indeed Petrie (1970) pointed out this possibility even before the launch of the first American civil Earth Observation satellite in the Landsat series. He felt then that considerable value would be gained from using space imagery for topographic mapping purposes, especially where there was the potential for a large reduction in the cost and time required for the mapping of a large area at small scales. Since there already exists space imagery giving systematic coverage over Libya, it is important to ascertain whether this can meet the country's topographic mapping requirements at 1:50,000 scale and smaller.

- Libya is a developing country with a huge land area. Most of the country is very sparsely populated with extensive areas of desert. However quite small details like isolated buildings, tracks, wells and oases are so important locally that they must be incorporated and represented on the maps – which requires the availability of high-resolution imagery. Yet the government is asking for investigation into the use of a fast method for the coverage of a substantial large part of its territory at the 1:50,000 scale and of the whole country at 1:250,000 scale. In the author's opinion, since the area to be covered is so large, the production of conventional line maps is not appropriate. Indeed, most of Libya comprises a desert landscape which would almost certainly be represented more effectively by producing image maps rather than the traditional form of topographic line map.
- In fact, the author's country was the first in the world to undertake a very simple national space image map series at 1:250,000 scale comprising 127 map sheets for the whole country. As mentioned above, this series was produced from Landsat MSS images largely manually using the techniques available at the time of its production, i.e. between 1978 and 1980. Although it had substantial shortcomings in terms of its low ground resolution and its lack of cartographic symbolisation and annotation, it still proved to be very useful and has been utilized widely within the country. However it is now about 20 years old and is badly out-of-date. Thus consideration needs to be given to the production of a completely new series of space image maps using higher resolution imagery and modern digital image processing techniques, since there is a need for continuous updating given the rapid changes have been taking place in the country. Since the potential reduction in the time and cost of the production of this proposed new map series is another significant consideration, the use of modern digital image processing techniques is a possibility that needs to be investigated thoroughly.
- As will be discussed later, since most existing space image maps have been produced by non-cartographers (usually by image processing and remote sensing specialists), these map products have suffered from the absence of good cartographic design – they are largely lacking in annotation, in the use of appropriate symbols and in the appropriate use of colour. In spite of space imagery having been available for nearly 30 years, curiously there has been very little investigation into its use for cartographic purposes on a national scale. As will be seen later, many of those space

maps that have appeared are one-off productions and, in a quite a number of cases, appear to be "wall paper" rather than detailed maps that can be used on an everyday basis by field scientists, engineers, planners, farmers and military personnel. Thus there is a need for quite basic research with a view to achieving a much better cartographic design before a new national series for Libya can be contemplated, let alone recommended and authorized. After reading the rather sparse literature on the subject and analysing the existing collection of space photo and image maps published by mapping agencies, educational organisations, and large companies involved in this field, the present author has come to the conclusion that really quite basic research work still needs to be conducted into the cartographic design aspects of utilizing space imagery for topographic mapping since many of the existing space image maps are poorly designed.

1.4 The Cartographic Design Aspects of Space Image Maps

The basic concept of the space image map is immediately attractive, since potentially it combines the advantages of both the space image and the line map through the incorporation of cartographic symbology added on top of the image. So, on the one side, there is the detailed naturalistic representation of the actual features of the terrain provided by the space image, while on the other, there is the measurability, interpretability and added value provided by the symbolised detail shown on the conventional line map. In an ideal world, it would appear that the combination of the two in the form of the space image map should be capable of exploiting these advantages to provide a fuller and more realistic representation of the terrain than either is capable of when being viewed separately and individually. But the reality is that it is very difficult to combine the two very different types of data and achieve a harmonious and balanced final result that satisfies both the cartographer and the users.

The basic design of any space image map must follow similar principles to the basic design aims of conventional line maps. Clarity and legibility, both of the detail, and of the map as a whole, are of prime importance. However, the fact that the whole map area will be occupied with the space image as a background poses particular problems, since the space image must have a sufficient range of contrast within itself to be clear, while, at the same time, any superimposed symbolization and annotation must exhibit sufficient contrast against this background image. Furthermore, there is the problem of combining the "naturalistic" space image with the artificial and abstract conventional symbols that add value to the final image map product. Essentially the problem is to combine two entirely different types of information – pictorial information and abstract symbology. The map designer is faced with the problem of attempting to rationalise and harmonize both, while still trying to maintain and exploit the two different types and levels of information.

The cartographic treatment and design of a space image map will often require a mix of solutions to what are quite complicated problems. In this sense, it is clear that this is not a straightforward task, and will often be strongly influenced by factors such as the scale, map purpose, and terrain characteristics of the area to be mapped. The design complications of this type of map product increase in those areas having a pre-dominance of cultural features. From the cartographic design point of view, the requirement for additional symbolisation and names then increases, and, as a result, the clarity, legibility and the overall appearance of the image map could be affected harmfully. However, in the context of Libyan mapping, outside the narrow coastal belt, cultural features are relatively few – which helps to minimize this particular problem – though their inclusion and representation are still important matters to be considered. In arid and semi-arid regions, where most of the features are those of the natural physical landscape and there are few man-made features, image maps would seem to be the best way of representing the terrain cartographically. Furthermore, the cartographic design problems would appear to be much easier to solve in these areas in the sense that relatively few names and a very limited number and range of symbols are needed. In this situation, potentially the final product should be more informative than any conventional line map – provided, of course, that good use is made of the space image data.

Other important considerations are the relevant economic factors, which might, for example, help to constrain the number of separate colours permissible in the finally produced map and thus, also influence the design of any space image map. The facilities available for mapping and map publishing and their technical limitations will also influence the design, both in the treatment of the space image, and in the addition of symbolized detail. In turn, this last factor will be influenced by the specification of the content that needs to be defined for a particular map series.

The needs of certain categories of specialist users – geologists, engineers, geographers, hydrologists, surveyors, agriculturists, foresters, city planners, etc. – who form a substantial proportion of the map user community in Libya – must also be considered. A full-scale survey of user requirements should be carried out prior to the commencement of the task of re-mapping Libya, so that the basic requirements of these important groups of map users can be met. However inevitably some kind of compromise must be reached if a general-purpose space image map is to be produced that will be acceptable to at least the majority of these users.

Since the intention in this research project is to investigate the possible replacement of the conventional topographic line map series with a new series of space image maps, this in itself will create more design problems, since the design of each individual image map very much depends on the nature of any particular area being mapped. Yet, at the same time, from the users' point of view, a common specification needs to be adopted for the whole series and not be changed from one sheet to the next. For any conventional topographic map series (e.g. the S.D.L. 1:50,000 scale series of Libya), the same design and symbol specifications are applied over the entire country. Unfortunately, this may not be so easy to achieve, nor may it be appropriate when designing image maps series for a country, where considerations such as differences in the physical landscape, the land cover and vegetation, building types, etc., must be taken into account. The maps for each individual area need to be designed and treated carefully in order to secure the maximum legibility of the detail appearing in each map sheet, while still lying within the context and adhering to the conventions of an overall national specification. However it may not be practical or possible to implement such a desirable situation.

1.5 The State of Research into the Cartographic Design of Space Image Maps

After a thorough literature search, the author has found that the subject of the cartographic design and production of space image maps is a matter that has received very little attention. In fact, very little (not exceeding one page) has been published on this topic even in those well-known standard cartographic text books written by Keates (1989), Robinson et al (1995), etc. This simply reflects the current situation that, as far as space image mapping is concerned, neither the production methodology nor the cartographic design of these maps have been given the attention that they should have – especially when compared to the vast amount of literature published about the cartographic design and production of conventional line maps or thematic maps. The result of this situation is that most cartographers, even in national mapping agencies in highly developed countries, do not posses sufficient knowledge about space image maps and their cartographic design and production. Furthermore, there is an almost complete absence of information about the technology and the procedures needed to produce space image maps. Certainly this is missing in books on remote sensing besides those on cartography.

Quite apart from the main text books, only a very small amount of research has been carried out that addresses the design aspects of space image mapping. As a result, only a very small number of research papers have been published about this particular field of mapping. Apart from a very few research papers published by the USGS, only the Cartographic Institute of the Technical University of Berlin (TUB) has really mounted any systematic research into this area. However, even in the TUB research work, most attention has been given to the image processing procedures – radiometric enhancement, geometric corrections, mosaicing, merging and so on – and to the treatment of the space image background rather than the overall design of the space image maps and the detailed design of the symbols and names that need to be included on these maps. In summary, it seems that comparatively very little research work has been done into the cartographic design of space image maps.

Often individual space image maps have been produced to simply provide a rough overview of a huge area through the production of a very large format gridded image mosaic without symbols that can often be placed on a wall (the so-called "wall paper"). Quite often, it is a one-off image map of an area of special tourist importance – e.g. a scenic mountain area. Furthermore, few attempts have been made by the cartographers of the national mapping organisations concerned to exploit the advantages of the space image maps in showing the terrain of arid and semi-arid regions. In the developing countries, where this type of map product can be considered to be potentially more suitable than conventional line maps, still no systematic national coverage has been undertaken anywhere.

The main question that arises from the above discussion is why has so comparatively little work been done into the design of space image map? Moreover, why have cartographers tended to shy away from this area? In the author's opinion, it is difficult to give specific answers to these questions, since many factors appear to be involved in this particular matter. It is quite possible that most cartographers suffer from a lack of real knowledge with regard to the geometric and radiometric characteristics of space imagery and remote sensing in general. Furthermore, there is a general lack of experience of the subject area, since cartographers in highly developed countries already have complete national coverage of line maps and do not feel the same need to employ space mapping techniques. Thus cartographers in North America, Europe, etc. may feel that, since these types of map are not needed or are not suitable for adoption in their own highly developed countries, they should not worry or pay too much attention to space image mapping. In which case, the required knowledge and expertize have simply not been developed. Furthermore, particularly in developing countries, the perception among most cartographers is that, the total package of space imagery; digital image processing systems; digital mapping systems; and the other technologies and facilities needed to produce a good quality space image map are simply too expensive for them to obtain and far too complicated for them to master. Indeed most are quite intimidated by the technology.

However, the author feels strongly that now is the right time to carry out research into the basic cartographic design aspects of space image maps for topographic mapping purposes, since:

(i) many sensors with relatively high ground resolution are now available and their image data can be obtained comparatively easily;

(ii) more advanced digital image processing systems and techniques are now becoming available at more reasonable prices;

(iii) more advanced digital mapping systems are now available on the market that can handle both raster and vector types of data; and

(iv) far better quality colour printers and plotters are available, by which good quality space image maps can be produced in an economic manner.

Last but not least, the invention and development of the Internet provides a great opportunity for the transfer of image and map data from one place to another – though it must be said that this is not as yet operational in developing countries, since the appropriate infrastructure is not yet in place.

1.6 The Overall Aim and the Main Objectives of the Research

So far, the importance of mapping from space has been discussed; in addition, the justification of carrying out this research project in the context of the future national mapping programme for Libya has also been presented. In addition, some of the basic problems of space image mapping have been set out and the lack of basic research within this field has been pointed out. Based on the above discussion, the overall aim and the main objectives of the project can be stated to be as follows:

The overall aim of the current project is to conduct research into and to devise and apply methods using SPOT Pan digital data and digital image processing techniques to produce experimental space image maps at medium- and small-scale for a test area in **Libya**. In this context, the analysis, development and evaluation of the cartographic design aspects of these space image maps form the major component of the research.

1. The first objective in the author's research study has been to obtain a very clear idea about the current status of space image mapping with specific reference to its cartographic design aspects. Obviously this will involve a detailed investigation of the present situation followed by the systematic analysis and evaluation of existing space photo and image maps published by national mapping agencies, large commercial companies involved in this field and educational institutes and research organisations. The analysis of the large amount of existing heterogeneous material is a necessary preliminary to the main research project in that it will highlight both the deficiencies of the present maps and those that have produced successful solutions or partial solutions to the problems of space image mapping.

2. Another objective has been to critically assess which types of high-resolution space image data are available that could be used to produce a national topographic map series for **Libya** and the suitability of this data for the execution of this particular task.

3. Another objective of the project is to plan the content and the actual acquisition of the information required for the production of space image maps at 1:50,000 and 1:250,000 scales within the **Libyan context**. Furthermore, the establishment of this specification will require tests to be carried out to establish the extent to which image-interpretation and feature extraction techniques can be used to obtain the required topographic information directly from the space images. In addition, the specification of the additional information that will need to be derived from external sources (such as aerial photography, existing topographic maps and field completion procedures) needs to be defined.

4. The author has also had as a major objective that of conducting quite basic research into the cartographic design aspects of utilising space imagery for topographic mapping. This will include the requirement to be able to handle large numbers of individual images taken at different times and under different conditions and to mosaic them into a single seamless image of a high geometric and radiometric quality suitable for mapping using digital image processing techniques. The challenge will then be for the author to conduct research and to design and add suitable symbols and text to produce a superior cartographic product.

5. Another major objective of this project is to conduct research into and to devise procedures and apply methods using digital space image data and digital image processing techniques to produce experimental space image maps at 1:50,000 and 1:250,000 scales for a test area in **Libya**. Closely associated with this particular objective is the requirement to carry out research into the cartographic design aspects of a national space image map series, in this case for **Libya**. Clearly a practical methodology has to be devised and implemented to allow this to take place. Equally obviously, the methodology that is developed should be capable of being applied by the national mapping agency on a production basis and not only by a researcher producing an experimental map or two.

6. A final objective will be to carry out tests to evaluate the user reaction to the experimental space image maps produced through the author's research project.

Basically these last five objective of the research project are very heavily focussed on carrying out a thorough investigation of the possibilities of producing new space image map series that would replace the existing inadequate national mapping of **Libya**.

1.7 Outline of This Dissertation

Apart from this introductory Chapter, the rest of this dissertation has been structured as follows. **Chapter 2** discusses the status of mapping in Libya, since this is the specific area for which the research work for a new national space image map series has been carried out. **Chapter 3** comprises a review of the general cartographic requirements for medium and small-scale topographic line and image maps that constitute a national series and provide country-wide coverage. **Chapter 4** presents the characteristics of the different types of high resolution space photographic sensors that are available at present and the topographic mapping potential of the space photography produced by them. In particular, attention has been focused on the high-resolution space photography produced by Russian cameras and their mapping capabilities and potential use in the production of a space image map series. **Chapter 5** reviews the various high resolution spaceborne scanner systems that are operational and the imageries produced by them. It then analyses in detail their capabilities in the context of national topographic mapping programmes in general and their application to the mapping of Libya in particular. **Chapter 6** is a major chapter that gives a systematic analysis of existing space image maps with a detailed review and analysis of their cartographic design aspects. **Chapter 7** deals in some detail with general considerations of cartographic design with respect to image mapping in the light of the analysis conducted in the preceding chapter. Essentially these initial seven chapters give the background and analyze the different fundamental matters that affect space image mapping in general and the particular research undertaken by the author within the Libyan context.

In **Chapter 8**, the overall strategy and the general considerations regarding the potential for space image mapping of Libya are discussed and described in some detail. Next, the actual imagery, materials, systems and procedures that have been used for the experiments in cartographic design of space image maps for a test area in north Libya are outlined and discussed in **Chapter 9**. This discussion includes the design considerations for two experimental space image maps at 1:50,000 and 1:250,000 scales as required for the proposed national series to cover Libya. This leads on directly to **Chapter 10** which describes in detail the production of the space image mosaic for the project area that has been used in the design and final production of the experimental maps. In particular, this involves the description and explanation of the steps or procedures (such as radiometric enhancement, geometric corrections and mosaicing) that have been used in the production of the digital image data set used as the basis for the experimental space image maps. In **Chapter 11**, the planning and specification of the content and the actual acquisition of the information required for the production of the image maps at 1:50,000 and 1:250,000 scales are described in some detail. In summary, this middle part of this dissertation deals with the preparatory stages of the author's research project.

Chapters 12, 13 and **14** deal with the actual research work and the extensive series of experiments into the cartographic design of space image maps that have been carried out by the author. **Chapter 12** describes and discusses in some detail the planning of and the many experiments that have been carried out into the graphic representation and the detailed symbol design required for the space image maps at 1:50,000 and 1:250,000 scales. In **Chapters 13 and 14**, the author deals with the overall image map design incorporating and integrating all the different individual elements, and, in turn, the establishment of the final design specifications of the experimental space image maps of the test area in Libya. In these three Chapters, the methodology that has been developed or adopted, the procedures used, the problems encountered and the solutions that have been devised and implemented to overcome various problems are all explained. Next, the overall production procedures used with the experimental space image maps and the proposal for a series covering Libya are given in **Chapter 15**. Then **Chapters 16** and **17** present a full discussion of results of the user tests and evaluation of the cartographic design aspects of the experimental space image maps (at 1:50,000 and 1:250,000 scales respectively). Finally **Chapter 18** forms the conclusion to this dissertation, giving an overall summary of the results of the author's research project and the conclusions reached, together with recommendations for future work.

CHAPTER 2: STATUS OF MAPPING IN LIBYA

2.1 Introduction

Since 1971, the Surveying Department of Libya (SDL), which comes under the Secretariat for Planning, has been responsible for the country's surveying and topographic mapping activities. In this chapter, first of all, some background information will be given about the country including its topography, climate, population, etc. Following this section, a brief description will be given about the structure and activities of the Surveying Department of Libya (SDL), its main duties and its responsibilities for nation-wide surveying and mapping activities. Next a historical background regarding the major geodetic activities carried out in Libya will be given together with an outline of the problems encountered during the execution of this work and those hindering the surveying and geodetic development in the country. Afterwards some details will be given regarding aerial photographic and topographic mapping coverage in Libya. Finally, the situation regarding remote sensing in the country will be also discussed. Thus the overall objective of this chapter is to provide the reader with the background to mapping in Libya to enable him to understand the present situation and to appreciate the problems that will have to be faced if the proposal to undertake new image mapping of the whole country is to be implemented.

2.2 Background Information

Libya is located in North Africa (Figure 2-1), lying approximately between latitude 18° and 33° north and longitude 9° and 25° east. It is bounded by the Mediterranean Sea to the north; while Egypt lies to the east; Sudan to the south-east; Chad and Niger to the south; and Algeria and Tunisia to the west and to the north-west respectively. In many ways, its most important physical asset is its strategic location at the midpoint of Africa's northern rim. Thus it lies within easy reach of the major nations of southern Europe and links the Arabic speaking countries of North Africa with those of the Middle East. Libya has an area of 1,759,540 sq. km., of which more than 90% is desert.

The human population is about 4.5 million inhabitants, the capital city being Trabulus (Tripoli). The population is by no means distributed evenly across the country. About 65% reside in Tripolitania, 30% in Cyrenaica, and 5% in Fezzan. The United Nations (UN) placed the annual rate of increase in population for the 1980-1984 period at an extremely high 4.5%. The high rate of population increase has reflected an official policy of fostering rapid growth to meet labour needs and to fuel economic development.

Figure 2-1: The location of Libya in North Africa

2.2.1 Topography and Climate

Regarding its topography, the main contrast is between the narrow enclaves of fertile lowland strung out along the Mediterranean coast and the vast expanse of arid, rocky plains and sand seas to south. The coastal lowlands are separated from one another by the pre-desert zone and are backed by plateaus with steep, north-facing scarps. The country's only true mountains, the Tibesti range, rise out of the southern desert. The country has several saline lakes but no perennial watercourses. The topography can be sub-divided into four main geographical regions (see Fig. 2-2):

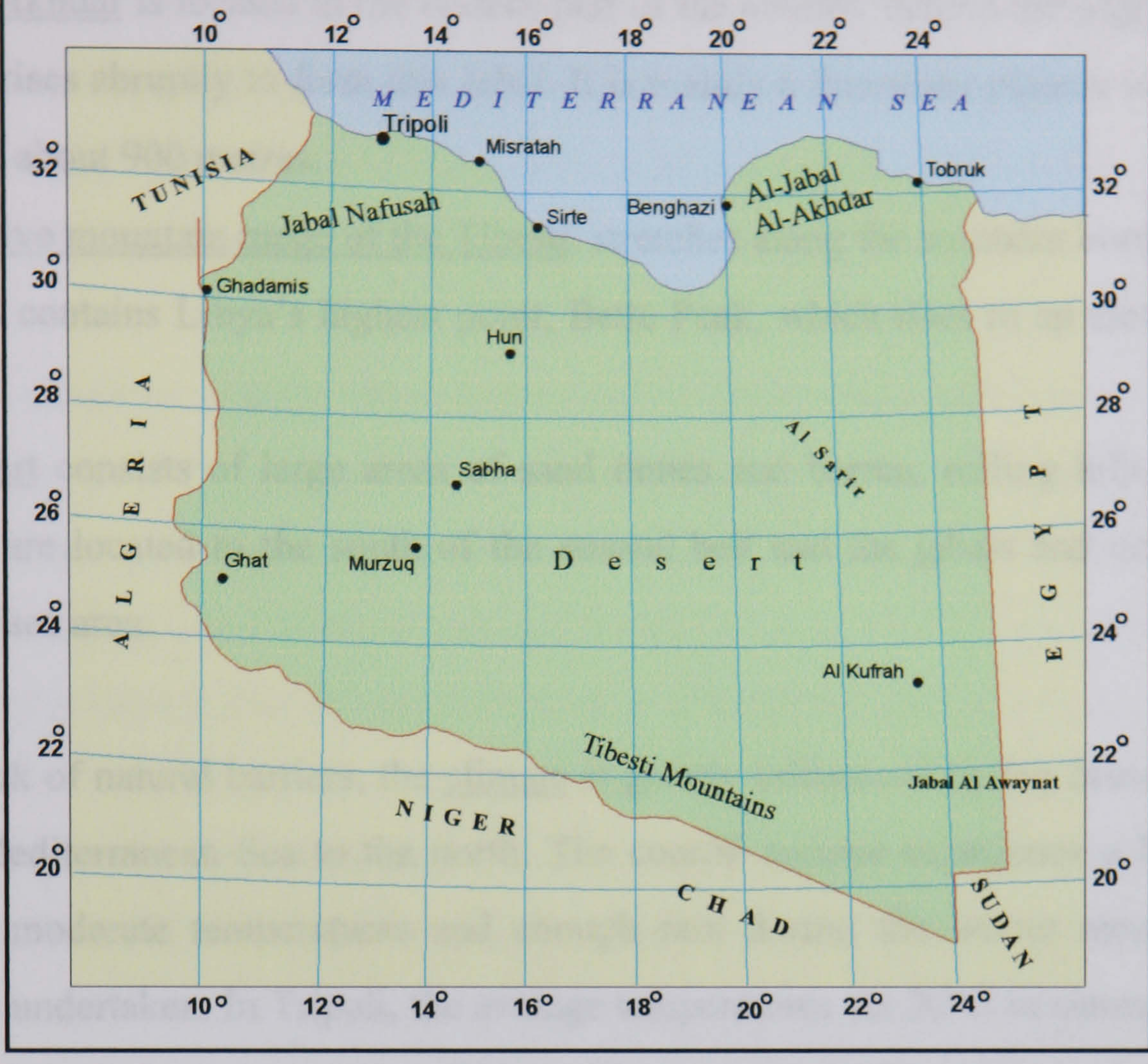


Figure 2-2: Map of Libya shows the main topographic areas, towns and oases

(i) The coastal belt is a relatively narrow strip varying in width between 5 and 25 km which stretches for 1,820 km along the Mediterranean coast, from Zuwarah in the west to Al-Bardia in the east. This is the country's most densely populated area. The north-west region, once known as Tripolitania, rises from the narrow coastal plain in a series of steps until it reaches the Jafara Plain and the Jabal Nafusah Plateau. In the north-east region, once known as the province of Cyrenaica, this region extends from the coastal plain to the Jabal Al-Akhdar. Between these two regions lies the Gulf of Sidra, where along the coastal stretch of 500 km is a wasteland where the desert extends northwards to reach the sea.

(ii) There are two distinct and geographically separate areas of mountain (Jabals) located immediately south of the coastal belt. These mountains form plateaux that are generally rocky and stony and are intersected frequently with many wadis. These mountains are:

- The Jabal Nafusah or Jabal Al-Gharbi ranges which are located in the north-western part of the country, starting from the Tunisian border and extending to Al-Khums City. This plateau area has an elevation of up to 1,000 metres.

- Jabal Al-Akhdar is located in the eastern part of the country behind the Marj Plain, where the terrain rises abruptly to form this Jabal. It is mainly a limestone plateau with maximum altitudes of about 900 metres.

(iii) The massive mountain range of the Tibesti, stretches along the southern border with Niger and Chad and contains Libya's highest point, Bette Peak, which rises to an elevation of over 2,200 metres.

(iv) The Desert consists of large areas of sand dunes and barren, rolling hills and gravelly plains which are located to the south of the coastal belt and the jabals and occupy most of country's surface area.

Due to the lack of natural barriers, the climate is greatly influenced by the desert to the south and by the Mediterranean Sea to the north. The coastal regions experience a Mediterranean climate with moderate temperatures and enough rain during the winter months for grain farming to be undertaken. In Tripoli, the average temperatures are 30°C in summer and 8°C in winter; annual percipitation averages 380 mm. By contrast, in the southern deserts, frequent periods of drought occur. A scorching wind called the "Ghibli", which is a hot, very dry, sand laden wind that can raise the temperatures in a matter of hours to between 40°C and 50°C, occasionally blows into the usually humid coastal towns.

The deficiency in rainfall is reflected in an absence of permanent rivers or streams, and the fact that the twenty or so perennial lakes are brackish or salty. The allocation of the limited water supply is considered of sufficient importance to warrant the existence of a special Secretariat of Dams and Water Resources, while the damaging of a source of water can be penalised by a heavy fine or imprisonment.

2.2.2 Water Resources

The government has constructed a network of dams in wadis, which are dry, steep-sided water courses that become torrents after heavy rains. These dams are used both as water reservoirs and for flood control. The wadis are heavily settled because the soil in their bottoms is often suitable for agriculture, and the high water table in their vicinity makes them logical locations for digging wells. In many wadis, however, the water table is declining at an alarming rate, particularly in areas of intensive agriculture and near urban centres. The government has expressed concern over this problem, and because of it, has diverted water development projects, particularly around Tripoli, to localities where the demand on underground water resources is less intense.

There are also numerous springs: those best suited for future development occurring along the scarp faces of the Jabal Nafusah and the Jabal Al-Akhdar. The most talked-about of the water resources, however, are the great subterranean aquifers of the desert. The best known of these lies beneath Al-Kufrah Oasis in south-eastern Cyrenaica, but an aquifer with reputedly an even greater capacity is located near the oasis community of Sabha in the south western desert.

In the late 1970s, wells were drilled at Al-Kufrah and at Sabha as part of a major agriculture development effort. An even larger and more far-sighted undertaking is the Great Man-Made River, which is the World's biggest civil engineering project of its kind. It was initiated in 1984 and, when completed, will deliver large quantities of water over immense distances from deep in the desert (Al-Kufrah, Sarir, and Sabha Oases) to the coastal agricultural areas. The project is planned for development in five phases. The first phase, the largest, has been completed and consists principally of a system that extracts and carries 2 million cubic metres of water daily to the coastal region where the majority of population lives. However the system is designed to be expanded to carry 3.68 million cubic metres of water daily in the future, utilising a total of about 1,900 km of pre-stressed concrete cylindrical pipe, ranging between 1.6 metre in diameter for the wellfield network and 4.0 metres in diameter for the main conveyance pipeline, which is laid and buried in a six to seven metres deep trench.

2.2.3 The Agricultural Sector

Agricultural production is dominated by crop production, which accounts for 5% of the Gross Domestic Product (GDP) and occupies about 13% of the total labour force. The total arable land is about 2,170,000 ha, of which 355,000 ha have permanent crops, while the permanent pasture and range land occupy about 13,300,000 ha and the forest and woodland about 320,000 ha.

The agriculture production depends mainly on the private sector. The private farms owned by individuals are producing the biggest part of the agricultural products. Some government agricultural projects have been established utilizing irrigation in the desert, mainly for cereal and forage production.

2.2.4 Oil and Gas Production

Libya is the biggest oil and gas producer in North Africa. Indeed, the oil and gas industry in Libya is very active and contributes about 95% of the country's revenue. The oil and gas fields are distributed both in-shore and in off-shore areas. The in-shore oil and gas fields are located in the north western and north eastern part of the country. To transfer the crude oil to different countries in Europe, five tanker terminals have been established in Tobruk, Azzuwaytinah, Al Brayqah, Ras Lanuf, and As Sidrah. There are also three refineries for oil and gas processing, which are located in Az Zawiyah, Al Brayqah and Tobruk. The infrastructure (roads, oil pipelines, gas pipelines, etc.) is quite extensive in these areas and form important elements that require mapping and need to be depicted on image maps.

2.2.5 Communications Network

Libya's road network has been considerably expanded since 1978. At that time, Libya had only about 8,800 km of roads, of which perhaps one-half were paved. However, by 1985, Libya possessed between 23,000 and 25,000 km of paved roads. Surfaced roads now exist between the coastal towns of the north and the southern oases of Al-Kufrah, Murzuq, and Sabha. These roads have done much to end the isolation of these remote settlements. In particular, the agricultural projects that are underway in the desert oases have benefited from the more efficient crop marketing made possible by these roads. The National General Company for Roads oversees all new construction and maintenance.

Apart from the abandoned railways that were built during the Second World War, Libya has no railroads, although discussion has been held with China over the possibility of technical assistance in railway construction. The major cargo-handling sea-ports are located at Tripoli, Benghazi, Tobruk, and Qasar Ahmed (near Musratah). The three international airports are located at Tripoli, Benghazi, and Sabha. Smaller airfields are located at Marsa Al-Burayqah. Tobruk, Ghat, Ghadamis, Al-Kufrah, Sirte, Musratah, and other several other locations.

2.3 The Surveying Department of Libya (SDL)

The national survey department for Libya (SDL) was established in February 1968 as an office within the Secretariate of Planning. After 42 months, i.e. in late 1971, it became an independent body which is responsible for surveying and mapping activities nation-wide. Since then, continuous efforts have been made by SDL to meet the increasing requirements for surveying and cartographic services in a fast developing country such as Libya. The main duties of the SDL were defined as:

(a) To establish a modern geodetic network in Libya;

(b) To carry out aerial photography according to required scales for the Secretariat and other government departments;

(c) To produce topographic and thematic maps at all scales for different purposes;

(d) To undertake continuous updating and revision of all maps;

(e) To provide all Secretariats and governmental departments with the survey information necessary for development projects;

(f) To set up a map library to include all necessary topographic and survey information;

(g) To carry out research and studies to develop surveying and mapping production techniques;

(h) To offer cartographic services and advice to different governmental agencies;

(i) To train nationals to meet the needs of SDL and other governmental departments;

(j) To supervise the cartographic work done for the government by private firms;

(k) To carry out research into the use of remote sensing and its applications for mapping;

(l) To collect, arabise, and standardise the geographical names for Libya; and

(m) To guard the security and safety of all survey information.

According to the law governing the Department and its activities, SDL consists of four technical divisions and one administrative and financial division, plus a research and planning office. The technical divisions are concerned with geodesy, photogrammetry and remote sensing, cadastre and cartography, respectively. The Cadastral Division, however, was left under the authority of the Department of Land Registration until the SDL could build up an organisation capable of carrying out the cadastre.

2.3.1 Technical Staff

The technical staff of the Surveying Department of Libya comprises 120 qualified employees. These include graduates of the Civil Engineering, Computer Science, Geology, Geography and Mathematics Departments of the different Universities in the country. These university graduates are recruited by SDL and are provided with special practical and educational training programmes in order to qualify them for work in the topographic science area. Some graduates, on the other hand, are given a different training programme which mainly comprises on-the-job training, in order to prepare them to specialise in either cartography, digital mapping, and photo-interpretation. On the lower technical level, the Department has hired graduates of the Institute of Applied Engineering of Tripoli, which is a four-year technician training programme after preparatory school (i.e., after grade 9). Furthermore the SDL has sent 79 students abroad for further training and university studies: 29 to the USA; 10 to the Netherlands; 10 to Germany; 5 to the UK; 10 to Poland; 5 to France; 5 to Egypt; 2 to Sweden; and 2 to Nigeria.

2.4 Geodetic Surveys

The geodetic work in Libya is relatively recent if one is to exclude the geodetic activities carried out during the Italian colonization. Until the end of World War II, Libya was an Italian colony, and its survey and topographic mapping were the responsibility of the Instituto Geografico Militare (IGM) in Florence. In fact, Libya was completely covered by a network of horizontal control points that had been surveyed by the Italians during the period between the two World Wars. These were based on the Bessel ellipsoid. Unfortunately most of these horizontal control points were destroyed during World War II and the post-war period. Thus it was necessary to repeat all the work and to establish a new geodetic framework on which surveying and mapping activities could be based.

In 1956, a programme for land survey was introduced, This included the first major geodetic work for Libya which was established by the American Army Map Service (AMS). A basic arc of first-order triangulation was initiated extending from the vicinity of Azizia south to the Great Stony Desert and eastwards along the entire coastal line until it terminated at the Libyian-Egyptian border as shown in Figure 2-3.

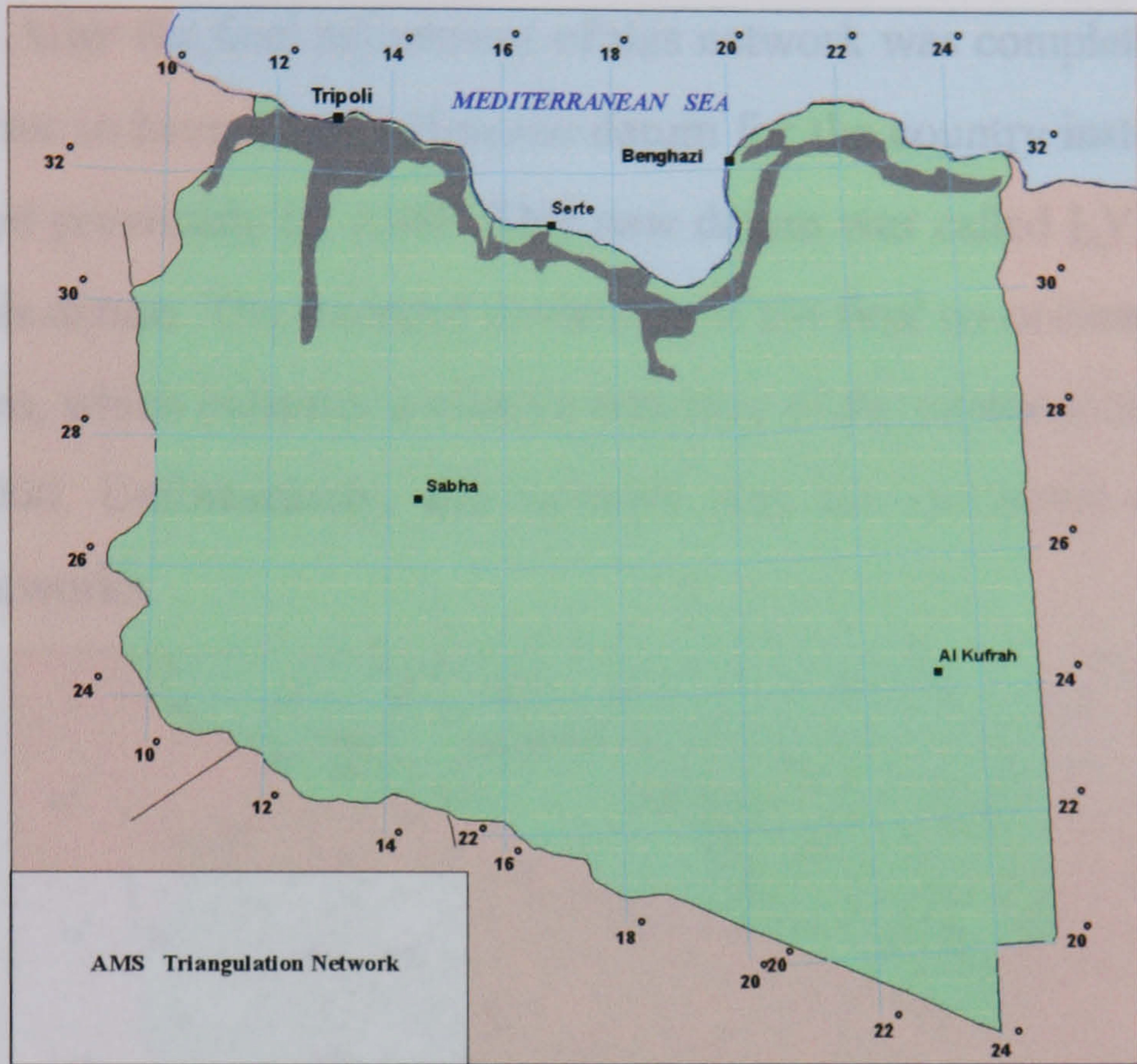


Figure 2-3: AMS triangulation network

This network was restricted to those areas of the country north of 28° latitude which covers about 5% of the total area of Libya. This triangulation arc is based on the International Ellipsoid and was connected to the European Datum. After the final computation and adjustment, the results have been considered of be of first, second or third order of accuracy respectively. This triangulation network was completed in the early 1961 and formed the geodetic base for many of the development projects that followed until the late 1970s.

2.4.2 Second Major Geodetic Work

In 1976, the horizontal control supernet was started. This consisted of 45 points spaced throughout the country at distances of 200-450 km, as shown in Figure 2.4. It was done by the French National Geographic Institute (IGN) which worked very actively with satellite doppler networks in Africa during the 1970s and 1980s. Each point in the Libyan network was observed and positioned by satellite doppler using the translocation method in the hope that an accuracy of less than a decimetre could be attained. These points were observed using JMR satellite receivers and the Transit Satellite System. Astronomical observations to determine geographic latitude, longitude, and azimuth were also made on all of the supernet points. Some of these points were tied to each other and to the AMS network by ground traversing and by geometric levelling. After the final adjustment of this network was completed, it was concluded that it would be better to have a new reference datum for the country instead of the European Datum that was used previously by AMS. This new datum was called LY79, all supernet data being adjusted to this datum. The standard deviations of the final co-ordinates were found to be in the order of 0.35m, which indicates a relative accuracy of the points within the network to be better than 1/600,000. Unfortunately, this network was not connected to the Tunisian and Egyptian control networks.

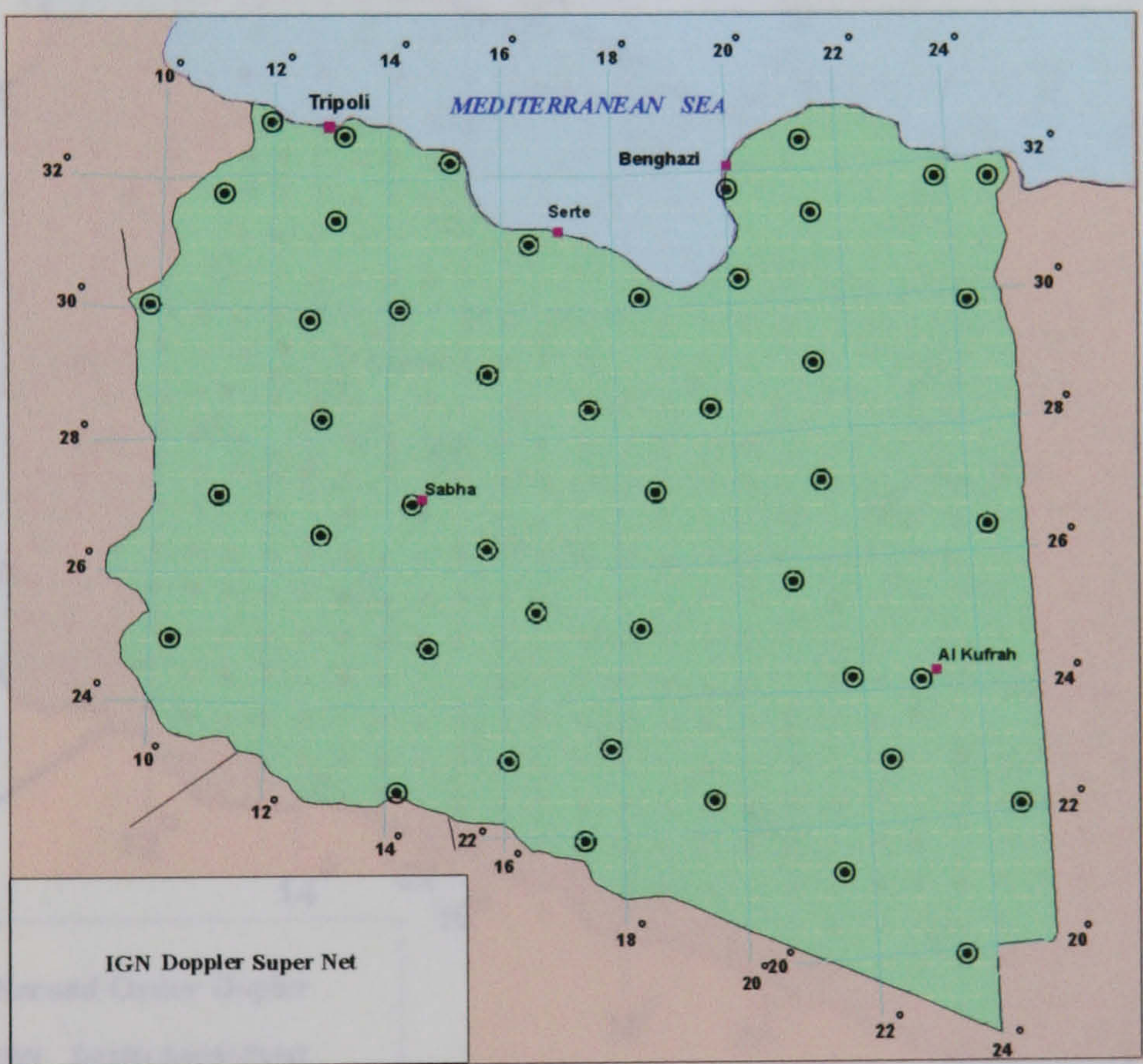


Figure 2-4: IGN doppler supernet

2.4.3 Third Major Geodetic Work

During the early 1980s, SDL started the National Cartographic Project. This project was designed to map the whole territory of Libya, a task that triggered the need for extensive new geodetic work, which was conducted by two international companies – the Aero-Service Corporation (ASC) from the USA and Pol-Service/Geokart from Poland.

1) Aero-Service Corporation (ASC): This company was awarded the contract to establish, measure, and adjust 670 second-order satellite doppler points, of which 619 were totally new points and 51 were re-observed points as illustrated in Figure 2-5. ASC also measured astronomical azimuths on 667 of these points. ASC was also awarded a contract to conduct first and second order traversing of about 14,850 kms which ended by establishing 942 traverse stations and 138 full Laplace stations – see Figure 2-6. This traversing was an enormous task: part of it was carried out by British surveyors employed by ASC, including a number of Topographic Science graduates from Glasgow.

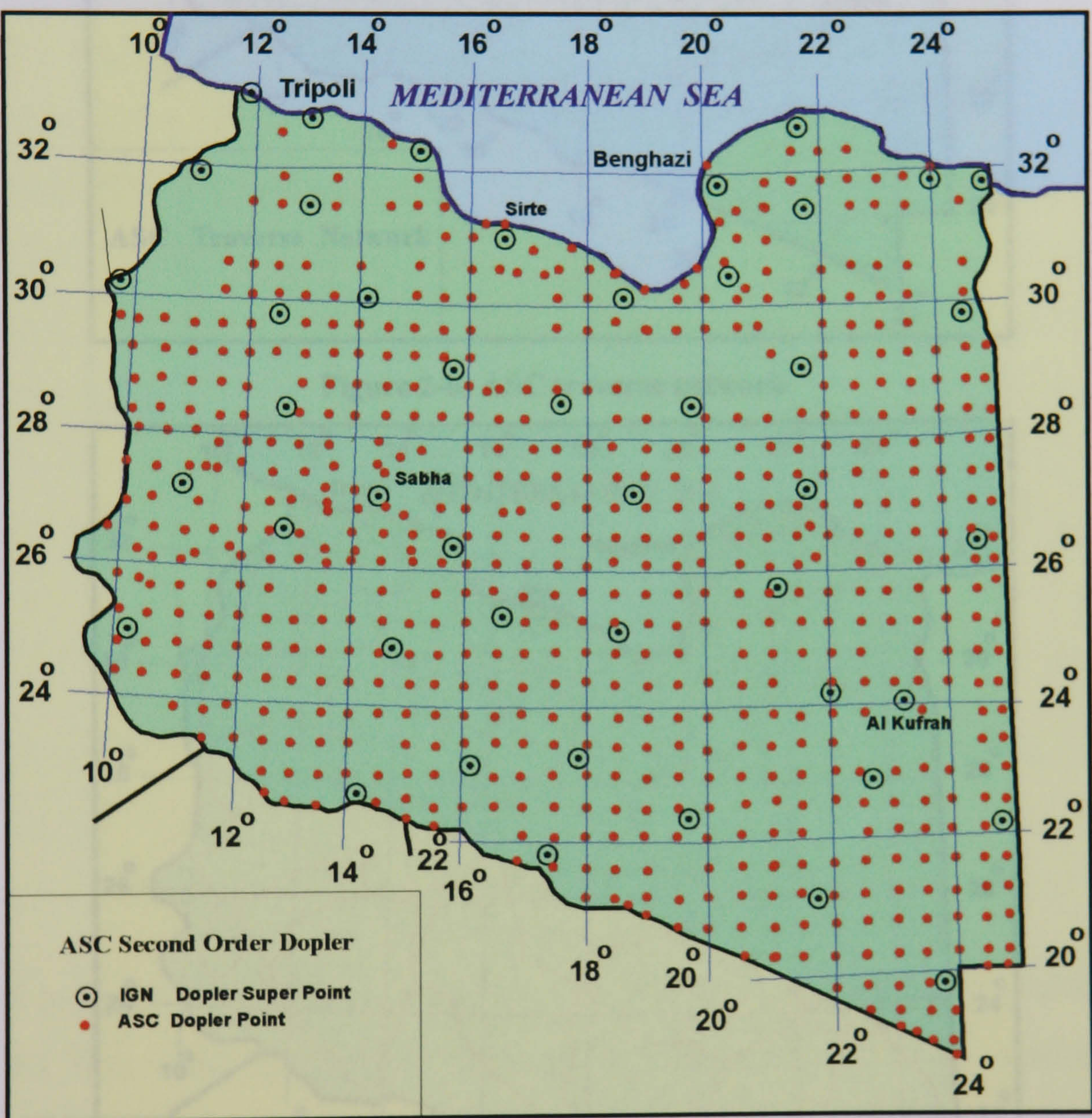


Figure 2-5: ASC second order doppler network

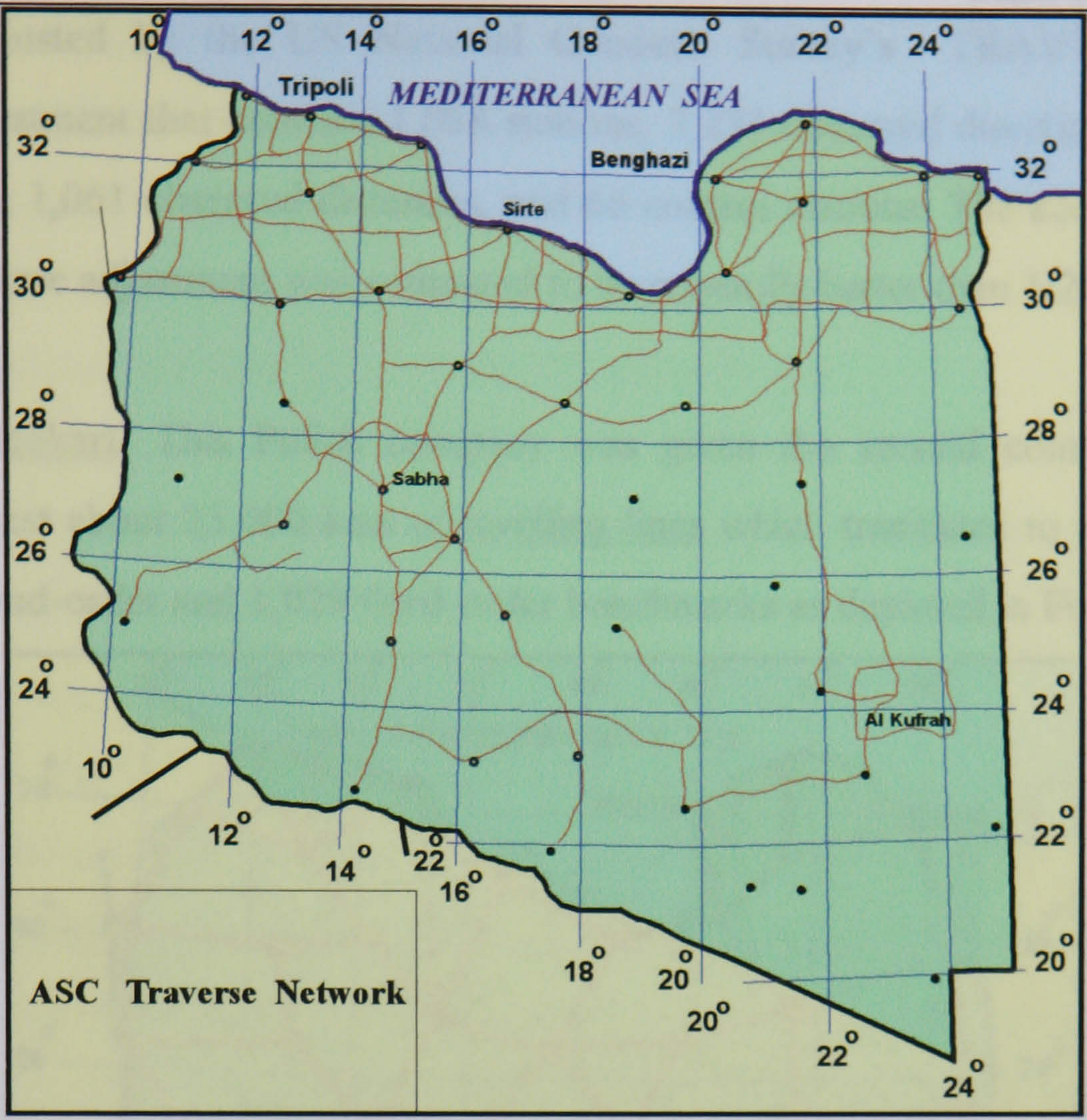


Figure 2-6: ASC traverse network

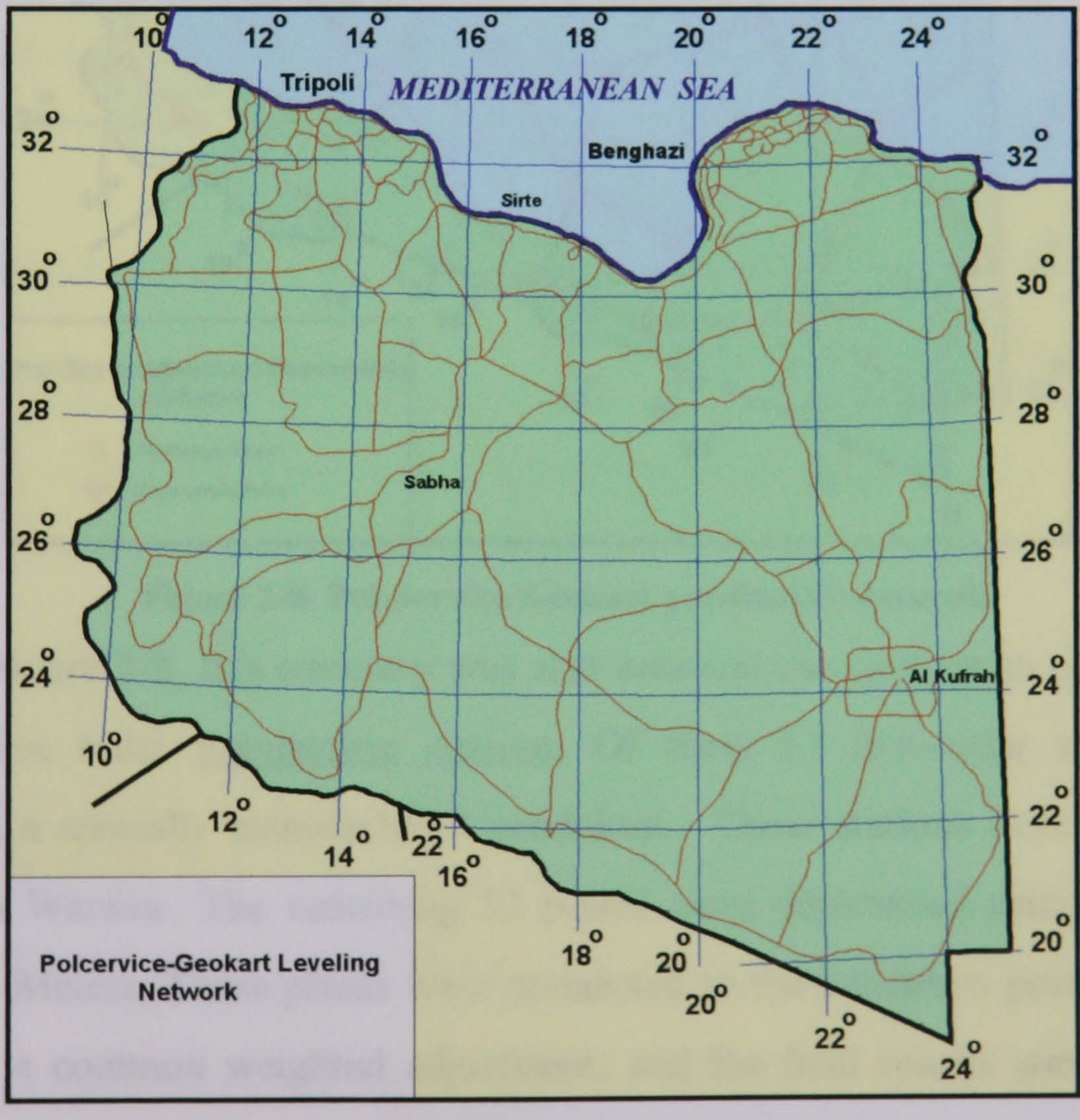


Figure 2-7: Pol-Service/Geokart levelling network

The doppler network was adjusted using Magnavox's MAGNET program, the final relative accuracy of the points in this network was in the order of 1/150,000 or better. The traverse network was adjusted by the US National Geodetic Survey's TRAV10 program in a simultaneous adjustment that contains 1,038 stations, 2,233 observed directions, 187 observed Laplace azimuths, 1,061 observed distances, and 66 control stations. The accuracy of the final result of this traverse adjustment was estimated to be generally better than 1/250,000.

2) Pol-Service/Geokart: This Polish company was given the second contract to establish, measure, and adjust about 23,000 kms of levelling lines which translates to about 3,015 first-order, 3,424 second-order and 1,029 third-order benchmarks as depicted in Figure 2-7.

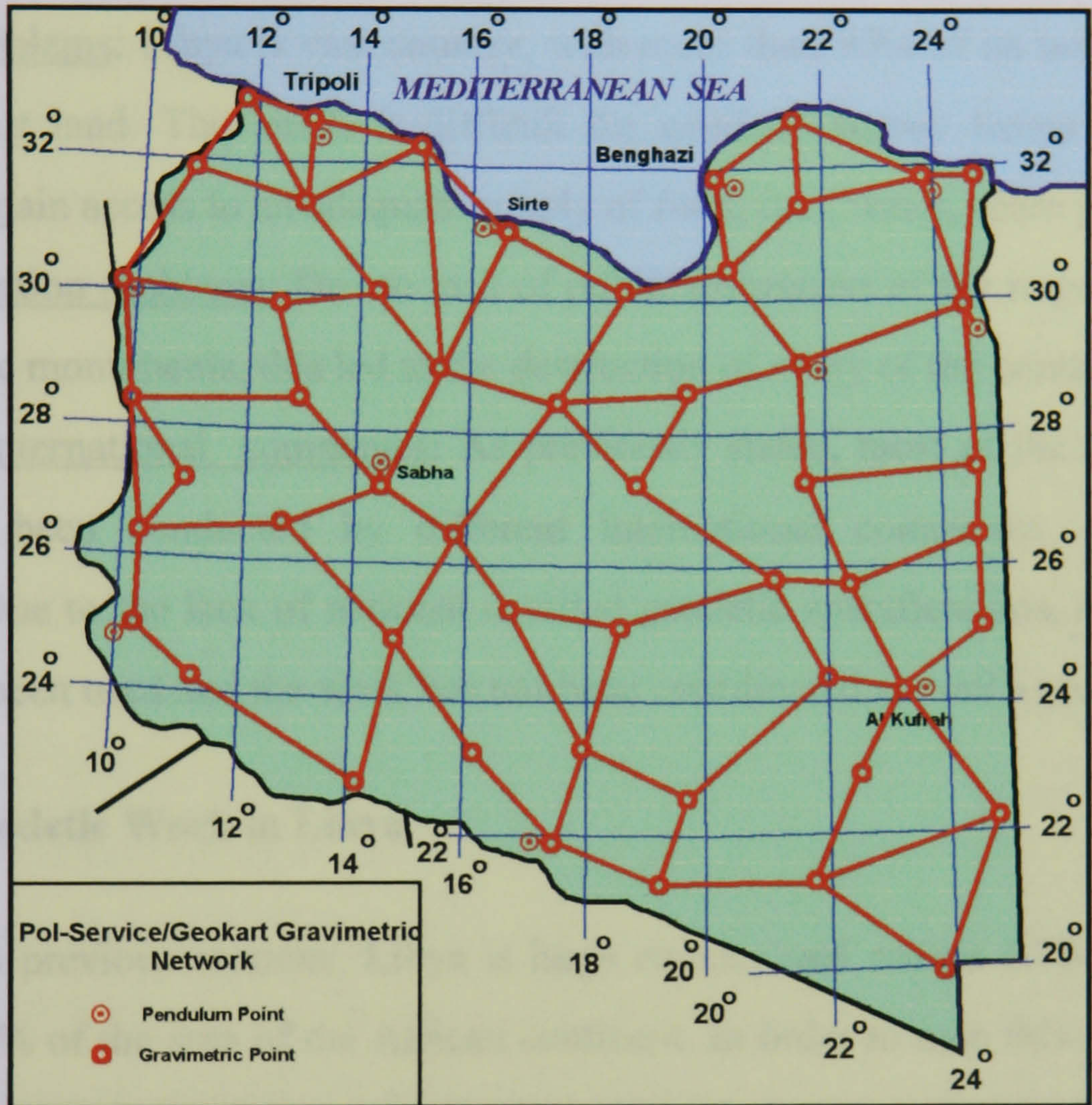


Figure 2-8: Pol-Service/Geokart gravimetric network

As illustrated in Figure 2-8, this company was also awarded the contract to establish, measure, and adjust 63 first order gravimetric stations. Of these 63 first-order stations, 11 were determined using a specially manufactured pendulum. These stations were tied to a datum station located in Warsaw. The remaining 52 points were determined using Worden Master Geodetic Gravity Meters, These points were connected to the pendulum points. All the points were adjusted in a common weighted adjustment, and the final results were presented with respect to the New Potsdam System of 1971 and IGSN 1971. The average mean square error obtained in this adjustment was about 0.05 mgal.

Pol-Service/Geokart was also awarded the contract to construct 4 tidal stations located in Tripoli, Sirte, Benghazi and Tobruk, and to continuously observe the level of the Mediterranean Sea at these stations for a period of 24 months.

2.4.4 Problems Associated with the Geodetic Work in Libya

The problems hindering the geodetic work in Libya can be divided into several different categories, the principal ones being the following:

1) Natural problems: Libya is vast country, with more than 90% of its territory covered by arid and desert land. This made it difficult for geodetic survey teams to travel and to maintain and gain access to an adequate supply of food, fuel, water, spare parts, ...etc.

2) Monumentation problems: Due to lack of public awareness of the importance and value of the geodetic monuments, this led to the destruction of many of the control points.

3) Different international companies: As previously stated, most of the geodetic work, if not all, has been conducted by different international companies, agencies, and/or institutions. Due to the lack of national detailed geodetic specifications, different geodetic datums have been used and the work has not been coordinated as well as was hoped.

2.4.5 Future Geodetic Work in Libya

As mentioned in previous sections, Libya is huge country and covers 1.75 million sq. kms, which is about 6% of the area of the African continent. In order to map this vast country, still more geodetic survey is needed to provide the required control network. Thus the geodetic department in SDL is planning a further densification of the control network to fulfil the requirements of the National Cartographic Project. It is also concentrating on using Global Positioning System (GPS) survey techniques during this densification programme. Since proper computer facilities are now available within the Department, and adequate funding has been allocated, SDL will conduct a common re-adjustment of all its existing geodetic data.

2.5 Aerial Photographic Coverage

Aerial photography has been used extensively for almost all mapping purposes, excluding some engineering project surveys of limited extent and the few cadastral surveys undertaken to date. During the 1950s, the whole country was covered by small-scale aerial photographs taken at the scale of 1:60,000 by a number of specialist foreign aerial photographic companies. The coastal area was also covered by medium-scale aerial photography. The main purpose of acquiring these aerial photographs was the production of two general series of maps at scales 1:50,000 and 1:250,000. Later during the period 1963-1966, the British Royal Air Force (RAF) assumed responsibilities for the production of aerial photography in the Cyrenaica area.

Figures 2-9, 2-10, and 2-11 show the main areas of the country photographed in the 1970s and 1980s; minor areas photographed for special projects are not shown. The photographic scales used were 1:20,000, 1:25,000, 1:40,000, 1:50,000, 1:60,000, 1:80,000. and 1:90,000. Aerial photography at the scales 1:4,000, 1:6,000 and 1:15,000 also exists, and covers scattered areas in the country; these were taken for mapping purposes associated with specific projects concerned with town planning, harbour and airfield design, road design and agricultural reform studies.

From the cartographic point of view, the aerial photographs taken at scales 1:25,000 and 1:20,000 were adopted for plotting of medium-scale base maps. To date, the other smaller scales (1:40,000, 1:50,000, 1:60,000, 1:80,000, and 1:90,000) have been used mainly for the purposes of photo-interpretation and the production of an extensive series of photo mosaics at 1:50,000 scale (see Figure 2-12) rather than topographic map production. These controlled photo mosaics have been produced by applying the conventional methods of mosaicing. Since the required mosaics are at 1:50,000 scale, enlargement and reduction procedures have been applied to bring the available photographs to the required scale. These controlled photo mosaics have been produced using a Swiss rectifier available in the SDL and the co-ordinates of the ground control points (GCPs) which have been obtained by aerotriangulation. Each produced sheet has a number within the series. Quite a large number of sheets of a standard format size, each covering 15′x 15′ latitude and longitude, have been produced in this series. From this, it can be seen that Libyan users are well used to handling photo mosaics and to interpreting the photographic images. Indeed they are often used in conjunction with line maps and as a map substitute where no line maps exist.

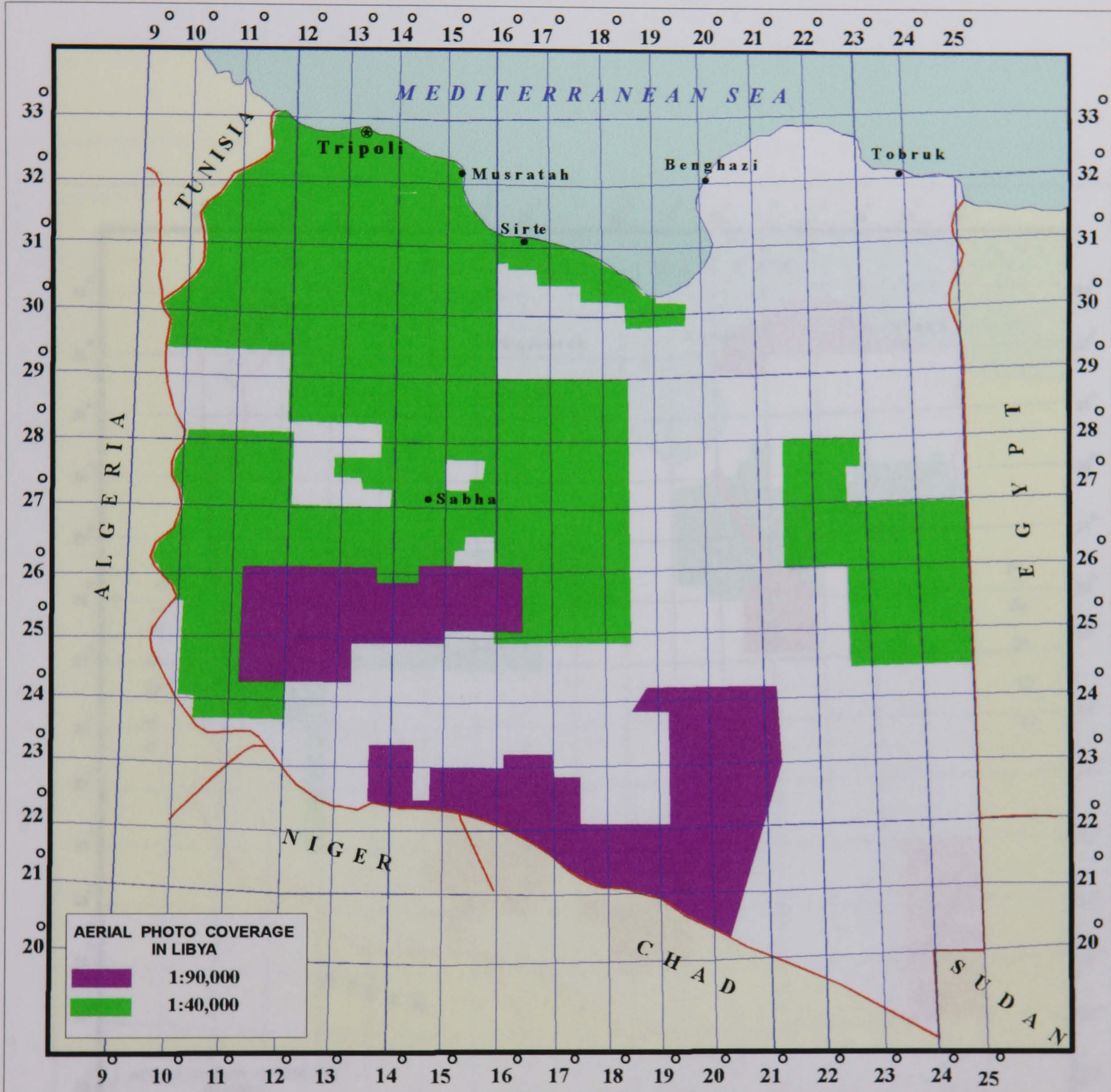


Figure 2-9: The present aerial photographic coverage in Libya at 1:90,000 and 1:40,000 scales

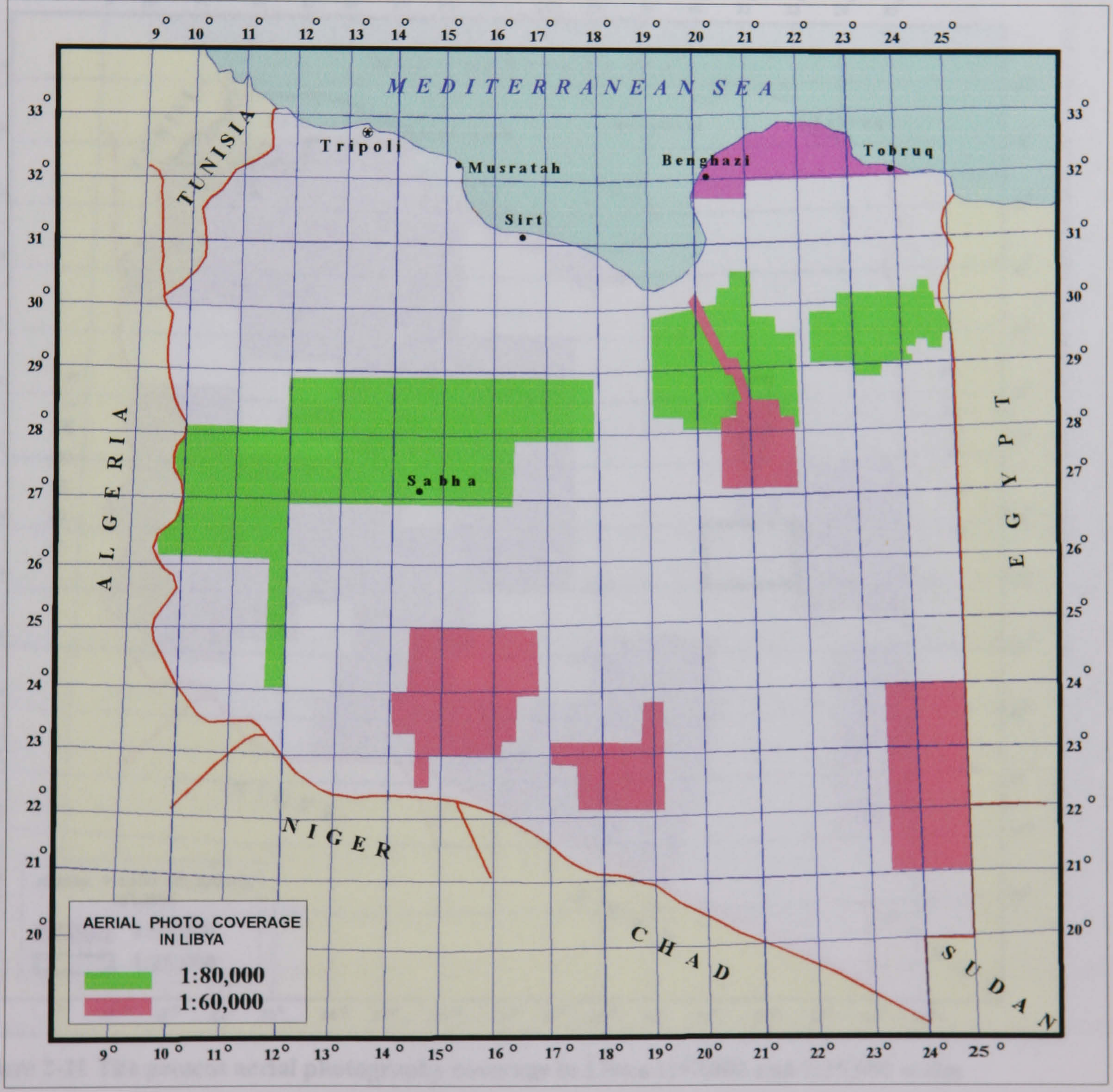


Figure 2-10 The present aerial photography coverage in Libya 1:80,000 and 1:60,000 scales

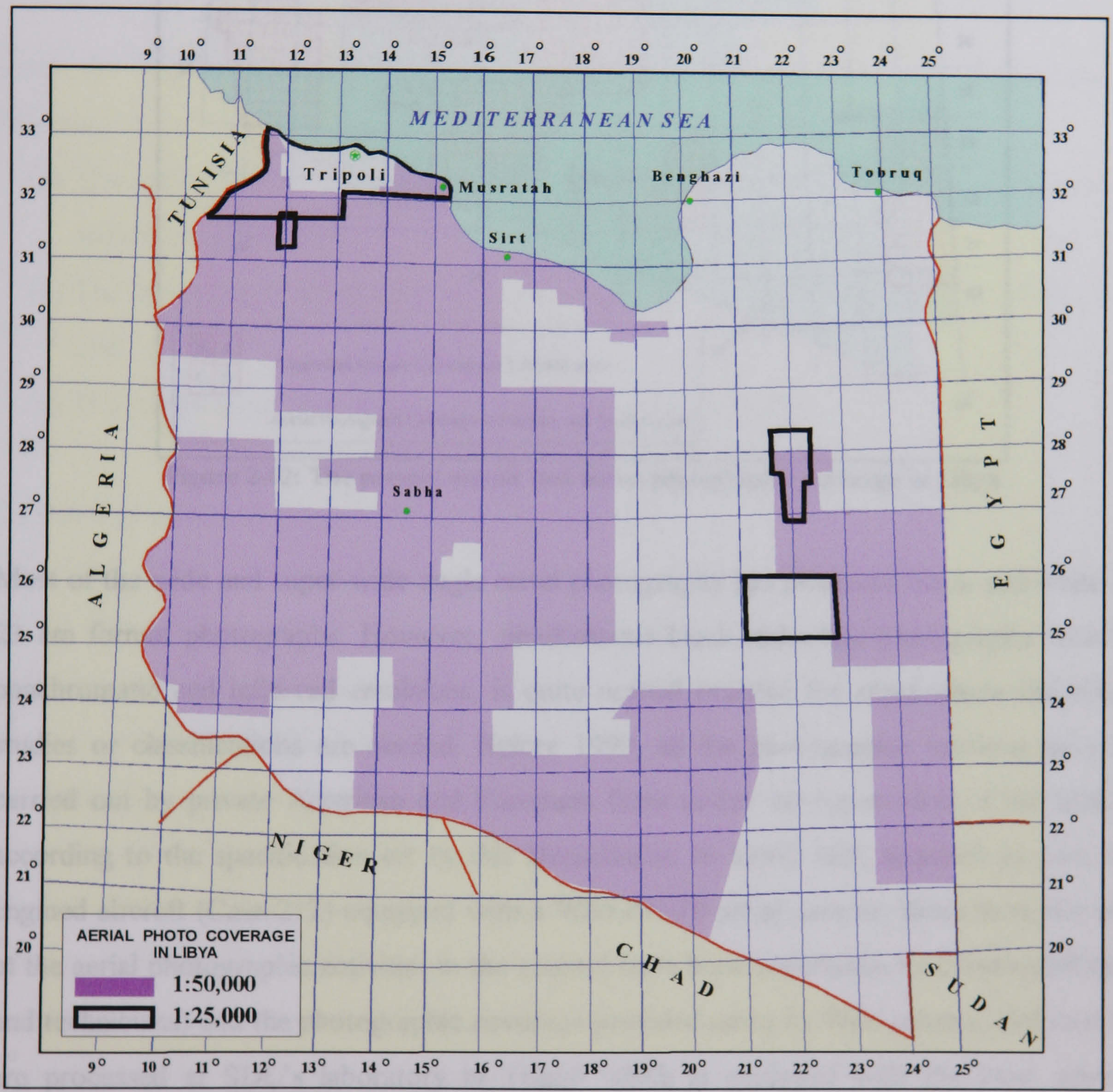


Figure 2-11 The present aerial photography coverage in Libya 1:50,000 and 1:25,000 scales

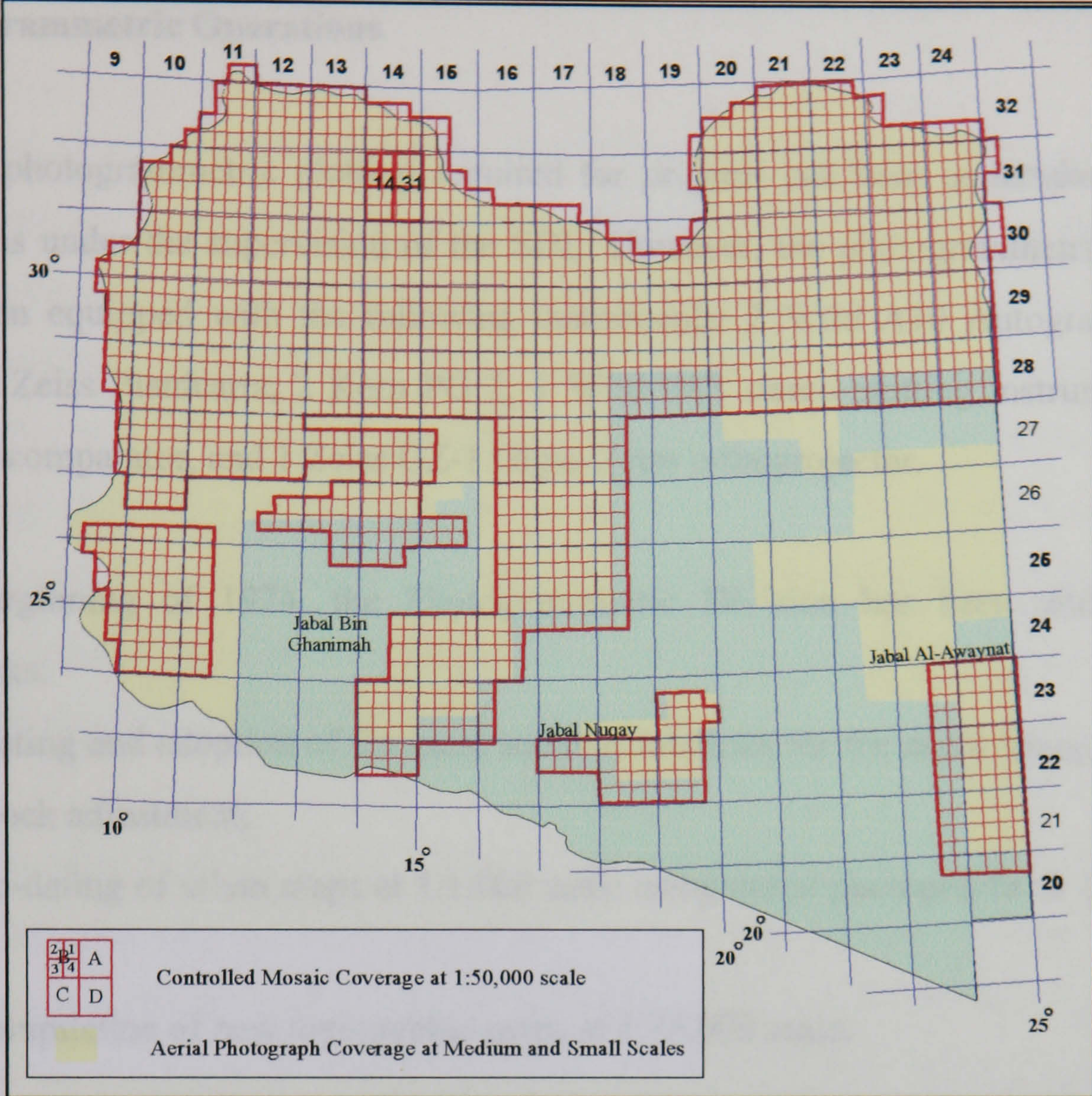


Figure 2-12: The present mosaic and aerial photographic coverage in Libya

Most of the wide and super-wide-angle aerial photography has produced black-and-white 23 x 23 cm format photographs. However, simultaneous black-and-white photography with both panchromatic and infra-red emulsions, is quite normal practice for areas where hydrological studies or classifications are needed. Before 1990, all the photographic missions have been carried out by private American and European firms under the supervision of the SDL and according to the specification set by this Department. In 1990, SDL acquired its own twin-engined aircraft (Casa 212) equipped with a Wild RC-10 aerial camera. Since then, the whole of the aerial photographic activities in the country have been undertaken by Libyan staff (pilots and technicians) and the photographic coverage provided using its Wild camera. Exposed films are processed at SDL's laboratory in Tripoli which is equipped with the most advanced processing technology.

2.5.1 Photogrammetric Operations

Most of the photogrammetric plotting required for projects has been undertaken by private overseas firms under the supervision of the SDL. However, the photogrammetric division of SDL has been equipped with the following instruments: 2 Wild A10 Autographs; 4 Zeiss Planimats; 2 Zeiss Planicarts; 2 Kern PG 2, 1 Wild B8S stereo-plotting instrument: 1 Wild STK-1 stereocomparator, and 1 Zeiss GZ-1 Gigas-Zeiss orthoprojector.

Since the beginning of 1974, the Photogrammetric Division has been undertaking the following tasks:

(a) The testing and adoption of the most suitable solutions for the aerial triangulation strip-and-block adjustment;

(b) The up-dating of urban maps at 1:1,000 scale using aerial photographs at 1:4,000 scale; and

(c) The compilation of new topographic maps at 1:25,000 scale.

2.6 Cartographic Production Facilities and Methods

A full suite of conventional cartographic and associated equipment is available in SDL, including light tables, drawing tools, instruments and material for scribing and masking, etc. Also a computer-based typesetting system is available. As noted above, advanced photographic labs for coloured and black and white film processing and the production of prints are available, including photographic enlargement and reduction equipment. The SDL has two vacuum frame cameras, one large-format process camera and two Swiss offset printing machines for light and heavy printing duties. In fact, the conventional methods of cartography using scribing, masking, and photoset lettering are still applied in SDL. However, in the near future, when the author goes back to his country, there is a plan to start applying digital cartographic methods for both map and image map production.

2.7 Remote Sensing in Libya

Remote sensing is an essential tool for the exploration, mapping, monitoring and assessment of natural resources. Being well aware of the importance of remote sensing in these fields, in 1976, the Government set up the National Committee on Remote Sensing. Its primary goal was to find practical applications for remote sensing technology in Libya; and secondly, to follow scientific and technological developments in this field. The Committee publishes a journal, *Remote Sensing - Information*, to provide those persons who are involved or are expected to be involved in the application of remote sensing technology with theoretical and practical knowledge about remote sensing science, technology, and applications and to inform them about the experience of other countries in this field.

By 1986, the advantage of using remote sensing science and technology for certain applications had been fully realised. In particular, there was an urgent need to build a national capability for using remote sensing data in various fields of earth sciences in order to fully apply it to the development of the national resources of the country. To this end, two remote sensing centres have been established in Tripoli: the Al-Beroni Remote Sensing Centre and the Libyan Centre for Space Research. Both centres are well equipped with up-to-date and advanced facilities in terms of satellite imagery, hardware and software. Technical staff members from these two centres are sent abroad for higher education and training on the different applications of remote sensing.

SDL has its own remote sensing section which falls under the Photogrammetric Division. It is mainly concerned with the application of remote sensing and image processing to the field of cartography. In the near future, it is planned to develop this section and to provide it with the advanced equipment and software packages required for processing and evaluating space imagery.

2.8 Topographic Mapping Coverage

Topographic maps of Libya were compiled and published in Italian during the Italian occupation of Libya. An Italian reconnaissance map series at 1:400,000 scale covered the whole territory. This complete coverage was provided in 45 sheets produced between 1934-1941. During the same period, another complete coverage of 11 sheets at 1:1,000,000 scale was also undertaken by the Italians. Limited areas of the coastline of Tripolitania and Cyrenaica were also mapped at 1:100,000 scale in 1932, and some sheets at 1:50,000 scale were compiled by the British and allied forces during the extensive fighting which took place in Libya during World War II.

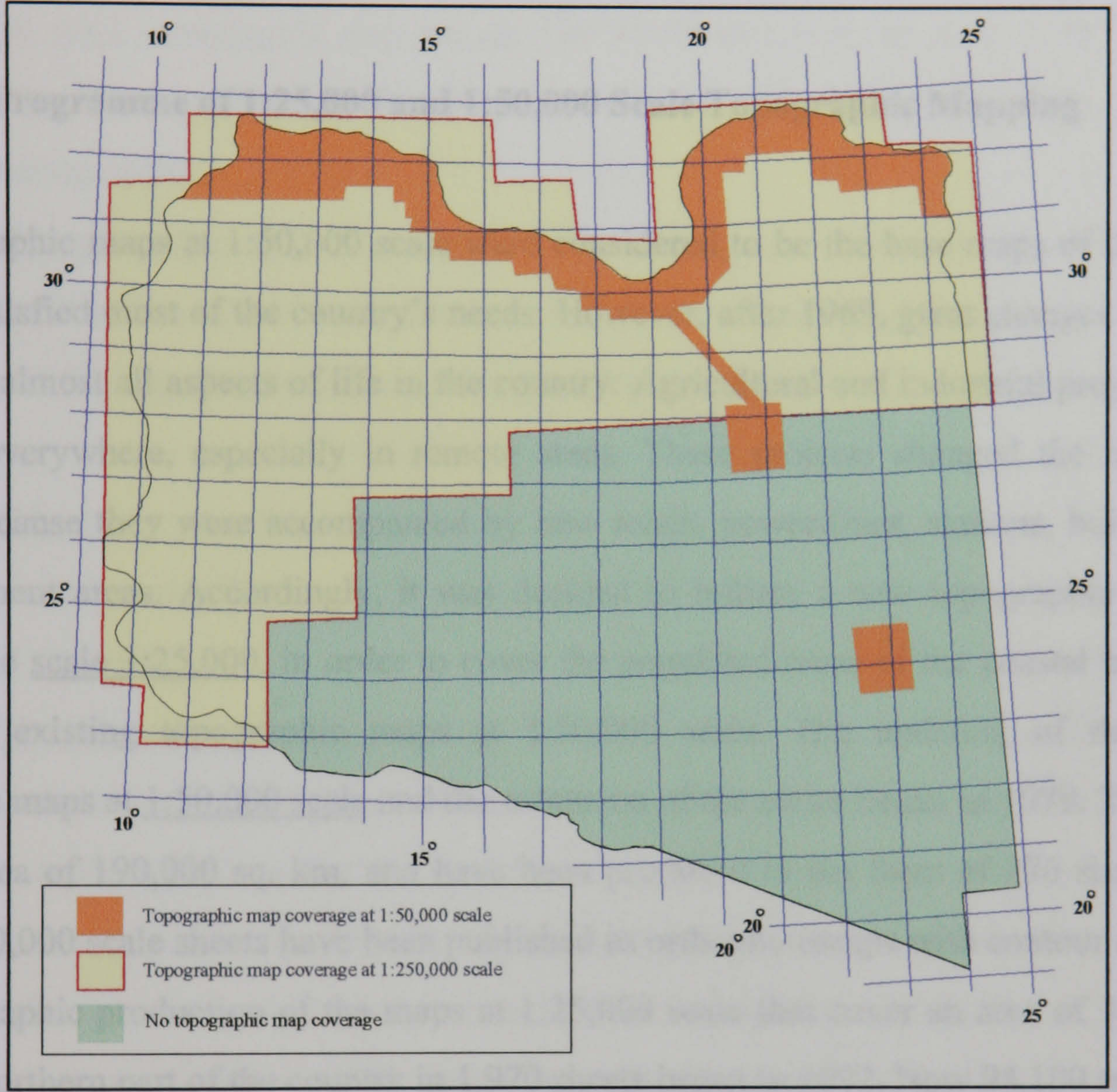


Figure 2-13: Topographic mapping coverage of Libya at 1:50,000 and 1:250,000 scales produced by the US Army Map Service (AMS)

2.8.1 American Programme of 1:50,000 and 1:250,000 Scale Topographic Mapping

Following on from the geodetic network described in Section 2.4.1, since the early 1960s, the coastal band of Libya has been covered by topographic maps at 1:50,000 scale, comprising 240 sheets of a standard format size, each covering 15′ x 15′ latitude and longitude. These maps were compiled from aerial photographs at 1:60,000 scale taken in 1956. The same photographs were also used for the compilation of the 58 topographic maps at 1:250,000 scale which cover the area north of Latitude 28°. Each map has a standard format of 1.0° x 1.5° in latitude and longitude respectively. Both of these series, see Figure 2-13, were produced by the US Army Map Service and used a UTM grid. They represented a huge mapping effort and constituted a large aid programme on the part of the American Goverment. It is worth to mention that the U.S. Defence Mapping Agency (DMA) have also produced a topographic/aeronautical series of 11 sheets at 1:500.000 scale that cover 85% of Libya.

2.8.2 SDL Programme of 1:25,000 and 1:50,000 Scale Topographic Mapping

The topographic maps at 1:50,000 scale were considered to be the base maps of the country and they satisfied most of the country's needs. However, after 1969, great changes took place and altered almost all aspects of life in the country. Agricultural and industrial projects began to spread everywhere, especially in remote areas. These projects changed the face of the country, because they were accompanied by new roads, power-lines, stations, buildings and new settlement areas. Accordingly, it was decided to initiate a new topographic base map series on the scale 1:25,000, in order to cover the populated areas of the coastal belt, and to update the existing topographic maps at 1:50,000 scale. The updating of the existing topographic maps at 1:50,000 scale and the extension of the series began in 1979. These maps cover an area of 190,000 sq. km. and have been produced in the form of 276 sheets. Some revised 1:50.000 scale sheets have been published as orthophotomaps with contour overprints. The cartographic production of the maps at 1:25,000 scale that cover an area of 340,000 sq. km of the northern part of the country in 1,970 sheets began in 1992. Now 94,100 sq. km (547 sheets) are ready for printing. Technical assistance was provided by the Polish organisation Pol-Service/Geokart and by the French IGN, and related particularly to compilation of the new 1:25,00 scale series.

2.8.3 Russian Programme of Topographic Mapping

Between 1976 and 1988, other topographic map series of Libya have been produced at 1:200,000 and 1:100,000 scales by Russian military cartographers – presumably based on space imagery – without the knowledge or cooperation of the Libyan government. This mapping work formed part of the military plan of the former Soviet Union to cover the entire globe with topographic maps at different scales. Of course, a comparable programme was undertaken by the United States and its NATO allies. Full knowledge about the coverage of the Russian-produced series has only come to light in recent years with the end of the Cold War. When it comes to the topographic maps of Libya produced by the Russians, a variety of basic series exists depending on scale. Naturally, the degree of coverage and number of available sheets associated with each scale varies:

-1:500,000 scale topographic map series: The whole of Libya, as well as the rest of the entire globe, is covered by topographic maps at 1:500,000 scale produced by the Rusian military cartographers.

- 1:200,000 scale topographic map series: This is likely to be the most popular and useful series since it offers virtually complete coverage of the entire country in 263 sheets. They appear to be high quality maps, and 1/4 of the sheets have extensive descriptive text on the reverse.

- 1:100,000 scale topographic map series: This is another topographic map series that has been produced by the Russian military mapping agencies. This map series covers most of Libya in 412 sheets.

- 1:10,000 scale city topographic maps: These maps are regular topographic maps that include contour lines, power lines, etc., and are mainly produced for Tripoli and Benghazi cities. The topographic maps of Tripoli have been produced in 1985 in two sheets, whereas the Benghazi topographic map has been produced in 1977 in only one sheet.

All of these Russian topographic maps currently use the Gauss-Krassovsky grid projection system based on the Pulkovo 1942 datum and the Krassovsky spheroid. These Russian topographic maps are generally published in the Russian language, regardless of the location of the territory depicted. Fortunately, the language barrier is easily overcome by virtue of the inherent intuitive nature of maps. Recently a large number of formerly classified and difficult-to-obtain topographic maps produced by the Russian agencies have become available.

2.8.4 Large-Scale Mapping by SDL

On the large-scale side, more than 300 cities, towns, and main villages were covered by topographic maps at 1:1,000, 1:5,000, or 1:10,000 scale for town planning purposes, compiled by the SDL from large scale aerial photographs. Prior to 1956, a standard UTM 6° band projection and grid was employed, but in 1974, a modified version employing a 2° band projection was introduced in order to minimise the distortion present in large scale mapping at 1:5,000 and 1:2,500 scales. In addition, a new sheet numbering system was employed based on this new system.

2.9 Thematic Maps

Thematic maps at 1:25,000 and 10,000 scale for a forest inventory of the north-west part of the country have also been published. The 10,000 scale maps are provided in 218 sheets and covering an area of 7,900 sq. km of the north-west coastal belt.

Initial small scale geological mapping of the whole country was compiled by the United States Geological Survey (USGS) in the 1970s: A series of maps at 1:2,000,000 scale covering the whole country on a single sheet were prepared for geology and mineral resources, tectonics and palaeogeography, water resources and geology. Only the geology sheet, compiled in the mid-1960s, was published as a full-colour edition. There is also a small-scale geological map series of the Arab World which was compiled and published by the British company Robertson Research – sponsored and paid for by the Saudis. There are sheets in this series for Libya.

Since then, geological map production has been the responsibility of the Industrial Research Centre (IRC). A 72-sheet series of geological maps at 1:250,000 scale was began in the mid-1970s under an aid project carried out in collaboration with the Czech agency Kartografie. This was completed in the early 1980s and the sheets were issued between 1975 and 1983.

The National Atlas of Libya was published in Arabic and English editions in 1978. At the same time, a relief map of Libya at 1:1,000,000 and 1:1,500,000 scales was published for educational purposes for the Ministry of Education.

Small-scale and tourist map coverage has been produced by a variety of overseas agencies. In addition to the above-mentioned small scale maps, a number of aeronautical and marine charts exist.

It is worth to mention, that a lot of mapping activities have been carried out in connection with exploration of Libya's oil and gas resources. Many national and overseas oil companies working in Libya have produced their own maps. These maps include geological maps and image maps to locate the oil fields.

2.10 Satellite Image Maps

Given the characteristics of the Libyan landscape, which consists largely of huge areas of desert, there has been much interest in producing satellite image maps at small scales. Amongst these have been the 127 sheets of satellite image maps at 1:250,000 scale covering the whole country and produced by the American Earthsat Corporation in 1978 on the basis of Landsat MSS imagery. These image maps were produced for the Secretariate of the Municipalities under the supervision of SDL in Libya. These have been heavily utilized in the past, but they are now 20 years old and out-of-date. Also the use of MSS imagery meant that they had limited ground resolution.

Early in 1998, a commercial company, Nigel Press Associates (NPA), based in the U.K. was awarded a contract by two oil companies (AGIP and Saga) working in Libya to produce satellite image maps at 1:50,000 and 1:250,000 scales for specific areas in the country. This satellite image mapping project can be divided into two sub-divisions as will be discussed below. Some more detailed discussion about the methods used has been included becuase of its relevance to the author's project.

2.10.1 Satellite Image Maps at 1:50,000 Scale of the North Western Part of Libya

Agip, an independent Italian oil company operating in Libya, required a set of satellite image maps at 1:50,000 scale with the best possible resolution for an area of some 100,000 sq. km in N.W. Libya (in the area south of Misratah). The aim of producing these image maps is for them to be used as basemaps to plan and guide logistic and geologic operations both in the field and at the operational base in Tripoli. Thus there was a substantial thematic component contained in the specification. A total of 35 colour satellite image maps at 1:50,000 scale are being produced by NPA based on SPOT panchromatic images and Landsat TM imagery. In fact, to achieve coverage of this area, a total of 28 SPOT panchromatic images with a ground pixel size of 10m were used. In addition, a number of Landsat TM images with 30m ground pixel size were also available to be merged with the higher resolution SPOT panchromatic images. Thus the Landsat TM data provided the wider spectral component needed for geological purposes while the SPOT panchromatic data gave the spatial resolution, resulting in the production of the required operational maps at 1:50,000 scale. The Landsat TM data that was used was more than 10 years old (so providing low cost data). To obtain the greatest colour variation and discrimination of lithology, Landsat TM bands 2 (green), 4 (NIR) and 7 (SWIR) were selected to be used in the map production process. The higher resolution SPOT panchromatic imagery used in this project was from or after 1995, such that the recent constructed roads and tracks, particularly those associated with the Great Man-Made River development, were shown on the image maps.

The second step of the project was to acquire ground control points (GCPs) to accurately position the satellite data on a true geographic grid. This was achieved using points derived from the Russian 1:100,000 scale topographic maps available for the project area, together with GPS co-ordinates acquired by the Agip surveyors during field visits. An accuracy of better than 100m, which was sufficient for the desired applications, has been achieved. Using the TNT-mips and Digital Mapping System (DMS) software packages available in-house, digital image processing techniques have been applied to satellite images for geometric and radiometric corrections and for mosaicking. The Landsat TM scenes with their larger coverage were mosaicked together for the entire area based on the ground control points (GCPs). By image-to-image registration procedure, the SPOT Pan images were then georeferenced to the Landsat TM mosaic and each other and then filtered with a proprietary filtering technique to extract the high and medium frequency spatial variations. The resulting filtered SPOT data was mosaicked and used to modulate the Landsat TM mosaic to introduce the spatial detail from the original SPOT Pan. data and produce the resulting colour imagery (merging both data sets) with a 10m ground pixel size. This procedure ensured the colour balance of the Landsat TM data was not altered, as can be the case with alternative procedures.

In addition to the image maps, elevation data was derived from the digitised contours at 20m and 40m intervals from 1:100,000 and 1:200,000 scale Russian topographic maps of the same area. Afterwards, by using the DMS software package. a Digital Elevation Model (DEM) for the project area has been extracted from the contours. This DEM is then used to rectify the mosaic and produce the ortho-image. Unfortunately, due to the project deadlines, it was not possible to ortho-correct the image data precisely, however, the image data had been selected as much as possible to be close to vertical incidence.

The superimposed cartographic data was very limited. However, spot heights extracted from the existing maps were superimposed on the image background for reference and elevation data, together with other customer-supplied data. These were compiled digitally using the MapInfo mapping system.

2.10.2 Satellite Image Maps At 1:250,000 Scale of the South Western Part of Libya

These image maps have been required by the Norwegian Saga oil company working in Libya. A set of satellite image maps at 1:250,000 scale has been produced by the NPA Group to help plan the acquisition of seismic data in the Murzuq region. For this project, 14 Landsat TM scenes have been used to produce the image maps. To ensure the best colour results, once again, Landsat TM bands 2, 4, and 7 have been selected and used. These satellite image maps have been produced using the same software packages and following the same image processing procedures as those explained above. The final digital data of the satellite image maps at 1:50,000 and 1:250,000 scales have first been transferred to a 10" x 8" format film (negative) using a film writter with 1,200 dpi resolution. Finally the image has been printed on Agfa papers to produce the final image maps at the required scale.

2.11 Conclusion

As elsewhere in the world, mapping is still an activity that is actively going on in Libya. The fact that Libya is huge country in terms of its physical area, increases the cost and extends the time needed for any national topographic mapping project or programme to be carried out.

Moreover, map revision has not been as active as it is in many mapping organisations in other developing countries which has resulted in the present conventional line maps being badly out-of-date. Besides, most of Libya comprises a natural physical landscape where man-made features are very limited. For these reasons, SDL is planning to replace the conventional topographic line map series with a satellite image map series. Thus an overview will be given in Chapters 4 and 5 to describe the high resolution space sensors and their potential cartographic applications. Before doing so, it is necessary to discuss the cartographic requirements and specifications for topographic base maps, with specific reference to image maps. Such a discussion will be given in the next Chapter (3).

CHAPTER 3: CARTOGRAPHIC REQUIREMENTS FOR MEDIUM AND SMALL-SCALE TOPOGRAPHIC LINE AND IMAGE MAPS

3.1 Introduction

In several fields (e.g. in communications and meteorology), Earth orbiting satellites have become operational tools. In the field of remote sensing, starting with Landsat in 1972, various satellite-borne imaging systems have promoted the development of the discipline itself. Furthermore, remote sensing techniques used in conjunction with space imagery have found numerous applications in many other disciplines. Among these applications is topographic mapping. In general terms, this application requires imagery with a high spatial resolution in order to detect and interpret the topographic details needed for inclusion in maps. Preferably too it needs overlapping imagery that will provide a stereo-viewing capability for measuring the 3rd dimension. Marek (1990) has stated that an assessment of producing conventional topographic line maps and image maps from space images should take place on the basis of:

(i) their geometric resolution and scale,
(ii) the planimetric and height accuracy that is achievable, and
(iii) the content and completeness of the topographic features or objects that can be detected, interpreted and compiled from the space imagery.

These matters will be discussed in some detail in this Chapter.

3.2 Resolution and Scale

At the initial stage of the discussion, it is important to define the term resolution and to state the relationship between the ground resolution and the ground pixel size, since these terms will be used frequently both in this Chapter and later on in other Chapters of this dissertation. Often the two terms are regarded by the remote sensing community as being the same, whereas they have quite different meanings when used by the photogrammetric, topographic mapping and cartographic communities.

Resolution (or resolving power) is a measure of the ability of an optical system to distinguish between signals that are spatially near or spectrally similar (Valadan Zoej, 1997). Usually three kinds of resolution are distinguished – spatial, spectral, and radiometric resolution.

(i) Spatial resolution is a measure of the smallest angular or linear separation of the object from its surroundings that can be resolved by the sensor.

(ii) Spectral resolution refers to the ability of the sensor to discriminate fine spectral differences or the number of specific wavelength intervals in the electromagnetic spectrum to which a sensor is sensitive.

(iii) Radiometric resolution refers to the ability to discriminate very slight energy differences.

Of the above defined terms, spatial resolution is especially important to the topographic mapping community.

In conventional aerial photogrammetry, the spatial resolution of an aerial photographic image is best defined and represented in terms of the Modulation Transfer Function (MTF). However the procedures needed to obtain these values are complex and the results are not easy to interpret, so the use of MTF is somewhat impractical in production topographic mapping operations. Therefore the photogrammetrist generally defines the geometric or spatial resolution of a photographic image in terms of the number of line-pairs per millimetre $(R_{lp/mm})$ that it can resolve. In other words, a resolution of n lp/mm means that a maximum of n pairs of alternating black and white lines from a bar target can be imaged distinctly over a 1mm distance on a low (e.g. 1.6:1 or 2:1) contrast image. Theoretically at least, it should be possible to obtain a space image with any desired ground resolution, simply by selecting the appropriate scale of photography. This can be produced by selecting a lens with an appropriate focal length in conjunction with an appropriate lens/film combination having a specific spatial resolution. In this respect, it is desirable sometimes to express the ground resolution of a space photograph or the resulting orthophotograph that is used as the basis of an image map in terms of metres per line-pair $(R_{m/lp})$. In fact, the two terms – the image resolution $(R_{lp/mm})$ and ground resolution $(R_{m/lp})$ are related together as follows (Doyle, 1984):

$$(R_{m/lp}) = (\text{photo scale}/1{,}000) \,/\, (R_{lp/mm}) \qquad (3.1)$$

In the context of remote sensing, a somewhat different use is made of the term resolution. Frequently it refers to the pixel dimension, which is the equivalent to the pixel size for a scanning sensor. The pixel is a two-dimensional discrete picture element occurring on the image. Thus the spatial resolution in this context is defined in terms of the ground pixel size and is denoted as $(R_{m/pixel})$. In fact, the ground pixel size is determined by the angular dimension of the Instantaneous Field Of View (IFOV) of the sensor and the distance of the sensor from the object. In other words, the information contained within the area or region on the ground covered by the IFOV is represented by a single pixel in the image plane. Whereas the maximum angle of view over which a sensor can effectively detect the electromagnetic energy reflected from the ground is defined as the Field Of View (FOV) which will usually cover thousands of pixels. Particularly in the case of scanners, the coverage of the ground corresponding to the FOV is called the swath width.

Naithani (1988, 1990) compared $R_{m/pixel}$, as used in remote sensing, with $R_{m/lp}$, as used in photogrammetry and mapping. The two resolution terms are related through the Kell-factor of $2\sqrt{2}$ as follows:

$$R_{m/lp} = 2\sqrt{2} \times R_{m/pixel} \tag{3.2}$$

$$\text{Or } R_{m/lp} \approx 2.5\, R_{m/pixel}$$

Doyle (1984) has defined the relationship between ground resolution and ground pixel size and related both to the image scale number, stating the following two formulas for photographic and electro-optical scanner systems respectively:

$$S_m = 4{,}000\, R_{m/lp} \quad \text{(photographic sensors)} \tag{3.3}$$

$$S_m = 10{,}000\, R_{m/pixel} \quad \text{(scanners)} \tag{3.4}$$

Where S_m = the image scale number,

$R_{m/lp}$ = the ground resolution in m/lp (used by the mapping community).

$R_{m/pixel}$ = the ground resolution in m/pixel (used by the remote sensing community).

In fact, the numbers 10,000 and 4,000 are related to each other directly to the Kell-factor given in equation 3.2, i.e. by 2.5:1.

The relationships stated by Doyle in Equations 3.3 and 3.4 above can be used to set out the specific values relating to the medium and small scales commonly used in topographic mapping. These are shown in Table 3-1. The basis of the ground resolution figures which are given in Table 3-1 involve the concept of the smallest resolvable object on an image map – this is taken to be 0.1mm. Which can be shown by the following:

For 0.1mm at 1:250,000 scale,

since 1mm on map = 250,000mm = 250m on the ground

So 0.1mm = 25m

Or

For 0.1mm at 1:25,000 scale,

since 1mm on map = 25,000mm = 25m on the ground

So 0.1mm = 2.5m

The same relationships can be applied to 1:100,000 and 1:50,000 scale, in which case, 0.1mm will be equal to 10m and 5m respectively.

Scale No. S_m	Doyle's Method	
	$R_{m/pix}$	$R_{m/lp}$
1:250,000	25	63
1:100,000	10	25
1:50,000	5	12.5
1:25,000	2.5	6.3

Table 3-1: Requirements for Image Map Series

3.3 Choice of Scales for National Topographic Map Coverage

Since Libya is a huge country with enormous areas of desert or semi-arid land with little or no population, and only relatively few cultural (man-made) features, the question arises as to whether comprehensive national topographic mapping at 1:50,000 scale (as used in almost all European countries) is necessary or, whether, if implemented, it is overkill. Petrie (1997) quoted Namibia as an example of the latter. Like Libya, much of its area is desert, while its land area amounts to 824,000 sq. km. and its population is only 1,400,000. Nevertheless it has a complete topographic map coverage at 1:50,000 scale in the form of 1,250 sheets produced by the South African Trig Survey organization. Now that it is independent from South Africa, it does not have the financial and manpower resources needed to maintain this series: in other words, coverage at 1:50,000 scale is not sustainable.

With this in mind, many other African countries have adopted a multiple-scale strategy for their topographic mapping coverage. As an example, many francophone west and central African countries and Djibouti have specified 1:200,000 as the basic mapping scale, with coverage at 1:50,000 scale restricted to the more developed areas of their countries. A dual-scale strategy has been also adopted by several former British-ruled territories (Kenya, Zambia and Botswana), with 1:50,000 adopted as the mapping scale for the more populated and developed regions and either 1:100,000 or 1:125,000 scale for the mountainous or more remote arid regions.

In other North African countries with terrain characteristics similar to those of the Libyan landscape, e.g. Algeria, a triple-scale strategy has been adopted for mapping the whole of this huge country with its area of 2,400,000 sq.km. The basic scale used for national coverage is 1:200,000 and this is being used to map the Sahara Desert covering the southern part of Algeria. However 1:100,000 is the scale that has been adopted for the mapping of the mountains and plateaux of the southern Atlas, while mapping at 1:50,000 scale is confined to the more developed and populated areas in the northern part of the country. In the case of Tunisia with its relatively small area, as reported by Petrie (1997a), a somewhat similar strategy has been adopted with 1:100,000 being used as the basic mapping scale for the southern part of Tunisia (comprising desert and arid areas); 1:50,000 has been the scale adopted for the central and south-eastern parts; while 1:25,000 is used as the basic mapping scale only for more developed and populated areas in the northern and north-eastern parts.

In Libya, where most of the terrain is pure desert, the basic topographic map coverage for the country is at 1:250,000 scale, which has been produced as an image map series (127 sheets) using MSS imagery by the Earthsat Corporation in the United States in 1978. As discussed in Chapter 2, the 1:50,000 scale coverage is restricted to the more developed and populated areas between latitudes 28°N and 32°N. As discussed above, the basic mapping scales adopted in nation-wide topographic mapping in Africa are 1:50,000, 1:100,0000 and either 1:200,000 or 1:250,000. For a country like Libya, and certainly from both the economic and cartographic points of view, the author can see no point in attempting to cover the whole country with maps at scales larger than 1:200,000 and indeed coverage at 1:50,000 scale should be restricted to the more populated and developed areas. In the Libyan context, the establishment of a new national image map series at 1:250,000 scale – but with improved ground resolution as compared with the first series based on the use of MSS imagery – would appear to be a logical and appropriate solution to the country's current mapping problems.

3.4 Accuracy Specifications

Until now, no international standards for mapping accuracy have been established. However the American standards have been widely adopted by many countries, including the NATO countries in the case of their military map series. The required accuracy for position and height data on U.S. maps is specified by the National Map Accuracy Standards (NMAS).

3.4.1 Planimetric Accuracy

En route to the adoption of these standards, the American Society of Photogrammetry (ASP) had recommended that the planimetric accuracy for topographic mapping prepared by photogrammetric methods should be that 95% of all well-defined detail be within ±0.5mm of their correct positions at the publication scale. However the United States Geological Survey (USGS) recommended that 90% instead of 95% of well-defined points should be within ± 0.5mm of their correct positions at the publication scale.

Furthermore, in another sumission to the debate, two classes of planimetric accuracy were distinguished by the Federal Board of Surveys and Maps (FBSM):

(i) Class A accuracy, in which 90% of well-defined features should be mapped within ±0.6mm of their correct positions at the publication scale.

(ii) Class B accuracy, in which 90% of well-defined points should be mapped within ±1.0mm of their correct positions at the publication scale.

Applying the usual statistical methods at a 90% confidence level, the planimetric standard error (m_{pl}) to be reached by Class A maps should be ≤ ±0.4mm, while that in Class B should be ±0.6mm.

The NMAS planimetric accuracy specifications were developed from all these various recommendations. The final conclusion was that 90% of the details existing on the map (excluding those features which are unavoidably displaced by exaggerated symbols) should lie within ± 0.5mm of their correct planimetric positions. According to Doyle (1982, 1984), these can be expressed in terms of standard errors as follows:

$$\textit{Planimetric data error } \sigma_P = 0.3mm \times \textit{map scale number} \qquad (3.5)$$

This planimetric accuracy specification (with r.m.s.e. values set at ±0.3mm) has been adopted by NATO and many other countries world-wide. However, for some developing countries, the Class B planimetric accuracy recommended by the FBSM may be quite adequate.

3.4.2 Height and Contour Accuracies

Elevation is most often depicted on topographic maps by contour lines supplemented by spot elevations. In the U.S.A, the NMAS stated that the contour accuracy requirements are set such that 90% of the points lying on the contours shown on topographic maps should lie within half the contour line interval of their correct positions. Again, according to Doyle (1982, 1984), the standard error of elevation is given by:

$$\textit{Elevation data error } \sigma_E = 0.3 \times \textit{contour interval} \quad (3.6)$$

The accuracy required for spot elevations shown on topographic maps is usually about 1/5 to 1/8 of the required contour interval (Tham, 1968). For example, for a map at a particular map scale that requires contours to be mapped at a contour interval of 40m, the accuracy of the spot heights or elevations shown on this map needs to be within the range ±5m to ±8m.

The actual contour interval adopted for a specific map scale not only varies from one country to another but it may also vary from one area to another within a single country, depending to a large extent on the physical characteristics and elevation range of the terrain. Ghosh (1987) studied the frequency of the contour intervals used in world mapping and gave the most used contour intervals at each of the commonly used map scales as shown in Table 3-2. The smaller values are those applied to flat ground, while the larger intervals are those utilised in hilly or mountainous terrain with a large elevation range and (often) steep slopes.

Map-Scale	Contour Interval (m)
1:5,000	2, 5
1:10,000	2, 5, 10
1:20,000	5, 10
1:50,000	10, 20, 40
1:100,000	20, 50

Table 3-2: Most Used Contour Intervals

3.4.3 Combined Resolution and Accuracy Requirements for Topographic Mapping

With mapping from space images in mind, Doyle (1982, 1984) summarised the overall resolution and accuracy requirements for topographic mapping at small scales as shown in Table 3-3.

Scale No.	Resolution m/pixel (at 0.1mm)	Plan Accuracy (m) (±0.3mm)	Contour Interval (m)	Contour Accuracy (m)	Spot Elevation Accuracy (m)	Ground Resolution	
						$R_{m/lp}$	$R_{m/pixel}$
1:50,000	5	± 15	10	± 3	± 2	7	3
1:100,000	10	± 30	20	± 6	± 4	14	6
1:250,000	25	± 75	25	± 8	± 5	36	14

Table 3-3: Overall Requirements for Small Scale Map and Image Map Production (Doyle, 1982, 1984).

As noted in Chapter 2, the basic scales used in the nation-wide topographic map coverage of Libya are 1:50,000 and 1:250,000. Most of the mapping specifications of these maps have been established either by the American Army Mapping Service (AMS) or by those American and European mapping agencies and companies that were awarded contracts for significant mapping programmes in Libya in the 1970s and 1980s. As a result, the typical specifications for map accuracy and content used in Libya are not too dissimilar to those employed in highly developed countries, e.g. typically 90% of the height points shown by contours should lie within 1/2 of the contour line interval. For the two basic scales being mentioned, these Libyan specifications are summarized in Table 3-4.

Scale	Plan Resolution (at 0.1mm)	Plan Accuracy (±0.3mm)	Spot Elevation Accuracy (m)	Contour Interval (m)
1:50,000	5m	± 15m	± 3m	10 to 20m
1:250,000	25m	± 75m	± 15m	25 to 40m

Table 3-4: Topographic Map Specifications Used in Libya.

3.5 Topographic Mapping Considerations

The main reason for the mapping community acquiring photographs and images from space is to provide the basic information needed to compile the different types of maps – topographic line maps and image maps – required by users. Three different kinds of information can be found on these maps (Doyle, 1984):

(i) Content Information: comprising the individual features to be included and how these features are to be depicted on the map.

(ii) Position Information: This type of information relates the features depicted on the map to the geodetic reference system of the Earth.

(iii) Height Information: The terrain elevation and physical landscape is shown principally on topographic maps by contour lines at a given vertical interval supplemented by individual spot heights.

3.5.1 Content Specification and Completeness of Map Detail

The topographic features that are usually shown in medium and small-scale topographic maps can be classified as follows:-

(i) Man-made features, including roads and railway lines, bridges and dams; transmission lines and pipelines, buildings, etc.;

(ii) Land forms such as mountains, hills, sand dunes, valleys or wadis, marshes, etc.;

(iii) Water features such as seas, lakes, rivers, reservoirs, etc.; and

(iv) Vegetation and land use areas such as forests, woodlands, orchards, cultivated areas, pasture, etc.

To a large extent, the extraction of such detail from space imagery depends on the ground resolution of this imagery. In general, the most critical items are the communication features and the buildings. Doyle (1975) and Konecny et al. (1982) have stated that, in order to extract these features from monoscopic space images for topographic mapping at 1:50,000 and 1:100,000 scales, the ground pixel sizes that are needed are 3m and 7m respectively. While the ground pixel sizes required to extract small cultural features from stereoscopic space images for topographic mapping at 1:50,000 and 1:100,000 scales are 6m and 14m respectively.

Generally speaking, the suitability of a particular type of image for topographic mapping is determined by the percentage of map detail which can be obtained from this type of image. If the percentage of detail that can be extracted is 75% or higher, then the images can be considered for use for topographic mapping. In which case, the undetected and unidentified features need to be derived from other sources (field completion, aerial photos, or existing topographic maps). However the expense involved in acquiring this additional information may make the procedure uneconomic especially in comparison with small-scale aerial photography from which 90% (or more often 95%) of the detail required to be included in the map can usually be extracted without too many difficulties arising.

3.5.1.1 Cartographic Specifications

The question about how these features are to be depicted on the topographic map is of course fundamentally a matter of cartographic design. To a large extent, line maps follow well established conventions with much the same symbols being used world-wide for roads, buildings, water features, etc. The same can be said also regarding colours, where again certain conventions – blue for water features; green for vegetation; brown for contours; etc. – are followed world-wide. Thus the specification for Libyan line maps at 1:50,000 scale (Figure 3-1) does not contain symbols and colours that are very different from those used in Europe or North America. However this does not prevent distinctive national cartographic styles arising – though often these are produced partly by the character of the landscape itself and partly through the use of a distinctive text and layout that has been decided upon by the cartographers involved, often adhering to a national tradition or style.

Of course, image maps have to follow, to a certain extent, certain basic principles of cartographic design and some of the specification that is applied to conventional line maps. However obviously, their design is fundamentally different to that of line maps in the sense that the white space of a traditional line map is wholly absent and many of the conventional symbols are inappropriate for incorporation in an image map. Instead there is an overall continuous tonal image, which may range from light to dark at any point. Of course, the additional visual information that is inherent on an image map – such as more complete drainage patterns; detailed vegetational features including individual trees and shrubs; tonal patterns to show changes in soil and drainage; the distinctive appearance of field lines and buildings – all in their true planimetric position – cannot be shown on a standard topographic line map by conventional methods and symbols. However, to produce an image map that is acceptable to users, a minimum requirement is to include certain additional essential information such as a grid, names and contours. The cartographic specification can be extended to enhance the background image with map symbols, and to improve contrast, clarity and legibility by introducing additional contrast and colour. Since the addition of the maximum level of information will obscure a certain amount of the image detail and cause more design problems, it is clear that it is simply not possible to use the same cartographic specifications for image maps as those applied to conventional line maps. For example, in conventional line map design, it is the convention to use standard colours and patterns to depict different types of vegetation, while in image maps, this may be an undesirable solution and may grossly disturb the natural image. Also, because of the variation in terrain characteristics from region to region, it is almost certainly not possible to have a standard specification for the whole national image map series. In fact, terrain with different conditions may well need a different set of specifications.

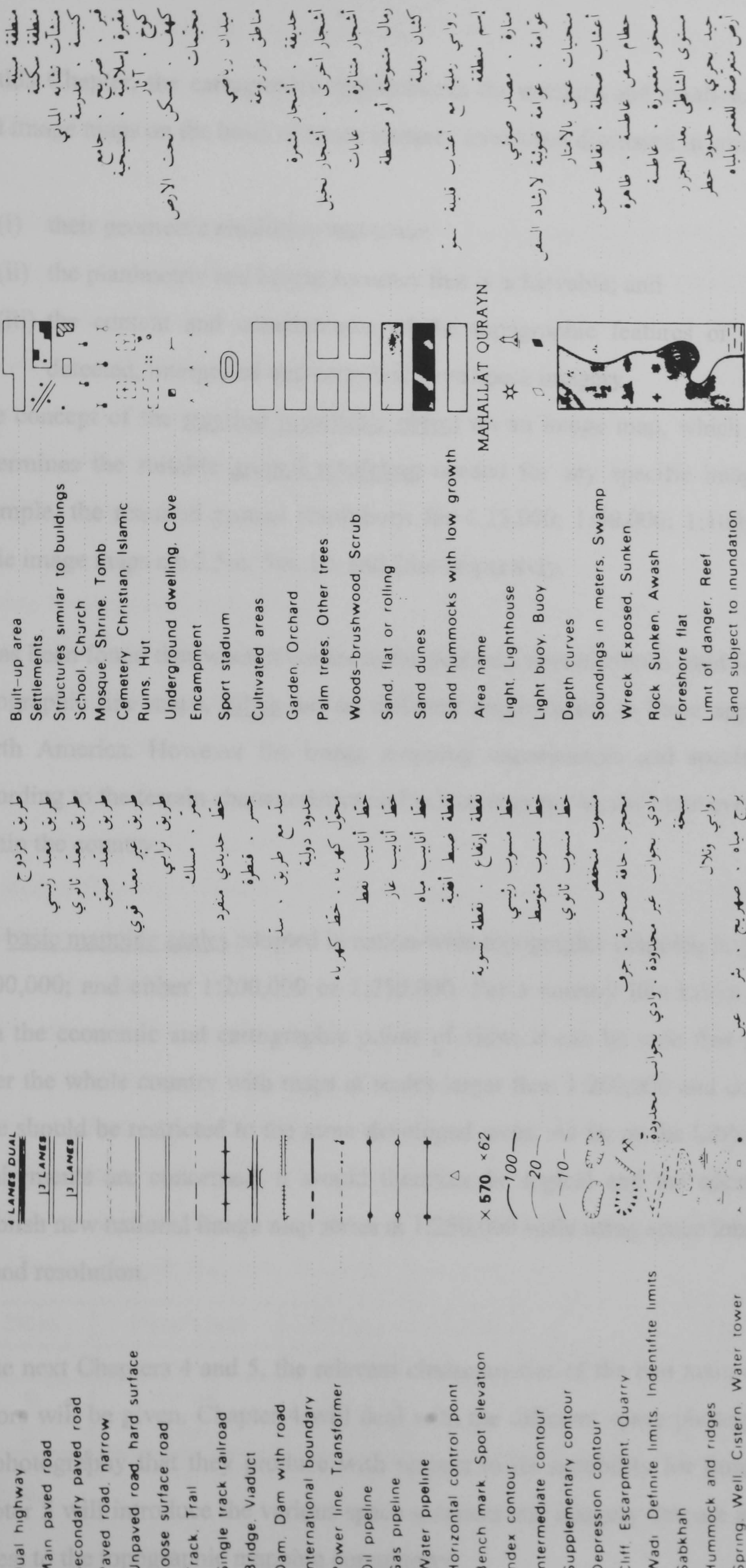


Figure 3-1: Content specifications for Libyan topographic line map series at 1:50,000

3.6 Conclusion

In this Chapter, the cartographic requirements for medium and small-scale topographic line and image maps on the basis of space imagery have been discussed in some detail on the basis of:

(i) their geometric resolution and scale;

(ii) the planimetric and height accuracy that is achievable; and

(iii) the content and completeness of the topographic features or objects that can be detected, interpreted and compiled from space imagery.

The concept of the smallest resolvable object on an image map, which is equal to 0.1mm, determines the suitable ground resolution needed for any specific image map scale – for example, the required ground resolutions for 1:25,000; 1:50,000; 1:100,000 and 1:250,000 scale image maps are 2.5m, 5m, 10, and 25m respectivly.

It has been found that when it comes to the accuracy specifications used for the production of topographic line maps, Libya has no different requirements to those applied in Europe and North America. However the image mapping requirements and specification may differ according to the terrain characteristics and indeed may not be the same even for different areas within the country.

The basic mapping scales adopted in nation-wide topographic mapping in Africa are 1:50,000; 1:100,000; and either 1:200,000 or 1:250,000. For a country like Libya and certainly from both the economic and cartographic points of view, it can be seen that there is no need to cover the whole country with maps at scales larger than 1:200,000 and coverage at 1:50,000 scale should be restricted to the more developed areas. As far as the Libyan current mapping requirements are concerned, it would therefore be logical and the appropriate solution to establish new national image map series at 1:250,000 scale using space images with improved ground resolution.

In the next Chapters 4 and 5, the relevant characteristics of the two main categories of space sensors will be given. Chapter 4 will deal with the different space photographic sensors and the photography that they produce with respect to its suitability for image mapping, while Chapter 5 will introduce the various space scanners and imagery that are available and are of interest to the topographic mapping community.

CHAPTER 4: HIGH RESOLUTION SPACE PHOTOGRAPHIC SENSORS AND THEIR TOPOGRAPHIC MAPPING POTENTIAL

4.1 Introduction

For the purposes of this Chapter, the definition of high resolution means optical imagery with a ground resolution of 10m and better (see Table 4-1). The latest generation of military Earth Observation (EO) satellites now provide imagery of the land surface with still higher resolutions - reputedly better than (i.e. less than) 1m in terms of ground pixel size. Recent developments in both sensor and platform technology have contributed significantly to this trend towards ever higher resolutions. However, as yet, civilian users have not had access to this latest type of imagery.

Taking those optical sensors that are available to civilian users and which generate space imagery that is suitable for topographic mapping purposes, it is convenient to classify them on the basis of ground resolution. A convenient classification is the following:-

(i) images having a ground resolution < 5m;

(ii) images having a ground resolution of between 5m and 10m; and

(iii) images having a ground resolution > 10m.

Because of their very different formats and products – which are very important in the context of image mapping – it is also convenient to differentiate space sensors into two categories:-

(a) film cameras that generate images in the form of photographic film; and

(b) scanners that employ solid-state CCD detectors to generate images in the form of digital data.

Combining these two classifications, the following Table (4-1) can be generated to summarize the main space sensors that are currently of interest for topographic mapping and, in particular, image mapping. This Chapter (4) will deal with the space photographic sensors: the next Chapter (5) will deal with the space scanner sensors.

Class	Resolution	Photographic Sensor	Scanner
1	< 5m	KFA-3000; KVR-1000	IKONOS-1; EarlyBird; QuickBird; OrbView3
2	5 to 10m	KFA-1000; TK-350; MK-4	IRS-1C, 1D; SPOT Pan
3	>10m	MC; LFC; S-190B	TM; SPOT XS; MOMS-2P; JERS-1 OPS

Table 4-1: The Classification of Space Photogrammetric and Scanner Systems Based on Ground Resolution

4.2 Spaceborne Photographic Systems and Imagery

Photography taken from space has been available ever since the first manned space missions of the 1960s. However, generally speaking, space photography of a useful resolution for topographic mapping was not available for public access and use. A useful experimental mission was conducted from the Skylab in the mid-1970s, including photos taken with the S-190B reconnaissance camera. However it was only when the Space Shuttle appeared that the first non-military photogrammetric photography of the Earth was taken from space in 1983 with the ESA Metric Camera (MC) followed by the NASA Large Format Camera (LFC) in 1984. Recently, photographs from the Russian space camera systems, which originally had been designed for military purposes, have been made available on the international market. This photography has been provided by several different camera systems such as KFA-1000, KFA-3000, MK-4, TK-350 and KVR-1000. The main characteristics of all these different types of space camera and photography are set out in Table 4-2.

Film Camera Type	Format (cm)	Focal Length (m)	Angular Coverage	Flying Height (km)	Ground Coverage (km)	Photo Scale	Ground Resol. (m)	Orbital inclination	B:Ht. Ratio
S-190B	11.5x11.5	0.46	14 x 14°	435	109 x 109	1:946,000	15-30	50°	0.10
MC	23 x 23	0.30	42 x 42°	250	190 x 190	1:820,000	16-33	28.5°	0.3
LFC	23 x 46	0.30	42 x 75°	225	170 x 340	1:740,000	10	57°	0.6
KFA-1000	30 x 30	1.00	17 x 17°	270	80 x 80	1:270,000	5-10	83°	0.12
KFA-3000	30 x 30	3.00	6 x 6°	270	27 x 27	1:90,000	2-3	83°	0.04
TK-350	30 x 45	0.35	46 x 65°	220	190 x 280	1:630,000	7-10	67°	0.52
MK-4	18 x 18	0.30	33 x 33°	280	160 x160	1:930,000	10	83°	0.24
KVR-1000	18 x 18	1.00	8.5 x 8.5°	220	40 x 40	1:220,000	2	67°	-

Table 4-2: Characteristics of Space Cameras and Photography

4.2.1 American Satellite Reconnaissance Programme

However one cannot write about space photography without first mentioning the American satellite reconnaissance programmes conducted during the Cold War period. In fact, CORONA was the programme name for this first operational space reconnaissance project, which, along with two other satellite programmes (known as ARGON and LANYARD), was managed jointly by the CIA and the US Air Force. Within this project, each satellite would periodically eject and de-orbit a capsule containing exposed film, which would be sent to the

CIA's National Photographic Centre for development, interpretation and analysis of the photographs (McDonald, 1995a, 1995b).

(i) **ARGON** was a mapping photographic system which flew on seven successful missions between May 1962 and August 1964. Project ARGON was designed to satisfy the urgent need of the US Army Map Service (AMS) to obtain precise geodetic data for pinpointing targets in the Soviet Union using a reconnaissance satellite. ARGON's camera was designated as the KH-5 system.

(ii) **LANYARD** was a project designed to provide a significant information for intelligence purposes using super high resolution photographs of suspected military sites. Although designed to produce images with a resolution of less than 2 feet (0.6m), it collected photographs with a best ground resolution of only 6 feet (2m). Because of this, its single mission in 1963 was considered to be only partially successful. LANYARD's camera was known as the KH-6 system.

(iii) **CORONA** was the longest lasting American reconnaissance satellite programme which was operated from August 1960 to May 1972. During its missions, CORONA collected over 800,000 images that were used for both intelligence and mapping purposes. Initially, the images were acquired at a ground resolution of 8m and then quickly improved to 2m. CORONA's cameras were designated as the KH-1, KH-2, KH-3, and KH-4 systems. The two final modifications of the CORONA camera were designated as the KH-4A and KH-4B models. The dual KH-4 camera system was the first camera system to provide stereoscopic imagery. This increased the information content by a factor of 2.5 times. The KH-4B camera was developed further to give the best quality images; in some cases, its resolution was as good as 4.5 feet (1.5m).

All of this imagery has recently been declassified and archived in the EROS Data Center located in Sioux Falls, South Dakota and is now available to civilian users. Its main value is almost certainly in providing baseline images from the 1960s that can be used in environmental monitoring. Its 30 year age and the matter of its panoramic camera operation and format will almost certainly preclude the use of CORONA photographs for the production of a new image map series.

4.2.2 Skylab S-190B ETC

The manned Skylab project was planned and implemented by NASA, the space station being launched into a circular orbit with an altitude of 435 km in May, 1973. The Skylab S-190B Earth Terrain Camera (ETC) was included in the payload to meet the objective of providing earth scientists and cartographers with high resolution satellite photographs (Welch, 1976). This type of camera had a small (5 x 5in) format and a limited field of view (14°). When operated with a 60% overlap, its base:height ratio was very low (0.10). Thus the use of this camera for stereoscopic height determination was restricted. Keller (1976) carried out an accuracy test on the S-190B photography, which gave a planimetric accuracy (r.m.s.e.) of ±17m and a height accuracy of ±115m. More extensive tests carried out at the University of Glasgow by El Hassan (1978) resulted in a planimetric accuracy ranging from ±20 to ±25m and an elevation accuracy of ±60 to ±90m. According to Welch (1976), the production of photomaps using S-190B photos had to be limited to scales smaller than 1:50,000 and 1:100,000 for products derived from the panchromatic (black and white) and colour/colour infra-red photos respectively. This camera only operated on an experimental basis and no systematic coverage was obtained with it. Obviously too the photographs record the landscape of 25 years ago. Accordingly, the S-190B photography is not suitable for any current national mapping programme.

4.2.3 Metric Camera (MC)

The Metric Camera (MC) was a European and West German experiment in 1983 in which a modified Zeiss RMK 30/23 camera equipped with a normal angle lens was carried into space mounted in the Spacelab within the Space Shuttle. Unfortunately the camera was not equipped with forward motion compensation and the flight was carried out in December under a very low sun angle, as a result of which, the photo resolution was lower than expected. Many accuracy and interpretation tests were carried out by several investigators to determine the degree to which the MC photographs could contribute to topographic mapping. Engel and Konecny (1985) carried out one of these tests at the University of Hannover in Germany to evaluate the use of MC photographs for orthophoto generation, which is required for the production of orthophotomaps. In this test, they confirmed the usefulness of the MC photographs for orthophoto mapping at 1:100,000 scale, but they also concluded that any further enlargement would reduce the possibility of interpretation due to the visibility of the film grain.

In the African context, several other experimental tests designed to produce space orthophotographs from MC stereo-pairs were carried out over various areas in the Sudan by European experimenters. These included an orthophotograph of the Khartoum area produced by the French IGN (Ducher, 1985) and another of the Gezira area produced at the University of Hannover using a Kern analytical plotter in conjunction with a Zeiss Orthocomp Z2 analytically-controlled orthophotoprinter (Engel and Konecny 1985; Schroeder et al 1985).

However the most detailed tests in the Sudan were those carried out at the University of Glasgow (El-Niweiri 1988; Petrie & El-Niweiri 1992) using a test area located in the arid Red Sea Hills. A quite dense DEM amounting to 182,000 height points was first measured and extracted from the stereo-pairs using a Kern DSR-1 analytical plotter. This formed the basis for production of the orthophotograph at 1:250,000 scale using an analytical controlled Wild OR-1 orthophotoprinter. This scale was chosen since it gave the maximum possible enlargement from the MC photographs at 1:820,000 scale that could be accommodated in the OR-1. The results from a planimetric accuracy test carried out on the orthophotograph gave an RMSE value of ±48m at 30 control points and ±36m at 45 check points. These values were well within the planimetric accuracy requirements for topographic maps at 1:250,000 scale where an RMSE = ±0.3mm on the map is equivalent to ±75m on the ground. The tests carried out by El-Niweiri were extended further to include an assessment of the interpretational qualities of the MC photography. In general terms, these showed that the boundaries of many hydrological features, landforms and vegetation/landcover types could be detected and extracted from the MC space photographs. However the results of trying to identify and measure many of the communication features (minor roads and tracks, railways, etc.) were poor, as were those concerned with the detection of settlement features. Obviously all of this important information would have to be obtained via an extensive supplementary field completion operation, that inevitably would be time-consuming and expensive.

In the Libyan context, it is interesting to note the tests carried out by Meneguette (1985, 1988) over areas in France and Libya. From these, she concluded that the MC photos with its ground resolution should be suitable, purely in terms of geometric accuracy, to produce 1:100,000 scale topographic line maps and photomaps, but the identification of detail was insufficient for mapping at such a scale without very substantial field completion. Moreover, due to the limited height accuracy, only 50 to 70m contour intervals could be achieved. So she felt that the MC photography could be used for mapping and map revision at 1:250,000 scale and smaller; for orthophotographs with enlargements up to 1:100,000 scale; and for thematic mapping. However this photography is now 15 years old and its coverage over Libya (only two strips) is quite small and fragmentary. Arising from this, the MC photography cannot be adopted for the further production of the national image mapping series in the country.

4.2.4 Large Format Camera (LFC)

In October 1984, approximately one year after the MC experiment, another space photographic system – the Large Format Camera (LFC) – was orbited by NASA on Space Shuttle mission STS-41G with much the same scientific objectives as the Metric Camera (MC). This camera was built by Itek Optical Systems with an advanced optical system designed to satisfy the specifications of topographic mapping at 1:50,000 scale. An attitude reference system had also been built for use with the LFC. Again, the main characteristics of the LFC and its photography are summarised in Table 4-2. From this Table, it will be seen that the photo scale is 1:740,000. Also it is interesting to note that the base-to-height ratio was improved through the orientation of the larger side of the format in the direction of the flight. The common operating mode was 80% forward overlap, but 60% and 10% were also used. Stereo-models could be provided with a base-height ratio of 0.3 to 1.2 by selecting the appropriate frames.

Many tests using LFC photography taken over various test areas have been reported (see Table 4-3) in various publications by Derenyi & Newton (1986, 1987); Petrie & El-Niweiri (1992, 1994); and Dowman (1988). Other tests carried out by Togliatti, Hartley, and Jacobsen (1987) indicate similar results. The general conclusion was that mapping can be carried out at 1:100,000 scale using the LFC photography but a considerable amount of field completion would still be needed.

Reference	Test Area	Accuracy (r.m.s.e)		Remarks
		Planimetric (m)	Height (m)	
Derenyi & Newton (1986, 1987) at New Brunswick University	- Canada	±13.5 to ±16.2m ±12.5 to 15.3m	±15.5 to ± 24.4m ±13.1 to ±16.4m	In their tests, it has been concluded that topographic maps at 1:50,000 scale with contour intervals of 75m (using analogue methods) or 50m (using digital methods) can be compiled from LFC photos.
El Niweiri (1988), Petrie & El Niweiri (1992, 1994) at Glasgow University	- Sudan	±20m	±19m	According to their results, both planimetric and height accuracy values were improved over those using MC photography. Also it has been reported that the amount of details which can be obtained from the LFC photos is larger than that which is estimated to be possible with MC photographs.
Dowman (1988) Ordnance Survey tests on behalf of OEEPE	- Sudan	Average of: 187m	±30m	These results are very much poorer than those reported by Petrie and El Niweiri. As described by Hartley (1987), the main reasons for these very disappointing results were poor photographic quality and resolution and difficulties in GCPs identification and transfer.

Table 4-3 The Results of Tests Carried Out by Several Investigators Using LFC Photos.

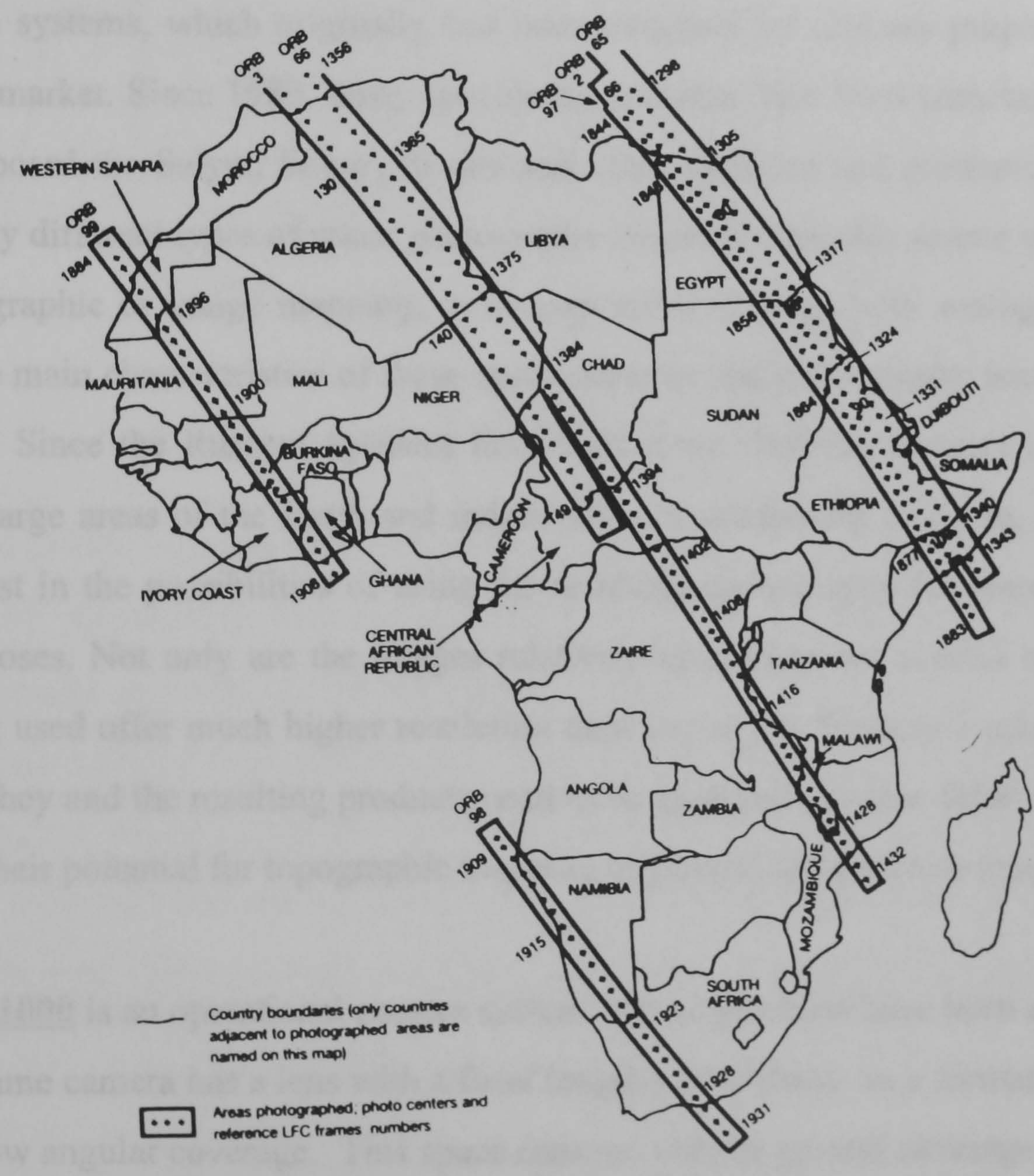


Figure 4-1: LFC Coverage in Africa

Since the LFC space photography is now 15 years old and has almost no coverage over Libya, this type of photograph cannot be used for national mapping purposes in Libya. As a matter of fact, the space photographic camera systems such as MC and LFC utilised by Western Countries have only operated on an experimental basis for a short time in 1983/1984 and only collected patchy and discontinuous coverage (see Figure 4-1). This was a result of the Challenger disaster in 1986 and the stopping of further Space Shuttle flights for 4 years. As a direct consequence of this decision, further scheduled flights of the MC and LFC cameras were first badly postponed and eventually cancelled. This was a great disappointment to the topographic mapping community since much was expected from the follow-on flights.

4.2.5 Russian Spaceborne Photography

The collapse of the Soviet Union made it possible to bring the photography from the Russian space camera systems, which originally had been designed for military purposes, on to the international market. Since 1980, many spaceborne cameras have been launched by Russians agencies on board the Salyut, Soyuz, Resurs and other satellites and platforms. As a result, there are many different types of space photographs available from this source which could be used in topographic or image mapping, or in map revision using both analogue and digital methods. The main characteristics of these space cameras and photography have been set out in Table 4-2. Since the Russian agencies have used these cameras to carry out systematic coverage of large areas of the Earth and indeed are still continuing to do so, there is much current interest in the possibilities of using the resulting photography for mapping and map revision purposes. Not only are the images relatively up-to-date but several of the cameras that are being used offer much higher resolution than any of the Western cameras mentioned above. Thus they and the resulting products need to be analyzed in some detail with a view to establishing their potential for topographic mapping in general and photo or image mapping in particular.

(i) The **KFA-1000** is an operational camera system, whose products have been available since 1987. This frame camera has a lens with a focal length of 1,000mm on a format of 30 x 30cm giving a narrow angular coverage. This space camera, with its ground coverage of 80 x 80km and a ground resolution of 5 to 10m from its normal orbital height of 270km, has a superior performance in this respect to any other space photographic sensor so far discussed. Normally two cameras are mounted in the satellite to photograph a strip to either side of the sub-flight track (Fig. 4-2). Both of the cameras are inclined outwards by 8 degrees from the nadir direction. An overlap of 60% is available between the two adjacent along-track images, allowing the possibility for viewing the images stereoscopically. However, the base:height ratio of the adjacent photographs is too small (0.12) for these images to be considered seriously for height determination. Calibration standards and grey level scales are not given with each photograph, and so the potential for the detailed analysis of the radiometric data is restricted to relative brightness levels.

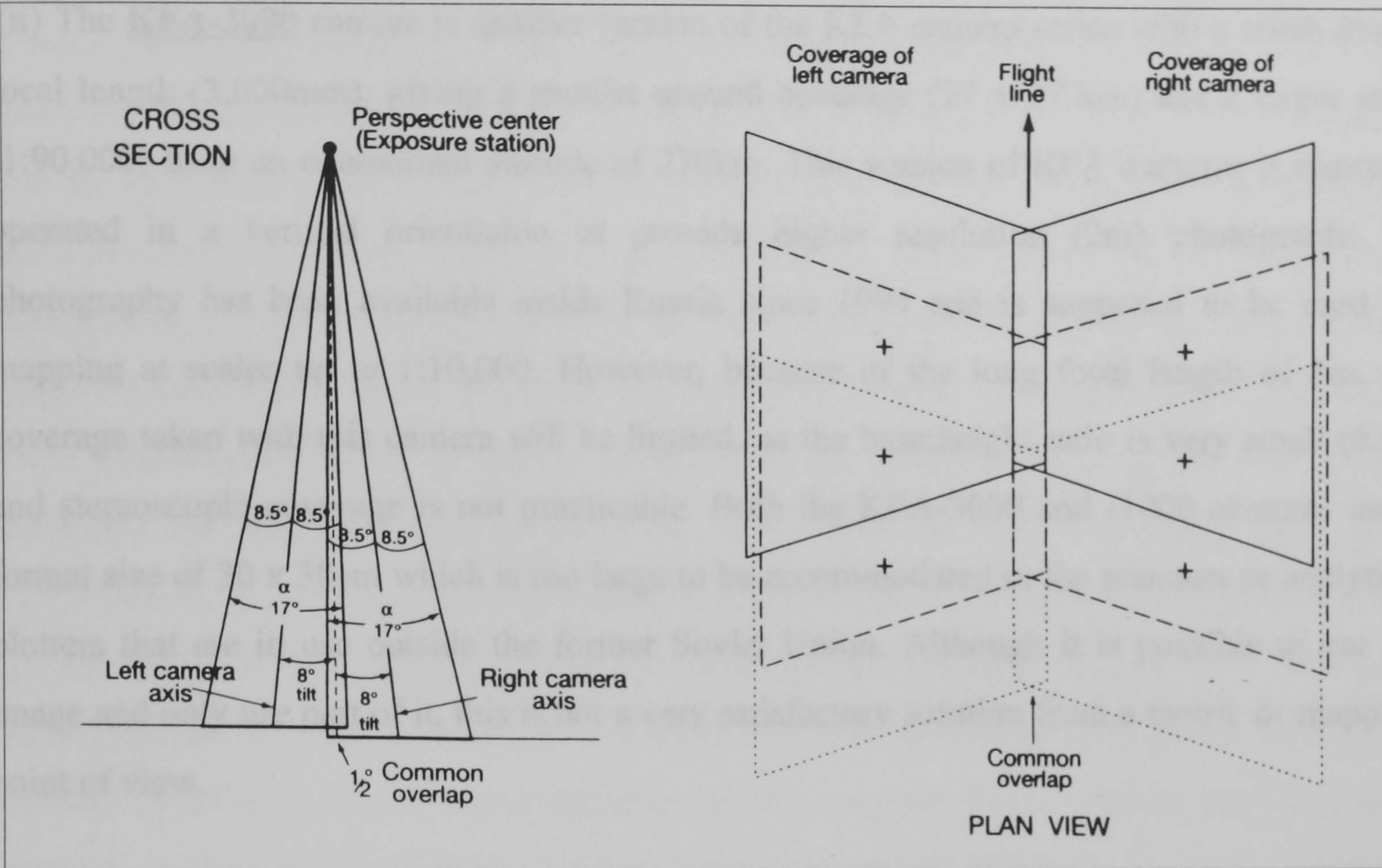


Figure 4-2: Geometric Arrangement of KFA-1000 Photography

Konecny et al (1988) reported the results of tests carried out using a bundle block adjustment of 7 KFA-1000 photographs over the areas of Munich and Hannover in Germany. In these tests, a planimetric accuracy of ±10.6m (for the Munich area) and ±6.9m (for the Hannover area), and height accuracies of ±29.9m and 32.9m respectively were achieved. Similar results for horizontal and vertical accuracy have been obtained for the Hannover area by Jacobsen (1993), who reported that built-up areas, rivers, railways, highway and main streets can be identified with near 100% accuracy, whereas narrow streets, small buildings, etc. cannot be detected.

As reported by Kaczynski (1996a), the image co-ordinates measured on KFA-1000 photographs have to be corrected for the big radial distortion that is characteristic for the lens of this space camera and for the deformation of the Russian spectrazonal film. Kaczynski (1996b) has also published the results of his tests carried out at the Institute of Geodesy and

Cartography in Poland using KFA-1000 photographs. A planimetric accuracy of ±7m and a height accuracy of ±30m were achieved. As a result of all his tests, Kaczynski felt that the KFA-1000 photographs can be used for production of orthophotomaps and the updating of maps at scales up to 1:50,000. However about 20% of the topographic details which should be presented on a map at 1:50,000 scale must be acquired through field completion.

(ii) The **KFA-3000** camera is another version of the KFA camera series with a much longer focal length (3,000mm), giving a smaller ground coverage (27 x 27 km) and a larger scale (1:90,000) from an operational altitude of 270km. This version of KFA cameras is normally operated in a vertical orientation to provide higher resolution (2m) photographs. Its photography has been available inside Russia since 1994 and is supposed to be used for mapping at scales up to 1:10,000. However, because of the long focal length of 3m, the coverage taken with this camera will be limited, so the base:height ratio is very small (0.04) and stereoscopic coverage is not practicable. Both the KFA-3000 and -1000 cameras use a format size of 30 x 30cm which is too large to be accommodated in the scanners or analytical plotters that are in use outside the former Soviet Union. Although it is possible to cut the image and only use part of it, this is not a very satisfactory solution from a metric or mapping point of view.

(iii) The **MK-4** camera system has been used in the RESOURS-F-2 satellite since 1989. It is usually operated with four cameras in a multi-spectral mode with four-coupled lenses which operate simultaneously. One of them is loaded with a two-layer colour (spectrazonal) film while the other three utilize black-and-white films with differing spectral filters used to separate the spectral bands. The MK-4 was designed as mapping camera with a focal length of 0.30m and providing photos with ground coverage of 160 x 160km and a photo scale of 1:930,000 from an orbital altitude of 280km. This scale is still smaller than that of the MC and LFC cameras (see Table 4-2). This camera can provide photos with 60% forward overlap which gives a stereo-coverage with a base:height ratio of 0.24: again these are poorer (i.e. lower) values than those achieved with the MC (0.3) and LFC (0.6). In comparison with the other Russian cameras, the MK-4 photography has a somewhat better base-to-height ratio but less ground resolution (said to be approximately 10m) than the KFA cameras, although its ground resolution still lies in the class of the LFC. The camera is equipped with forward motion compensation. For a more general description of the camera, see Kienko et al (1990).

According to Jacobsen (1992), the MK-4 photography is also characterised by quite large and irregular image distortions. These distortions appear to be a consequence of substantial asymmetric lens distortions and/or a lack of film stability. Thus image co-ordinates measured on the MK-4 photos have to be compensated for before further photogrammetric computations or mapping operations can be undertaken. A series of geometric accuracy tests were conducted on the MK-4 photos by Jacobsen (1993), who reported a planimetric accuracy (r.m.s.e.) of $m_X = \pm 14.6$m and $m_Y = \pm 14.4$m, and a height accuracy of $m_Z = \pm 28.5$m. According to Jacobsen (1992), MK-4 photos are also useable for mapping at 1:50,000 scale. Due to their format size (18 x 18cm), they also have the advantage of allowing simple photogrammetric handling similar to that of aerial photographs. They can even be used in analogue stereo plotters such as Wild A10 or Zeiss Planicart which can accommodate photos with f = 30cm. Marek (1990) also pointed out that the multi-spectral mode may permit a little better identification of some linear features and of different agricultural areas. Marek concluded that the production of line maps up to 1:50,000 scale and image maps up to 1:25,000 scale is possible using MK-4 photos. However this does seem very optimistic, since the MC has the same focal length (0.3m), produces photos with larger format (23 x 23cm), has better lens and film specifications, and still can only provide photos with ground resolutions between 16 to 33m – yet no one would claim or even suggest that it could be used for image mapping at that scale. Indeed to produce image maps at 1:25,000 scale from the 1:930,000 scale of the original MK-4 photography would require an enlargement ratio of 37.2:1 which, in any practical terms, seems quite unlikely.

(iv) The Russian **TK-350,** camera seems to have much more favourable photogrammetric characteristics than those discussed above. This camera system was developed by Russian military mapping agencies to provide both high resolution imagery and accurate surface elevation data from space imagery. In many respects, it is similar to the American LFC camera. The TK-350 is generally flown on the KOSMOS series of spacecraft from an altitude of 220km which, using its f = 0.35m lens, gives a photographic scale of 1:630,000. It can provide an along-track overlap of up to 80%, providing good stereo-imagery with B/H ratio as high as 0.52. The ultra-large format (30 x 45cm) of the TK-350 covers an area of approximately 190 x 280 km from a flying height of 220km. Photography taken with the TK-350 camera is also characterised by both a reasonably high ground resolution (7 to 10m) and good geometry as a result of its better base:height ratio of 0.52. The TK-350 is a fully metric camera and provides photographs which are used to produce maps up to 1:100,000 scale.

However these photographs with their 30 x 45cm format are not easy to accommodate in western photogrammetric instrumentation built to handle either the standard 23 x 23cm format or, in the case of those few instruments designed to accommodate the LFC photography, the 23 x 46cm format.

The TK-350 photographs have been used widely by Russian military mapping agencies in cartographic applications since there are only relatively low spatial distortions in its data. The photos can be enlarged to a scale of 1:50,000 without significant loss of detail. Kaczynski (1996b) has carried out a set of tests in Poland and reported that a digital terrain model (DEM) has been generated using TK-350 stereo photos with an accuracy (r.m.s.e.) of ±13m in planimetry and ±7 to 10m in height. Again, according to Kaczynski (1996b), the TK-350 photos have been tested by the Defense Mapping Agency (DMA) in the USA and in Russia to give r.m.s.e. values of ±13m in planimetry and ±10m in height. Obviously, this planimetric accuracy is sufficient for producing topographic line maps and image maps up to the scale of 1:50,000 (where 0.3mm = 15m) and updating maps in the scale 1:25,000. – though the ground resolution (7 to 10m) may not be sufficient to allow the required features to be extracted. On the other hand, the height accuracies point to a minimum contour interval of 30m which may not be adequate to represent areas of flat terrain.

(v) The **KVR-1000** is a panoramic camera with a focal length of 1,000mm. It has a rectangular format of 18 x 72cm, with the longer length oriented in the cross-track direction. Thus its image scale will vary greatly over the longer dimensions of its frame. In fact, the KVR-1000 exhibits the extreme variations in scale and resolution across its scan field typical of any panoramic camera. However, the central part of the KVR image will have a near-vertical orientation, very high resolution and comparatively large scale (1:220,000 from an orbital altitude of 220km using its f = 1,000mm lens). With this in mind, this central area of 18 x 18cm is that supplied to most users and cuts the scale variations at the edges to 1:220,900. In this form, the KVR-1000 imagery has been offered to non-Russian clients both in hard copy and digital (DD-5) form. Since the camera can only be operated with 20% forward overlap, practical stereoscopic viewing is impossible.

Two film types can be used with the camera – either panchromatic or spectrazonal false colour. The real spatial resolution is said to be 0.7m in the original photograph, and this has been reduced to about 2m according to the space data handling regulations which have been imposed by the Russian government. More general descriptions of the camera and some results of using its photos for mapping at scales up to 1:25,000 have been given by Marek and Weigelt (1993), Söllner (1993), and Kaczynski (1996a, 1996b). As reported by them, the KVR-1000 photos have been used to produce satellite image maps and for map revision purposes. It is still in use and has covered quite a large part of the world. The black and white photos of the KVR-1000 are also distributed in digital form as SPIN2 images (having a 1.5m ground pixel size). They are often used together with TK-350 photos which provide stereoscopic coverage while the KVR gives high spatial resolution to aid the detection and interpretation of terrain features.

4.2.5.1 Analysis of the Potential Use of Russian Space Photography

In summary, it will be seen from the above discussion that much attention has been focussed recently on the photography produced by various Russian space cameras, especially those utilizing long focal length lenses resulting in high resolution images. According to Kaczynski (1996a), the KFA-1000, KFA-3000, and KVR-1000 photographs have been used mainly for satellite image map production and for map updating activities at 1:50,000 scale (from KFA-1000 photos), at 1:25,000 scale (in the case of KVR-1000 photos), and at 1:10,000 scale (from the KFA-3000 photos). Since the KFA-1000, KFA-3000, and KVR-1000 photographs do not have a base:height ratio that is useful for height determination, mapping operations carried out using these cameras can only be purely planimetric in character. Furthermore these photos should be used principally for mapping flat areas, otherwise relief corrections will need to be provided through the use of a DEM acquired from another source. Specific problems that have arisen are those related to photo distortions (in the case of the KFA-1000 and MK-4), and ultra-large format size (in the case of KFA-1000, KFA-3000, and TK-350). The latter are difficult to handle with the analytical plotters and scanners available outside the former Soviet Union and this will increase the time and cost of processing these types of photos and degrade the quality of such images.

4.2.5.2 The Suitability of Russian Space Photographs for Image Mapping in Libya

Turning next to the matter of Libyan coverage, the MK-4 and KFA-1000 cameras have produced some coverage of Libya of the areas around Tripoli and Benghazi and in the southern part of the country (the border area between Libya and Chad) – see Figures 4-3a and

-b which have been obtained from a web site (http://www.tentoten.co.uk/coverage/africa.html). Furthermore the TK-350 and KVR-1000 cameras are reputed to be able to cover any latitude up to 70° either side of the Equator – cloud permitting. However it seems not to be easy to obtain detailed information regarding the Russian photographic coverage, availability and quality, and to be sure that the images will indeed be supplied in a reliable and regular manner. This is of course partly a consequence of the quite short duration of the Russian photographic flights – which leads to frequent flights to get extensive areal coverage – and the need to recover the films for processing once they have been exposed. Thus, for a country like Libya, it may be difficult and unwise to rely on them for its national mapping programme.

Furthermore let us suppose that Libya was able to acquire complete and systematic coverage of its land surface using the different types of Russian space photography (the KFA-1000, KFA-3000, MK-4, TK-350, and KVR-1000 photos). The production of image maps by digital methods using these data requires the conversion of the analogue (hard copy) form of these photos to digital form through the use of scanners in order to process them applying digital image processing techniques. This leads to the problem of finding scanners that can handle the large (30 x 30cm and 30 x 45cm) Russian photo formats. Even if such a device can be found, as far as the image mapping of the whole of Libya is concerned, this will increase the time needed and cost for producing such products. Besides, among the Russian cameras mentioned above, only the TK-350 camera can produce photos with a reasonable base-to-height ratio (0.52) and allow the stereo-coverage which is necessary for DEM generation and in turn is required for ortho-image production. With all of these matters in mind, the author thinks that the Russian photography is not suitable for the production of a national image map series of Libya. Instead these photos can be considered for map revision purposes and may be used as an additional source of information in urban or developed rural areas where certain features are difficult to map from alternative lower resolution satellite scanner imagery such as that provided by SPOT or IRS-1C/1D.

(A) MK-4

(b) KFA-1000

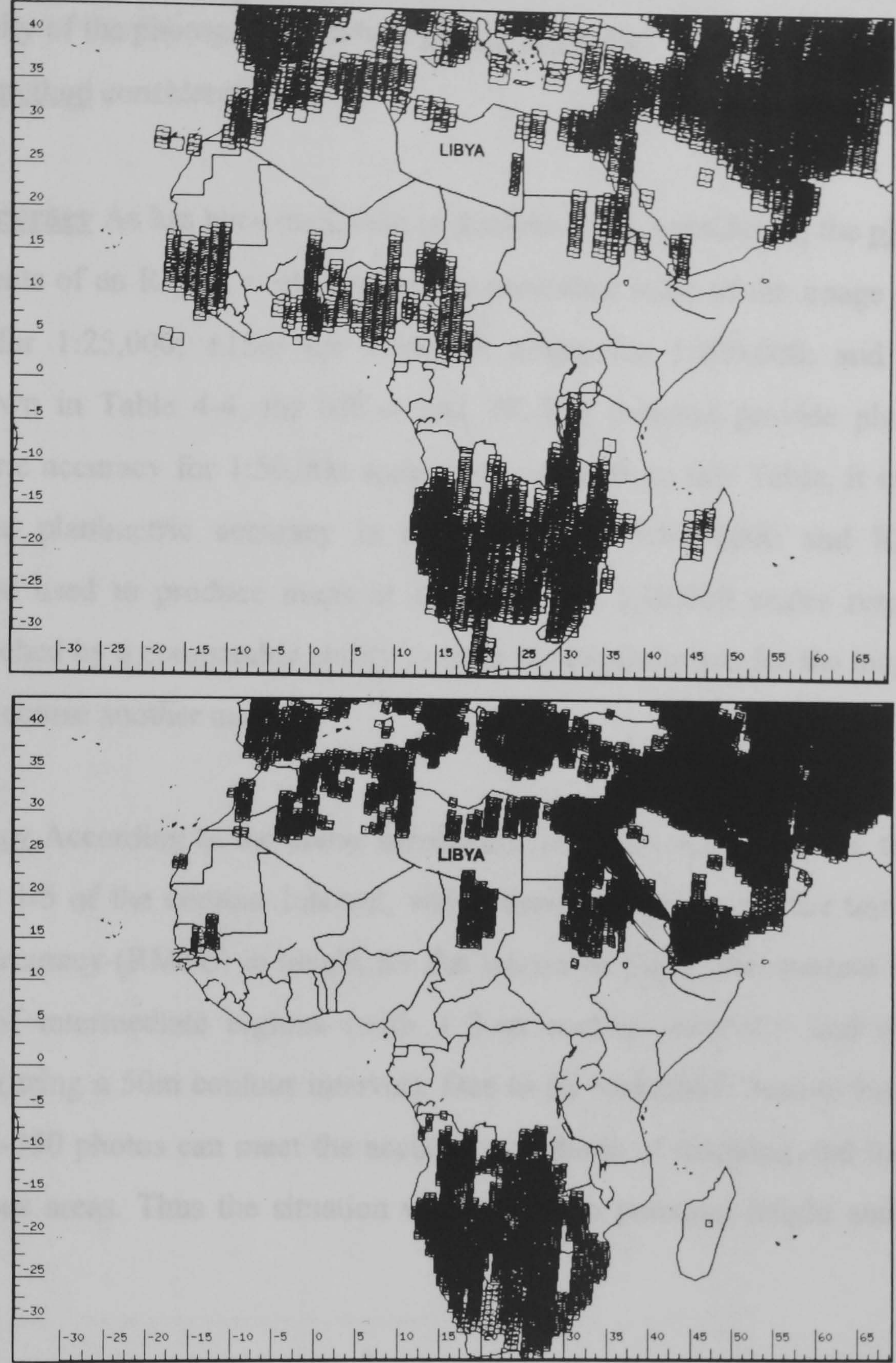


Figure 4-3: The photographic coverage of (a) the MK-4 and (b) the KFA-1000 cameras over Libya

4.2.5.3 More Detailed Analysis

To evaluate the suitability of the Russian space photography for image mapping in Libya in more detail, six criteria must be considered:-

(i) the <u>planimetric accuracy</u>;

(ii) the <u>height accuracy</u> achievable;

(iii) the <u>detectability</u> of objects from the imagery;

(iv) the availability of a systematic coverage of the imagery over the whole country;

(v) the availability of the photographic data in digital form; and

(vi) production method considerations.

(i) **Planimetric Accuracy** As has been explained in Section 3.2.4, considering the planimetric accuracy requirements of an RMSE = ±0.3mm at the published scale of the image map, this results in ±7.5m for 1:25,000; ±15m for 1:50,000; ±30m for 1:100,000; and 75m for 1:250,000. As shown in Table 4-4, the MK-4 and TK-350 cameras provide photos with sufficient planimetric accuracy for 1:50,000 scale maps. Also from this Table, it is obvious that, as far as the planimetric accuracy is concerned, the KFA-1000 and KFA-3000 photography can be used to produce maps at 1:25,000 and 1:10,000 scales respectively. Whether this is matched by a comparable ability to meet the requirements for the map content at these scales is of course another matter.

(ii) **Height Accuracy** According to the above mentioned map accuracy standards, the height accuracy should be 1/5 of the contour interval, which depends entirely on the terrain. This means ±2m point accuracy (RMSE) in height for flat terrain (using a 10m contour interval); ±4m in the case of intermediate regions (with a 20m contour interval); and ±10m for mountainous areas (using a 50m contour interval). Due to its reasonable base-to-height ratio (0.52), only the TK-350 photos can meet the accuracy standards of mapping and then really only for mountainous areas. Thus the situation with regard to potential height and contour accuracy is poor.

(iii) **Detectability** requirements rely on the ground resolution of the photography; the nature of features or objects to be mapped; and the contrast of the features with their surroundings when detecting individual map elements. Considering the Kell factor to be equal to 2 results in requirements for a 2m ground resolution for urban buildings; a 5m ground resolution for minor roads and fine hydrological features; and a 10m ground resolution for major roads and building blocks. For information content and feature extraction, the photographs produced by the KFA-3000 and KVR-1000 cameras obviously give much better results than the others (see Table 4-4), but a substantial amount of field completion will still need to be carried out to acquire the missing information.

Space Camera	Ground Resolution (m)	Planimetric Accuracy (m)	Height Accuracy (m)	Content/Feature Extraction	Photomap Scale	Mode of Operation/ Coverage of Libya	Suitability for Libyan National Mapping Programme
KFA-1000	5-10	±7 to 10.6	±30	80% of detail can be extracted	1:25,000 and smaller	Commercial / Fragmentary coverage	No contour or height data Not suitable
KFA-3000	2-3	±3	poor	85% of the detail can be obtained and shows the capability of having more detail	1:10,000 and smaller	Commercial / Fragmentary coverage	No contour or height data Not suitable
MK-4	7-10	±14.5	±28.5	75% of detail can be extracted	1:50,000 and smaller	Commercial / Fragmentary coverage	Inadequate height or contour data Not suitable
TK-350	10	13	10	75% of detail can be extracted	1:50,000 and smaller	Commercial / and covers area between longitude of 70° north and south the Equator	Height and contour data is OK for hilly and mountainous terrain. Large format size is a problem.
KVR-1000	2	±3 to 5	poor	85% of the detail can be obtained and shows the capability of having more detail	1:10,000 and smaller	Commercial / Fragmentary coverage	No contour or height data Not suitable

Table 4-4: The different photographic cameras and their mapping characteristics

(iv) **Systematic Coverage** The availability of a systematic coverage of the whole area needing to be mapped is a very important factor to be considered as far as Libyan national mapping is concerned. All of the older systems (S-190, MC and LFC) which have been discussed above in Section 4.2.2 to 4.2.4 have not produced systematic coverage for the country. It appears too that so far the MK-4, KFA-1000 and KFA-3000 cameras have only acquired a partial coverage of Libya. TK-350 and KVR-1000 are the only cameras that might have a complete coverage for the entire country, because they are both said to be covering areas up to 70° latitude north and south of the Equator.

(v) **The Availability of Digital Data** The availability of the photographic data in digital form is also important, since the digital image map production can save time, cost and gives better image map products.

(vi) **Production Method Considerations** For any mapping organisation that intends to produce a national image map series from space photographs for its country, considerations of the production methods that can be used cannot be ignored since they have a direct impact on the time and cost needed to accomplish the task. Moreover, arising from the non-availability of some specific facilities that may be required for the production procedures, this could result in the desired method of production facing more difficulties and so it may not be practical to use it. This matter will be discussed below in more detail.

4.3 Possible Methods of Producing Image Maps from Space Photography

In practice, there are three main methods of producing image maps using space photography – (a) the analogue method of production, (b) the digital method of production, and (c) the hybrid method of production. These three methods of producing image maps from space photography will be described and considered in some more detail in the following sections given below.

(a) **The Analogue Method**: Orthophotographs can be produced from the analogue film of space photography to form the basis of the final image map. In this case, one of these methods should be adopted:

- Space photo rectification: In this method, each individual space photo has to be rectified by means of a rectifier and the use of ground control points (GCPs) which can be derived by field survey methods, aerotriangulation or from existing maps. In fact, such a rectification only eliminates the effects of tilt and yields an equivalent vertical photo. However, unless the terrain is perfectly flat, a rectified photo will still contain scale variations as a result of the image displacements due to changes in relief which are not eliminated by the rectification process. Since an increase in ground elevation produces an increase in scale on the photograph, this may be reduced by decreasing the scale of projection correspondingly, thus achieving a constant overall scale. In this way, an optical rectifier can be used to correct relief distortion as well, but the method has several disadvantages. For this method to be applied, either an existing contour plot has to be available or a new one has to be created which demands the use of a photogrammetric plotting machine. This is a time consuming addition to the process and does not provide accurate enough results especially if long-focal length photos are being used. Then, the individual zones of the photos lying between each pair of contours can be projected to a common scale. Finally the individually rectified photographs have to be assembled into a mosaic using feathering techniques to form the basis of a specific map sheet. Altogether this is a very elaborate and time-consuming procedure which demands much skill and still might not give good results. It is inconceivable that the method could be used nowadays.

- Orthophotograph production: Since most terrain has some relief present, it is evident that the production of an orthophotograph is an essential first step towards the production of accurate image map using the space photographs. However this is only practical if a suitable stereo-model can be created and measured. As discussed previously, only the TK-350 has a base-to-height ratio that is really suitable for the purpose. In which case, an orthophotograph can be produced by the use of an analytical plotter plus an orthophotoscope or orthophotoprinter specifically designed for this purpose. Individual orthophotographs can then be joined together to form an orthophotomosaic of the area to be mapped.

The final negative orthophotograph mosaic which is produced by any of the above described methods, will be used afterwards to produce the background image for the final orthphotomap. As discussed above, the first method is time consuming, tedious and costly. Although the second method provides highly accurate results, it requires suitable photos and appropriate photogrammetric instruments designed specifically to produce orthophotographs. In such a situation, due to format differences and poor base:height ratios, most of the Russian space photography cannot be handled using the stereo-plotters available on the international market. Besides, if SDL intended to use space photography for orthophotomap production for the whole country in this way, the lengthy processing time and very high cost must also be considered.

(b) **The Digital Method:** It is possible to produce orthophotos using space photos in digital form. In this procedure, the space photographs must first be converted to digital form by means of a scanner and transferred to a suitable computer system. Through the use of suitable digital image processing and appropriate software packages and techniques, each space photo can be geometrically and radiometrically corrected. In turn, the individual rectified or orthorectified photos can be mosaiced to produce a mosaic for the whole area to be mapped. Afterwards, additional cartographic symbolisation will be added for the final photomap production. Indeed, nowadays it would be better to convert the space photos to digital form to take the advantage of the possibilities offered by digital image processing methods.

No.	Scanner	Scan Area (cm)	Linear Res (µm)	Accuracy (µm)	Pixel Size (µm)	Grey Levels	CCD Sensor	Roll Film	Computer
1	Geosystem Delta Scan	30x30	1	± 3	14	256	2048x1	No	PC
2	ISM DiSC	25x25	1	±5	9x9	1024	8000x1	yes	PC
3	Leica Helava DSW 100	25x25	1	± 3	8 to 75	256	1270x1270	No	Sun/PC
4	Leica Helava DSW 200	26.5x26.5	1	± 3	9 to 15	256	2029x2044	?	SUN
5	Leica Helava DSW 300	27x27	0.5	± 2	5 to 6	1024	2029x2044	Yes	Sun
6	Lenzar Lenzpro 2000/2001	30x30	0.25	<1	3 to 254	256/1024	Patch	Yes	SGI/Sun
7	Rollei-Metric RS	22x22	1	?	12x18	16 of 256	2048	No	?
8	Topcon PS 1000	24x24	1	3	11.5x13.5	?	280x488	No	PC
9	Vexcel VX 3000	25.4x50.8	1	3	8.5 to 160	256	512x512	Yes	SGI/Sun
10	Wehrli Raster-Master RM1	24.5x24.5	0.5	± 4	12 to 96	256	2048x1	No	PC
11	XL Ortho Vision	23x23	1	± 3	9 to 73	256	24,000x1	Yes	PC
12	Zeiss/Intergraph PS-1	26x26	1	± 3	7.5 to 120	256	2048x1	No	Interpo
13	Zeiss/Intergraph SCAI/TD	25x27.5	1	± 3	7 to 224	1024	5632x1	Yes	SGI/PC

Table 4-5: Digital Photogrammetric Scanners (Petrie, 1997)

However, there are also a number of disadvantages. One is the time and cost needed to carry out the conversion of the photos to digital form. It is worthwhile to mention, that, in this context, the conversion of space photos to digital form brings up the matter of the scanners that are currently available on the market (see Table 4-5). As can be seen from the Table, clearly there is a lack of devices that are able to handle Russian space photos. The only suitable device for use with the 30 x 30cm format is that from the Ukranian supplier Geosystems – though of course it could be that the Russian do have other suitable scanners for the task that could supply the data in digital form.

Even using digital data, the matter of correcting the digital versions of the space photographs for the variable relief displacements present on the images will still arise. Either a DEM must be available (e.g. derived from existing contour maps) or the displacements need to be eliminated either through manual operator-controlled measurements in a stereo-model or via automatic correlation (i.e. image matching) techniques. In which case, once again, the only photography having a suitable base-to-height ratio for such an operation is that taken with the TK-350 camera.

(c) **The Hybrid Method:** This is a mixture of the two methods described above (i.e. the analogue & digital methods), since it starts with the use of stereo-pairs of space photos (two film diapositives) in an analytical stereoplotter and ends up with the production of an ortho-image in a digital form which can be converted to a hard copy product by means of a high resolution raster plotter. The method is well illustrated by the PROMAP system which has been introduced by Adam Technology.

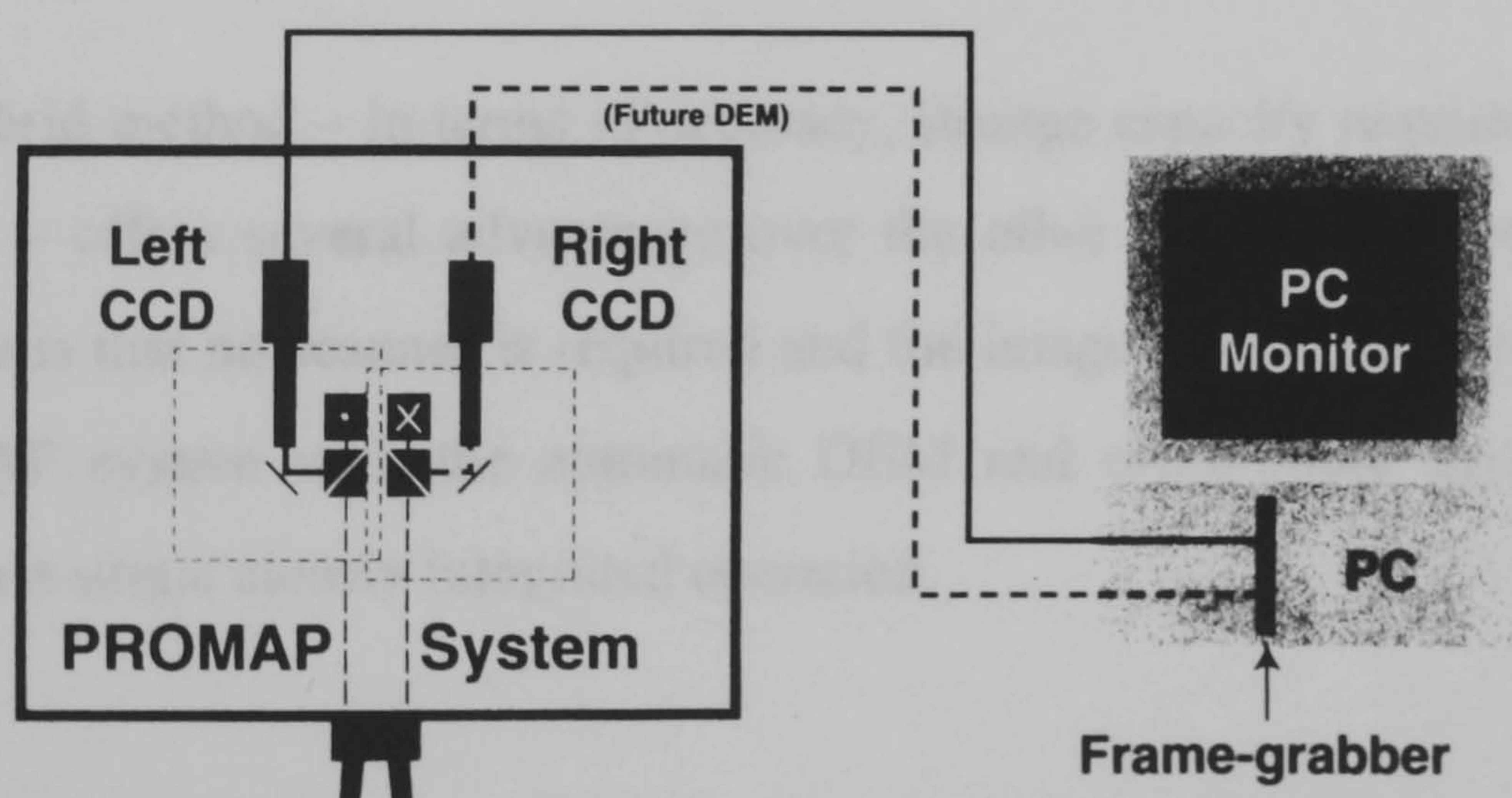


Figure 4-4: The main components of the Adam PROMAP System

As illustrated in Figure 4-4, the hardware associated with the Adam automatic DEM and ortho-photo generation option consists of two CCD cameras mounted in the Adam PROMAP analytical stereoplotter and a frame grabber mounted in the host PC. The CCD cameras view the same portion of the stereo-model as the operator, however with a smaller field of view. The frame grabber converts the video images from the cameras into digital images which can then be processed in the PC through the use of digital image processing techniques.

For DEM generation, the images are captured from the left and right CCD cameras. By means of image correlation software, a DEM can be generated. In addition, the operator has the ability to check the correlated points in stereo using either an anaglyph display (using red/blue glasses) on a basic stereo monitor or on a digital 3-D display. The DEM can also be checked via drive-back in the stereoplotter itself. The extracted DEM will be stored on hard disk and can also be used immediately for ortho-photo generation.

For ortho-photo production, the working image can be acquired in either colour or monochrome from the left image and simultaneously corrected for relief displacement. The DEM required for ortho-photo rectification to remove the height displacements present in the photographs can either be derived from another source or can be that generated in the analytical plotter. These corrected ortho-photo patches are stored on disk; in fact, the system works on one patch at a time until the whole model area is covered. The ortho-photos generated from the system can be exported to any image processing software system where they can be enhanced and joined together and mosaiced into completed map sheets. They can also be printed directly to any supported raster plotter. These ortho-photos will form the basis of the final image map.

In fact, this hybrid method – in terms of accuracy, storage capacity required, and cost & time reduction – offers several advantages over the other methods of production. The main advantage is that no scanner is required and the images are scanned patch by patch in the PROMAP system with the automatic DEM and ortho-photo generation being implemented in a single closely integrated operation.

4.4 Conclusion

In this Chapter, the characteristics of the different types of space cameras have been given. In particular, attention has been focused on the space photography produced by the Russian cameras and their topographic mapping potential. Based on a number of relevant criteria, the suitability of the space photography available for image mapping activities in Libya has been fully analyzed. Based on the detailed analysis conducted above, the author thinks that none of the products from the Russian photographic cameras that are now available can be adopted for the production of a nation-wide image map series of Libya at 1:50,000 and 1:250,000 scales. However they could be used in a supplementary role to aid interpretation and feature extraction in certain situations where imagery such as that produced by the SPOT and IRS-1C scanners may not provide an adequate ground resolution for such purposes.

The next Chapter will deal with the second main category of space sensors that are suitable for mapping purposes – which are the space scanners. Again a similar analysis will be carried out regarding their potential for national topographic mapping with a particular emphasis on their suitability for the comprehensive national mapping of Libya.

CHAPTER 5: HIGH RESOLUTION SPACEBORNE SCANNER SYSTEMS AND THEIR TOPOGRAPHIC MAPPING POTENTIAL

5.1 Introduction

The other group of satellite sensors that provide high resolution images suitable for topographic mapping purposes, employ imaging scanners to acquire digital image data from space. Among these sensors, the first and best known are those mounted on the American Landsat series of satellites, which have operated continuously since 1972. The Landsat MSS and TM sensors have both used optical-mechanical scanners in which a rotating mirror directs the ground radiation to the detector elements. Initially the MSS scanner was used giving a ground pixel size of 80m. The Thematic Mapper (TM) instruments have been operated since 1982 on board Landsats 4 and 5 and have provided space imagery with a ground pixel size of 30m. However the initial use of this technology was followed by a new approach using linear arrays of detectors employed in a pushbroom mode of operation that started with the MOMS sensor in 1983. A further advance came with the advent of the SPOT system in 1986 which allowed overlapping orbital images to be acquired from adjacent orbits to give stereo-coverage of the ground with a base:height ratio of up to 1. To a large extent, SPOT has been the main space sensor providing digital image data for medium and small scale topographic and thematic mapping over the last ten years. Other space sensors utilising linear array sensors such as the IRS and JERS-OPS have been developed more recently. They will be discussed in more detail later in this chapter, as will the forthcoming American commercial satellites (EarlyBird, QuickBird, IKONOS-1 and OrbView-3).

The intention in this Chapter is to analyze the various space scanning sensors with regard to their suitability for small-scale topographic mapping in general and to image mapping in particular. This analysis will be carried out with the specific needs for national mapping in Libya in mind. As will have already become apparent from the discussion in Chapter 4, the use of the digital image data acquired from scanners offers quite different possibilities for the implementation of image mapping to those that are possible using space photography.

5.2 Spaceborne Scanner Systems and Imagery

As mentioned above, initially scanners such as the optical-mechanical MSS and TM devices utilized in the Landsat series were used to acquire images of the Earth. Since then, pushbroom or linear array scanners based on the use of CCDs have been used ever since the MOMS-01 device was orbited in 1983 and 1984. This has been followed by the MOMS-02 mission from 1993 and the follow-on MOMS-2P mission since 1996. However these MOMS missions have all been experimental in nature – in this respect, the MOMS-01 and -02 missions were all carried out during short-duration flights on the American Space Shuttle 1983/84 and 1993 respectively. By contrast, linear array scanners have been deployed operationally on the SPOT series (1 to 4) since 1986 and on the Indian IRS-1C and -1D satellites since 1995. Also the Japanese JERS-OPS device launched in 1993 is of this type. The characteristics of all these various types of scanner imagery and those of the forthcoming missions (ASTER, EarlyBird, etc) are set out in Table 5-1.

Scanner System	Sensor Array Type	Orbital Height (km)	Swath Width (km)	Ground Coverage (km)	Ground Pixel (m)	Pointing		Orbital Inclination	B:Ht. Ratio
						Along Track	Cross Track		
Landsat TM	Opt. Mech.	705	185	185 x 185	30	No	No	98.2°	No
MOMS-01	Linear	300	140	140 x 140	20	No	No	28.5°	No
MOMS-02	Linear	296	78	78 x 78	13.5	±21.4°	No	28.5°	0.8
MOMS-2P	Linear	380/405	97/105	100 x 100	18	±21.4°	No	51.6°	0.8
SPOT 1 to 4	Linear	832	60	60 x 60	10	No	±27°	98.7°	Up to 1.0
IRS-1C/D	Linear	817	70	70 x 70	6	No	±26°	98.7°	Up to 1.0
JERS-OPS	Linear	570	75	75 x 75	18x24	0°/15.3°	No	98°	0.3
ASTER	Linear	705	60	60 x 60	15	0°/27.7°	±24°	98.2°	0.6
EarlyBird	Areal	475	6	6 x 6	3	±30°	±30°	97, 3°	Variable
QuickBird	Linear	470	36	36 x 36	1	±30°	±30°	52°	Variable
IKONOS 1	Linear	680	11	11 x 11	1	±45°	±45°	98, 1°	Variable
OrbView 3	Linear	460	8	8 x 8	1	±45°	±45°	97, 3°	Variable

Table 5-1: Characteristics of Space Scanner Imagery (Pan Only)

5.2.1 Landsat TM

The launch of Landsat-4 in July 1982 was the first in the second generation of satellites in the Landsat series. The two satellites (Landsat-4 and -5) were launched into near polar, circular, sun synchronous, repetitive orbits. However, their orbital altitude was lowered by 215 km to 705 km as compared with the first generation Landsat-1, -2, and -3 satellites. This was done to give a faster repeat period of 16 days and also to make the satellite potentially retrievable by the Space Shuttle. Furthermore the lower orbit also gave a smaller ground pixel size (30m v 80m) and a better ground resolution with the then new Thematic Mapper (TM) sensor as compared with that of the previous MSS scanner. This later system (TM) also offered data acquisition in seven spectral bands (each chosen for specific applications) instead of the four used in the first generation MSS scanners (see Table 5-2). In early 1983, Landsat-4 began to experience a number of spacecraft malfunctions which limited its functionality. This matter led to the earlier launch of Landsat-5 in March 1984. This has operated perfectly; indeed it is still operational 14 years later! However the follow-on Landsat-6 suffered a launch failure in October 1993. The latest in the series (Landsat-7) has just been launched in 1999. It features the so-called Enhanced TM (ETM) panchromatic sensor using an optical-mechanical scanner and having a 15m ground pixel size. However the main emphasis will remain on the multi-spectral side with its multiple wavelength bands and the possibility of producing colour and false-colour images primarily for thematic applications.

Many investigators, including Welch et al (1985), Fusco et al (1985), Dowman et al (1986), Isong (1987), El Niweiri (1988) and Petrie & El Niweiri (1992, 1994) have analyzed TM images for their cartographic potential and reported the results of tests carried out using this imagery over areas in the USA, UK, Canada, Sudan, etc. From the results published in their various papers, planimetric accuracies ranging from ±15 to ±66m were obtained. The wide variation in the results is of course dependent to a large extent on the amount of relief present on the ground and on the quality of the GCPs used. Much poorer results are obtained in mountainous areas unless a DEM is available to correct up for relief displacements. Still, in general terms, these results confirm that, from the point of view of geometric accuracy, TM imagery can be used for topographic mapping at scales of 1:100,000 and smaller. The U.S.G.S. has produced many image maps at 1:100,000 and 1:250,000 scales digitally from TM images. As reported by Colvocoresses (1986), accuracy tests carried out on satellite image maps of Dyersburg and Washington DC at 1:100,000 scale gave planimetric accuracy (r.m.s.e.) values of ±24m and ±28m respectively which easily meet the geometric accuracy requirements for planimetry in medium-scale topographic maps.

However, it has also been apparent from these numerous tests that the smaller man-made features required for inclusion in such maps cannot be seen or extracted from TM imagery – i.e. the information content is quite seriously deficient, which must be considered a major limitation from the point of view of topographic mapping. Obviously, the Landsat TM is one of the main operational Earth observation systems that could be of interest to the Libyan topographic mapping community especially since it has a complete coverage over the country. However, as noted above, TM imagery has limited spatial resolution (30m ground pixel size and 45m ground resolution) and no stereo capability. As a result, its possible use would be restricted to purely planimetric mapping and to map revision activities at 1:100,000 scale and smaller. In fact, TM with its wide spectral coverage (7 bands) – see Table 5-2 – is much more suited to the needs of thematic mapping than topographic mapping. However, as discussed previously in Chapter 2, it has been used as the basis for the satellite image maps of parts of Libya by companies conducting oil and gas exploration in the country. For this application, the suitability of the multi-spectral capabilities for geological interpretation has played a decisive part in the decision to use TM imagery as the basis for the maps, notwithstanding its shortcomings in ground resolution.

Band No.	Wavelength (μm)	Spectral Location	Ground Pixel Size (m)	Applications
1	0.45-0.52	Blue	30	Water penetration
2	0.52-0.60	Green	30	Reflectance from vegetation
3	0.63-0.69	Red	30	Vegetation discrimination
4	0.76-0.90	Near infra-red	30	Delineation of water bodies
5	1.55-1.75	Middle infra-red	30	Differentiation of snow from clouds
6	10.4-12.5	Far infra-red	120	Thermal mapping applications
7	2.08-2.35	Middle infra-red	30	Geological mapping

Table 5-2: Thematic Mapper Spectral Bands

Arising from all these various considerations outlined above, the author does not support the opinion of those who have suggested adopting the TM imagery for the national topographic mapping programme of Libya. For this application, its ground resolution is simply inadequate for the purpose. However there is little doubt about its continuing value and widespread use and popularity among geologists, ecologists, etc. for whom the multi-spectral aspect of the data is paramount rather than the high resolution and geometric accuracy that are of such concern to the topographic mapping and cartographic communities.

5.2.2 MOMS Sensor System

MOMS is the acronym for the Modular Opto-electronic Multi-spectral Scanner which has been developed by Messerschmitt-Bolkow-Blohm (MBB), now DASA, for the Ministry of Research and Technology in West Germany under a contract from the German Aerospace Research Establishment (DFVLR, now DLR). Scientific guidance for the mapping aspects of the various MOMS experiments has been provided by the departments of photogrammetry in a consortium of German universities (TU Munich, Stuttgart and Hannover). The design of the scanner system was based on the use of solid state linear arrays (using CCD technology) deployed in a pushbroom mode rather than the optical-mechanical scanning operation of the Landsat MSS and TM scanners.

5.2.2.1 System and Orbital Characteristics

(i) A first experimental version of the sensor, called MOMS-01, was tested twice on-board the Space Shuttle on missions STS-7 in June 1983 and STS-11/41-B in February 1984. The main objective of these initial experimental flights was to prove the applicability of high resolution linear array data for medium-scale topographic and thematic mapping. Both flights yielded images with 20 x 20m ground pixel size from about 300 km orbital altitude. As noted previously, MOMS-01 was the first civilian space imaging system to employ linear arrays of CCDs. Its optical system contained four linear solid state sensor arrays with 1,728 pixels per array. Figure 5-1 illustrates the somewhat unusual geometry of the optical system employed with MOMS-01. The combination of the dual lens system and the four linear arrays allowed a single line of 6,912 pixels, each 0.01mm wide, to be imaged simultaneously. Only monoscopic imagery could be acquired with this sensor with a swath width of 140 km. The data covered scattered parts of Africa/Arabia, Australia, East Asia, India, South America, South East Asia and the USA.

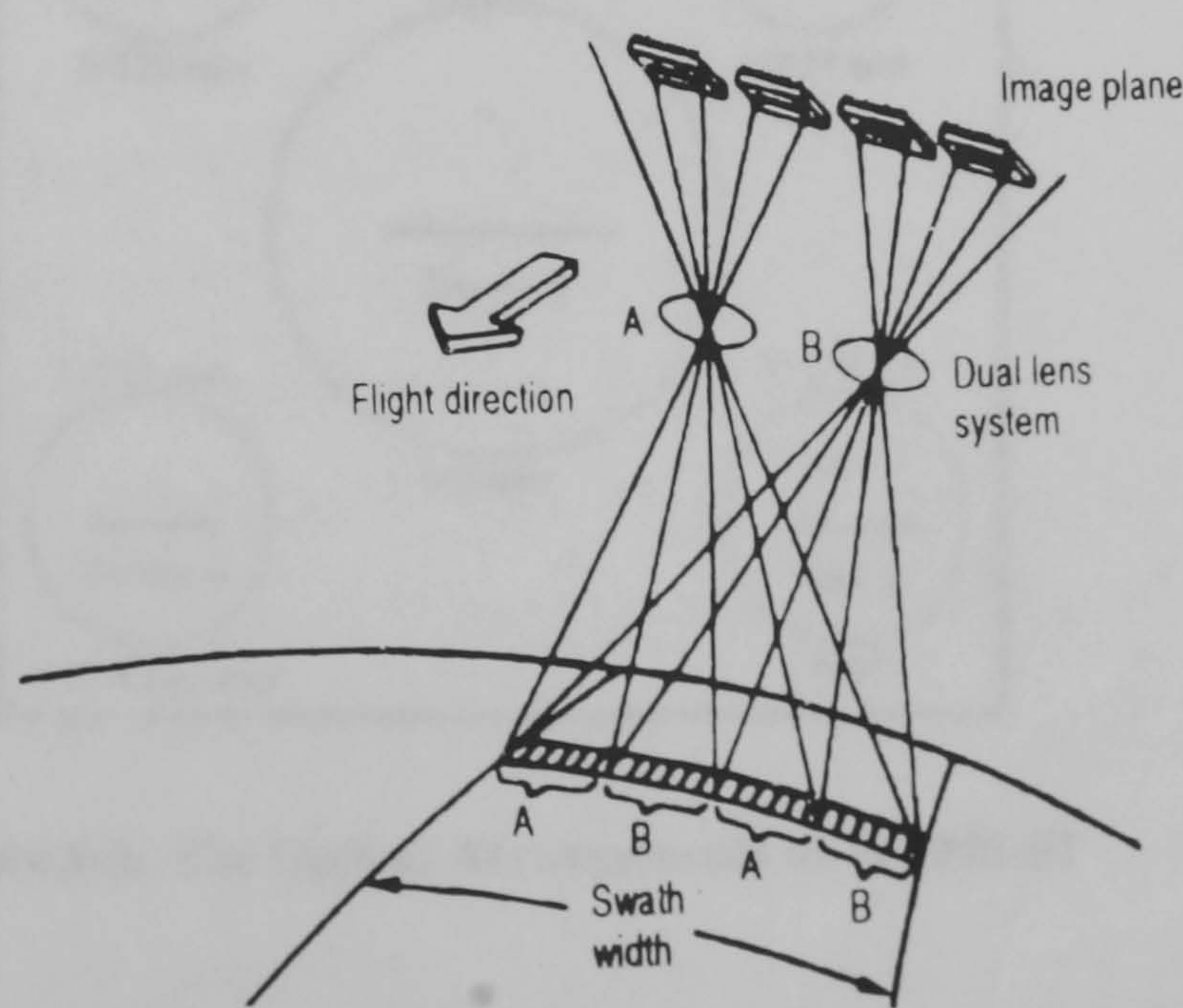


Figure 5-1: Geometric Arrangement of the MOMS-01 Optical System

(ii) MOMS-02 was a development and continuation of the MOMS-01 sensor. Again it was designed and oriented specifically towards the needs of both the topographic mapping community and the thematic field sciences. The MOMS-02 system was first flown on-board the second German Spacelab Mission (D2) that was launched on April 26, 1993 on board a Space Shuttle. The major task of the MOMS-02 mission was to generate, through the use of photogrammetric methods, 3-D co-ordinate outputs that would satisfy the requirements of terrain models; the topographic data required for mapping and map up-dating; the production of ortho-images; and the data needed for input to GIS.

In order to meet these varied requirements, MOMS-02 was designed to acquire simultaneously: (i) three-fold stereo imagery taken in an along-track mode; and (ii) multi-spectral imagery (Seige, 1993). The optical system comprises five lenses, three of which are designed to provide the along-track stereoscopic imagery using one nadir and two forward and backward looking lenses. The remaining two lenses collect multi-spectral data in a nadir pointing orientation. The focal lengths of the corresponding lenses are 660mm for the high resolution nadir pointing objective; 220mm for the two multi-spectral objectives; and 237mm for the forward and aft oriented stereo objectives. Thus MOMS-02 provides a fixed base-to-height ratio of 0.8 when using these two forward and backward pointing lenses (stereo bands 6 and 7) that are inclined ±21.4° relative to the flight direction. The other two lenses acquire the multi-spectral images in the VIS and NIR range (providing MS bands 1, 2, 3, 4). Figure 5-2 shows the MOMS-02 optical system arrangement.

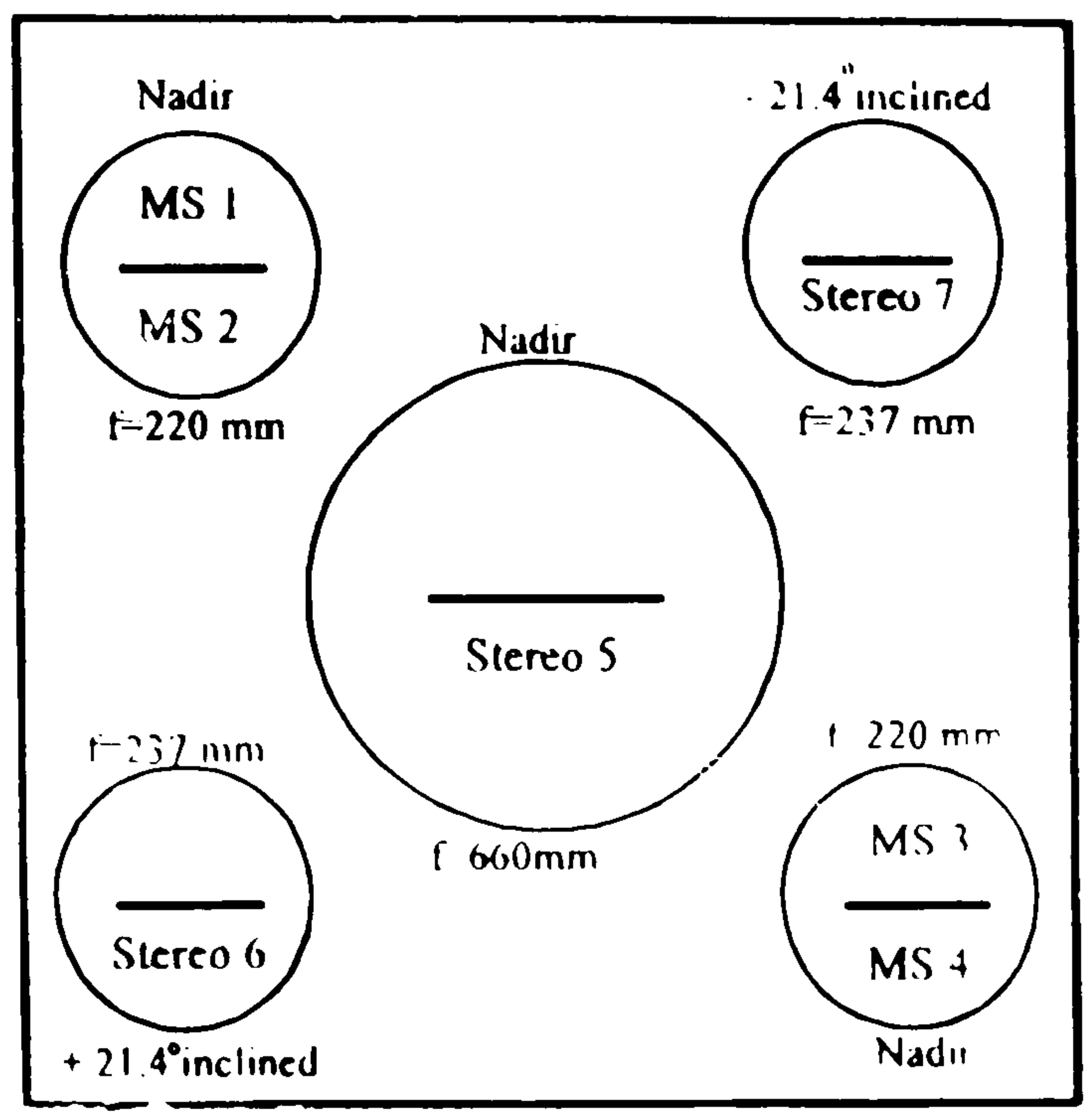


Figure 5-2: The Optical Arrangements of MOMS-02

The nadir-viewing central lens with its focal length of 660mm, acquires the highest resolution imagery (Band 5) with a ground pixel size of 4.5m x 4.5m from an orbital altitude of 296 km. The focal lengths of each of the other two lenses were chosen to obtain a direct 3:1

relationship between the ground pixel size (4.5m x 4.5m) of the high resolution channel and the two inclined stereo channels (each having a ground pixel size of 13.5m x 13.5m). The imaging geometry and the ground track resulting from this unusual arrangement of the optics are illustrated in Figure 5-3.

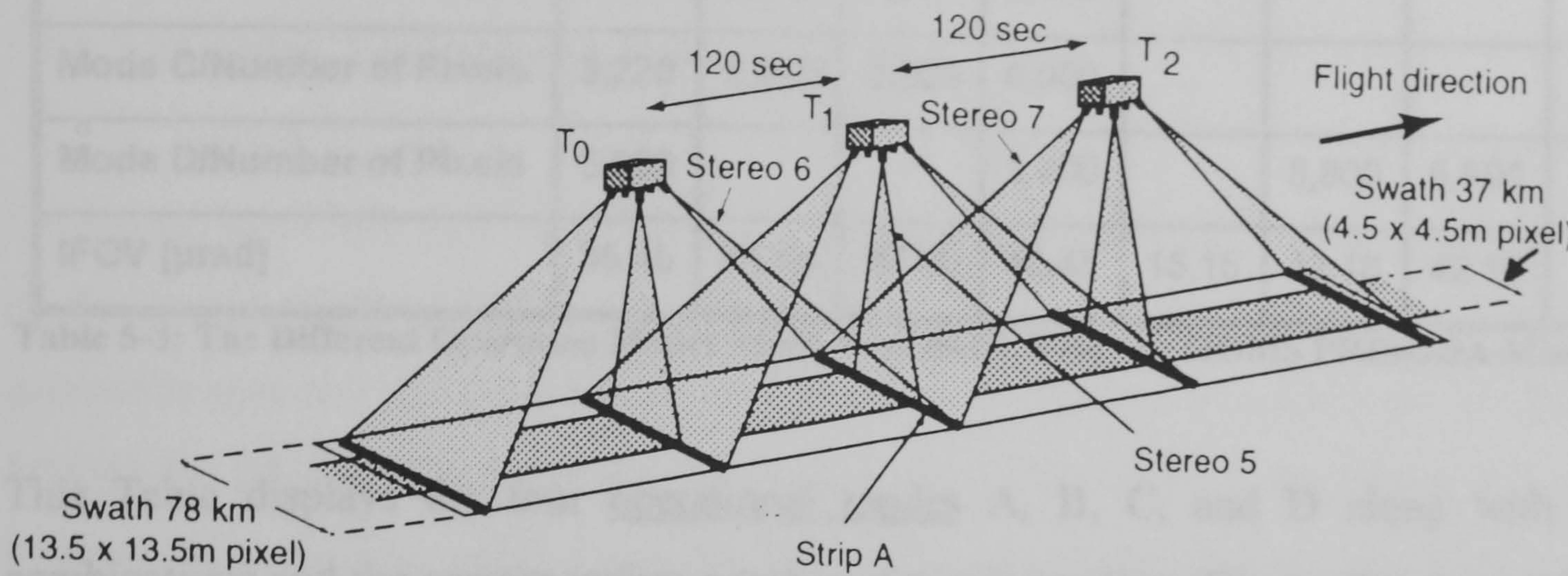


Figure 5-3: MOMS-02 Imaging Geometry with its Stereo Imaging Capability

The swath width for the nadir high-resolution channel is 37 km, and is 78 km for each of the other lower resolution channels. These swath width values are relative to the nominal orbital altitude (296 km). MOMS-02 takes along-track stereo images at an interval of 120 seconds (see Figure 5-3) during a single orbit instead of waiting days, weeks, or months (as in the case of SPOT or IRS-1C/1D) to obtain the second overlapping image. This removes a major problem that occurs with systems having cross-track coverage taken from different orbits where big changes in the appearance of ground objects will often occur between successive recordings of the terrain as a result of their exposure at different seasons (summer/winter or dry/wet).

(iii) MOMS-2P Following the success of the experimental MOMS-02 mission on Spacelab D2, after being refurbished, the MOMS package was installed in the PRIRODA module of the Russian MIR space platform and returned to space in the summer of 1996. MOMS-2P offers several major advantages over MOMS-02. These include a long term observation capability and the ground coverage of higher latitudes between ± 51.6° instead of the ±28.5° that was only possible with MOMS-02. Additionally, a new navigation package has been included consisting of a high precision gyro system and a GPS system in order to provide the necessary position and attitude data for supporting the control requirements associated with the extraction of DEMs. Table 5-3 shows the four operational modes that have been defined for the PRIRODA mission:

Band	1	2	3	4	5	6	7	Swath Width (km)
Mode A/Number of Pixels					8,304	2,976	2,976	50
Mode B/Number of Pixels	5,800	5,800	5,800	5,800				105
Mode C/Number of Pixels	3,220	3,220	3,220	6,000				36(58)
Mode D/Number of Pixels	5,800			5,800		5,800	5,800	105
IFOV [µrad]	45.45	45.45	45.45	45.45	15.15	42.16	42.16	

Table 5-3: The Different Operation Modes which were Defined for the MOMS PRIRODA Mission

This Table displays the four operational modes A, B, C, and D along with the band combinations and the corresponding number of pixels per line. The performance table (Table 5-4) indicates the different viewing angles of the seven bands, as well as the corresponding spectral band ranges. The ground pixel size for each of the bands is related to an average orbital altitude of MIR of 400km. The 18m ground pixel size caused by the higher orbital altitude of MIR as compared with that of the Space Shuttle is of course a disadvantage in terms of using MOMS-2P imagery for topographic mapping purposes – being approximately the same as the 20m ground pixel size of the earlier MOMS-01. MOMS-2P data are recorded on a tape recorder mounted on-board the MIR station, which has a capacity of 1 hour, and are dumped at a later time over one of the two ground receiving stations (Neustrelitz and Obninsk).

Band	Mode	Orientation	Band Width (nm)	Ground Pixel Size (m)
1	M/S	Nadir	449 - 511	18 x 18
2	M/S	Nadir	532 - 576	18 x 18
3	M/S	Nadir	645 - 677	18 x 18
4	M/S	Nadir	772 - 815	18 x 18
5	HR	Nadir	512 - 765	6 x 6
6	Stereo	+ 21.4°	524 - 763	18 x 18
7	Stereo	- 21.4°	524 - 763	18 x 18

Table 5-4: The System Characteristics of the MOMS-2P Satellite System

However unfortunately, this version of the MOMS system has been affected by all the many problems of the damaged MIR space station and, as a result, this mission has produced only a comparatively small number of images with scattered coverage so far. This is extremely unfortunate since the specification and geometry of the system are such that it could have been of great interest in the context of undertaking the systematic image mapping of a country such as Libya.

5.2.2.2 Mapping Tests Using MOMS Imagery

During the late 1980s and the 1990s, a number of tests have been carried out in different areas of the world (Sudan, Chile, Ethiopia, Kenya, Mali, and Saudi Arabia) to establish the geometric accuracy and the information content of topographic maps that can be derived from MOMS-01, MOMS-02 and MOMS-2P space imagery (including both monoscopic and stereo images) over various sites. Organisations that have carried out these tests include the University of Glasgow (El Niweiri, 1988; Petrie & El Niweiri, 1992, 1994; Valadan Zoej, 1997), University of Munich (Bodechtel, 1987) and TU Munich (Kornus et al, 1998). In general, from the results of these tests, it can be concluded that, in terms of purely planimetric accuracy, MOMS imagery can be used successfully for the production of topographic line maps and image maps at 1:50,000 scale and smaller. Heights are however another matter. The best figures giving an RMSE value of ± 8 to 10m (Kornus et al, 1998) point to a minimum interval of 25 to 30m which is not suitable for flat or gently undulating terrain.

Furthermore the results of the interpretational tests carried out by Valadan Zoej (1997) using MOMS-02 imagery over test area in Sudan showed that only 70% of the topographic map information that needs to be represented on the topographic maps of Sudan at 1:100,000 scale could be obtained from the MOMS-02 images with the 13.5m ground pixel size. In particular, many man-made features – although they are required to be shown on the 1:100,000 scale maps – could not be detected and identified. Schiewe (1998) also reported the results of interpretation tests carried out using the higher resolution nadir images with 4.5m ground pixel size of the MOMS-02 images which have been taken over the cities of Dubai in the United Arab Emirates and Harare in Zimbabwe. He summarized that, comparing these to SPOT data, there is an obvious progress in terms of the detectability rate, and that the information content of MOMS-02 is capable of fulfilling the mapping tasks in the medium-scale range down to a scale of 1:25,000. However a disadvantage of using the 4.5m ground pixel data is its narrower swath width. Furthermore the MOMS-2P mission has acquired very little imagery using Mode A that collects the higher resolution 6m imagery of Channel 5.

Unfortunately, the MOMS-02 along-track stereo scanner system with its highly good geometry (base:height ratio 0.8) has, until this moment, been largely experimental. The MOMS-02/D2 mission from 1993 only achieved limited and fragmentary coverage to date mostly of the north-eastern part of Africa – see Figure 5-4. From this map it will be seen that only a part of Libya – mainly in the south of the country – has been covered. Due to the problems experienced with the MIR space station, the coverage achieved with the MOMS-2P mission – shown in Fig. 5-5 – is even more fragmentary. However further coverage is being acquired till the end of the 1999 when the MIR station will be de-commissioned. Until the results are forthcoming, it is difficult to plan or rely on acquiring or using MOMS-2P imagery for mapping purposes in any country.

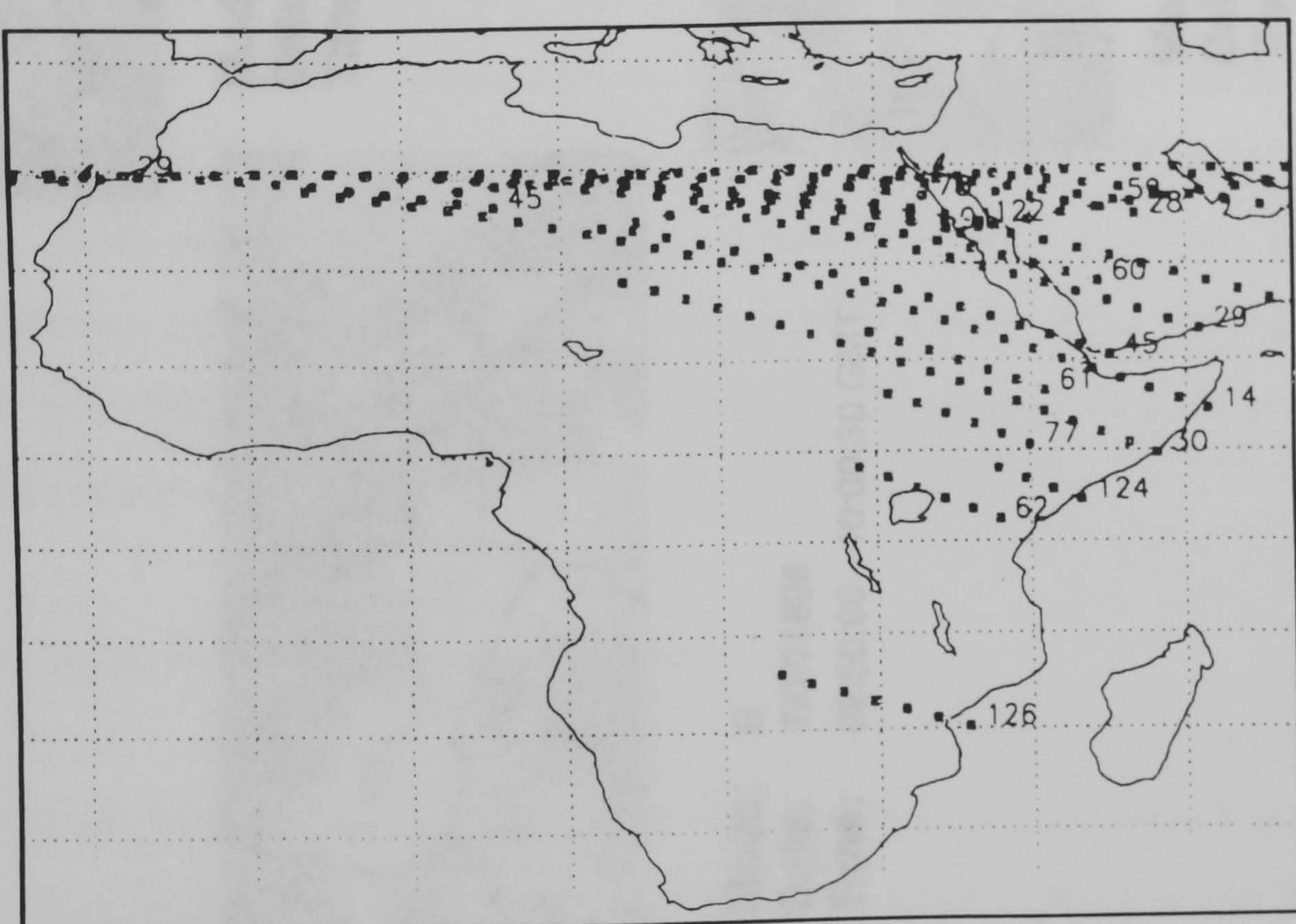


Figure 5-4: MOMS-02/D2 ground tracks over Africa are concentrated in the north-eastern part of the continent.

This leads to the conclusion that, for the time being, MOMS imagery has no systematic coverage over Libya (see Figures 5-4 and 5-5). Along with the rather inadequate ground pixel size of 18m, this makes it difficult to consider MOMS imagery as far as the Libyan national mapping programme is concerned.

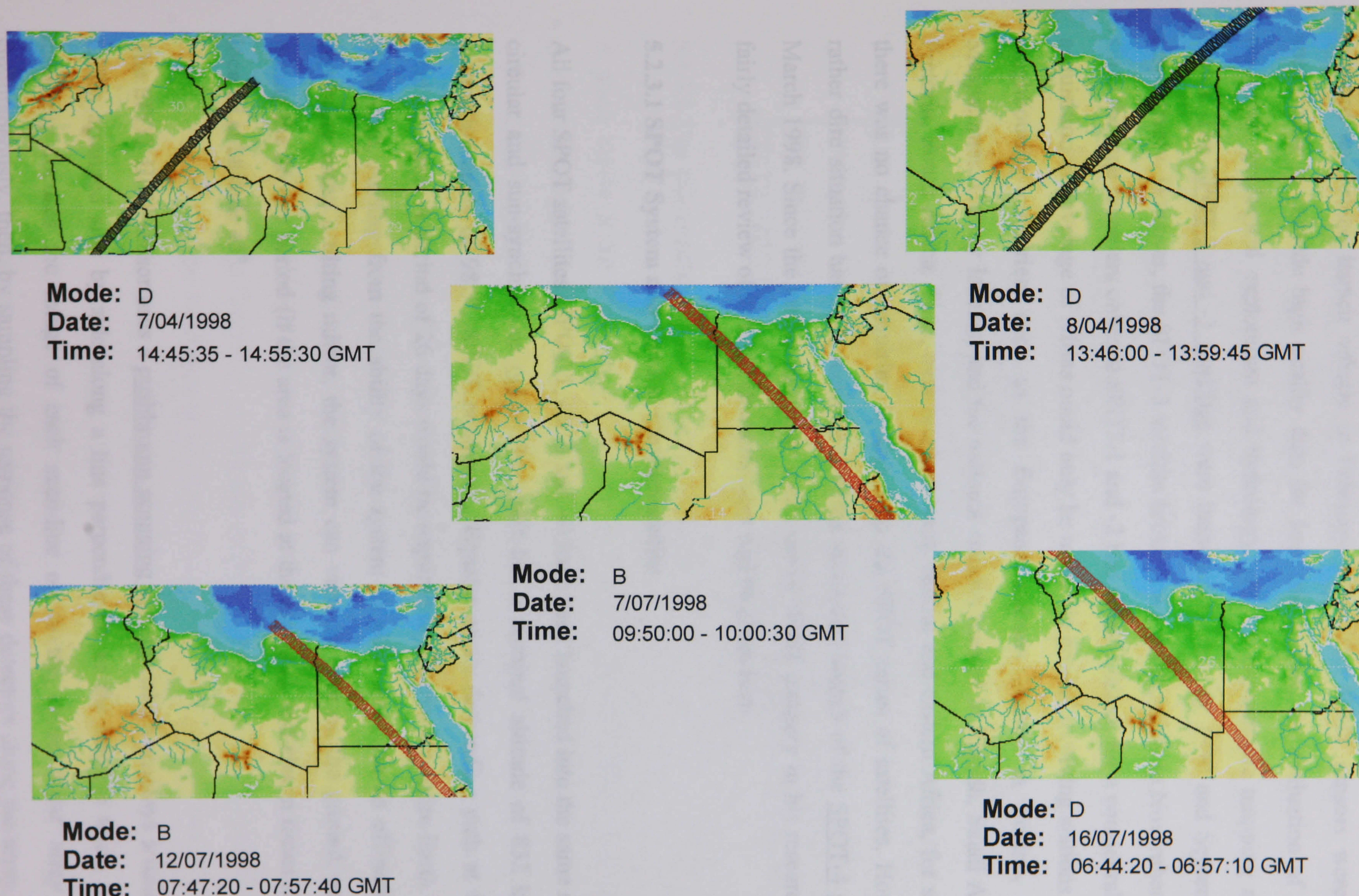


Figure 5-5: The current coverage of MOMS-2P over Libya

5.2.3 SPOT HRV Sensors

SPOT is an operational satellite system that was initiated through the launch of SPOT-1 onboard an Ariane launch vehicle in February 1986. The SPOT sensors were designed specifically to provide high quality data for land use studies, the evaluation of renewable resources, geological exploration and hydrology, and for topographic mapping at medium scales. The SPOT-2 and -3 satellites were launched in January 1990 and September 1993 respectively. However, the SPOT-3 satellite broke down irretrievably in November 1996 and since the tape recorders onboard SPOT-1 and -2 had already failed, for a considerable period, acquisition of coverage of Africa could only be made via ground receiving stations located in neighbouring countries, such as the European stations located in Fucino, Italy and Maspalomas, Canary Islands, and the national stations located in Riyadh, Saudi Arabia, and Pretoria, South Africa. Thus, over much of west, central and eastern Africa, for some time, there was no chance of acquiring images from the SPOT series of satellites. However this rather dire situation has been rectified with the successful launch of the SPOT-4 satellite in March 1998. Since the author has made much use of SPOT imagery in his research work, a fairly detailed review of its main characteristics will be given here.

5.2.3.1 SPOT System and Orbital Characteristics

All four SPOT satellites (SPOT-1, -2, -3 and -4) have been launched into the same near-polar, circular and sun-synchronous orbit. This orbit has a nominal altitude of 832 km and an inclination angle of 98.7°. SPOT crosses the Equator on its descending path at 10:30 a.m. local sun time. A period of 26 days would be required to observe the entire Earth – if it was cloud-free. Arising from the ability of the system to view areas via its off-nadir viewing capability using a tilting mirror, the system can view an area on the ground, seven times during the 26 day period (if the area is located at the Equator), and eleven times if an area is located at latitude 45°.

The SPOT HRV sensor uses a pushbroom scanning system which employs a linear array of CCDs arranged side by side along a line perpendicular to the satellite track. The optical assembly focuses the image of each scan-line on to the entire linear array of CCDs simultaneously, then, by sampling the response of these detectors along the array, the image data is produced. As with MOMS, successive lines of coverage are obtained by repeated sampling along the array as the satellite moves along its orbit over the Earth. Both HRVs are designed to operate either in panchromatic mode or in multi-spectral mode (Table 5-5). A 6,000-element sub-array is used in panchromatic mode to image a 10m pixel on the ground. In the case of the multi-spectral mode, three 3,000-element sub-arrays are used to record data in three different spectral bands with a 20m ground pixel size. Most topographic mapping applications use the panchromatic images because of their higher geometric resolution, but the multi-spectral imagery is useful for feature identification and thematic applications. The output from each HRV instrument is in 8-bit form providing 256 levels in both modes (panchromatic and multi-spectral), and is transmitted to the ground station at a rate of 25 Mbps.

Channels	Waveband (μm)	SPOT No.	Channel mode
1	0.50-0.59	SPOT-1,-2, -3, and -4	Multi-spectral
2	0.61-0.68	SPOT-1,-2, -3, and -4	
3	0.79-0.89	SPOT-1,-2, -3, and -4	
4	1.58-1.75	SPOT-4	
1	0.51-0.73	SPOT-1, -2, and -3	Panchromatic
2	0.61-0.68	SPOT-4	

Table 5-5: SPOT Spectral Bands

5.2.3.2 The Use of SPOT's Off-Nadir Capabilities

A plane mirror is the first element in the optical system for each HRV: it is steerable by ground commands through an angle of ± 27° from the nadir. This enables the satellite to utilize either vertical (nadir) or oblique (off-nadir) pointing (Figures 5-6a and -b) of this mirror. For nadir viewing, the two HRV instruments are pointed to cover adjacent fields, each 60 km wide, so that the total swath width is 117 km (i.e. the two fields overlap by 3 km). The off-nadir capability allows each HRV to image an area up to 475 km to either side of the satellite track. The width of the swath actually observed varies between 60 km for nadir viewing and 80 km for extreme off-nadir viewing. This manner of obtaining coverage provides much greater flexibility in data acquisition, and enables the time interval between successive views of the same area on the ground to be decreased from 26 days to 2 to 3 days (in cloud-free conditions).

In addition to the comparatively high resolution of this satellite, another very interesting feature of SPOT imagery from the mapping point of view is its stereoscopic viewing capabilities. By using the lateral overlap in the cross-track direction between adjacent runs,

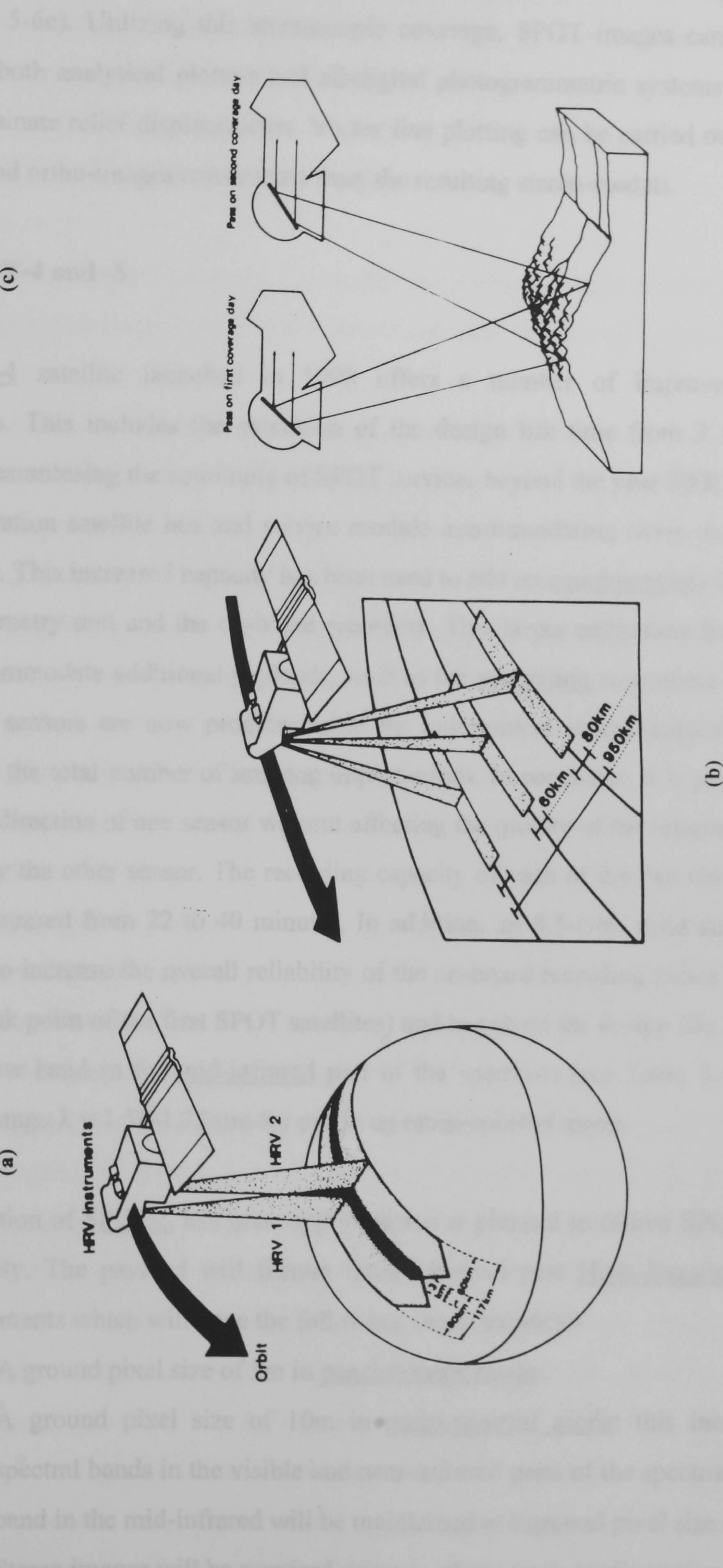


Figure 5-6: The use of the two HRVs on the SPOT Satellites: giving (a) Nadir Viewing, (b) Off-Nadir Viewing, and (c) Stereoscopic Imaging Capabilities respectively

overlapping images are recorded from different angles during adjacent different passes over the same area. In this way, stereo-pairs can be obtained having a base-to-height ratio of up to 1.0 (Figure 5-6c). Utilizing this stereoscopic coverage, SPOT images can be successfully handled in both analytical plotters and all-digital photogrammetric systems – which can be used to eliminate relief displacements. Vector line plotting can be carried out, DTMs can be generated and ortho-images constructed from the resulting stereo-models.

5.2.3.3 SPOT-4 and -5

The SPOT-4 satellite launched in 1998 offers a number of improvements over its predecessors. This includes the extension of the design life time from 3 to 5 years, thus hopefully guaranteeing the continuity of SPOT services beyond the year 2000. It comprises a new-generation satellite bus and service module accommodating twice the payload of the SPOT-3 bus. This increased capacity has been used to add an equipment bay housing both the payload telemetry unit and the on-board recorders. This larger equipment bay has also been used to accommodate additional payloads, such as the vegetation instrument. The two HRV-IR imaging sensors are now programmable for independent image acquisition, increasing significantly the total number of imaging opportunities. In particular, it is possible to change the viewing direction of one sensor without affecting the quality of the images acquired at the same time by the other sensor. The recording capacity of each of the two on-board recorders has been increased from 22 to 40 minutes. In addition, an 8.5-Gbit solid state memory has been added to increase the overall reliability of the on-board recording (since this has proven to be the weak point of the first SPOT satellites) and to extend the design life. SPOT-4 has an additional new band in the mid-infrared part of the spectrum (see Table 5-5) covering the wavelength range λ = 1.58-1.75 μm for use in its multi-spectral mode.

The construction of SPOT-5 has been approved and is planned to follow SPOT-4 to provide data continuity. The payload will feature three identical new High Resolution Geometric (HRG) instruments which will have the following characteristics:-

(i) A ground pixel size of 5m in panchromatic mode.

(ii) A ground pixel size of 10m in multi-spectral mode: this includes all three spectral bands in the visible and near-infrared parts of the spectrum. The spectral band in the mid-infrared will be maintained at a ground pixel size of 20m.

(iii) Stereo images will be acquired using an along-track configuration.

(iv) Each HRG will still have a cross-track capability for optimal revisits.

(v) Each HRG will still have a 60 km swath width.

The SPOT-5 satellite is planned to be launched in 2001, although, at the moment, there are some difficulties regarding its funding by the French government.

5.2.3.4 SPOT Imagery and Products

In order to meet different user needs and quality requirements, basically there are six types or levels of data which are pre-processed from the raw data and can be supplied to users. These are:

(i) *Level 1A* - This is essentially raw data, since the only processing performed is the equalisation of the response of the detectors using calibration data. No geometric correction takes place.

(ii) *Level 1AP* - This is intended for photogrammetric applications involving analytical plotters. In this Level, contrast enhancement is carried out in addition to the system correction. The small influences of roll, pitch and non-linear movements of the satellite are eliminated and the size of the image is enlarged to give 1:266,000 scale images on the 23cm x 23cm standard format by resampling with a pixel size of 25 μm on the image (which provides a 6.7m ground pixel size).

(iii) *Level 1B* - For this Level, both radiometric and geometric system corrections are carried out for the tilts, Earth rotation, Earth curvature effects and any variation in orbital altitude with respect to the reference ellipsoid. The image is brought to a constant sampling interval of 10m.

(iv) *Level 2A* - This is a high-precision Level which includes the radiometric pre-processing performed in Level 1B together with bi-directional geometric corrections to rectify the image according to a given map projection system (UTM, Lambert Conformal, etc.). Corrections are performed using only the satellite's position and attitude data – i.e. variations in the satellite's position and attitude angles during imaging – without using ground control points.

(v) *Level 2B* - This is a high-precision Level which includes the radiometric pre-processing corrections performed in Level 1B and bi-directional geometric corrections involving the use of ground control points. To perform Level 2B pre-processing, existing maps of sufficient accuracy – preferably at 1:25,000 or

1:50,000 scales – are normally required for acquisition of GCPs. Each scene is rectified according to a given cartographic projection which makes it directly registerable with a map.

(vi) *Level 2S* - In this Level, processing to give scene-to-scene registration is executed using land marks. Registration between scenes of the same area is estimated to be about ± 0.5 pixel.

SPOT products can be supplied to the user community in digital form on CCTs and CD-ROMs and as hard-copy film or print images at 1:400,000 scale and larger (e.g. the 1:266,000 scale used in the Level 1AP product)

5.2.3.5 Tests of Data Acquired from SPOT Images

5.2.3.5.1 Planimetric Accuracy

The results obtained from geometric accuracy tests were first presented at a conference held in Paris from 23rd to 27th November, 1987 to evaluate the capabilities of SPOT. As reported by Hartley (1988), the results obtained from the planimetric accuracy tests carried out on the SPOT panchromatic images by several investigators over different test areas using analytical plotters gave a planimetric accuracy of ±8 to ±10m. Later Hartley (1988), Murray & Farrow (1988) and Murray & Newby (1990) gave the Ordnance Survey (OS) experience in using SPOT images for the 1:100,000 scale mapping of the Yemen Arab Republic. In this project, they reported that a planimetric accuracy of ±12m was reached at the ground control points. Rather exceptionally, Gauthier (1988) gave the results of a number of experiments using SPOT panchromatic imagery, reporting that a planimetric accuracy (r.m.s.e) of around ±6m was obtained. Several other published results – e.g. those by Konecny et al (1987); Kratky (1988); Jacobsen (1988, 1990 and 1995); and Ghosh & Cherkaoui (1990) – gave the horizontal accuracy which can be achieved from SPOT panchromatic images over different test areas as ±8m on average. These results indicate that, using GCPs of a suitable quality, SPOT images can satisfy the planimetric accuracy requirements of 1:50,000 scale topographic maps.

5.2.3.5.2 Height Accuracy

On the other hand, the height accuracy that can be obtained from SPOT stereo images depends basically on the base:height ratio. Again, as reported first by Hartley (1988), the published results of the geometric tests of the SPOT images which have been carried out by various investigators showed that a height accuracy of between ±4m to ±10m (depending largely on the base:height ratio) could be obtained. Valadan Zoej (1997) carried out a number of geometric tests on the SPOT Level 1A & 1B stereo-pairs covering the Badia project area in Jordan. He again reported that a height accuracy value of ±8.2m (on average) was obtained. Thus there is a general agreement about the capability of the SPOT system in terms of its height accuracy by almost all investigators.

However this standard may not be achievable in many developing countries where quite often well defined GCPs are very difficult if not impossible to find in many arid or remote areas. What is still more serious is that, even if the SPOT height accuracy of ±8 to 10m can be achieved, it translates to a minimum contour interval of 30 or 35m that can be reached in such areas. According to the mapping requirements given in Section 3.4, this wide contour interval value shows that SPOT images can only be used for contouring in mountainous terrain and on small-scale maps. Of course, for some areas in developing countries, a contour interval value of 40 or 50m is quite adequate, say on 1:100,000 scale maps. This conclusion has been supported by the OS experience in the Yemen Arab Republic, where it was found that adequate topographic maps at 1:100,000 scale with a contour interval value of 40m could be produced from the SPOT images. But this still excludes areas of flat or undulating terrain where 10m or 20m contours are required to pick out the main features of the physical landscape.

5.2.3.5.3 DEMs and Ortho-image Accuracies

A digital elevation model (DEM) can also be generated by automatically correlating SPOT stereo-images of a region of interest to form a stereo-model, so that they can be geocoded and registered with a map. DEMs can then be generated and used to orthorectify images and to produce contours for topographic maps. The accuracy of the DEMs obtained from SPOT Level 1A stereo-pairs is very varied. From the results of the DEM accuracy tests carried out at many organisations and reported by different researchers (Priebbenow & Clerici, 1988; Ley, 1988; Theodossiou & Dowman, 1990; and Heipke et al, 1992), one can say that the accuracy of the DEMs derived from SPOT stereo-pairs as defined by the RMSE values obtained from validation tests is ranging from ±7m to 30m. This corresponds to topographic maps having

20m to 100m contour intervals according to USGS mapping standards. Al Rousan (1998) and Al Rousan & Petrie (1998) have also reported the results of extensive DEM accuracy tests that have been carried out at the University of Glasgow using SPOT Level 1A & 1B stereo-images taken over the Badia area in Jordan. Three different digital photogrammetric systems (EASI/PACE, OrthoMAX, and DMS) have been used for automatic DEM generation from the SPOT stereo-pairs. They reported that DEM accuracy values of ±6.0m, ±8.4m, and ±9.3m have been achieved using the EASI/PACE, OrthoMAX, and DMS systems respectively. Again these figures translate to possible contour intervals of 20 to 30m.

As a part of his Ph.D. research programme, Al Rousan (1998) also produced ortho-images for his test area in Jordan using both SPOT Level 1A & 1B stereo-images. He reported planimetric accuracies of ±13.3m (for Level 1A) and ±12.3m (for Level 1B) for the final ortho-image products using a 20m pixel size. He also concluded that these ortho-images satisfy the accuracy requirements of maps at 1:50,000 scale and smaller.

5.2.3.6 Image Interpretability and the Map Content that can be Extracted from SPOT Images

Various tests on the interpretation of SPOT imagery and the map content that can be extracted from this imagery have already been carried out at the University of Glasgow (Liwa, 1994; Petrie & Liwa, 1995) and by other organisations (Dowman & Peacegood, 1988). These show that SPOT images (Pan and XS) can only provide the information content for a preliminary or provisional edition of a 1:50,000 topographic map or for the rapid but incomplete revision of an existing map at that scale. Obviously from the results of these tests, the present SPOT imagery is still substantially deficient in providing the details needed for producing a full or final edition of a new 1:50,000 scale map or for the comprehensive revision of an existing published map at that scale. Any specification that requires the depiction of small man-made cultural features, isolated settlements, narrow motorable tracks, etc. is unlikely to be met by SPOT panchromatic data. On the other hand, a majority of urban areas, railways, major roads and area features can be detected. In order to overcome these deficiencies – which can amount to 30% of the total map content – an additional comprehensive field completion is necessary. Hence much extra time and cost may be required to fully meet the map specification.

5.2.3.7 Difficulties with SPOT Imagery Used for Mapping

In summary, although the French SPOT system can provide enough positional accuracy for the compilation of 1:50,000 scale maps, the accuracy of its elevation data is marginal. In general terms, it cannot provide the small contour intervals (10 to 20m) needed in flat terrain. A further problem may be experienced with SPOT stereo-imagery arises when the images making up a stereo-pair are acquired at different times. This results in images with a quite different appearance to one another due to the changes occurring in vegetation, land use, etc. arising from seasonal climatic conditions. These differences in appearance may hinder stereo-viewing and measurement and lead to a failure in the stereo-correlation process used to generate elevation data. However this is less likely to be a problem over the large areas of desert that make up most of the Libyan landscape.

Based on many experiences, the other difficulties that can be faced using SPOT images for topographic mapping are now well known to the mapping community. In particular, its lack of sufficient ground resolution – 15 to 18m in the case of panchromatic imagery with a 10m ground pixel size – leads to the loss of 30% on average of the content required for small-scale topographic maps. Consequently, this leads to the need for an extensive field completion programme to acquire the missing information.

5.2.3.8. Topographic Mapping Carried out by Various Mapping Agencies world-wide Using SPOT Imagery

Notwithstanding the various difficulties mentioned above, Jacobsen (1988) pointed out that the mapping of large areas with SPOT (with its systematic coverage) would be more economic than with high altitude conventional aerial photography – especially if the alternative was a total lack of map coverage. However only a relatively few national mapping agencies have taken an interest in the possibilities of systematic small-scale mapping of large areas using SPOT stereo-coverage. As might be expected, these are mainly developing countries.

From SPOT images, two forms of topographic mapping can be generated – topographic line mapping and image mapping. Examples of topographic mapping operations using SPOT imagery undertaken by some of the mapping agencies in the world can be given and assessed.

These include mapping programmes in Algeria, Ethiopia, Yemen Arab Republic. Djibouti, Cameroon, the Baltic States, Philippines, Malaysia, Guinea-Bissau, etc.

(i) Algeria Referring to the Algerian national report submitted to the 18th ISPRS Congress in Vienna in July 1996, an ortho-image map of the Ghardaia region in the desert area of southern Algeria has been produced from SPOT images by the Algerian Cartographic Institute (INC) in collaboration with the French IGN. Since this initial test was considered successful, the Algerian national report submitted to the United Nations Regional Cartographic Conference for Africa in November 1996 included a strategy for this method to be adopted based on the use of analytical plotters to map the Sahara Desert for the 27 sheets needed to complete the whole coverage of the country's basic mapping scale of 1:200,000.

(ii) Yemen Arab Republic As reported by Murray & Farrow (1988) and Murray & Newby (1990), line mapping from SPOT stereo-pairs acquired in panchromatic mode was carried out for the eastern part of the Yemen Arab Republic by the British Ordnance Survey to cover an area of 25,000 sq. km. by topographic line maps at 1:100,000 scale. Contours have been generated from DTMs with a 50m grid which have been created by the use of SPOT stereo-pairs and Kern DSR analytical plotter. Contour capture progressed with few difficulties. The mountainous area could not support contours closer than 40m vertical intervals. While, in the desert area, it was possible to plot supplementary contours or form lines at a 20m interval. This project has shown that SPOT data can be used successfully to produce series mapping, though only with the help of a substantial field completion operation.

(iii) Djibouti was also mapped from stereo SPOT images by IGN (France) at the end of 1980s. A line map at 1:200,000 scale covers the entire country, while the 1:50,000 scale was used to map the more developed and populated areas (Petrie, 1997a).

(iv) Ethiopia Besides Sudan and Eritrea, the only other country in Eastern Africa that has a very substantial shortfall in its topographic map coverage is Ethiopia. An initial pilot project to asses the possibilities of utilizing stereo SPOT images was undertaken by SSC Satellitbild and Swedesurvey over the Asela area (Rosenholm, 1995). In this project, advanced digital techniques, including multi-point matching, were used to produce a DEM and ortho-image (Westin et al. 1988). Since then, stereo SPOT imagery has been used by the Ethiopian Mapping Authority (EMU) for the continuation of the 1:50,000 scale mapping of the country (Medhin, 1993). However this has been done using hard-copy SPOT Pan images in an analytical plotter (WILD BC-2) running the Aviosoft package.

Composite sampling – comprising a grid of measured elevation values plus height values measured along the rivers, watersheds, and terrain break lines – is carried out manually by photogrammetric operators to generate a DEM (Petrie 1997a, Al Rousan et al. 1997). For this task, ground control points (GCPs) are provided via the use of GPS receivers. In this project, the final output is a hard-copy ortho-image produced at 1:50.000 scale using a Wild OR-1 analytical orthophotoprinter. The contour plots were derived by interpolation from the DEM data.

(v) Cameroon Details of this project have been given by Kaczynski (1996b). In this project, the northern part of Cameroon has been mapped using nine SPOT Level 1A pan stereo-pairs. The work resulted in the production of 49 individual 1:50,000 scale image map sheets and was carried out jointly by a commercial company (CHS) in France and the Institute of Geodesy and Cartography (IGiK) in Poland. The north Cameroon project used digital image data and processing techniques throughout. The GCPs were measured using GPS methods and additional points generated by aerotriangulation. The DEM data has also been generated from the SPOT stereo pairs. Using this DEM data, the space ortho-images were then generated. Contours at 20m intervals were also generated from the DEM data, and these were added to the topographic map features to produce the final map at 1:50,00 scale.

(vi) Baltic States As reported by Rosenholm (1995) and Klang (1996), a number of on-going projects are producing a new series of image maps in the Baltic States using SPOT images. This work has been carried out by the Swedish Space Corporation (SSC) Satellitbild in co-operation with the national mapping authorities in Estonia, Latvia and Lithuania respectively. Contours and administrative boundaries were digitised from the existing but out-of-date Russian maps. From these digitised contours, DEMs have been created for ortho-image production which has been carried out on the basis of monoscopic SPOT images. In fact, the project has given broad basic experience in how satellite images can be used for the production of new or updated maps.

(vii) Philippines Again based on a combination of existing old topographic line maps and SPOT images, the Swedish Space Corporation (SSC) Satellitbild produced 27 topographic line map sheets at 1:50,000 scale of the islands of Cebu and Bohol and some neighbouring smaller islands. This project has been undertaken in co-operation with the National Mapping and Resource Information Authority (NAMRIA). Height information from SPOT stereo images in this project did not give any major advantages compared to digitising the contours on the existing maps. Many difficulties were experienced in this project: these were related to cloud cover, varying base-to-height ratios and large differences in the acquisition dates of the individual images, causing substantial differences in the appearance of overlapping and adjacent images.

(viii) Malaysia The Swedish Space Corporation (SSC) Satellitbild also produced 14 satellite ortho-image map sheets at 1:50,000 scale using SPOT imagery. These image maps have been produced in co-operation with the Department of Survey and Mapping (DSMM) of Malaysia and again were used for the revision of existing topographic line maps rather than new mapping. For 5 more map sheets, DEMs and 20m contours were also produced (Rosenholm, 1995).

(ix) Guinea-Bissau Very recently (over the first half of 1998), the production of an image map series of the whole of this West African country has been undertaken by a Belgian company, I-MAGE Consult, funded by the European Community. The SPOT images have been mosaiced and georeferenced to an existing topographic line map series comprising 72 sheets at 1:50,000 scale. The georeferenced SPOT images have then been carved up to produce 72 individual image maps corresponding to the original line map series. Additionally a DEM has been produced for the whole of the country. This has been achieved by first raster-scanning the 72 existing topographic map sheets and then digitizing all the contour lines contained on the sheets. The DEM was then extracted from the digitzed contours.

(x) Other Countries In addition, SPOT satellite image maps at 1:50,000 scale and smaller have also been produced by the Technical University of Berlin, Germany; the Institute of Geodesy and Cartography, Poland; Nigel Press Group; etc. For different countries in Africa (Libya, Egypt, Somalia, etc.), Bolivia (S. America); Macedonia (SE Europe); and Viet Nam (SE Asia), SPOT images have been also used to produce small-scale topographic maps for their countries, notwithstanding their shortcomings in terms of ground resolution.

5.2.3.9 The Suitability and Availability of SPOT Images for Topographic and Image Mapping for Libya

As described above, SPOT images have some difficulties when it comes to their height accuracy and their information content. However SPOT does offer mapping capabilities arising from its systematic coverage (see Figure 5-7) over the whole country of Libya, especially since the recent launch of SPOT-4 satellite which ensures continuity and up-to-date coverage. Thus the author feels that, notwithstanding its shortcomings, SPOT data can still be considered for the production of maps and image maps at 1:50,000 scale and smaller since, for most of the country, the requirements for field completion should be small, given the few cultural or man-made features occurring in the desert areas that constitute most of the country's landscape. Thus it should be considered for adoption for Libyan national mapping programmes. As far as the use of SPOT imagery for the production of Libyan maps is concerned, other advantages such as having scenes of the stereo-pairs acquired with short time differences, the availability of cloud-free data and using data of good base-to-height ratios are also apparent. To assist in the process, the use of digitised contours from the existing 1:50,000 maps of the northern part of the country could be adopted. Also the availability of other sources of data such as existing larger-scale maps and aerial photos should be taken into consideration when planning the use of SPOT data for mapping purposes. Certainly for the production of maps at 1:250,000 scale, SPOT is a strong candidate for adoption. For 1:50,000 scale, obviously the current alternatives are either small-scale aerial photography or the use of the IRS-1C/1D satellite imagery with its superior ground resolution to that provided by SPOT.

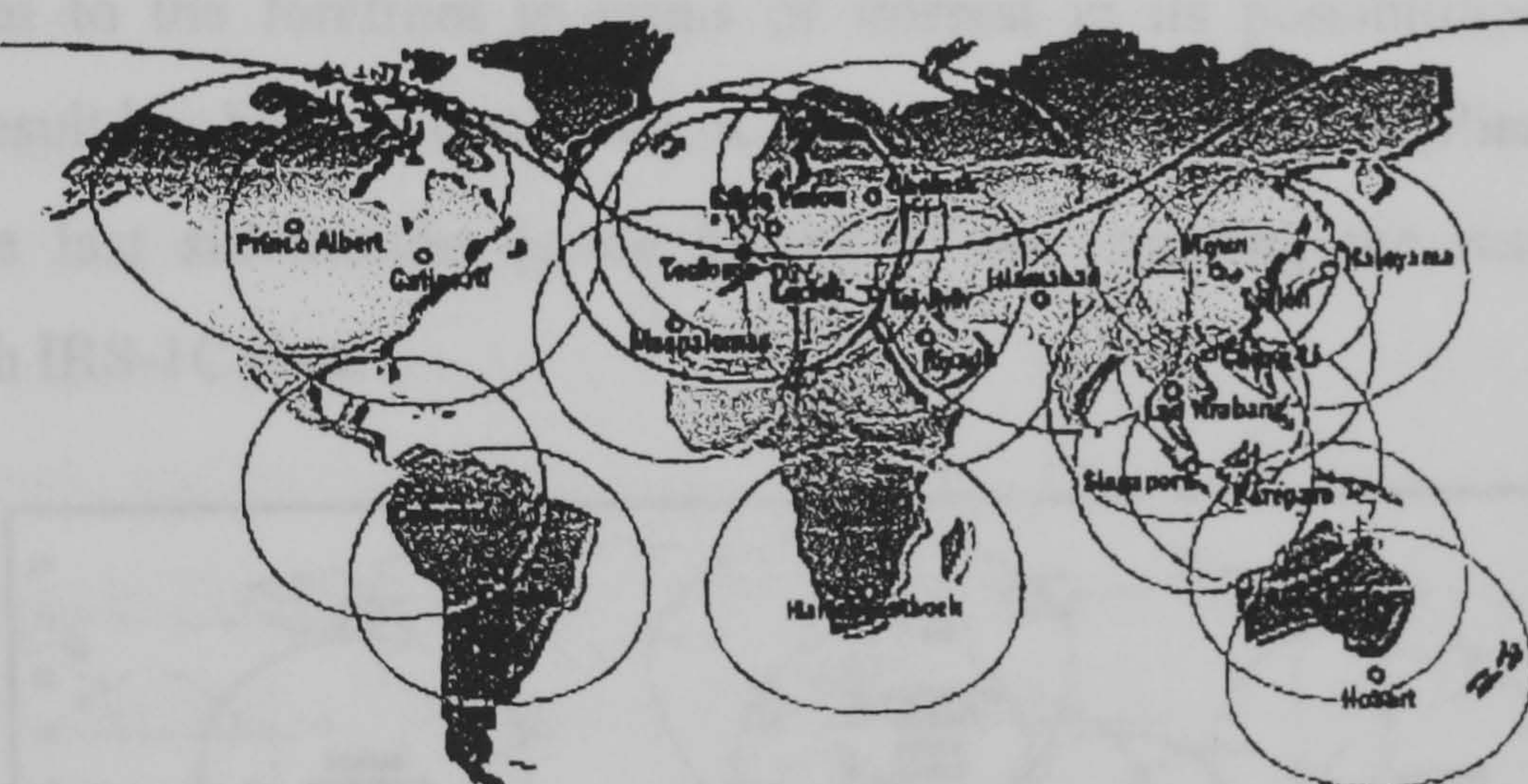


Figure 5-7: The coverage of SPOT receiving stations

5.2.4 IRS-1C/ 1D

The IRS-1C and 1D satellites form the second generation in the series of Indian remote sensing satellites, having enhanced capabilities over the first generation of IRS satellites in terms of their higher spatial resolution and larger number of spectral bands. IRS-1C was successfully launched in December 1995, while IRS-1D was launched in September 1997. The IRS-1D satellite has the same equipment on-board as IRS-1C but allows an increase in its data acquisition rate. Weather permitting, it is possible now to receive an image of the same area every 3 days. In April 1997, the Swedish Space Corporation (SSC) entered into a partnership with the Indian space organisation by which the image data from one of the IRS satellites can either be received directly for the area of North Europe in the view of satellite while it is over the ground station or the image data stored on the on-board tape recorder can be downlinked to the antenna in Kiruna. This extended greatly the coverage which previously was confined to the area of the Indian sub-continent that was in view of the Indian ground station.

Over the last year or so, the situation regarding the acquisition of ground coverage by the IRS satellite has altered quite dramatically. In particular, the agreement made between the Antrix Corporation in India (which markets the IRS imagery on behalf of the Indian government) and the Space Imaging EOSAT company has led to the establishment of a whole series of ground receiving stations covering a substantial part of the world. Thus Space Imaging EOSAT and its associates have established ground stations at Norman, Oklahoma in the U.S.A.; at Neustrelitz in Germany (in collaboration with DLR); at Athens in Greece; and at Dubai in the United Arab Emirates. Other stations are planned to be established in Asia, Australia, South Africa and South America – see Figure 5-8. This development has brought the IRS-1C/1D image data right to the forefront in terms of interest in its possibilities for topographic mapping. The result has been an explosion of interest resulting in the publication of numerous papers over the last six months (since March 1998) reporting the results of tests and experiences with IRS-1C data.

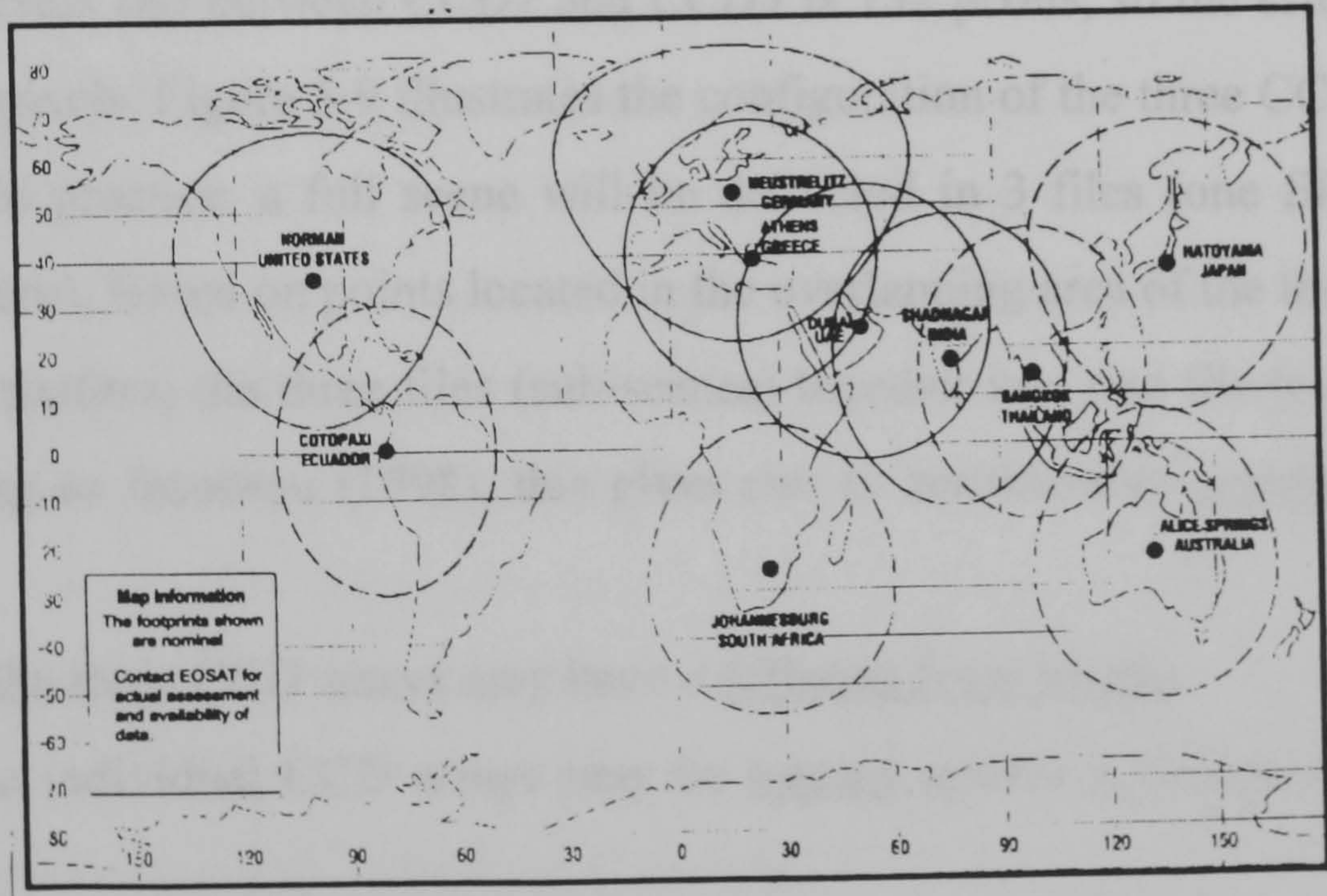


Figure 5-8: The coverage of IRS-1C – (a) the current coverage (given by the full line); and (b) the additional coverage in the near future (given by a dashed line).

5.2.4.1 IRS-1C Satellite and Imagery

This satellite has high resolution linear array scanners operating from an orbital altitude of 817 km. It was placed in a polar sun-synchronous circular orbit with an orbital inclination of 98.69°, and has an equatorial crossing time of 10:30 a.m. at the descending node. Over a 24 day period, this satellite will make 341 orbits (14 orbits per day with a 117.5 km distance between paths) before entering a repeat cycle. However with the capability of off-nadir pointing of ± 26°, similar to that of SPOT, it is possible to obtain repeat coverage every 5 days. There are three imaging scanners on-board, but, from the point of view of topographic mapping, the most important of these is its panchromatic sensor (PAN) which gives images with a ground pixel size of 5.8m; a 6-bit (64 grey levels) radiometric resolution; and a spectral bandwidth of 0.50-0.75μm, This sensor is a CCD pushbroom scanner, capable of acquiring a 70 km swath width.

In fact, currently there is no CCD linear array available with 12,000 pixels and a pixel size of 7μm. Thus, in order to get the required swath width, the sensor consists of three separated CCD linear arrays, each with 4,096 pixels. The three CCD linear arrays overlap but unfortunately they have not been set in an exactly parallel or aligned position (Cheng and Toutin 1998; Jacobsen 1998; Armenakis and Savopol 1998). The overlap between CCD1 and CCD2 is 243 pixels and between CCD2 and CCD3 is 152 pixels, so the effective size of the array is 12,000 pixels. Figure 5-9 illustrates the configuration of the three CCD sensors on the image plane. In practice, a full scene will be delivered in 3 files (one file for each CCD linear-array sensor). Based on points located in the overlapping area of the three sub-scenes, it is possible to transform the three files (sub-scenes) together into one file to make up the full scene. According to Jacobsen (1998), this gives rise to considerable geometric problems as follows:

(1) Each of the three CCD arrays may have a different focal length.

(2) The three individual CCD arrays may be rotated against a straight line in the image plane.

(3) There may be a rotation against the image plane.

(4) There may be a shift in the image plane.

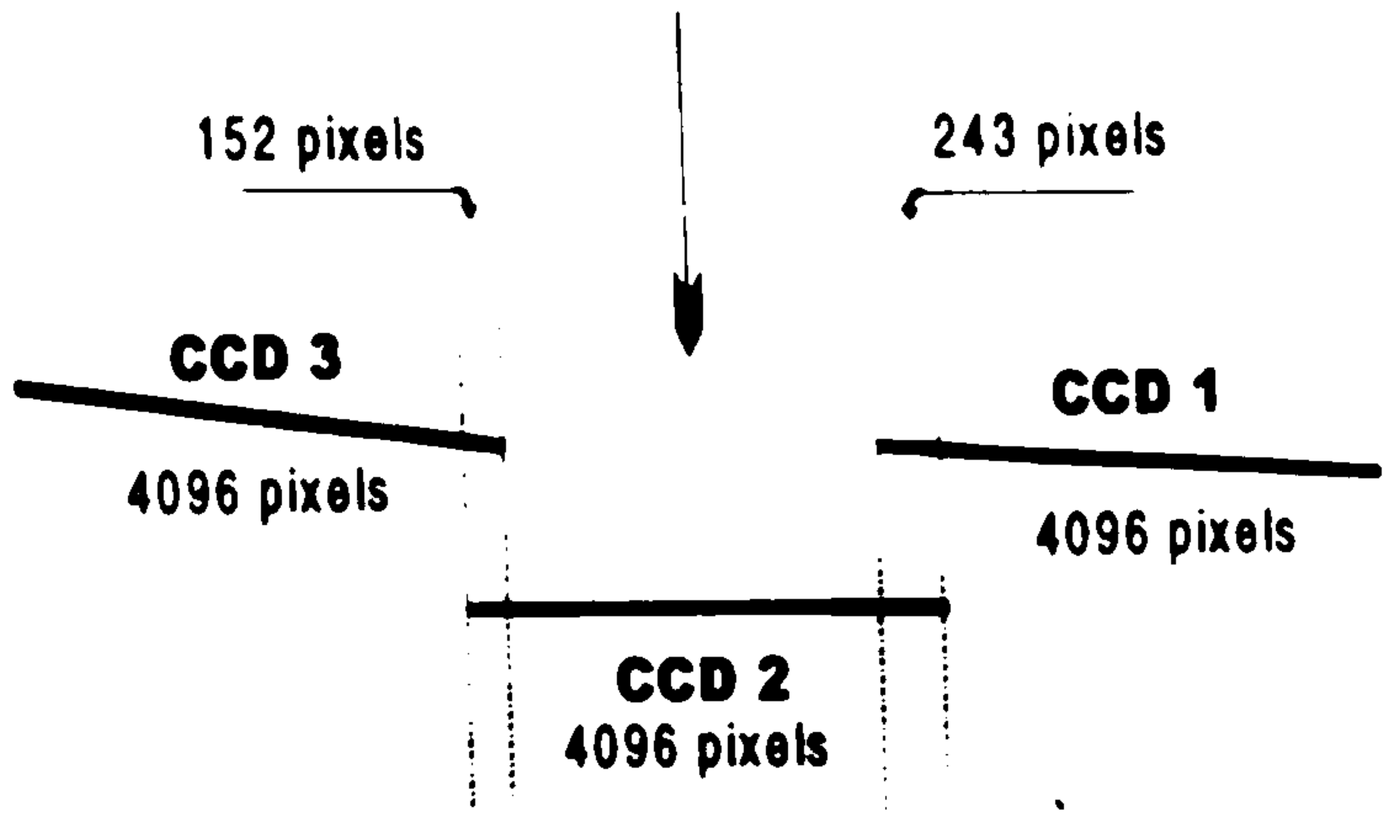


Figure 5-9: IRC-1C PAN camera configuration (after Armenakis and Savopol, 1998)

Because of these problems, it is almost always necessary to rectify and mosaic together the three sub-scenes. In turn, this requires the use of a number of GCPs and tie points and needs additional image processing effort. This requirement may give rise to considerable problems, particularly in areas with few man-made features where GCPs or tie points are very difficult to find on the image. When fully processed, the IRS-1C is resampled to 5m and the three individual images (sub-scenes) are mosaiced to form a single scene that covers an area of 70km x 70km. As well, the radiometric resolution is scaled to 8-bit quantization levels (256 grey levels). However, if required, the imagery from each of the image arrays (left, middle, and right) can be purchased individually as well.

5.2.4.1.1 Geometric Accuracy

(i) Regarding planimetric accuracy, Jacobsen (1998) and Jacobsen et al (1998) have carried out geometric tests using IRS-1C images which were taken over a test area near Hannover in Germany. Also a similar series of geometric accuracy tests have been carried by Cheng and Toutin (1998) using IRS-1C images. As reported in these papers, the RMSE value for planimetric accuracy is close to 1 pixel (±5.8m). In other words, given the availability of accurate GCPs, the required horizontal accuracy can be achieved for scales up to 1:25,000 without any problems.

(ii) Height Accuracy. Jacobsen (1998) and Jacobsen et al (1998) has also reported that, in the case of tests of the height accuracy, using overlapping images with a base:height ratio of 0.8, an RMSE value of ±10m was achieved. Thus the vertical accuracy is still limited to about that of SPOT. Thus the achieved height accuracy is sufficient for topographic mapping at 1:50,000 scale only if there is a wide contour interval such as 30 to 40m.

5.2.4.1.2. Interpretability and Content of Data that can be Extracted from IRS-1C Imagery

The IRS-1C and -1D systems are, in many respects, similar to SPOT but with considerably better ground resolution arising from the use of a 5.8m pixel size. In the same manner as SPOT, the images can provide enough planimetric accuracy for 1:50,000 scale maps. Furthermore Rosenholm and Akerman (1998) have demonstrated that ortho-images can be produced successfully from IRS-1C imagery using DEMs of relatively low accuracy. However some of the same problems as those experienced with SPOT will occur in terms of the detectability of the objects present on the ground. Both the spatial resolution and radiometric resolution as well as the seasons, the sun angle and the atmospheric conditions will affect the feature identification and extraction from the IRS imagery. With 6-bit (64 grey levels) dynamic range, the IRS-1C imagery has a more limited range of grey level values and this results in a lower contrast being present in the imagery, thus making the detection and identification of features somewhat more difficult. Notwithstanding these drawbacks, this imagery with its superior ground resolution to that of SPOT is already of considerable interest to the mapping community. Therefore, from both the geometric and content aspects, the IRS-1C imagery may well have the potential to support the national 1:50,000 topographic map scale, but additional information about the potential map content and the requirements for field completion is still needed.

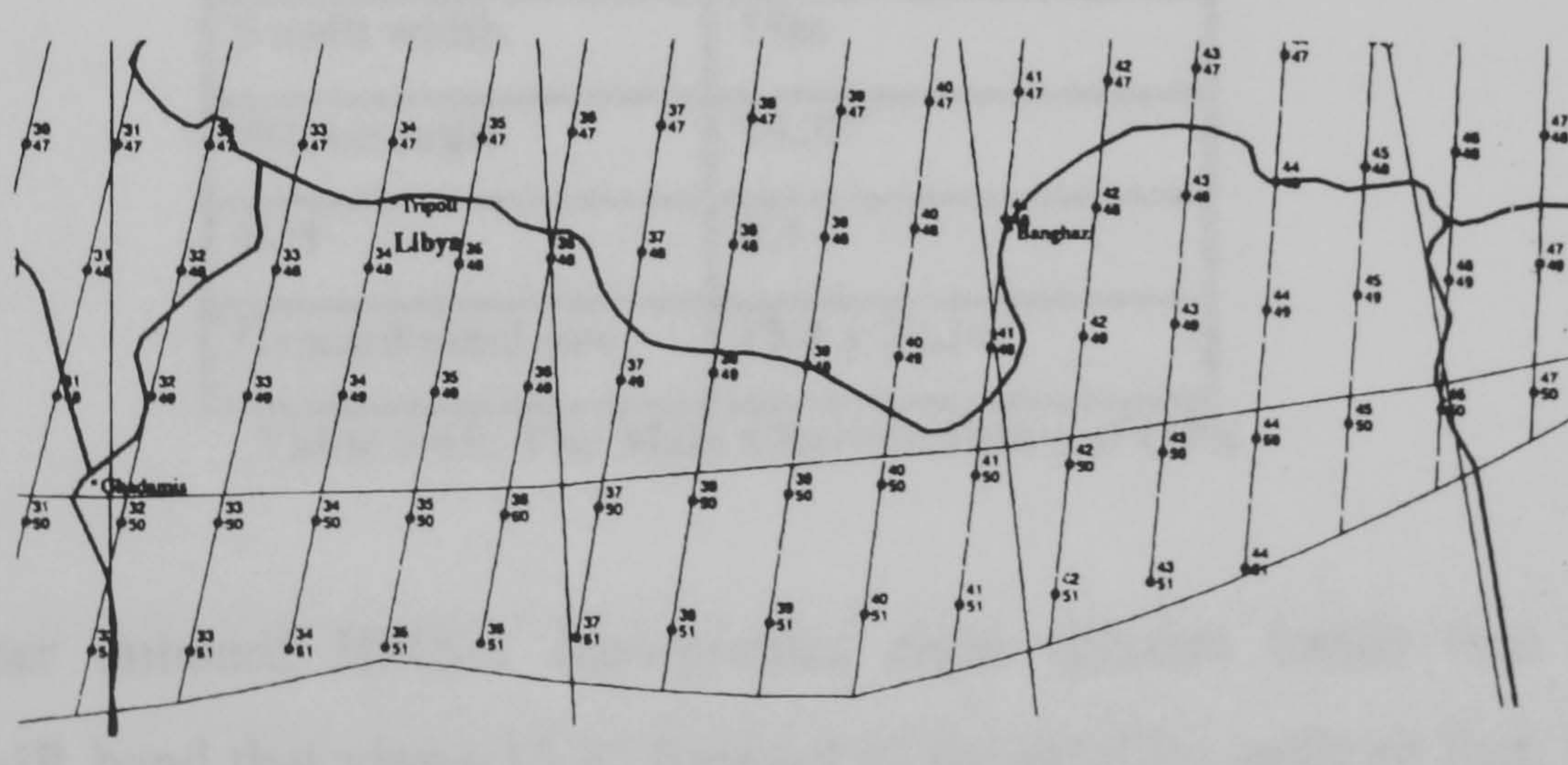


Figure 5-10: The current coverage of the IRS-1C over Libya

As far as Libya is concerned, currently the major problem lies in getting the full coverage of the country, since much of it does not lie within the footprint of the IRS ground receiving station at Neustrelitz at Germany (see Figure 5-10). However, with the recent establishment (early in 1998) of the new ground receiving station of Space Imaging Europe at Athens in Greece, this situation will almost certainly change in the near future and full coverage of Libya can then be obtained over a period of time. This makes the IRS-1C/1D imagery of extreme interest in the debate about the possible use of spaceborne scanner imagery for the new topographic mapping of Libya.

5.2.5 Japanese Earth Resource Satellite (JERS-1) OPS System

JERS-1 is a joint project between two Japanese organisations – the National Space Development Agency (NASDA) and the Ministry of International Trade and Industry (MITI). In Japan, NASDA is the main Japanese space agency, so it is in charge of the satellite construction and launch, while MITI is responsible for the provision of the observation equipment. The JERS-1 satellite was launched on-board an H-I space vehicle in February 1992, and was positioned into a sun-synchronous orbit with an altitude of 570 km and an inclination angle of 98°. Both a Synthetic Aperture Radar (SAR) and an Optical Sensor System (OPS) are carried on-board the JERS satellite. As an Earth observation system, OPS employs eight linear array sensors to observe the Earth (Honda, 1993). Tables 5-6a and -b show the main OPS system characteristics.

Bands	1	2	3	4	5	6	7	8
(μm)	0.52-0.60	0.63-0.69	0.76-0.86	0.76-0.86	1.60-1.71	2.01-2.12	2.13-2.25	2.27-2.40

Table 5-6a: The Spectral Range of OPS Bands

IFOV	18m
Swath width	75m
Stereo angle	15.33°
B/H	0.3
Ground pixel size	18.3 x 24.2m

Table 5-6b: The Main Characteristics of OPS

The OPS scanner onboard JERS-1 incorporates eight spectral bands (see Table 5-6a), including a near-IR band that views 15.3° forward of the satellite nadir so that, when used in conjunction with the corresponding nadir view, it provides along-track stereoscopic coverage and viewing. Thus JERS acquires stereoscopic images during the same orbital pass in a way similar to that used in MOMS-02, whereas SPOT and IRS-1C/1D acquire them from different passes to give cross-track coverage. Both the forward and nadir-looking sensors observe 75km swaths, and have an 18 x 24m ground pixel size.

Even though the Japanese JERS-1 OPS has a systematic coverage over most of the Libyan terrain, obviously, with its reduced ground resolution, it cannot really meet the requirements for medium-scale map compilation either in terms of accuracy or content. This results from the fact that it cannot provide a good elevation accuracy (due to its poor base:height ratio (0.3)) while its poor object detectability of 35 to 50m affects both the planimetric accuracy and the information content that can be extracted from the imagery. According to this, it cannot be considered seriously for adoption for any national topographic mapping programme since its geometric and resolution characteristics are inferior to all of the rival systems – MOMS-02, SPOT and IRS-1C/1D – considered above.

5.2.6 ASTER

ASTER – an acronym for Advanced Spaceborne Thermal Emission and Reflection Radiometer – is a cooperative effort between Japan's Ministry of International Trade and Industry (MITI) and NASA, with the collaboration of scientific and industry organizations in both Japan and the USA. ASTER was mounted on-board the first platform in NASA's Earth Observing System (EOS AM-1) which was launched in December 1999. The orbital parameters are shown in Table 5-7.

Items	Description
Orbit	Sun Synchronous Descending
Time of Day	10:30 (A. M.) ±15 minutes
Altitude	705 km
Inclination	98.2°
Repeat	16 days (233 revolutions/16 days)
Orbit period	98.9 minutes

Table 5-7: EOS AM-1 Orbital Characteristics

The ASTER instrument consists of three separate instrument sub-systems. Each of these sub-systems operates in a different wavelength band, and is built by a different Japanese company. These sub-systems will operate in the following spectral regions:-

(i) the Visible and Near Infrared (VNIR),

(ii) Short-wave Infrared (SWIR), and

(iii) the Thermal Infrared (TIR) respectively.

5.2.6.1 Visible and Near Infrared (VNIR)

The VNIR subsystem has two telescopes – one nadir looking with a three-spectral band detector, and the other backward looking with a single-band detector (see Table 5-8).

Band No.	Telescope	Spectral Range (μm)
Band1	Nadir looking	0.52-0.60
Band2		0.63-0.69
Band3		0.76-0.86
Band3	Backward looking	0.76-0.86

Table 5-8: The Spectral Characteristics of the VNIR Subsystem.

The VNIR images are obtained by pushbroom scanning employing linear array CCDs. The VNIR system incorporates the following characteristics:-

(i) a ground pixel size of 15 x 15m and swath width of 60km from an orbital altitude of 705km with each VNIR image covering an area of 60 x 60km on the ground.

(ii) an off-nadir pointing cabability (±24°) in the cross-track direction.

(iii) acquisition of stereoscopic (nadir- and backward- looking) image data on the same orbit; and

(iv) Automatic correction of positional deviation between the acquired stereoscopic image data due to Earth rotation.

As with MOMS-02, since the backward looking sensor can image the same location scanned by the nadir-looking telescope with a time lag of about 55 seconds (equivalent to 27.6° visual gap in a flight direction), along-track stereoscopic images with base:height ratio of 0.6 can be obtained. These images can be employed to produce DEMs, ortho-images and other topographic mapping products.

Obviously, the VNIR images will have a rather better ground resolution and, of course, a better base:height ratio (0.6) than the other Japanese JERS-1 OPS imagery. Furthermore, if the ASTER system is launched and operates successfully, the VNIR sub-system will produce systematic coverage over the whole terrain of Libya. Unfortunately, with its reduced ground resolution, it cannot really satisfy the requirement of medium-scale mapping in terms of content. Because of this defect, the author cannot really advocate the adoption of the ASTER VNIR images for the national topographic mapping of Libya since the images from other rival systems (SPOT Pan and IRS-1C/1D) with higher ground resolution are already available in the market.

5.2.7 American Commercial Earth Observation Satellites

Currently three American companies - EarthWatch, Space Imaging, and Orbital Sciences - are developing high resolution imaging satellites utilising pushbroom scanners (Fritz, 1996a, b, c) for introduction to service in the near future. These and other proposed pushbroom scanners will provide panchromatic images with ground pixel sizes of 1 to 3m, and 4 to 15m in their multi-spectral bands.

(i) EarthWatch Inc. This company was established in 1995 by the merging of World View Imaging and the Ball Aerospace Technologies Corporation. The EarthWatch satellites are intended to provide complete global coverage and are named EarlyBird and QuickBird.

* *EarlyBird* with its staring (or areal) array imaging system was successfully orbited on December 24, 1997 using a Russian launcher. The satellite was placed into a near perfect circular orbit with an altitude of 470 km and an inclination angle of 97.3°. However communication with the satellite was lost on December 28, 1997 and has not been re-established. EarlyBird was equipped with two advanced sensors: a panchromatic sensor with 3m ground pixel size and a multi-spectral sensor (three bands) with 15m ground pixel size. The multi-spectral frames were designed to cover an area of 30 x 30 km, over which a series of 6 x 6 km panchromatic scenes could be imaged simultaneously. 36 panchromatic scenes would therefore have been contained in one single multi-spectral frame. Unfortunately, EarlyBird failed after few days, so it never become operational and now the efforts of EarthWatch will be focused on the construction and launch of QuickBird.

* The *QuickBird* satellite is scheduled to be launched in 1999 on a Russian Cosmos SL-8 space vehicle. It will employ a pushbroom linear array system, and will be put into a non sun-synchronous orbit with an inclination angle of 52°, and an altitude of 600 km. QuickBird will feature two advanced sensors which are: (i) a panchromatic sensor with a 0.82m ground pixel size; and (ii) a multi-spectral sensor with a 3.28m ground pixel size. The spectral range for the panchromatic band will be 0.45 to 0.90 μm, while the four bands used in multi-spectral mode will provide images with a spectral range in the blue (λ = 0.45 to 0.52 μm), green (λ = 0.52 to 0.60 μm), red (λ = 0.63 to 0.69 μm), and near-infrared (λ = 0.76 to 0.90 μm) parts of the spectrum. QuickBird is designed to acquire images over a broad area and will also have the ability to provide along-track stereo images of the Earth with a viewing angle of ± 30° which will result in a B/H ratio

of 1.0. An in-orbit Global Positioning System (GPS) will be used for the precise positioning of the satellite.

(ii) Space Imaging EOSAT. This American company has launched its pushbroom imaging system (IKONOS-1) in April 1999, but unfortunately this failed to be launched properly. A second satellite (IKONOS-2) is now being prepared. This will be launched into a polar sun-synchronous orbit with an altitude of 680 km. Again it will be using GPS as its positional sensor in conjunction with three digital star trackers for maintaining precise sensor attitude and pointing. Thus it is intended to provide absolute positioning in the 12 to 15m range without use of ground control points (Fritz, 1996a). The IKONOS sensor employs a flexible pointing system which has the capability to provide both along-track and cross-track stereo images with an optimal B/H ratio. Like QuickBird, its panchromatic sensor is designed to provide images with a 0.82m ground pixel size. In addition, four bands will be available in its multi-spectral mode with a ground pixel size of 4m.

(iii) Orbital Sciences Corporation is planning to launch its pushbroom imaging system - *OrbView-3* into a polar sun-synchronous orbit with a 470 km orbital altitude late in 1999. This imaging instrument will provide both panchromatic imagery with a 1m ground pixel size and 4m multi-spectral imagery with a swath width of 8km. OrbView-3 will revisit each location on Earth in less than 3 days and features an electro-optical scanner that has the capability to record images 45° off-axis in all directions. This will enable the system to provide along-track and cross-track stereo images with an optimal B/H ratio. Like QuickBird and IKONOS-1, OrbView-3 will use in-orbit GPS positioning of the satellite to enable the sensors to conduct precision-pointing to the customer areas of interest. If OrbView-3 becomes successfully operational, it will provide imagery useful for a variety of applications such as mapping and surveying, oil and gas exploration, national security, agriculture and forestry, and telecommunications and utilities.

Of course, a full analysis and discussion of the mapping potential of the imagery to be provided by each of these forthcoming systems must await their successful launch and introduction into regular service and the availability of test images. Obviously the higher ground resolution will be of great interest to the mapping community – though this will be counterbalanced to some extent by the restricted areal coverage of an individual scene – see Table 5-1. Also the quoted costs of this imagery are much higher than those of existing space imagery. Furthermore, since all of these companies (EarthWatch Inc., Space Imaging Inc. and Orbital Science Corporation) have policies of not providing raw imagery, but only fully processed (i.e. value added) image data products to the users, this will increase the cost of this data. This has huge implications for those countries (such as Libya) wishing to carry out systematic topographic mapping coverage and also for the suppliers of systems to the mapping community.

5.2.7.1 Other American Commercial Space Imaging Systems

In addition to those companies discussed above, three other American companies (GDE, Resource 21 and the GER Corporation) have received licences and permission from the US government to undertake commercial remote sensing from space. Their systems are being developed over a much longer time frame than the three systems described above.

* ***GDE System Inc.*** is planning to launch its imaging system in late 1999 into a sun-synchronous orbit with an orbital altitude of 743 km. This high resolution system is being designed to collect monoscopic images with 0.80m ground pixel size in 15km x 1,700km strips or in 120km x 120km patches. The GDE system is also designed to have a flexible pointing stereo system to acquire along-track and cross-track stereo images in 15km x 15km strips or in 70km x 70km patches. Thus it appears to have quite similar characteristics to those of the QuickBird, IKONOS and OrbView satellites discussed above.

* ***Resource 21*** is a commercial remote sensing information, system and services company that plans to develop and operate a constellation of four satellites primarily acquiring multi-spectral imagery. The four satellites will be put in exactly the same orbital plane, but with tightly controlled phasing. This phasing will result in two satellites being placed in each of two ground tracks that repeat every seven days. Each of the two satellites within a particular ground track revisits the same ground sites every third or fourth day, with the same access geometry. This strategy results in twice weekly revisits of all sites. The Resource 21 multi-spectral pushbroom imaging system is called M10 and is mainly designed for the collection of vertical (nadir) images in 205 km wide swaths with 10m ground pixel size. It has also the capability to provide off-nadir data collection. This system is designed specifically to provide precise monitoring of agricultural sites which use sophisticated farm equipment and so can carry out precision farming techniques.

* ***The Geophysical & Environmental Research Corporation (GER)*** is going to launch its GER Earth Resource Observation System (GEROS) which will include a group of six satellites. Each will carry (a) a multi-spectral sensor having a 10m ground pixel size and

(b) a panchromatic pushbroom sensor with a ground pixel size less than 10m. GEROS is also being developed with an initial emphasis on precision farming applications.

Excluding the last two systems (Resource 21 and GEROS), the forthcoming American systems should provide the required geometric accuracy as well as enough detectability to meet the requirements of topographic maps at 1:50,000 and 1:25,000 scales. From the user's point of view, because of their flexibility, they should also be able to acquire stereo images of the area of interest at any time provided that the area is cloud-free.

5.3 Possible Methods of Producing Image Maps from Space Scanner Images

The possibilities of producing image maps from space photography have already been outlined in Section 4.3. The corresponding methods that can be utilized with space scanner imagery can be somewhat different – since the image data is available from the outset in digital form and therefore does not need to be converted using a scanner. Thus the wholly digital processing method, including the implementation of the appropriate geometric and radiometric corrections mentioned in Section 4.3 is the most obvious procedure to be followed when producing such maps. The final ortho-image output can either be purely image data or it can be produced in analogue (hard-copy) form, e.g. on photographic film or paper or as a high-quality inkjet plot.

However, it is also worth noting the extensive use of space scanner imagery in hard-copy form – especially SPOT stereo-pairs – in analytical plotters (APs), as mentioned previously in Section 5.2.3.8. For this purpose, quite a large number of software packages have been developed. These include the Aviosoft and SPOT-MS packages for use with the Leica DSR, BC and SD series; the Trifid software for use with the Intergraph IMA instruments; the IGN software used with Matra Traster APs; the Adam Technology SPOTMap for its PROMAP instrument; etc. Mostly these have been used to carry out vector line plotting in the APs. However, in a few cases, e.g. with EMA's use of SPOT stereo-pairs, the final output has been a hard-copy ortho-image produced using a Wild OR-1 analytically-controlled orthophotoprinter.

5.4 The Suitability of the Different Scanner Sensors for Image Map series in Libya

The same criteria used in Section 4.5 will be used to evaluate the suitability of the scanner systems that are presently available for image mapping in Libya.

(i) In terms of planimetric acccuracy, MOMS-02/-2P and SPOT Pan images meet the standards required for image mapping at 1:50.000 and smaller. While IRS-1C imagery can satisfy the horizontal accuracy standards to produce image maps at 1:25.000 scale.

(ii) When it comes to the elevation accuracy, MOMS-02/2P, SPOT and IRS-1C/1D imagery all provide much the same results. However this is still marginal at ±10m, which means that only a fairly wide contour interval can be used even using stereo-imagery with a very good base:height ratio.

(iii) As Table 5-9 shows, all of the space scanner images still suffer from the lack of sufficient detectability of the small objects that need to be mapped. This means that a substantial production of the information required for mapping purposes cannot be obtained from these images. This leads to a need for a substantial field completion to provide the missing information. Although the IRS-1C imagery has better ground resolution than its rivals, it also has less contrast, because of its lower radiometric resolution (6-bit or 64 grey levels). It remains to be seen whether this is an important point or not.

(iv) Until now, the MOMS-02 and -2P have only achieved fragmentary coverage of Libya and this makes it unsuitable for use by the mapping programmes in the country. Also the 18m ground pixel size of MOMS-2P is not very promising either.

(v) The Landsat TM and SPOT systems have both produced systematic coverage of Libya and operate on a commercial basis. However TM is now 15 years old and SPOT has much the better ground pixel size and has a stereo-capability which is the reason why it has been considered as being more suitable for image mapping in the country. Now, with the establishment of a new ground receiving station in Athens, IRS-1C imagery is going to become available and the station should be able to produce a complete coverage of Libya –

Space Sensor	Ground Coverage (km)	Ground Pixel Size (m)	Planimetric Accuracy (m)	Height Accuracy (m)	Content/Feature extraction	Image Map Scale	Suitability for Libyan National Mapping Programme
Landsat TM	185 x 185	30	±15 to 66	No stereo	Smaller man-made features cannot be seen or extracted	1:100,000 and smaller	Not suitable
MOMS-02/-2P	100 x100	13.5 18	±16	±8	70% of the information needed can be extracted	1:50,000 and smaller	Not suitable
SPOT Pan	60 x 60	10	±8 to 12	±4 to 10	70% of data needed can be extracted	1:50,000 and smaller	Suitable
IRS-1C/1D	70 x 70	5.8	±5	±10	60 to 70% of the information can be obtained	1:25,000 and smaller	Suitable
JERS-1 (OPS)	75 x 75	18 x 24	±20 to 30	Poor	it is not possible to extract small man-made features	1:100,000 and smaller	Not suitable

Table 5-9: The different space scanners and their mapping characteristics

in which case, for the time being, it may be more suitable for the national mapping programme in the country than any other available space imagery.

(vi) All of the mentioned above space scanners provide data in digital form which make them more useable by the mapping community.

In summary, based on the previously mentioned five criteria, currently IRS-1C and SPOT Pan imageries are the most suitable products for image mapping applications in Libya. However there is undoubted potential in the imagery that will be forthcoming from the American commercial high-resolution satellites.

5.5 Conclusion

In this Chapter, the various high resolution space scanner sensors and imageries have been reviewed and their capabilities have been analyzed in detail in the context of national topographic programmes in general and their application to the mapping of Libya in particular. In this chapter, the author has paid special attention to the different space images acquired by scanner sensors and their actual or potential mapping capabilities in terms of their geometric accuracy; the information content that can be obtained for small-scale mapping (1:50,000 scale and smaller), especially in the arid and semi-arid areas of developing countries; and the suitability of these space scanner images for image map production. As far as a new Libyan national mapping programme is concerned, the availability of the various space images to the mapping community in Libya has also been a matter of great concern.

According to these criteria, currently SPOT panchromatic images with their ground pixel size of 10m (15 to 18m ground resolution) are the most suitable imagery available now for producing topographic line maps and image maps for Libya at 1:50,000 scale and smaller. Although SPOT can provide images with sufficient horizontal accuracy for the compilation of 1:50,000 scale maps and smaller, its elevation accuracy is marginal, and generally, it cannot provide sufficient information required for inclusion in 1:50,000 scale maps. This would lead to an urgent need for field completion to acquire the missing data. However, in the Libyan context, with so little cultural detail occuring in the huge areas of desert that make up most of the country. This may not be a major problem.

In the immediate future, it is obvious that the Indian IRS-1C/1D imagery will soon become available for Libya. In which case, it must be considered seriously as an alternative to SPOT. Many of its characteristics and capabilities are similar to those of SPOT – e.g. its cross-track stereo-coverage and its similar heighting accuracy. But its superior resolution (6m v. 10m ground pixel size) could produce some substantial gains both in planimetric resolution and in the information content and features that can be extracted from the IRS images.

Further down the line, the imagery from the forthcoming American high-resolution satellites will enter consideration. However the higher resolution has only been achieved by a drastic reduction in coverage (6 x 6km for EarlyBird and 11 x 11km for IKONOS-1), so that a very much larger number of images will need to be handled which has far reaching implications for the number of images needed to cover the country; and thus for the image processing and the provision of ground control points. Besides which, the cost of the overall mapping operation based on the use of these high-resolution images will be substantially increased.

In the next Chapter, a systematic analysis of the cartographic design aspects of the existing satellite image maps will be presented and discussed.

CHAPTER 6: A SYSTEMATIC ANALYSIS OF EXISTING SPACE IMAGE MAPS – A Review of their Cartographic Design Aspects

6.1 Introduction

Over the last two decades, a great deal of attention has been paid to space image maps. According to Dahlberg (1993), "The concept of photo and image maps is that of a mosaiced image tied to a co-ordinate base and accompanied by appropriate explanatory and correlative material to fulfil the purpose of the map". As far as these new maps are concerned, experimental work on producing this type of map has been undertaken by different mapping organisations and universities world-wide. The result of their efforts has been the publication of a variety of these new maps which differ in scale, purpose, projection, data source, format and design. Some of these maps form part of a series giving regional or national coverage; others are "one-off" experimental sheets.

The main objective of this chapter is to analyse systematically and to evaluate the cartographic design aspects of a representative sample of existing space photo and image maps that have been published by many different organisations. A total of 37 image maps have been collected for this part of the author's research project, representing experimental and publication work over a period of more than 25 years. These have been produced at a variety of scales, have been made for different purposes, and cover different areas in the world. Their image data have been acquired by different sensors (spaceborne cameras and scanners) and have been produced using different technologies (including both analogue and digital techniques). A great variety of solutions have been adopted resulting in a wide range of quite different map products. These range from simple monochrome products with a minimum of annotation to quite complex multi-colour products with extensive additional information.

6.2 Analysis and Discussion

The analysis will concentrate on the cartographic design aspects of the collected photo and image maps. In particular, it will discuss in some detail the nature of the background space image and the production methods used to generate it. It will also examine the amount and type of information that has been added to the basic image, including contours, grids, names, text and the graphic (point, line, and area) symbols which, through the use of colour and pattern, depict the different geographical elements (boundaries, roads and railways, water features, vegetation, and other cultural features) that have been included in the map. It will also include the marginal information (title, scale, legend, etc.) given by the map. The analysis is based partly upon the world wide experience as understood through the literature as well as the detailed examination of published photo and image maps. In this analysis, the writer will also rely partly on the background and experience that he has gained through his Master's degree study in the United States of America, and during the ten years period of his professional cartographic work in the Surveying Department of Libya. The 37 space photo and image maps that have been collected for this analysis, will be examined and evaluated from the point of view of a cartographer to see how much and what type of cartographic enhancement was added and how the design aspects of these maps have been treated or handled.

6.2.1 Important Elements

For the purpose of this analysis, the whole collection of photo and image maps has been classified into four groups. This classification has been based on their scale; thus each group of maps that carry the same scale have been placed in one class. Four tables (6-2; 6-3; 6-4; 6-5) have been compiled to record several of the most important elements found on these maps. As can be seen in these tables, the maps vary widely in scale, projection used, format and design, sensor and image type, and so on. The main characteristics of each of these individual elements will be outlined in the sections that follow.

6.2.1.1 Map Scale

The scales of the space image map products that have been analyzed vary from 1:50,000 to 1:1,000,000 but the most common scales are 1:50,000; 1:100,000 and 1:250,000 which have been used for 11; 10; and 8 maps respectively. Table 6-1 shows the number of photo and image maps at each scale used in the survey and subsequent analysis.

Scale	Number of Image maps
1:1,000,000	2
1:500,000	5
1:250,000	8
1:150,000	1
1:100,000	10
1:50,000	11

Table 6-1: The Number of Photo and Image Maps at each Scale.

As discussed in Section 3.2, there is an important relationship between the ground resolution of the sensor and the scale used for image map production. It has been reported by a number of researchers (Doyle, 1984), that reliable identification of the small cultural features or objects – such as roads, railroads and buildings – that are normally displayed on line maps at medium scale, requires a ground resolution of 1 to 2m or better. This means that, if the space images used for image mapping do not provide this level of resolution, then the small man-made (cultural) features will not be detected unless they are derived from an external source of data such as an existing map or through a field completion operation. The outcome of this consideration is that most space maps are not normally produced at medium scales. Up till now, 1:50,000 scale has been the largest scale that has normally been utilized for space image maps. However recently a few maps from Poland have been produced at 1:25,000 scale on the basis of high-resolution KVR-1000 and KFA-1000 images (Kaczynski, 1996a, 1996b).

Thus scale has a direct relationship with the ground resolution of the space image data that has been utilized to produce the space image maps. Analyzing **Table 6-2**, it can be seen that most of the 1:500,000 and 1:1,000,000 scale image map sheets are quite old. All date from late 1960s and 1970s, except the single sheet of Aswan, Egypt at 1:500,000 scale that has been produced by Technical University of Berlin (TUB) in 1993. Most of these sheets are based on old space photography that has been taken by the 70mm space cameras (6cm x 6cm format) on-board the manned Gemini and Apollo missions or they are based on Landsat MSS data. These early space images are characterised by their comparatively poor ground resolution that cannot meet mapping requirements except at these scales.

Turning next to **Table 6-3** which summarizes the eight space image maps at 1:250,000 scale, it will be noted these are spread over a longer time period (20 years) from 1969 to 1989. It will also be seen that, once again, they are mostly based on the use of Landsat MSS imagery, although two of them make use of Landsat RBV or TM images with their 30m ground pixel size, instead of the 80m pixel size of the Landsat MSS images.

From **Table 6-4**, it can be noticed that most of the ten 1:100,000 scale maps have been produced much later (in the 1980s), and most are based on the use of Landsat TM images – which only became available after 1984 and provided imagery with a higher ground resolution that could meet the requirements of 1:100,000 scale maps.

Whereas **Table 6-5** shows that all eleven 1:50,000 scale maps have been produced since 1990 – starting four years after the launch of the SPOT satellite. This means, that it was only the advent of still higher resolution space imagery – such as SPOT Panchromatic data and/or the Russian space photography (e.g. taken with the KFA-1000 camera) – that made it possible for cartographers to produce space image maps at this larger scale.

Along with the development of the imaging technology giving improved ground resolution and the advent of these larger map scales, more attention has had to be paid to image geometry and the removal of relief displacements using a DEM. The resulting orthophotomap or ortho-image map with its high information content and improved positional accuracy has attracted a lot of different map makers to carry out further experimental work which, in recent years, has resulted in the publication of these image maps at 1:50,000 scale.

From this simple analysis, it can be seen that there is quite a strong correlation between the scale that is used and the type of space imagery that was available at the time of production. Furthermore, among the 1:50,000 and 1:100,000 scale image maps produced in recent years, there have been many examples where two different types of space data have been merged together to produce maps with a better quality and giving more information. The fusion of SPOT Panchromatic images and the Landsat TM imagery is a typical example of this merging procedure. This allows the fused image to have the advantage of the higher spatial resolution of SPOT together with the possibilities offered by the multi-spectral colour or false colour TM imagery. The merging or fusion of these different images has also become more common now that this procedure is being provided in commercially available image processing software. This results from the fact that the geometry of the different imaging devices is becoming better understood.

No.	Scale & Format	Title	Publishing Year & Authorities	Data Source	Projection	Coordinate System	Colour Scheme Of Background	Additional Colours Employed	Final Output
1	**1:1,000,000** —	Land Use in the South-western U.S.A.	Univ. of California LA 1970	Space Photography: Gemini & Apollo.	—	• Geographic Coordinate System: Marginal & body ticks.	Monochromatic	Multiple Colours	Space Photomap
2	**1:1,000,000** 90 X 42cm	Victoria Land Coast Antarctica	U.S.G.S. 1972/73	Landsat: MSS: Band 7.	Universal Polar Stereographic	• Geographic Coordinate System: Full grid lines.	Monochromatic	Only One Colour: Black.	Satellite Image Map
3	**1:500,000** 46.5 X 134cm	Phoenix South U.S.A.	U.S.G.S. 1969	Space Photography: Gemini & Apollo.	Lambert Conformal Conic	• Geographic Coordinate System: Marginal & body ticks. • U.T.M.: Full grid lines.	Simulated Natural Colour	Three Colours	Space Photomap
4	**1:500,000** 36 X 37cm	Upper Chesa-peake Bay U.S.A.	U.S.G.S. 1972	Landsat: MSS: Bands 4, 5, 6,and 7.	Lambert Conformal Conic	• Geographic Coordinate System: Marginal & body ticks. • U.T.M.: Full grid lines.	False Colour	Only One Colour: Black.	Satellite Gridded Image
5	**1:500,000** 130 X 116cm	Arizona U.S.A.	U.S.G.S. 1972/73	Landsat: MSS: Bands 4, 6, and 7.	Lambert Conformal Conic	• Geographic Coordinate System: Marginal & body ticks. • U.T.M.: Full grid lines.	Monochromatic	Only One Colour:Black.	Satellite Image Map
6	**1:500,000** 130 X 98cm	Land Use Association Bangladesh	World Bank 1979	Landsat: MSS Data	—	• Geographic Coordinate System: Marginal ticks.	—	Multiple Colours	Satellite Image Map
7	**1:500,000** 44.5 X 61cm	Aswan Egypt	Technical Univ. of Berlin 1993	Landsat: MSS Data	Gauss Conformal	• Geographic Coordinate System: Lines & marginal ticks.	Simulated Natural Colour	Multiple Colours	Satellite Image Map

Table 6-2: Group I – Analysed photo and image maps at 1:500,000 and 1:1,000,000 scale.

No.	Scale & Format	Title	Publishing Year & Authorities	Data Source	Projection	Coordinate System	Colour Scheme Of Background	Additional Colours Employed	Final Output
8	**1:250,000** **44 X 74.5cm**	Phoenix U.S.A.	U.S.G.S. 1969	Space Photography: Apollo.	Universal Transverse Mercator	• Geographic Coordinate System: Marginal & body ticks. • U.T.M.: Full grid lines.	Simulated Natural Colour	Three Colours	Space Photomap (A map on verse)
9	**1:250,000** **74 X 78.5cm**	Mc Murdo Sound Region Antarctica	U.S.G.S. 1973	Landsat: MSS Data	Universal Polar Stereographic	• Geographic Coordinate System: Full grid lines.	Monochromatic	Only One Colour:Black.	Satellite Image Map
10	**1:250,000** **56 X 56cm**	Land Cover Of Puget Sound Region U.S.A.	U.S.G.S. 1975	Landsat: MSS Digital Data	—	—	Simulated Natural Colour	—	Satellite Image Map
11	**1:250,000** **32 X 33cm**	Khartoum Sudan	I.G.N. Paris 1978	Landsat: MSS Images	Polyconic	• Geographic Coordinate System: Full grid lines	Simulated Natural Colour	Three Colours	Satellite Image Map
12	**1:250,000** **30 X 40cm**	Khartoum Sudan	University of Glasgow 1979	Landsat: RBV Data	Universal Transverse Mercator	• Geographic Coordinate System: Full grid lines.	Simulated Natural Colour	Multiple Colours	Satellite Image Map
13	**1:250,000** **44 X 72cm**	Las Vegas U.S.A.	U.S.G.S. 1981	Landsat: MSS Data	Universal Transverse Mercator	• Geographic Coordinate System: Marginal ticks. • U.T.M.: Full grid lines. • National Coordinate System: Marginal ticks.	False Colour	Two Colours: Black & White.	Satellite Image Map (A map on verse)
14	**1:250,000** **44 X 61cm**	Baris Egypt	Technical Univ. of Berlin 1987	Landsat: -MSS -TM -RBV	Gauss Conformal	• U.T.M.: Full grid lines. • National Coordinate System : Marginal ticks	Simulated Natural Colour	Three Colours	Satellite Image Map
15	**1:250,000** **54.5 X 100cm**	Lesotho Lesotho	Lesotho Government 1989	Landsat: MSS:Bands 4, 5, and 7.	Universal Transverse Mercator	• Gegraphic Coordinate System: Full grid lines. • National Coordinate System: Marginal ticks.	Simulated Natural Colour	Three Colours	Satellite Image Map

Table 6-3: Group II – Analysed photo and image maps at 1:250,000 scale.

No.	Scale & Format	Title	Publishing Year & Authorities	Data Source	Projection	Coordinate System	Colour Scheme Of Background Image	Additional Colours Employed	Final Output
16	**1:150,000** 48 X 59.5	Kilimanjaro	NPA Ltd. 1986	Landsat: MSS Data	Universal Transverse Mercator	• Geographic Coordinate System: Margina ticks. • U.T.M.: Marginal ticks.	False Colour	Two Colours: Black and Red	Satellite Image Map
17	**1:100,000** 60 X 60cm	Land Cover Map Washington 1-858-E U.S.A.	U.S.G.S. 1978	Landsat: MSS Data	Universal Transverse Mercator	• Geographic Coordinate System: Marginal & body ticks. • U.T.M.: Full grid line.	False Colour	Multiple Colours	Satellite Image Map
18	**1:100,000** 60 X 60cm	Land Cover Map Washington 1-858-F U.S.A.	U.S.G.S. 1978	Landsat: MSS Data	Universal Transverse Mercator	• Geographic Coordinate System: Marginal & body ticks. • U.T.M.: Full grid lines.	False Colour	Multiple Colours	Satellite Image Map
19	**1:100,000** 55.5 X 90cm	Dyersburg Tenn. U.S.A.	U.S.G.S. 1982	Landsat: TM Data	Universal Transverse Mercator	• Geographic Coordinate System: Marginal & body ticks. • U.T.M.: Full grid lines. • National Coordinate System: Marginal ticks.	False Colour	Only One Colour: Black.	Satellite Image Map (A map on reverse)
20	**1:100,000** 37 X 50cm	Dubai UAE	ERSAC Ltd. 1984	Landsat: TM Data	Universal Transverse Mercator	• Geographic Coordinate System: Marginal ticks. • U.T.M.: Full grid lines.	Simulated Natural Colour	Multiple Colours	Satellite Image Map
21	**1:100,000** 64.5 X 56.5cm	Kazgail Sudan	U.S.G.S. 1986	Landsat: TM Data: Bands 2, 4, and 7.	Universal Transverse Mercator	• Geographic Coordinate System: Marginal & body ticks. • U.T.M.: Full grid line.	False Colour	Three Colours	Satellite Image Map

Table 6-4: Group III – Analysed photo and image maps 1:100,000 and 150,000 scale.

No.	Scale & Format	Title	Publishing Year & Authorities	Data Source	Projection	Coordinate System	Colour Scheme Of Background Image	Additional Colours Employed	Final Output
22	**1:100,000** 51 X 55cm	Baris Egypt	Technical Univ. Of Berlin 1987	Landsat: TM Data + Large Format Photos	Gauss Conformal	• Geographic Coordinate System: Marginal ticks. • U.T.M.: Marginal ticks. • National Coordinate System: Full grid lines.	Simulated Natural Colour	Four Colours	Satellite Image Map
23	**1:100,000** 66 X 77cm	Berlin Germany	Technical Univ. Of Berlin 1988	Landsat: TM Data SPOT: Pan. & XS Data	Gauss Conformal	• GeographicCoordinate System: Marginal ticks.	Simulated Natural Colour	Two Colours: Black & White.	Satellite Image Map
24	**1:100,000** 47 X38cm	Kuwait City Kuwait	Intergraph Co. 1991	Landsat: TM Data + SPOT: Pan. Data	Universal Transverse Mercator	• Geographic Coordinate System: Full grid lines.	False Colour	Two Colours: Yellow & Blue.	Satellite Image Map (Poster)
25	**1:100,000** 50 x 73cm	Cap Haitien Haiti	I-mage Consult Belgium 1998	Landsat: TM Data Bands 4, 5, 3.	Universal Transverse Mercator	• Geographic Coordinate System: Marginal ticks. • U.T.M.: Full grid lines. • National Coordinate System: Marginal ticks.	False Colour	Four Colours	Satellite Image Map
26	**1:100,000** 39 x 54.6cm	Kagera Region (Ngara area) Tanzania	I-Mage Consult Belgium 1998	Landsat: TM Data	Universal Transverse Mercator	• U.T.M.: Marginal ticks.	Monochromatic	Multiple Colours	Satellite Image Map

Table 6-4 (cont.): Group III – Analysed photo and image maps at 1:100,000 scale.

No.	Scale & Format	Title	Publishing Year & Authorities	Data Source	Projection	Coordinate System	Colour Scheme Of Background Image	Additional Colours Employed	Final Output
27	**1:50,000** 50 X 85cm	Slieve Bloom Mountains Ireland	ERA & Maptec International Ltd.1990	Landsat: TM Data: Bands 1, 2, and 3. & SPOT:Pan. Data	—	—	Simulated Natural Colour	Multiple Colours	Satellite Image Map (A map on verse) (Poster)
28	**1:50,000** 52 X 56cm	Leipzig Germany	FPK & KAZ Berlin 1990	COSMOS Satellite & KFA-1000	Gauss Conformal	• Geographic Coordinate System: Marginal ticks.	Simulated Natural Colour	Only One Colour: Black.	Satellite Image Map
29	**1:50,000** 37 X 54.4cm	LAAG Somalia	Technical Univ. of Berlin 1990	Landsat: TM & SPOT:Pan. Data	Gauss Conformal	• Geographic Coordinate System: Marginal ticks. • National Coordinate System: Full grid lines.	Simulated Natural Colour	Only One colour: Black.	Satellite Image Map
30	**1:50,000** 48.5 x 48.5cm	St. Louis Missouri U.S.A.	Intergraph 1990	SPOT: Pan. & XS Data	—	—	False Colour	Two Colours: white & yellow	Satellite Image Map
31	**1:50,000** 70 X 100cm	Ruhrgebiet Germany	FPK Berlin 1990	Landsat: TM & SPOT:Pan. Data	—	—	Simulated Natural Colour	Two Colours: Black & White.	Satellite Image Map
32	**1:50,000** 80 X 116cm	Berlin-Potsdam Germany	FPK Berlin 1991		—	—	Simulated Natural Colour	Two Colours: Black & White.	Satellite Image Map
33	**1:50,000** 50 x 70cm	Stockholm Sweden	SSC Satellitbild 1992	SPOT: Pan. & XS Data	—	—	Simulated Natural Colour	Only One Colour	Satellite Image Map
34	**1:50,000** 52X52cm	Oressaare Estonia	SSC Satellitbild 1994	SPOT: Pan. & XS Data	Universal Transverse Mercator	• Geographic Coordinate System: Marginal ticks. • U.T.M.: Marginal ticks. • National Coordinate System: Full grid lines.	Monochromatic	Multiple Colours	Satellite Image Map
35	**1:50,000** 54.5 x 55cm	Bigene Guinee Bissau	I-Mage Consult Belgium 1998	SPOT:Pan. Data	Universal Transverse Mercator	• Geographic Coordinate System: Marginal ticks. • U.T.M.: Full grid lines.	Monochromatic	Only One Colour: Black	Satellite Image Map
36	**1:50,000** 76.8 x 100cm	Sheet 17 Egypt	Hunting & SDS UK 1999	Landsat: TM & SPOT:Pan. Data	Universal Transverse Mercator	• National Coordinate System: Full grid lines.	Simulated Natural Colour	Only One Colour	Satellite Image Map
37	**1:50,000** 76.8 x 100cm	Sheet 24 Egypt	Hunting & SDS UK 1999	Landsat: TM & SPOT:Pan. Data	Universal Transverse Mercator	• National Coordinate System: Full grid lines.	Simulated Natural Colour	Only One Colour	Satellite Image Map

Table 6-5: Group IV – Analysed photo and image maps at 1:50,000 scale.

6.2.1.2 Sheet Format

The sheet formats of the analyzed image maps differ both in shape and in size. An examination of the space image maps contained in this survey shows that rectangular sheet formats are more used, but there are a considerable number of sheets in which a square or nearly square format has been utilized. Furthermore, with these square format image map sheets, entirely different sheet dimensions have been used. This means that there is no agreement about the most desirable sheet dimensions. Though of course this can be influenced by the dimensions of the devices (film writers, printing machines, etc.) that are available for image map production. In practice, the sheet size is also affected by the intended use of the image map. For example, those maps intended to be used in the office or to act as wall maps will probably have larger sheet dimensions than those needed to be taken to the field. Whereas, for those image map sheets likely to be used in the field, it will be more convenient to adopt a relatively small sized format. Of course, the smaller the sheet size, the larger the number of individual image map sheets that have to be produced in the series. This will require more individual map sheets to be produced.

6.2.1.3 Data Sources

As discussed above, space images can be provided either as analogue images or in digital data form. Space photography recorded by space cameras will be provided in hard copy form (film diapositives or paper prints) that can be converted to digital form using a scanner, while space imagery acquired by space scanners will be obtained directly in digital data form. For the production of the analyzed image maps, image data has been acquired by these quite different types of sensor. These data sources do include space photography (e.g. NASA's Large Format Camera and various Russian cameras) but, in general, only a very few of the maps being analyzed here have used such photographs since little or no systematic coverage has been acquired with these cameras. In practice, by far the largest number of space image maps have been produced using Landsat or SPOT imagery. These are the only true production systems; so there is systematic coverage and the images are very easily obtained from a variety of sources. As discussed in Chapter 3, to produce any general purpose space image map at 1:50,000 scale, a ground resolution of 1 to 2m is required for the smaller cultural features (roads, buildings, etc.). Since, in general, this level is not available for civilian users, SPOT

Pan imagery and the Russian space photography are the only data that come in any way close to satisfy mapping requirements as such a scale.

6.2.1.4 Projection

The space image maps contained in the sample have all been geo-referenced and are presented on five different projections:- Universal Transverse Mercator (16 maps), Gauss Conformal (7 Maps), Lambert Conformal Conic (3 maps), Universal Polar Stereographic (2 Maps), and Polyconic (only one map). Eight of the maps have no stated projection.

Projection has also a direct relationship with scale. From Table 6-2, it can be seen that the Lambert Conformal Conic projection has been used only for maps at 1:500,000 scale by a single agency (U.S.G.S). The Universal Polar Stereographic (Tables 6-2 and -3) is a special projection for polar areas and has been applied to the only two examples from Antarctica. Again only the U.S.G.S. has produced these maps. Almost all the maps at 1:250,000; 1:100,000 and 1:50,000 scales use the UTM or Gauss Conformal projections – which are essentially the same projection. The Polyconic projection has been used only for a single map produced by a French agency (IGN). Of course, this projection has been used for topographic maps during the 1950s and 1960s in the USA but it is not commonly used by IGN.

6.2.1.5 Co-ordinate System

As Table 6-6 shows, these space image maps are tied to one or other of three co-ordinate systems – the geographical co-ordinate system (latitude and longitude); the Universal Transverse Mercator (UTM) co-ordinate system; and various national co-ordinate systems. They are utilized in different forms – either as full grids or graticules, the use of marginal ticks only, or the use of both marginal and body ticks. Some of these maps are carrying all three of these co-ordinate systems in different forms; some of them carry two co-ordinate systems; while others just carry a single co-ordinate system. Five maps do not carry any co-ordinate reference system. See Table 6-7.

Co-ordinate System Used	The Number of Maps		
	Full Grids	Marginal Ticks	Marginal & Body Ticks
Geographical	7	12	10
U T M	14	3	–
National	4	6	–

Table 6-6: The Number of Maps and the Co-ordinate Systems Used in Different Forms.

One Co-ordinate System			Two Co-ordinate Systems			Three Co-ordinate Systems
G	UTM	N	G + UTM	G + N	UTM + N	G + UTM + N
10	1	0	11	1	1	6

Table 6-7: The Number of Maps and the Number of Co-ordinate Systems Used.

Where **G** = Geographical Co-ordinate System

UTM = UTM Co-ordinate System

N = National Co-ordinate System

6.2.1.6 Colour Scheme of the Background Space Image

The subject of space image maps only started 30 years ago with the advent of cameras and other imaging devices being orbited in space. At the beginning, most experimental work and publication was concerned with the production of monochrome photomaps at very small scales (see Maps 1 and 2 in Table 6-2) with simple annotation, mostly names and a title, added to the image. These products are characterised not only by their imperfect planimetric quality but also by the limitations of monochrome half-tone reproduction technology. In 1972, came the launching of Landsat-1 which ensured the availability of space images on a regular basis and helped to establish and develop digital image- processing techniques. In particular, space image maps then began to acquire colour – either false colour or simulated natural colour – making use of the 4 different channels giving images over different wavelength bands that were produced by the MSS sensor. This offered more possibilities to the cartographer and so more attention could be paid and more sophistication could be employed in the design aspects in the production of satellite image maps.

The colours used with the overall background image have a very strong influence on the final image map. The final choice as to which colour scheme should be used depends solely on the decisions made by the cartographer and will be strongly influenced in the first instance by the purpose for which the map is being produced. For example, simulated natural colour may be decided upon for non-specialist users; false colour may be appropriate if the final product is intended to be used by geologists or vegetation specialists; and a purely monochromatic representation may be employed if there is an urgent need for the map or it is necessary to work within a restricted budget. It should be noted that the availability of colour or false-colour images, e.g. those produced by multi-spectral scanners, will also play an important part in this decision. Here, in this case, the most common colour scheme that has been used as a background image is simulated natural colour (19 maps), with monochromatic images (7 maps), and false colour images (11 maps) used on a smaller number of space image maps.

6.2.1.7 Additional Colours Employed

The total number of colours employed in the cartographic design will often be more than those that are used for the background space image. The number of additional colours employed depends, to a certain extent, on the amount and type of annotation that will be added to the image map. The additional colours that have been utilized on the collected background image vary greatly from a single colour to multiple colours. The respective numbers used are: a single additional colour (on 10 maps), two colours (on 7 maps), three colours (on 6 maps) and multiple colours, i.e. four different colours or more (on 10 space image maps). Of course, the use of more colours will usually facilitate the cartographic design and allows more design possibilities, however, this practice also increases the effort, time and cost required in the map production.

6.3 The Amount & Type of Cartographic Treatment Used on the Analyzed Space Image Maps*

The advantage of employing space images as part of the map content over purely conventional line maps is that they can be highly informative and give information that cannot be given in any other way. However, at the same time, it should be recognised that, if the photos or images are used as the main content of the map, they will not contain certain types of information that are valuable to the user. Hence it is desirable to combine the images with certain relevant features such as national or administrative boundaries, communication lines, power lines, and other cultural features, together with certain vegetation, relief and topographic features that either do not show up on the space images or need enhancement to

* Various sources were used for this discussion, e.g. published papers, notes found on the maps themselves and the author's personal experiences.

help the user to discover them. Of course, the amount of detail and the type of features that need to be added and the method of cartographic representation that has been adopted must be that appropriate to the map scale and purpose.

As already discussed, the 37 analyzed space image maps differ greatly in scale. Furthermore they have been produced mainly for two rather different purposes – (i) general topographic mapping and (ii) land cover/land use mapping. As has been seen from Tables 6-2; 6-3; 6-4 and 6-5, the whole collection of image maps has already been divided into four groups regarding to their scale. A further set of Tables – 6-8 to 6-11 – has been produced setting out in more detail the content for each individual map contained within the group of maps that have been produced at the same scale. Those at one particular scale have been placed together in a single Table to examine how much cartographic symbolization and annotation has been added; what type of features have been added; and, last but not least, how these features have been represented on the map. In the following sections, all of the different elements that have been involved in the cartographic treatment will be discussed and analyzed fully in a systematic way. Thus, the analysis and discussion will be based on the scale and the purpose of these maps.

6.3.1 Group I – Analyzed Space Image Maps at 1:500,000 and 1:1,000,000 scale

These small-scale maps fall into three distinctive sub-groups – image mosaics; land use/land cover maps; and general-purpose topographic maps. Each sub-group will be analyzed separately in the first instance.

6.3.1.1 Image Mosaics

As can be seen from Table 6-8, three of the maps (Nos. 2, 4 and 5) at the smallest scales have no added symbolization or annotation whatsoever. Essentially they are image mosaics. In fact, all three maps have been produced as experimental sheets by USGS using Landsat MSS imagery with its limited ground resolution shortly after it become available. Maps 2 (of **Victoria Land Coast of Antarctica**) & 5 (of **Arizona**) have both been produced in 1972-73 just after the launch of the first Landsat satellite. Both sheets are printed in monochrome, and essentially they are gridded geo-referenced mosaics that attempt to give a general idea about the terrain to the map users. With their large sheet sizes, monochrome appearance and total lack of annotation, it would appear that they are intended more to give a general overview of a huge area of terrain at a small scale (1:500,000 or 1:1,000,000) rather than depict the area in any great detail. One has the impression that many of these ended up as wall maps for teaching, planning or illustrative purposes. It is difficult to envisage other uses for them.

Area of the Map	Image Map Number	Cultural Features																	Water Features			Vegetation		Relief		Names/Text
		Boundaries			Roads & Railways					Other Cultural Features																
		Primary Level (e.g. International)	Secondary Level (e.g. Provincial)	Tertiary Level (e.g. County)	Primary Roads	Secondary Roads	Motorable Tracks	Foot Paths	Railways	Towns	Villages	Isolated Buildings	Pipe Lines	Power Lines	Wells	Cemeteries	Mosques/Churches	Quarries	Rivers	Canals	Water Bodies	Cultivated	Natural	Contours	Spot Heights	
South-Western USA	1	✓	✓		✓				✓	✓	✓								✓		✓	✓	✓		✓	✓
Antarctica	2																									✓
Phoenix-South USA	3	✓			✓	✓	✓		✓	✓	✓	✓						✓	✓	✓	✓			✓	✓	✓
Upper Chesapeake Bay USA	4																									
Arizona USA	5																									✓
Bangladesh	6	✓			✓				✓	✓	✓															✓
Aswan Egypt	7				✓	✓	✓	✓	✓	✓	✓			✓				✓		✓					✓	✓

Table 6-8: Features added to image maps at 1:500,000 and 1:1,000,000 scale.

By contrast, Map 4 of **Upper Chesapeake Bay** (Fig. 6-1) has been produced using a false colour background image. Furthermore it has a much smaller format than the other two examples and so covers a very much smaller area of terrain. The use of the false-colour image is intended to pick out the distribution of the major different areal features (such as water, vegetation, etc.) of this area. However no attempt has been made by the USGS cartographers to classify or identify these features, so that their actual interpretation has been left entirely to the user. The value that the user can make of this information depends entirely on his reference level, in particular his background knowledge of the land cover that occurs in this particular area. Local knowledge would be essential to make good use of this sheet.

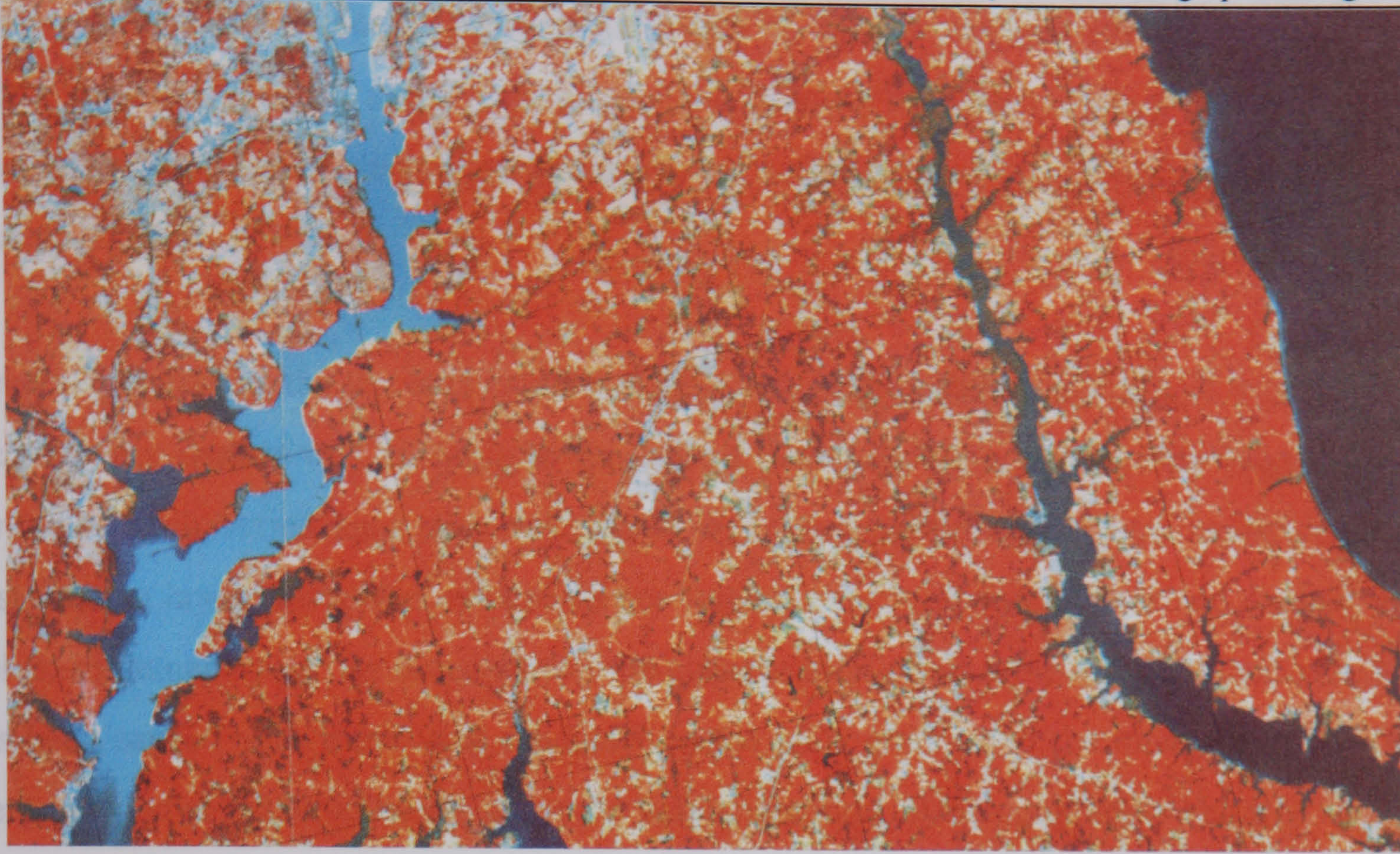


Figure 6-1: A small window from the USGS Upper Chesapeake Bay satellite image map at 1:500,000 scale.

6.3.1.2 Land Use/Land Cover Maps

Maps 1 and 6 are entirely different to the previous group of unannotated image maps. Thus they have been produced specifically to show the land use and land cover of the areas that they cover and far more effort – regarding interpretation, classification and cartographic representation – has been put into their production by the cartographers concerned in order to ease the problems of interpreting the space imagery and to provide users with additional valuable information. As can be seen from Table 6-8, a considerable level of symbolization has been added to both maps.

Map 1 (**Land Use in the South-Western U.S.A.**) has been produced in 1970 by a team working under Professor Thrower at the University of California, Los Angeles (UCLA). This space photomap has been produced utilizing Gemini & Apollo space photography. These photographs have not been taken in a systematic or regular manner resulting in a highly irregular shape in terms of the ground covered by the map. The space photographs have been rectified and enlarged to 1:250,000 scale and have been joined together by the classical method of cutting and sticking them together to form the hard-copy image mosaic of the area that constitutes the base of this space photomap. Photo-interpretation has then been carried out visually on the enlarged space photos by Professor Thrower's team. Since these early space photos are characterized by their poor resolution and clarity, by patches of cloud cover and changes in the appearance of adjacent areas due to time or seasonal differences, additional source materials such as aerial photography and existing topographic maps and field checks have been used to assist in the interpretation and delineation of a relatively small number of land use classes.

Generally speaking, the test area exhibits a considerable diversity of land use. It extends from the very dry deserts of California to the humid lands of Texas. Within this large area are contained such varied land uses as irrigated and non-irrigated agricultural lands; cropland: vast grazing lands; woodland and coniferous forests; hard rock mining sites and extensive oil fields; settlements; etc. As noted above, the classification of all these different land use types has been carried out visually and manually on the photographs. All the interpreted land uses were mapped at 1:250,000 scale using the corresponding USGS topographic maps of the area at that scale as a base with the space photos overlaid on top of them. Then the mosaic and the cartographic point, line and area symbolization have been reduced to 1:1,000,000 scale for the final production of the space photomap.

As can be seen in Figure 6-2, the different land use areas have been represented by a simple but quite varied colour scheme (red, blue, green, purple, etc.) with certain of the areal colours used in different degrees (2 green, 2 brown, etc.) to represent the different sub-classes of land use. Roads and railways have both been depicted using a single continuous red line with no attempt to differentiate between them. The cartographic production has been undertaken using the then conventional techniques of scribing for the line work and the cutting of open window masks. No contours have been included to represent relief, and instead only spot heights have been superimposed. Thus the only relief that has been picked out is that given by rock outcrops or the darker shadow areas of mountain areas.

In summary, this map is of particular interest in that it was a pioneering attempt to utilize space photography to produce a small-scale cartographic product of interest to geographers and other environmental scientists concerned with land use.

Figure 6-2: A small window from Land Use in the South-Western USA at 1:1,000,000 scale.

Map 6 (**Bangladesh Land Use Map**) has been published in 1979 by the World Bank (IBRD). A collection of 14 Landsat MSS images has been joined together to produce the image mosaic for the whole of the area of interest. Fortunately, 11 of these images had been imaged within a four day period. The time differences for the other three is about 55 days so that not too much change had taken place on the ground and these images do not stand out as being substantially different to the others. The identification and the delineation of the land use features appear to have been carried out digitally by means of a supervised (or unsupervised) classification technique on a digital image processing system. No attempts have been made from the cartographer's side to pick out any of the land use areas. Indeed, the cartographic symbolization has been restricted to the addition of a few point and line symbols and names. Of course, this has saved a considerable time, effort and cost. The use of the machine-based classification has resulted in the inclusion of quite a large number of categories of land use – such as water features, agricultural areas, agricultural crops, forests, urban areas, etc. In turn, each of these categories has been sub-divided into 5 or more classes. A large number of colours, such as red; green; blue; brown; yellow; orange; purple; grey; white and etc., have been used to depict these various classes of land use. The original colours of the image mosaic were various combinations of red, green, blue as displayed on the computer screen which then appear to have been converted to the four process colours – cyan, magenta, yellow and black – that have been for the final printing of the space image map.

Figure 6-3: A small window from Bangladesh Land Use satellite image map at 1:500,000 scale.

As Table 6-8 shows, only a few point and line symbols and names have been added to the machine-classified image. These represent international boundaries; primary roads and railways; towns, villages and names. The very detailed, colourful, yet somewhat confusing image given by the numerous land use categories has created a serious problem in the sense of decreasing visual contrast and clarity. It has also limited the use of colour to black for all the symbols and names. As a result, the international boundaries have been represented by interrupted lines in black. Primary roads have been depicted using black continuous lines with a white casing, while railways have been shown using black lines with extensions (small ticks). Solid black stars and circles have been used for towns and villages. As Figure 6-3 shows, in order to increase the visual contrast and clarity of all the added symbols and names, white halos have been added extensively to highlight them. In fact, this does not appear to be a good design practice since these halos have hidden more image detail and indeed have disturbed the visual balance of the final appearance of the map.

Since these two maps – Map 1 (at 1:1,000,000 scale) and Map 6 (at 1:500,000 scale) – differ in various ways, namely scale; the area being mapped; the space image data being utilized data and in the production methodology that has been adopted, the author in his analysis is not attempting to make some kind of comparison between them. Instead the intention is more to evaluate these two land use map products in terms of their potential use, and to what extent their cartographic design is successful.

Map 1 is characterized by (i) its very small scale; (ii) the very poor resolution and clarity of its detail; and (iii) the irregular shape of the map format. With all of these rather negative elements in mind, the big question is 'why has this map been produced for land use purposes?'. The answer appears to be that this map has mainly been produced to test the use of space photography for land use mapping. In fact, the release of this satellite photography for research purposes by the NASA stimulated interest in a number of Earth science disciplines. Geographers were especially interested in the potential utility of this type of photography for the construction of generalized land use maps at small scales, particularly for large areas where such information did not exist. As a preliminary step to the mapping of land use using space images, the space photos of the South-Western USA were used to develop interpretation techniques and classification systems appropriate to this type of generalized land use mapping. Indeed, this map is really an experimental sheet with no attempt to add the detailed drainage system through the use of cartographic representation which is very important as far as the different land use features are concerned. Almost no point symbols and very few linear symbols have been added. It will be noted too that no attempt was made to use digital image processing techniques – only the conventional manual photo-interpretation and cartographic methods of the 1960s were used to produce the sheet.

Map 6 is quite different to Map 1 in terms of using Landsat MSS imagery with its better resolution and systematic coverage. Also the availability of digital image data allowed the use of computer-based processing and classification techniques, so many more land use categories and sub-divisions have been included in this map. Furthermore the World Bank has published the map to be used for its own purposes of planning and carrying out development studies for the whole country (Bangladesh) being mapped. Although the resulting very colourful image has dominated and limited the cartographic design possibilities, a considerable level of point and line symbolization and annotation has been superimposed on top of this image – albeit in a very restrictive manner. However, the representation of the various land use classes through the use of colours as a part of the image, is successful in that it appears to have satisfied the specific requirements of the users at whom it was aimed. However, for the general map user seeking information on the location of settlements or the main communication networks, the map is extremely confusing and difficult to read. Nevertheless it has set a style for small-scale land use maps that is recognisable even today – as in the case of the land use maps of Europe produced from space imagery under the Corine Project.

6.3.1.3 Topographic Maps

Maps 3 and 7 are very different to the others in this scale group in that they are general-purpose topographic maps that have been produced at 1:500,000 scale. Although these two maps are similar in a sense of having the same scale and being produced for general purposes, they differ widely when it comes to the utilized space data, their sheet dimensions and the image and cartographic data processing that has been used in their production. Simulated natural colour has been used to produce the background image on both of these maps. The simulated natural colour tones of the image base are noticeably quite darker in the mountainous areas.

Map 3 (**Phoenix South**) has been produced as an experimental space map sheet in 1969 by USGS. The background image mosaic has been produced manually by joining together a number of rectified hard-copy space photographs acquired during the manned Gemini and Apollo missions. Again, as with Map 1 discussed above, these early space photos have not been taken in a systematic manner to cover the area of interest; indeed many small windows have been left without any photo coverage. The sheet dimensions of this map are 46.5 x 134cm. This highly rectangular shape format with its excessively large width may be quite difficult to handle in the field. Of course, it can be folded, but in this case, the user cannot view the whole sheet easily in a consistent manner. This map carries geographic co-ordinates in the form of marginal and body ticks. Furthermore, a full 50,000-metre UTM grid has been incorporated in order to facilitate comparisons between the image map and the corresponding conventional topographic line map at the same scale.

The background image mosaic has been printed in two sepia tones (light and dark tones). The cartographers involved in the design of this sheet did not attempt to pick out or highlight any of the urban areas or other settlements. Also no attempt was made to interpret and highlight the vegetation and forest areas. In fact, lakes and other water bodies are the only areal features that have been depicted on this map. As a result, to make good use of this map requires a skilful user who is capable of interpreting and identifying all these other areal features from the image mosaic. Furthermore a good local knowledge of the area is essential if good use is to be made of the map.

From Table 6-8 and Figure 6-4, it can be seen that a substantial number of symbolized point and line features and annotation have been added to this map to aid the user. These include international boundaries; roads and railways; towns and villages; water features and relief information. Although the scale of this map is quite small, very small point symbols such as those representing important buildings, quarries and airfields have also been included in the map. Once again, these features appear to have been derived from the USGS state base maps and have been added in black and blue colours. As can be seen from Figure 6-4, the names and the point, line and area symbols in black and blue contrast reasonably well against the variable sepia tones of the background image. Names can be read against the sepia image anywhere on this photomap. The water features such as rivers, canals and lakes have been represented using a blue colour. The rivers and canals have been depicted using continuous dark blue lines, while the lakes and other water bodies have been shown using light blue areal tints outlined by continuous dark blue lines. Besides the rock outcrops and darker shadow areas of mountain areas, contour lines with contour intervals of 500 feet and spot heights are the other means of relief representation that have been added in black. All the map production appears to have been carried out using the conventional methods of scribing for the line work and the cutting of open window masks – since this was the cartographic methodology in common use at the time of the production of the map.

Due to its lack of resolution, the background image of this photomap is not of a high quality and it is very difficult to identify most of the features on the image. Obviously, the intention of the USGS was to examine the potential of this early space photography for small-scale general topographic mapping purposes. This means it is an experimental sheet, and essentially there appears to have been no intention to produce it as part of a general series for use by a wide range of potential users. Moreover, the existing cultural plate of the area has been added to the map without any effort from the USGS cartographers to modify or change any of its symbolization or annotation to fit the photomap design requirements. In the author's opinion, the overall representation of the terrain and the cartographic design of this map have not been executed with a lot of thought.

Figure 6-4: A small window from the Phoenix South space photomap at 1:500,000 scale.

Map 7 (**Aswan, Egypt**) has been produced in 1993 by the Technical University of Berlin. Unusually for this comparatively recently produced map, the background space image is based on the use of the Landsat MSS imagery. However given the small scale and large areal coverage, this is perhaps not too surprising or restrictive. As reported by Mehlbreuer and Kähler (1988), a group of six adjacent images have been geometrically and radiometrically corrected and then joined together to form the image mosaic for the area being mapped. Using a modern approach to space image map production, the processing of the data appears to have been carried out entirely using digital techniques. That is to say no analogue-to-digital or digital-to-analogue conversion of the image data has taken place until the colour separations have been generated for the final printing process. In contrast to some of the older maps, the digital processing has preserved the image detail as far as possible and has yielded good image quality. Simulated natural colour has been adopted for the image mosaic to produce a natural colour impression of this desert area by the map. Topographic features such as mountains, ridges and wadis are displayed in great detail and quality without any need for additional cartographic enhancement; while the names of these features have been added in order to ease their interpretation and identification. Furthermore, the vegetation that is present in the area has been picked out in green from additional source materials. This map has been designed and produced using sheet dimensions of 44.5 x 61cm to make it easier for users to handle this map in the field. Map 7 only carries geographical co-ordinates in the form of full grids (1° x 1°) and marginal ticks.

Figure 6-5: A small window from Aswan, Egypt satellite image map at 1:500,000 scale.

As can be seen in Table 6-8 and Figure 6-5, a substantial level of symbolization and annotation has been added for the representation of roads and railways; canals; towns and settlements; quarries and mines; airports and airfields; ancient sites; wells; spot heights and names. Roads have been classified into five classes. According to their respective importance, these road classes have been given different line widths and have been represented by triple, double and single lines. The first four classes have been designed using continuous lines with either orange or yellow infill within black casings. Car tracks and paths must always be considered as very important communication lines in this type of desert area and they have been depicted by single dashed lines in yellow. This yellow line gives a high contrast in the darker areas of the background image but it may disappear and or hardly be seen in the lighter areas. Railways have been classified into two classes. The currently used railways have been represented with black and white lines, while disused or abandoned railways have been represented by single dashed black lines.

All point symbols excluding wells have been represented by geometric point symbols in black. Towns have been depicted by small areas of red colour outlined with black lines. Canals have been shown using continuous blue lines, while wells have been depicted by a solid blue circle outlined with black. Spot heights have been depicted in black and distributed all over the map. Although all the names have been printed in black, they vary in style and size. For example, the names of cultural features have been written using the sans serif Ariel font in different sizes, whereas serif fonts have been used for physical feature names. To distinguish wadis and wells as water features from the others, their names have been designed using italic letters.

As noted above, Map 7 has been produced by Technical University of Berlin, and its compilation and production has taken place within the scope of a special scientific research project – Geoscientific Problems in Arid and Semi-Arid Areas. In other words, the real users of this satellite image map were expected to be the geologists, hydrologists, geographers, etc. carrying out research (including field work) in the area. All of these users require a clear and well represented general topographic map both for use in the field and to act as the base for the recording of their scientific observations. In particular, the Aswan satellite map is characterized by the very good quality of the background image that has been printed using simulated natural colour. Features such as ridges and mountains; valleys and wadis; rivers; sand dunes have all been picked out and are displayed in considerable detail and can be identified without additional symbolization and annotation. From the cartographic point of view, this map has been well designed through the sensitive use of point and line symbols in different forms, dimensions and colours. Names have been selected and placed in a good manner. In the author's opinion, this map has resulted in a successful representation of this large area of desert terrain. It is a good pointer to what could be achieved over the very similar terrain that exists over most of Libya.

6.3.1.4 Summary Regarding the 1:500,000 and 1:1,000,000 Scale Space Image Maps

In general, as can be seen in Table 6-8, most of the maps at these very small scales do not show small point features such as isolated buildings, mosques and churches, quarries, etc. The only maps that have shown these features have been produced for desert and semi-desert areas where individual buildings, wells, tracks and paths are very important features and must be depicted on small-scale maps. Due to the poor resolution and clarity of the images used for the production of these maps, many of these additional features appear to have been derived from existing maps, aerial photos, other space data, or from field completion operations and superimposed over the space image. It can also be noticed that features such as vegetation, water features, contours, boundaries and other road classes have not been added to most of these maps.

Although the idea of producing these small-scale space image maps arose about 30 years ago, it should be noted that there is still a world-wide interest in producing such maps to give an overview of large areas in a single map sheet. For land use, a typical example is the Bangladesh land use map. This map gives a general review about the land use of the whole country in one sheet. As noted previously, the production of such maps is still being implemented, e.g. for western Europe, in the shape of the Corine Project. For general-purpose topographic maps, the availability of digital image processing software packages and techniques has enhanced the quality of the space images, and in turn has made it possible to bring out and display more details than was the case formerly. The satellite map of Aswan, Egypt is a good example showing the potential of very small-scale space image maps in arid and semi-arid regions. In fact, this space image map covers a very large area and provides a good level of detail for general topographic map users. It is worthwhile to say, that, when properly designed and executed, these very small-scale image maps can provide an excellent representation of desert terrain giving a good general view of the arid landscape, most of which has very few man-made features. By contrast, the conventional line maps of the same area either do not exist or, if they do, then they cannot represent the terrain as well as the space image maps do.

6.3.2 Group II – Analyzed Space Image Maps at 1:250,000 Scale

As with the previous group of maps, the maps at 1:250,000 scale fall into the same three distinct sub-groups – image mosaics; land use/land cover maps; and general-purpose topographic maps.

6.3.2.1 Image Mosaics

Turning next to Table 6-9 shows that two of the analyzed maps (Nos. 9 and 13) at 1:250,000 scale are essentially image mosaics that have little or no added symbolization. Both of the maps have been produced by USGS utilizing Landsat MSS imagery with its pixel size of 80m.

Area of the Map	Image Map Number	Cultural Features: Boundaries			Roads & Railways					Other Cultural Features									Water Features			Vegetation		Relief		Names/Text
		Primary Level (e.g. International)	Secondary Level (e.g. Provincial)	Tertiary Level (e.g. County)	Primary Roads	Secondary Roads	Motorable Tracks	Foot Paths	Railways	Towns	Villages	Isolated Buildings	Pipe Lines	Power Lines	Wells	Cemeteries	Mosques/Churches	Quarries	Rivers	Canals	Water Bodies	Cultivated	Natural	Contours	Spot Heights	
Phoenix USA	8			✓	✓	✓	✓		✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓				✓	✓
McMurdo Sound Region Antarctica	9																									
Puget Sound Region USA	10																					✓	✓			
Khartoum Sudan	11		✓		✓	✓	✓		✓	✓	✓								✓		✓					✓
Khartoum Sudan	12		✓		✓	✓		✓	✓	✓	✓								✓	✓	✓	✓	✓			✓
Las Vegas USA	13																									✓
Baris Egypt	14				✓	✓	✓	✓		✓	✓	✓			✓	✓									✓	✓
Lesotho	15	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓					✓	✓								✓

Table 6-9: Features added to image maps at 1:250,000 scale.

Map 9 (**McMurdo Sound Region, Antarctica**) has been produced in 1973 just after the launch of the first Landsat. This sheet has been printed in monochrome, and essentially it is gridded geo-referenced mosaic. Obviously, with its relatively large sheet size (74 x 78.5cm), the intention of producing such map is to show the general characteristics of the terrain to the various map users. Moreover, no attempt has been made from the cartographers` side to add any enhancement, symbolization or annotation.

On the other hand, map 13 (**Las Vegas, USA**) has been produced as an experimental sheet in 1981 using a false-colour background image. The image mosaic has been produced manually using four Landsat MSS images that have been acquired within a two day period to avoid the problems associated with the changes in the appearance of the terrain over a period of time. The mosaic has been fitted to identified ground points, and carries geographic co-ordinates (marginal ticks), a full 10,000-metre UTM grid, and a 100,000-foot grid of marginal ticks based on the Nevada state co-ordinate system. The reasonable size of this map sheet (44 x 72cm) makes it very handy for use in the field. The false-colour image shows land forms such as mountains, ridges and valleys in considerable detail and in a fairly clear manner. Unfortunately, no effort has been made to pick out any vegetation or to enhance the water features by the use of areal colours. As can be seen in Figure 6-6, no added symbols whatsoever have been added to this plain image. Instead only two names have been added in black and white to help the users locating the city of Las Vegas and Lake Mead. Without considerable local knowledge, it would be difficult to make use of this particular map sheet since so little extra value has been added to it by the USGS cartographers.

6.3.2.2 Land Use/Land Cover Maps

Map 10 of the **Land Cover of Puget Sound Region** has been produced in 1975 by USGS applying digital classification techniques. The map is based on Landsat MSS digital data. This land cover image is based on a supervised classification of Landsat MSS multi-spectral images. Using this technique, the analyst pre-defines the categories to be mapped and identifies those portions of the imagery containing good examples of each specific category. Training sets (statistics) are collected and analyzed to carry out this procedure. Once a good set of examples has been obtained, the full image is classified according to the training sets. For each image element, the classification programme identifies the training set that best matches the image and records the result. In the case of the Puget Sound Region map, categories such as urban and built-up-land; agricultural land; range land; forest land; water; wet land; barren land and perennial snow and ice have all been included. In turn, all of these main categories have been farther classified into 21 classes, and are displayed in different degrees of blue; red; green; yellow; orange; brown and black, as shown in Figure 6-6.

As can be seen from Table 6-9, no other symbolization or annotation have been added by the USGS cartographers, and, as with most USGS space image maps, the interpretation task has been left to the user. Of course, this depends solely on his background, skills, experience and local knowledge. However, the use of the MSS images in conjunction with the digital classification and processing of the land cover areas has made it possible to produce land cover maps in areas where either the existing maps are out-of-date or did not exist in the first place.

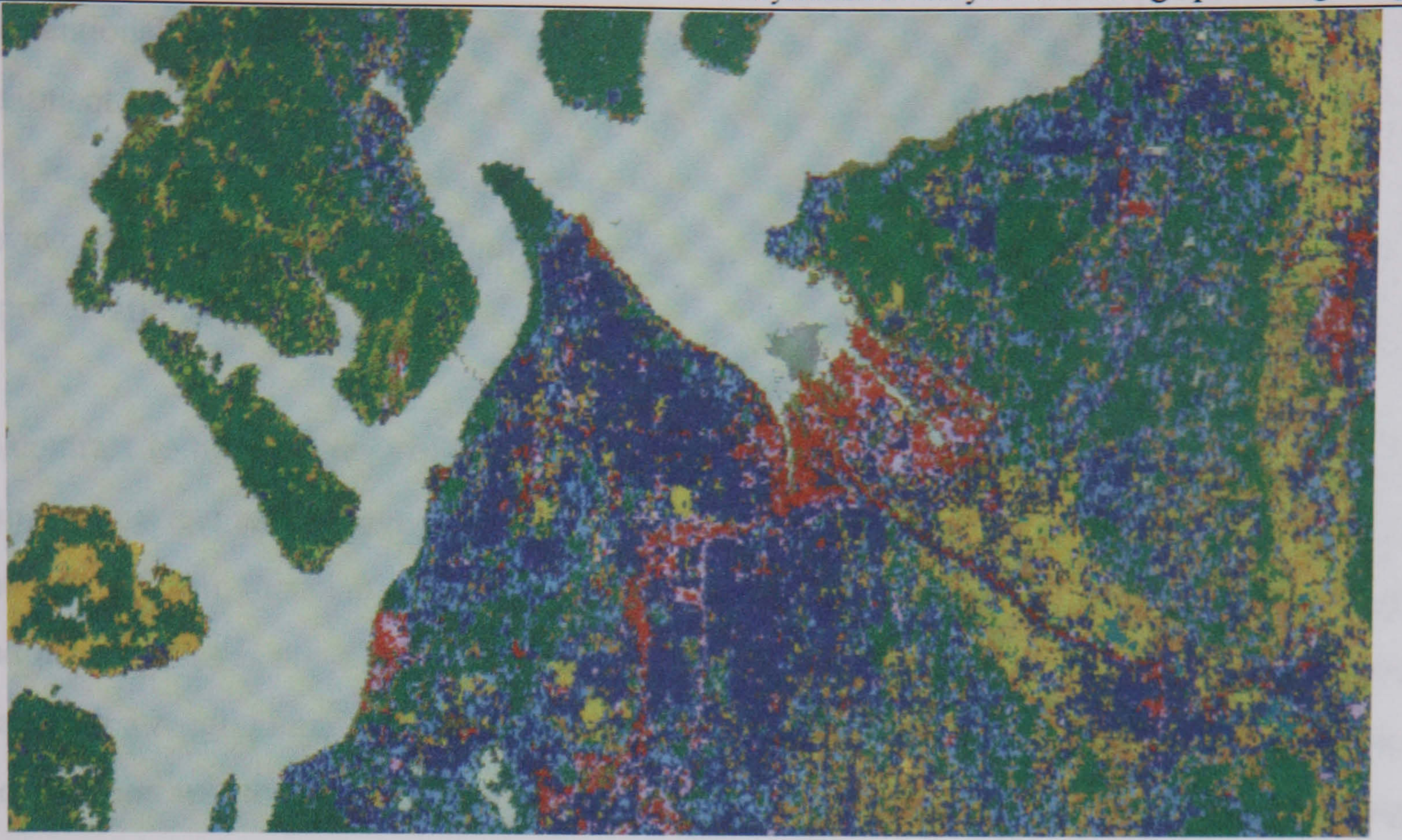


Figure 6-6: A small window from the Land Cover map of the Puget Sound Region at 1:250,000 scale.

6.3.2.3 Topographic Maps

This contains a sub-group of five general topographic maps (Nos. 8, 11, 12, 14 and 15). Table 6-3 shows that, although all of these maps have been produced at 1:250,000 scale and for the same basic purpose, quite a number of differences can be noticed between the individual maps contained within the sub-group. For the background image production, different space data – e.g. Apollo space photos or Landsat (MSS, RBV or TM) images – have been used, and also two different production methods (manual or digital) have been applied. The sheet formats of these maps vary greatly in size (small, medium or large). Besides, different levels of sympolization and annotation have been added to the individual maps.

Map 8 (**Phoenix, USA**) has been produced as an experimental sheet in 1969 by the USGS. It is covered by <u>two space photos</u> taken as a result of a NASA experiment carried out on the Apollo 9 flight using a Hasselblad film camera equipped with f = 80mm lens. The photographs were rectified and mosaiced manually, then fitted to the culture plate of the existing line map of the same area. The sheet dimensions (44 x 74.5cm) are more practical when compared to those of Map 3 covering much the same area. This space photomap carries a full 10,000-metre UTM grid, together with geographical co-ordinates in the form of marginal and body ticks (45′ x 15′). However, once again, no attempt has been made by the USGS cartographers to classify, identify and pick out vegetation, urban or built-up <u>areas</u>. On the reverse side, the full conventional line map has been printed with the UTM grid added. The advantage of this dual treatment is to present the relatively uncluttered line map as a working base and the photomap as a ready source of additional (and more recent) information not shown on the line map. But having to turn over the map is not too practical when making comparisons between the two representations of the same area.

In contrast to the treatment of the areas, as can be seen in Table 6-9, a large number of point, line symbols and names have been superimposed on the image mosaic of Map 8. Indeed, in the author's opinion, this map is characterized by the inclusion of too many point and line symbols and names! This is not a desirable practice, since it has resulted in having a conventional line map with a natural image underneath. Again, when USGS has produced this space photomap, the main aim was to test the potential of the early space photography for topographic mapping. This leads to the point that this combined conventional line map and the poor quality background image – poor in terms of its resolution and low visibility of detail – appears to have been prepared quickly and has not received the detailed cartographic treatment that it really needed. Indeed it is a one-off experimental sheet and no further examples have been produced with this treatment.

Map 11 **(Khartoum, Sudan)** has been produced manually in 1978 by IGN in France using Landsat MSS imagery. This map has been produced with a very small sheet size (32 x 33cm). It carries a full (45′ x 15′) geographic co-ordinates graticule. The background image has been printed in simulated natural colour to give a real impression of the mapped area to the users.

As Figure 6-7 shows, although the vegetation areas are shown in green on the image, the IGN cartographers have not made any attempt to classify and enhance them through the use of different green areal tint percentages. The limited interpretation and the identification of the map content extracted from the Landsat MSS imagery has been carried out by IGN with material such as very old 1:250,000 scale maps and aerial photography of the area being mapped used to give additional information. Apparently no field completion operations have been carried out and it does appear as if the IGN interpreters and cartographers who produced the map were not adequately familiar with the terrain of the Khartoum area.

Figure 6-7: A small window from the Khartoum, Sudan map at 1:250,000 scale. (IGN, 1978)

From Table 6-9, it can be seen that a considerable amount of symbolization and annotation have been added on top of the image. This included provincial boundaries; roads and railways; towns and villages; rivers and water bodies; spot heights and names, all taken from the old 1:250,000 scale line map. From the cartographic point of view, unfortunately, the point and line symbols are not well designed, since only black has been used for the purpose. Furthermore no self explanatory symbols have been used, and the names have not received the right treatment of selection and placement. Although this map has been published by the Sudan Survey Department (SSD), in my opinion, it has been produced quickly by IGN to test the use of Landsat MSS images for small-scale space image mapping in Sudan.

By contrast, Map 12 which also covers the area of **Khartoum, Sudan** has been produced in 1979 at the University of Glasgow by Ahmed Eltayeb Abdalla of the Sudan Survey Department (SSD) as part of his M. App. Sci. project. Quite unusually, it is based on the use of Landsat-3 RBV imagery – since its 30m ground pixel size is much superior to the 80m of the rival MSS imagery of that time. The Sudan is a developing country with an enormous land area much of which has a topographic map coverage of a rather poor quality even at small scales. The country desperately needs up-to-date topographic maps at 1:250,000 scale. With this situation in mind, Mr. Abdalla investigated the possibility of using Landsat imagery for this type of mapping and has compiled and produced this experimental space image map for the Khartoum area. This increased resolution of the Landsat-3 RBV imagery improved the quality of the map when compared to that produced by IGN from the MSS imagery. The interpretation of the RBV imagery provided the information about hydrology, the relief, the agricultural areas and some of the cultural features such as major towns, surfaced roads, railways and airports. But still the bulk of the cultural features, e.g. unsurfaced roads, medium-sized and small towns and the small but important topographic details, cannot easily be seen on the imagery. Since this information could not be derived directly from the RBV image, it was extracted from 1:40,000 scale aerial photography and from the existing 1:250,000 topographic map (sheet ND-36-B) of the area by Mr. Abdalla.

As stated by Abdalla (1980), the base image has been produced purely manually using a film copy of the RBV image and there was no need to mosaic images, since the area being mapped is covered by a single sub-scene. The original RBV image received from NASA in the form of a film positive was converted to a negative and then enlarged photographically to the required 1:250,000 scale of the map. Using this diapositive and the other available sources of information, the compilation of the map was carried out on a punch-registered plastic overlay. Each category that was to be shown by a different colour in the final map was produced as a separate image. All the line work was then scribed to obtain right-reading negatives (one for each required colour). In addition, four right-reading masks have been produced to show water areas; built-up areas; cultivated areas; and forest areas. For the background RBV image, in order to use colour to differentiate certain parts of the image from their surroundings, masking of the relevant areas was required. The image itself has been printed in solid yellow (which perhaps too strong) and topographic features such as mountains (jibals) have been overprinted in solid magenta to appear in red.

As can be seen from Table 6-9, a substantial amount of symbolization has been added on top of the RBV image. This included provincial boundaries, roads and railways, cultivated land and forest, rivers and water features, towns and built-up areas, villages, bridges and airports. Also this map carries the full geographical co-ordinates graticule for geodetic reference purposes.

Figure 6-8: A small window from the Khartoum, Sudan map at 1:250,000 scale. (Glasgow Univ., 1979)

Figure 6-8 shows that the map-maker (Mr. Abdalla) has made a great effort to identify, classify and pick out the various <u>areal features</u> in an attempt to help the user reading this map. Obviously, all the symbolization and annotation have been represented in a reasonably successful manner through the use of different forms, dimensions, colours and patterns. Comparing this map with Map 11 of the same area at 1:250,000 scale, Map 12 is of much better quality in the sense of (i) using space imagery with better resolution, (ii) the map-maker being very familiar with the area being mapped, and (iii) the cartographic treatment and design is of better and more thoughtful quality. Indeed, the production of a series along the lines of Map 12 in a country like the Sudan, where either the maps are out-of-date or do not exist in the first place, could have been of great help to many users in the area. Unfortunately, the lack of funding and the political turmoil and civil war that has afflicted the Sudan over the last twenty years prevented this being done.

Map 14 (**Baris, Egypt**) has been produced in 1987 by the Technical University of Berlin (TUB). It has been produced using <u>fully digital image and cartographic methods</u> for the same scientific project dealing with geoscientific problems in arid and semi-arid areas as Map 7 of Aswan which has already been reviewed in Section 6.3.1.3. Indeed in the production of its background image and in its cartographic treatment, this map is very similar to Map 7. The differences are (i) Map 14 is based on the <u>Landsat TM imagery</u> with its 30m pixel size instead of the MSS imagery with its 80m pixel size used in Map 7, thus giving a higher level of detail in the background image; and (ii) this map carries both a full 10,000-metre UTM grid and geographical co-ordinates in the form of marginal ticks.

From Table 6-9, it can be seen that a medium level of symbolization and annotation has been superimposed on the TM imagery. This included roads; towns and villages; isolated buildings; wells; cemeteries and spot heights. The background image shows ridges, mountains, wadis, sand dunes and vegetation in a detailed manner and can be used even without symbolization. Again, this satellite image map has been produced successfully to provide a good representation of an arid and semi-arid area. As such, it has a strong relevance to the situation being experienced in Libya just across the border from this Egyptian area.

Map 15 (**Lesotho**) is an experimental map that has been produced in 1989. It has been compiled using four Landsat MSS images. Bands 4, 5 and 7 have been composited to give a simulated natural colour image that has been used as the base for the map. These images were processed photographically and mosaiced into one continuous scene by the Regional Centre for Services in Surveying, Mapping and Remote Sensing (RCSSMRS) in Nairobi. The actual cartographic design and production has been carried out by the Lesotho Surveys & Mapping Authority, while the colour separation and the final printing have been carried out by the Ordnance Survey in the U.K.

This map carries full (15′ x 15′) geographical co-ordinates graticule and the national co-ordinate system in the forms of marginal ticks. From Table 6-9, it can be seen that a substantial number of point and line symbols have also been added to the map but with no attempt to pick out areal features. Boundaries, roads and railways, main towns and villages have been added. In the author's opinion, the representation of the additional symbols and names was not successful, since they have been depicted mainly using black against an overall dark green background image (see Figure 6-9). Obviously, this dark background image has decreased the contrast, clarity and legibility of these added features. Although this map has been published by the Lesotho authority to be utilised by the various local users, the many shortcomings in its cartographic treatment would not encourage them to do so. The overwhelming dark green background of the map makes it almost unreadable and, in turn, unusable.

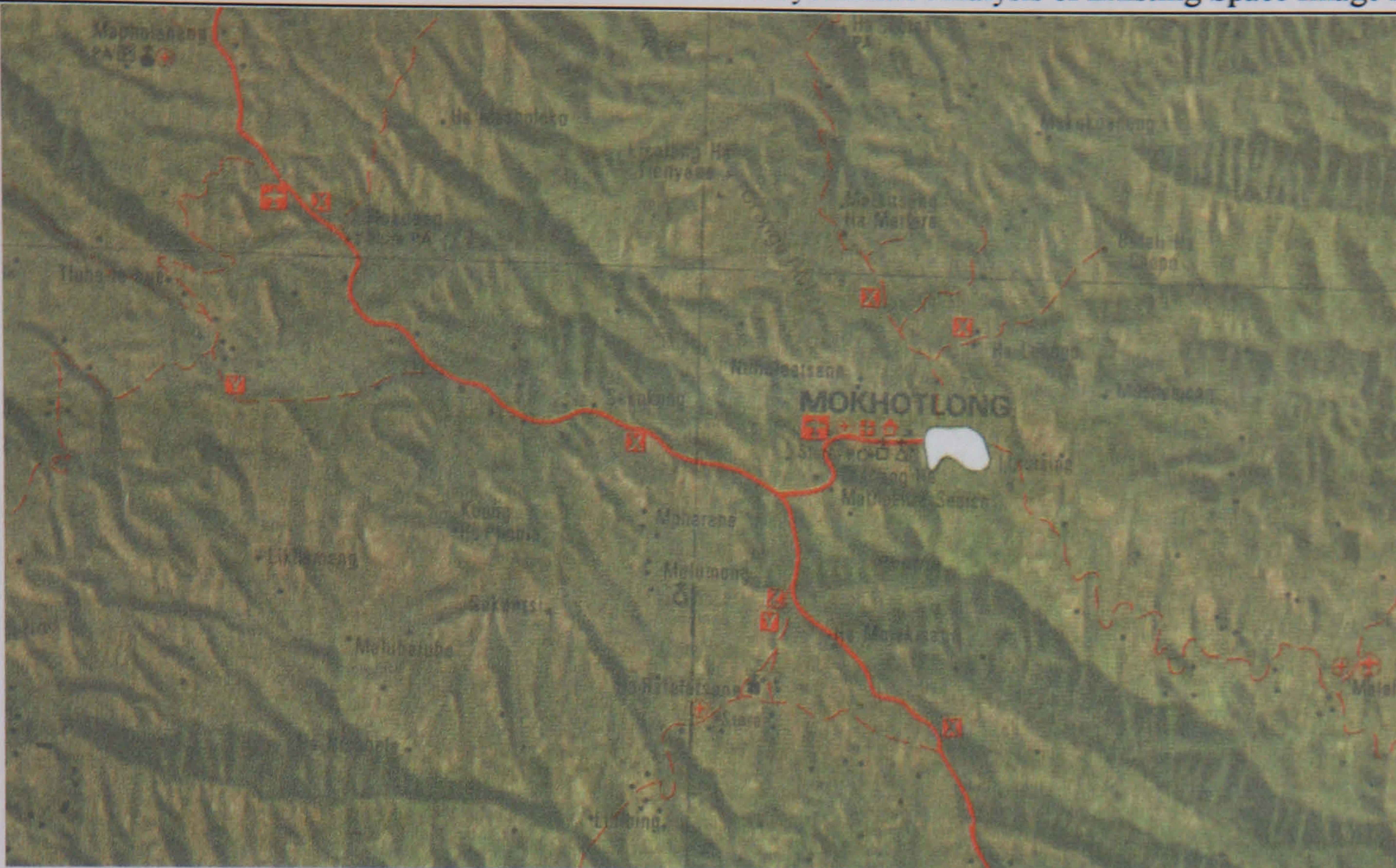


Figure 6-9: A small window from the Lesotho map at 1:250,000 scale.

6.3.2.4 Summary Regarding the 1:250,000 Scale Space Image Maps

As can be seen from the above analysis, apart from two early examples from the USGS produced as image mosaics, the 1:250,000 scale space image maps that have been reviewed have been produced either for land use/land cover purposes or as general topographic maps. These maps vary in terms of the space imagery used, the method of production, the format size, and the cartographic design and treatment. It is apparent from inspection of these products that, while the space image can be extremely valuable in representing natural features such as relief, structure, vegetation, etc., at this scale, the resolution is usually quite inadequate to represent cultural features such as roads, railways, settlement, etc. Arising from this, it appears that many of the man-made features have not been obtained from the imagery and, in fact, have been derived from external sources of information.

In a number of developing countries, 1:250,000 is the basic scale for their national topographic mapping series. Since most of the terrain in these countries comprises an arid or mountainous landscape with very few man-made features, space image mapping is often more suitable in terms of representing or depicting this type of terrain to the various users than any line map. As can be seen in Figure 6-10, the satellite image map covering Baris, Egypt shows an example of this type of terrain being represented in a very successful manner. In summary, some of these maps may be judged to be a reasonable success and certainly they can give users such as development planners, administrators, soldiers and field scientists a very much better impression of the topography or land use of the area being mapped than the existing line maps at 1:250,000 scale.

Figure 6-10: A small window from the Baris, Egypt map at 1:250,000 scale.

6.3.3 Group III – Analyzed Space Image Maps at 1:100,000 and 1:150,000 Scale

As with the previous two groups, the maps may conveniently be divided into three sub-groups – image mosaics; land use/land cover maps; and general-purpose topographic maps.

6.3.3.1 Image Mosaic

The first sub-group of these space image maps comprises a single map (No. 19) which is essentially a plain image mosaic with no added symbolization or annotation.

Map 19 (**Dyersburg, Tennessee USA**) has been produced in 1982 as an experimental sheet by the USGS. It is based on the use of Landsat-4 TM imagery (Bands 2, 3 and 5) taken in August 1982. No mosaicing has been carried out since the area being mapped is covered by a single sub-scene. The image base has been fitted to identified map features and carries a full 10,000-metre UTM grid, geographical co-ordinates (as marginal ticks), and the Tennessee state co-ordinate system in the form of marginal ticks. It has been produced in a folded edition for use in the field. This satellite image map has been produced in false colour by combining imagery that was produced in the green, red and infra-red wavelength bands. On this particular combination of false colour imagery, growing crops, grasses, and woodlands usually appear in shades of red; coniferous forests in shades of reddish brown; clear water as dark blue or black; turbid water as light blue or grey; and cultural features such as cities and highways as a steely blue-grey. However all of this identification has to be carried out by the users – no classification has been carried out by the USGS cartographers, nor is there any help given by the legend.

Area of the Map	Image Map Number	Cultural Features																	Water Features			Vegetation		Relief		Names/Text
		Boundaries			Roads & Railways					Other Cultural Features																
		Primary Level (e.g. International)	Secondary Level (e.g. Provincial)	Tertiary Level (e.g. County)	Primary Roads	Secondary Roads	Motorable Tracks	Foot Paths	Railways	TOWNS	Villages	Isolated Buildings	Pipe Lines	Power Lines	Wells	Cemeteries	Mosques/Churches	Quarries	Rivers	Canals	Water Bodies	Cultivated	Natural	Contours	Spot Heights	
Kilimanjaro	16	✓			✓	✓	✓	✓		✓	✓													✓		✓
Wshington D. C. USA	17		✓	✓	✓	✓			✓	✓								✓				✓	✓		✓	✓
Washington -D. C. USA	18	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓					✓	✓				✓	✓			✓
Dyersburg Tenn. USA	19																									
Dubai UAE	20				✓	✓	✓			✓	✓	✓			✓			✓			✓	✓		✓	✓	✓
Kazgail Sudan	21		✓	✓	✓		✓		✓																	✓
Baris Egypt	22				✓	✓	✓	✓		✓	✓							✓	✓	✓	✓					✓
Berlin Germany	23			✓															✓	✓	✓					✓
Kuwait City	24				✓	✓				✓																✓
Cap-Haitien Haiti	25				✓	✓				✓																✓
Kagera Reg-ion Tanzania	26	✓	✓	✓	✓	✓					✓											✓	✓			✓

Table 6-10: Features added to image maps at 1:100,000 scale.

Furthermore, as can be seen from Table 6-10, as in most USGS space image maps, no symbolization or annotation whatsoever have been added to this map. It is designed specifically to be used in conjunction with the standard Dyersburg line map at the same scale which is printed on the reverse side. This means, that to use both products, the map sheet needs to be cut into two pieces – each covering the same area – or else two copies of the product need to be used in combination with each other. From the practical and cost points of views, neither solution is successful and indeed could not be adopted in national series production for a whole country. Since this geo-referenced image has been produced not long after the launch of Landsat-4 TM, one can only assume that the USGS produced this map quickly to test the potential of TM imagery for topographic mapping at 1:100,000 scale. As can be seen in Figure 6-11, it is a colourful, indeed striking map, but its value would appear to be greatest for land use experts who have local knowledge and can interpret the colours that show up so vividly. Certainly without any annotation, symbolization, interpretation, classification or legend, it is difficult to use either as a general-purpose topographic map or as a land cover/land use map.

Figure 6-11: A small window from the Dyersburg, Tennessee USA map at 1:100,000 scale.

6.3.3.2 Land Use/Land Cover Maps

This sub-group comprises five maps that have been published at 1:100,000 scale for land use/land cover purposes. Three of the maps (Nos. 17, 18 and 21) have been produced by the

USGS, whereas the other two – Maps 25 and 26 – have been published recently by a commercial company named I-Mage Consult from Belgium. As the scale becomes larger, the area being covered by the map becomes smaller, in which case, this may result in the inclusion of fewer categories and classes than occurs at the smaller scales covering larger areas. Of course, it is also possible that the larger scale may allow the use of more categories.

Maps 17 (of **Washington D.C.- I-858-E**) & 18 (of **Washington D.C.- I-858-F**) are alternative versions of the same basic map – the first (E) with place names, the second (F) showing the boundaries of census tracts. Maps 17 & 18 are prototype products resulting from experiments to compile a land use and land cover inventory and to carry out change detection in the Washington area using data gathered by satellite-borne remote sensors. Both have been produced in 1978 by the USGS in co-operation with NASA. Each of the two sheets covers part of the Washington urban area, which occupies the central part of the Landsat MSS image of Chesapeake Bay that was acquired in Oct. 11, 1972 and formed the basis of the 1:500,000 scale image map of the same area [Map 3]. The same format size (60 x 60 cm) has been used for both maps. In both cases, they also carry the same co-ordinate systems, with latitude and longitude in the geographical co-ordinate system being given by marginal and body ticks at a 5-minute interval. The UTM co-ordinate system is also shown by a full 5,000-metre grid.

The base images of both of the 1:100,000 scale maps appear to have been produced and classified by means of a digital image processing system. A total of 11 area classes have been included to depict the land cover and land use of the Washington D.C. area. These 11 area classes have been represented using red, green, blue, yellow, orange, black, white, and other colours. Of course, this classified map will be of great interest to many users who are resident and working in this area, but it must also be recognised that the actual space image itself has been removed through this processing operation. Certainly the map marks a substantial step forward in terms of its cartographic treatment and its information value compared with the other USGS land cover/land use maps that have been reviewed earlier – where often the false-colour image that had been used had not been interpreted or classified in any way, leaving these tasks to be carried out by the map user.

Table 6-10 indicates that many linear features – those representing boundaries, roads and railways – and names have also been included in the maps to supplement the areal (land use/land cover) information. Inspecting both maps, the differences between Maps 17 & 18 lie mainly in these cartographic additions. Boundary lines (state, county etc.), roads and railways and names have been added in black to Map 17, whereas only boundary lines (of census tracts) and names have been added to Map 18.

Map 21 (**Kazgail, Sudan**) has been produced in 1986 jointly by the USGS, the Sudan Forest National Corporation (SFNC) and the Sudan Survey Department (SSD) as part of the Sudan Reafforestation and Anti-Desertification (SRAAD) project and funded by the United States Agency for International Development (USAID) – see Abdalla (1991). The USGS provided the two Landsat TM images that were used as the base document for the project. It also carried out the image processing of these TM images on a VAX computer running its own (USGS) software. This resulted in the adjacent images being merged geometrically and radiometrically to form the image mosaic of the test area. Bands 2, 4 and 7 corresponding to the spectral bands for green-yellow, near infra-red and middle infra-red have been printed in the process yellow, red and blue sequence to provide a simulated colour image of the area with vegetation appearing green; sandy areas, yellow; and bare rock, a red-brown colour. As has been stated by Mohie el Deen (1991), many areas show a slow transition between each vegetation class and its neighbour. This is seen on the TM image as a continuous change in colour, texture or both. The land cover has been divided into six classes – which include built-up areas and village; khor and wadi; trees; sand; clay soil and water reservoir. Rather than attempt to draw or delineate boundaries around areas falling into one or other of these classes, instead typical small representative images of each have been included in the legend to provide an interpretation key. This was a somewhat novel yet quite appropriate treatment for this area where mostly one class slowly changes into the next and it is difficult in fact to draw boundaries. Figure 6-12 shows a small window from the Kazgail satellite image map.

According to Falconer (1990) and Abdalla (1991), the actual compilation of the map features has been carried out by the SSD surveyors and cartographers. As can be seen from Table 6-10, the names; major roads and railways; tracks; provincial and county boundaries have been added from additional sources, including the field completion carried out by SSD.

Figure 6-12: A small window from the Khazgail, Sudan map at 1:100,000 scale.

The cartographic design used red roads, black railways, and black and white labels to give readability against the image background. In laying type, Abdalla (1991) reported that particular attention was paid to the content of the image background and attempts were made to avoid name placement where it would obscure visible features. Indeed, the use of colour for the principal roads and the use of white for the names of features occurring in dark areas has, in general, been successful. The SSD cartographers did the scribing of the final detail and the preparation of the marginal information. The USGS undertook the colour separation of the image base of the map, the production of registration overlays, and proofing. The actual map production has been carried out using conventional analogue means using positive film transparencies separated into the respective process colours and with the names also stuck up on a film transparency.

In summary, this land cover map represents a fast and cheap method of producing land cover/land use maps for areas like this in Sudan where no such maps exist. This type of map would be of great interest and use by many users such as soil scientists, foresters, agriculturists, planners, etc. Indeed, it is believed that the Sudan authorities have continued to produce maps of this type using the Kazgail sheet as the prototype, even though the USGS and USAID support has since been withdrawn.

Map 25 (**Cap-Haitien, Haiti**) has been produced in 1998 by I-Mage Consult from Belgium in cooperation with the Faculty of Agricultural & Environmental Sciences of the University of Quisqueya in Haiti with funding by the Walloon Region in Belgium. It has been compiled from a single Landsat-5 TM image acquired in 1996. This background image has been processed digitally and fitted to control points taken from the 1:50,000 scale DMA maps of the area. The map displays a UTM grid with a 1,000m interval and latitude and longitude ticks around the borders of the sheet. A false colour composite has been prepared from the multi-spectral Band 4, 5 and 3 images (red, green and blue) to act as the base for this map. Since the major concern in this map is to show vegetation types such as forests; cultivated areas; urban areas and water features, the Band 4, 5 and 3 image combination has been selected for this purpose using two infra-red bands (4 and 5) and the red band of the TM multi-spectral image. On the resulting composite false-colour image, 12 classes have been identified to represent mountain forests, open forests, cultivation, plantations, mangrove swamps, urban areas, etc. As with the Kazgail sheet, no attempt has been made to delineate the boundaries of particular areas falling within a single class. Instead an interpretation key has been provided with typical examples of each of the twelve types included as small patches in the legend – again in a similar way as has been done for the Kazgail sheet.

Figure 6-13: A small window from the Cap-Haitien, Haiti map at 1:100,000 scale.

As can be seen from Table 6-10, a very few line and point features have been included to depict major roads (in red), secondary roads (in white) and cities (using a black dot). Names and text have been also added in black (for land), white (along the coast) and blue (for marine names). Although the printing quality of this map is very high, unfortunately, the very bright and strongly red false-colour background image (see Figure 6-13) has decreased the clarity of the symbols and the legibility of the names and text. While it may be of some value to local planners interested in land use, from the cartographic point of view, it is a poor product with much difficulty being experienced in trying to discern the features that are present in the area.

Map 25 (of **Kagera Region, Tanzania**) has also been produced in 1998 by the I-Mage Consult company. The project was funded by the United Nations (UNHCR) in Geneva specifically to monitor the refugee situation and show the impact that the refugees were having on the environment in the Ngara area of the Kagera Region in Tanzania. The sheet has been divided into three separate maps. The first two smaller-sized (25 x 40.5cm) maps both cover the same area comprising the Ngara and Biharamulo districts and are based on Landsat TM false-colour composite images produced from Bands 4, 5 (infra-red) and 3 (red) respectively mainly to show the vegetation types that are present in this area. To monitor the changes in this area after being occupied by the refugees, two TM images have been used that have been acquired at different times two years apart. Thus the TM image for the upper map has been acquired in August 1994, while the TM image for the lower one has been taken in July 1996. No grid or graticule is provided for locational purposes. Interpretation and classification appear to have been carried out manually using the TM images and incorporating information from additional sources such as field workers – with some degree of symbolization and annotation added to ease the interpretation task. Obviously, these two false-colour composite maps show how the Landsat TM imagery could act as a powerful tool for monitoring the main changes that have taken place in the area over the two year period as a result of the influx of refugees. As with the Kazgail and Cap-Haitien sheets, an interpretation key with typical examples of each main land cover type has been provided to assist users.

Figure 6-14: A small window from the Kagera Region, Tanzania map at 1:100,000 scale.

By contrast, the <u>main map</u> is a smaller-scale map of the whole Kagera Region of which the two smaller maps cover only a small part. The format size of this map is 39 x 54.6 cm, and only carries the UTM co-ordinates in the form of marginal ticks. The background image has been produced digitally using a single black and white TM image of this region. The boundaries of eleven land cover and land use classes have been delineated and the resulting polygons are shown in the form of <u>areal tints</u> from which the background TM image has been masked out. As can be noted in Table 6-10, boundaries (international; provincial and county); primary and secondary roads; villages and vegetation types have all been added. Figure 6-14 shows that a substantial effort has been made by the cartographers concerned to pick out and delineate the different classes of land cover and land use in order to aid the interpretation of the map by the users. This Figure also shows that areal tints and patterns have been adopted to the maximum degree to represent these eleven classes. From a cartographic design point of view, perhaps this is not a successful practice, since it has obscured the detail and removed the TM image background. Furthermore, the appearance of the final map is that of a conventional land use/land cover map with the background space image only appearing as a border around the edges of the main part of the map that has been classified. However, considering the sheet as a whole, the other two smaller-sized but larger-scale maps which have retained the image detail do help the users to have an idea about the main characteristics of this piece of terrain. Overall, this is a really unusual special-purpose type of land use/land cover map that should be very useful for the purpose of illustrating the impact of the refugees and no doubt has been used by the United Nations experts and aid agencies to plan their operations in this area.

6.3.3.3 Topographic Maps

Map 16 (of **Kilimanjaro, Tanzania**), it is the only map in this sub-group that has been produced at 1:150,000 scale. It has been published in 1986 by Nigel Press Association Ltd. and Edward Stanford Ltd. A simulated colour image mosaic compiled from Landsat MSS data forms the basis of this map. The image has been enhanced and geometrically corrected by NPA Ltd. and fitted to the UTM grid, zone 37 using a DIAD image processing system.

As can be seen from Table 6-10, international boundaries; four classes of roads; towns and villages; and contours with an interval of 1,000 feet have all been added on this image presumably from other sources such as the existing maps of the area. Furthermore, very few names have been added to this map. The large area of forest has been picked out and is represented in a dark green colour which tends to dominate the whole map. Also supplementary information about the vegetation sequence within the forest area is shown by a diagram that has been included in the legend of this map. Overall, the resolution and the visibility of the detail included in the map are quite poor and, in the author's opinion, do not satisfy the needs of users for a topographic map at this scale. Besides the considerable text on the vegetation, quite a lot climbing information is given, so it would appear that this map was designed to be used mainly for trekking and climbing purposes in this area of one of the highest mountains in Africa.

Map 20 (of **Dubai, United Arab Emirates**) has been produced in 1984 by ERSAC Ltd., Livingston, Scotland. The map is based upon Landsat-5 TM imagery dated 13 April 1984 which has been fitted to base mapping supplied by BKS Surveys. The sheet size of this map is 37 x 50 cm, and the UTM co-ordinate system (with full grid lines) and geographical co-ordinate system (with marginal ticks) have been used to provide locational information.

Figure 6-15: A small window from Dubai, UAE map at 1:100,000 scale.

From Table 6-10, it can be seen that a substantial level of symbolization and annotation has been added to this map using multiple colours (black, blue and red) that have been overprinted over the background space image. Much cartographic work has been carried out – for example, contours, names, roads, built-up areas, sobkhas (salt marshes), isolated buildings and so on have all been added from existing maps of the area to supplement the satellite imagery. Names have been provided in dual languages (Arabic and English); in particular for the desert areas, this is quite useful. As can be seen in Figure 6-15, the cartographers have made a considerable effort to pick out areal features such as the built-up areas, water features and sobkhas through the use of areal tints and patterns. This Figure also shows that the built-up areas in this map have been represented by pink areal tints. From a cartographic design point of view, the use of this representational technique has obliterated the underlying image information and disturbed its natural appearance. Outside the built-up areas, the image detail is visible in a simulated natural colour and, in particular, in the main desert area, this satellite image map could be more useful than any conventional line map e.g. for orientation and navigational purposes, besides its use in providing the overview of the area needed for development projects, planning, work in scientific fields, etc.

Map 23 of **Berlin, Germany** has been produced digitally in 1988 by the Technical University of Berlin (TUB). This map covers a typical Central European area characterised by some dense vegetation, many small areas of varied land use in rural areas and, for the area of the city itself, a maximum degree of residential and industrial development. A main objective of this map project was to achieve a close-to-natural colour rendition. In fact, natural colour has been adopted for the background space image which carries the geographical co-ordinates only in the form of marginal ticks. The basis for the production of this map has been achieved by mosaicing and merging together six panchromatic SPOT scenes and two Landsat-5 TM images. As reported by Albertz and Mehlbreuer (1989), to achieve the close-to-natural colour rendition, the TM Bands 1, 2 and 3 were selected for the process and enhanced by suitable algorithms. However, by selecting these three Bands, the water areas could be hardly distinguished from the neighbouring forest areas, and the differentiation between deciduous and coniferous forests was also insufficient. To solve these problems, additional information has been derived from the Band 4 and 5 images of the same seen. In this context, a special masking procedure was applied. The result of this technique is that two digital masks were constructed, the one containing the water areas, the other one covering the forests. These water and forest masks were then used separately to manipulate the data within the Band 1, 2 and 3 images. For the production of the Berlin 1:100,000 scale map, no spatial filtering techniques have been applied. However, in order to preserve the high spatial resolution of SPOT data as well as utilizing the multi-spectral information of the TM data, it was necessary to apply some special processing techniques. Thus the actual processing needed for the merging of the SPOT and TM images has been carried out by means of the IHS colour transformation. The resulting image provides quite detailed topographical elements – which, in the author's opinion, has proved to be particularly successful.

Table 6-10 indicates that a minimum degree of symbolization and annotation has been superimposed on top of the very detailed background image of the Berlin area. This includes the addition of interrupted lines to depict the boundaries of the different counties. Water features such as rivers, canals and water bodies have been picked out using the masks mentioned above and enhanced using a combination of linear and areal symbols in solid black. In addition, the names of towns have been added in black and those of water bodies in white. However, as Figure 6-16 shows, no effort has been made by the cartographers involved in the production of this map to pick out or classify any of the built-up areas, roads, vegetation, relief features, etc. to aid its interpretation. This task has been left to the user who must rely entirely on his/her own skill, experience and local knowledge. Since the Berlin satellite image map is really a partially enhanced geo-referenced mosaic on which a minimum of annotation or cartographic treatment has been carried out, the purpose of producing this sheet appears simply to give a general overview of the area being mapped to various classes of knowledgeable local users already familiar with the area.

Figure 6-16: A small window from Berlin, Germany map at 1:100,000 scale.

Map 24 (**Kuwait City**) has been produced in 1991 by the Intergraph Corporation. The base image has again been created with digital image data collected by the two commercial production satellite imaging systems, Landsat TM and SPOT (Pan). A completely digital workflow has been adopted involving geodetic registration, image-to-image resampling and spectral and spatial enhancements. Following on from this, the various multi-spectral data fusion tasks were performed. During fusion, the multi-spectral information of the 30m pixel size Landsat TM data was combined digitally with the higher spatial information of the 10m pixel size SPOT panchromatic data, resulting in a single high quality image. The base image has been produced using simulated natural colour, and carries the full (5′ x 5′) geographic co-ordinates grid.

As has been noted from Table 6-10, only a few symbols and names have been added to the image. This means that the amount of the cartographic treatment is very limited. Primary and secondary roads have been enhanced using black. As can be seen in Figure 6-17, the built-up areas have been picked out in a very successful manner using an accentuated pattern of black lines. This appear to have been achieved through the use of effective image edge enhancement techniques which help to bring out the real structure of the streets and buildings in the area.

Comparing this with the technique that has been used in the Dubai map (Figure 6-15) where the built-up area has been represented by an areal tint, the Kuwait map is, of course, better since the retention of the urban street structure helps the user to understand it by having a more realistic impression of the area. In fact, this satellite image map has been published as a poster in an attempt to advertize the capability of Intergraph's image processing and cartographic software in producing high quality satellite image maps.

Figure 6-17: A small window from the Kuwait City map at 1:100,000 scale.

Map 22 (of **Baris, Egypt**) has been produced in 1987 by the Technical University of Berlin (TUB). The area covered by this map is located in the southern part of the El Kharga Oasis in Egypt, about 250 km west of the River Nile, and forms part of the same area covered by the 1:250,00 scale image map of Baris (Map 14) that has been reviewed above. Landsat TM data was chosen for the production of this image map because, in 1987, this data the best available imagery that was compatible with the requirements of data quality and fast availability for most areas throughout the world. The area of the map is fully covered by a single Landsat TM scene. Consequently, geometrical mosaicing was not required. To achieve a natural colour impression, Bands 1, 2 and 3 have been selected. For the small areas of vegetation, the requisite information from the TM spectral Band 5 has been inserted into the basic image data set. This procedure was important to avoid the vegetation of the oasis area remaining undifferentiated as it appeared on the colour composite formed from the Band 1, 2 and 3 images. A suitable masking technique was used to insert the image data from TM Band 5, and by this procedure, the colour combination resulted in suitably differentiated green coloured vegetation areas.

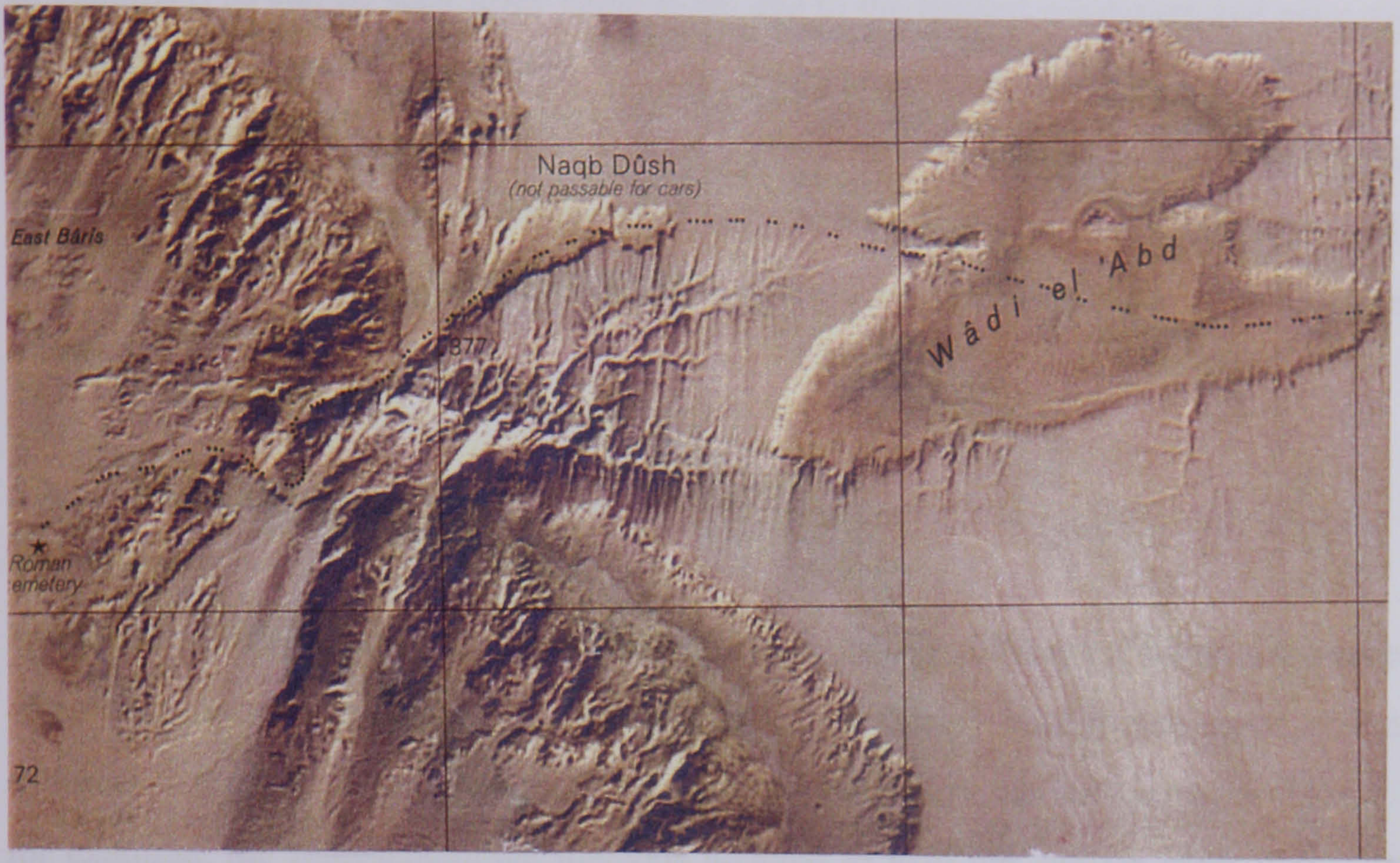


Figure 6-18: A small window from the Baris, Egypt map at 1:100,000 scale.

According to Mehlbeuer & Kahler (1988), the improved spatial resolution of the TM imagery compared with that of the MSS imagery, together with the use of special enhancement algorithms such as edge detection provided a good quality image of this desert area (Figure 6-18). Their use allowed smaller terrain details such as wind eroded channels and various kinds of growing sand dunes to be easily and clearly recognizable. However, the small man-made features that are present in the area were not visible due to the lack of resolution in the images and these had to be derived from additional sources such as existing maps and field information.

As can be seen from Table 6-10, a considerable number of line and point symbols and names have been added to represent boundaries, roads, towns, villages, wells, spot heights and etc. The final image maps have been used as topographic base sheets for navigation, location and orientation purposes and for recording fieldwork, as well as forming the topographic basis of the final published geological maps This map appears to be of a high quality and, in the author's opinion, it has a high degree of relevance to the design and production of image maps of Libya, so much of which is of a similar topographic character.

6.3.3.4 Summary Regarding the 1:100,000 Scale Space Image Maps

In summary, as can be seen from Table 6-10, due to the limited resolution and poor visibility of details on the satellite image data, most of the analyzed maps at 1:100,000 scale suffer from the lack of small man-made features such as isolated buildings; schools, mosques or churches: wells etc. However, these small man-made features are significant in arid and semi-arid areas. In which case, they must be included and represented on these maps by deriving them from other source material.

6.3.3.4.1 Land Use/Land Cover Maps

In the course of reviewing the maps contained in Group III, although a reasonable success has often been achieved in producing a reasonably good quality background space image, it is apparent that many other aspects of their cartographic design are still facing problems. Thus, for example, the representational methods adopted to help the various users understand the detail of the land use/land cover contained in the map have sometimes not been suitable for the purpose. This is very obvious, for example, when comparing the land use/land cover map of Kazgail, Sudan to that of Cap-Haitien, Haiti – which have been produced by different mapping agencies. Although the I-Mage Consult company has produced the Cap-Haitien map with a better printing quality, the use of the overall bright red false-colour has reduced the readability of the finer details of the background image. The land cover/land use has been better represented by the USGS/SSD space image map of the Kazgail area in Sudan through the adoption of simulated natural colour and a better and more sensitive cartographic design.

An innovative feature with all of the most recently produced land cover/land use maps – Kazgail, Cap-Haitien and Kagera – has been the inclusion of interpretation keys giving examples of the typical land use/land cover of the area. This removes the difficulties of the traditional type of non-image map in which boundary lines have to be drawn and polygons formed which are then infilled with colours. This traditional type of cartographic treatment is very unsuited to those maps covering mainly undeveloped areas such as deserts, savannah, mountains, etc. Where the land cover changes slowly over the area, the use of the background space image in combination with the interpretation key gives a much more realistic and appropriate representation of the situation that exists on the ground.

By contrast, in the much earlier Maps 17 and 18 of the Washington D.C. area, the space background image in these two maps has been replaced by the wholly classified map derived from the space images. In fact, this treatment has jumped from one extreme to the other, in that almost all the previous USGS land use/land cover maps produced from space imagery were simply unclassified false-colour image mosaics which were extremely user unfriendly while the Washington maps are highly interpreted and classified and contain no image detail whatsoever. However it must also be said that both of the Washnigton maps are characterised by their more suitable cartographic treatment and their higher information value as compared with the other USGS land cover/land use maps those have been analyzed earlier. Since the area covered by the maps is a highly developed area with strongly patterned fields and woods with definite boundaries, the use of the more traditional treatment is probably more appropriate than in the case of the three examples of land use/land cover maps from developing countries included in this review. Still it would have been interesting to see if the Washington maps would have been improved through the inclusion of the space image data as background.

6.3.3.4.2 Topographic Maps

From the review conducted above, it could be seen that the representation of the different features that are present in the area covered by a particular map through the inclusion of background space images and the use of good quality image processing techniques and suitable cartographic treatment can have profound effect on its final appearance and, in turn, its actual use. A good example can be given by comparing the two general-purpose topographic maps that have been produced for similar areas comprising a densely populated urban area surrounded by an area of desert. These are Maps 20 (of Dubai) and 24 (of Kuwait City). The representational quality of the Kuwait City map, which has been produced in 1991 by Intergraph, is much more successful than that of Dubai which has been produced in 1984 by ERSAC Ltd. The improvement in digital image processing and mapping techniques and facilities, have allowed Intergraph to produce a good quality image map through the use of suitable enhancement procedures and a more effective cartographic representation. Roads are enhanced in very successful manner using black. Furthermore the built-up areas are represented by showing the real structure of building pattern using the space image. Names are printed in black and contrast well on top of the light yellow background image of the map. The Intergraph cartographers have paid a great deal of attention to these matters in order to produce a map of Kuwait that has successfully represented both the city and its surrounding area. Furthermore, the printing quality of the Kuwait map is much higher. By contrast, the Dubai map lacks many of the cartographic elements that have been so successful with the Kuwait map – though the desert area is quite well represented by the background space image and the map does have the advantage of having incorporated many more names that are given both in Arabic and English.

Map 22 of Baris in Egypt also covers an arid and semi-arid area, but without the large urban areas of the Dubai and Kuwait maps. The adoption of natural colour for the background Landsat TM image, which has been enhanced using advanced image processing techniques, has provided a good quality image of the area. This image background shows the main topographic features of the area – such as mountains, ridges, wadis and sand dunes – in a quite successful manner that ensures that this image map can be used successfully without too much additional symbolization or annotation (though in fact this has done in a sensitive manner). By contrast, Map 23 of Berlin in Germany covers a highly developed area characterised by small areas of dense vegetation, many small areas of varied land use in rural areas and a maximum level of residential and industrial development in the large urban area. Images from Landsat TM and SPOT panchromatic data have been fused together to produce this image map. This enhancement technique has provided quite detailed topographic elements. However only a minimum degree of symbolization and annotation has been added to the background image and, for this highly developed area, this map is much less successful than the space image maps of desert areas produced by the same organisation (the Technical University of Berlin).

6.3.4 Group IV – Analyzed Space Image Maps at 1:50,000 scale

Once again, this group sub-divides clearly into three distinct sub-groups – image mosaics; a single tourist map; and general-purpose topographic maps.

6.3.4.1 Image Mosaics

Table 6-11 indicates that three of the maps (Nos. 35, 36 and 37) at 1:50,000 scale have no added symbols or names whatsoever. These three simple image mosaics are characterized by their large format size that may well make them unsuitable for use in the field. Almost certainly, they were envisaged to be used in an office environment or as wall maps.

Area of the Map	Image Map Number	Cultural Features																	Water Features			Vegetation		Relief		Names/Text
		Boundaries			Roads & Railways					Other Cultural Features																
		Primary Level (e.g. International)	Secondary Level (e.g. Provincial)	Tertiary Level (e.g. County)	Primary Roads	Secondary Roads	Motorable Tracks	Foot Paths	Railways	TOV Towns	Villages	Isolated Buildings	Pipe Lines	Power Lines	Wells	Cemeteries	Mosques/Churches	Quarries	Rivers	Canals	Water Bodies	Cultivated	Natural	Contours	Spot Heights	
Slieve Bloom Mountains Ireland	27				✓	✓		✓									✓									✓
Leipzig Germany	28			✓															✓	✓	✓					✓
Laag Somalia	29				✓	✓	✓	✓		✓	✓	✓			✓	✓	✓	✓							✓	✓
St. Louis Missouri USA	30				✓														✓	✓						✓
Ruhrgebiet Germany	31																		✓	✓	✓					✓
Berlin-Potsdam Germany	32																		✓	✓	✓					✓
Stockholm Sweden	33				✓	✓			✓																	✓
Oressaare Estonia	34			✓	✓	✓	✓	✓	✓	✓	✓		✓	✓			✓		✓	✓	✓	✓	✓	✓	✓	✓
Bigene Guinee Bissau	35																									
Sheet 17 Egypt	36																									
Sheet 24 Egypt	37																									

Table 6-11: Features added to image maps at 1:50,000 scale.

Map 35 (of **Bigene, Guinee Bissau**) has been produced in 1998 by the I-Mage Consult company using two SPOT panchromatic images acquired in 1997. This sheet has been produced and printed in monochrome black and white. It has a sheet size of 54.5 x 55cm with the appropriate UTM grid overprinted on it, together with the ticks of the geographical latitude and longitude appearing around the sheet edges. In fact, no cartographic treatment to pick out or highlight any of the water features, vegetation or any cultural features has been carried out by the I-Mage Consult cartographers. Moreover, the image background itself has been poorly treated. It gives a quite murky and mottled appearance and is somewhat unsharp;

indeed it appears that even a simple contrast stretch may not have been applied. Obviously, this geo-referenced image mosaic has been produced quickly and cheaply to act as a substitute or supplement to the out-of-date traditional line map produced by the Portuguese colonial administration. Overall, it gives a general though limited view of the area and can be used to monitor the flood plain of the river system in the area covered by this mosaic by hydrologists, emergency planners, earth scientists, etc. But, in summary, by any standards, it is a poor cartographic product and of little use to the general user.

Maps 36 (of **Sheet 17, Southern Egypt**) & 37 (of **Sheet 24, Southern Egypt**) have both been produced in 1999 by Hunting Technical Services Ltd. and Survey and Development Services Ltd. in the U.K. on behalf of the Nile Valley Gas Company (NVGC) in Egypt. These two plain image mosaics are among 12 that have been produced for a gas pipeline project in the area. They are based upon SPOT panchromatic and Landsat TM images that have been corrected and fused together to fit older topographic maps at 1:50,000 scale to give the up-to-date situation in this area. Both maps have been produced with an equal sheet size (77 x 100 cm), while simulated natural colour has been adopted for their background images. A full 1,000-metre UTM grid with false co-ordinates has been overprinted on both image mosaics. In this respect, they are obviously intended to be used in-house by the NVGC engineers and planners to give the current view of the area being covered by these image mosaics in order to allow them to select the best route for the construction of gas pipelines.

Essentially all three maps (Nos. 35, 36 and 37) are gridded geo-referenced mosaics. Since they are characterised by large sheet sizes and a complete lack of symbolization and annotation, it seems that they have been produced specifically for office use to give a general overview of the area being mapped to users who are already familiar with the terrain. It would probably be difficult for other people to gain access to these maps and, even if they did, to make good use of them. They certainly fall far short of being considered as general-purpose topographic maps.

6.3.4.2 Tourist Map

Map 27 of **Slieve Bloom Mountains, Ireland** has been produced in 1990 by ERA Maptec International Ltd. in Dublin, Ireland. This map has been produced by combining satellite imagery with a conventional cartographic treatment. The background Landsat TM image has been acquired on 7th August 1988. The first three bands (Bands 1, 2 and 3) in the visual spectrum have been used to create a true colour image. The computer-processed imagery has then been further sharpened through the addition of a high resolution SPOT panchromatic image which was acquired on 14th October 1988. The two sets of images were combined using the hue (colour) from the TM imagery and the intensity (brightness) from the SPOT (Pan) image. The combined image was geometrically corrected, i.e. geo-referenced, to the Irish National Grid prior to the addition of a substantial number of conventional cartographic elements.

The additional information needed for the compilation of this map has been derived from a number of sources, including existing maps, aerial photographs and field work. This cartographic information was processed initially on a digital mapping system before being overlaid on the composite space image. It can be seen from Table 6-11 and Figure 6-19, that main roads and other tourist information have been superimposed through the use of a limited number of line and point symbols of different form, dimension and colour. However, no attempts have been made to classify or pick out vegetation, built-up areas and water features. Names have been also added in blue, red and black surrounded with halos. Furthermore a quite detailed legend with additional textual information about features that are of interest to tourists has been provided to help inform the various users of this space image map.

Figure 6-19: A small window from the Slieve Bloom Mountains, Ireland map at 1:50,000 scale.

In addition to the main image map, two inserts have been included to display the perspective views of the Slieve Bloom Mountains as seen from two different viewpoints. These perspective views were generated by digitally overlaying the satellite imagery on to elevation information provided by the Ordnance Survey of Ireland. The digital elevation information was supplied in a gridded format as a DTM derived from stereoscopic pairs of aerial photos.

The main purpose of this map has been to show this piece of terrain with its great natural interest, and having a rich and diverse cultural landscape. This can only be properly explored and appreciated with a map that shows something of the landscape detail in which so much of the fascination of this mountain area resides. Indeed, from the cartographic point of view, this specially produced "tourist" map has been quite well designed and will have been of considerable use to the many visitors who are interested in exploring the area.

6.3.4.3 Topographic Maps

Seven maps (Nos. 28, 29, 30, 31, 32, 33 and 34) are included in this sub-group. They differ considerably in their sheet size, in the amount of cartographic symbolization and annotation added to their image background, and in the cartographic treatment applied to these space image maps. Four of these maps (Nos. 28, 29, 31 and 32) have been produced by the Technical University of Berlin (TUB); two maps (Nos. 33 and 34) by SSC Satellitbild; and one map (No. 30) by the Intergraph Corporation.

Map 28 (of **Leipzig, Germany**) has been produced in 1990 by the TUB and is based on a space photograph taken by a Russian KFA-1000 camera in 1986. Natural colour has been adopted for the background image. The format size of this space photomap is 52 x 56cm, and both the UTM grid together with geographical co-ordinate system have been used – in each case, in the form of marginal ticks.

As can be seen from Table 6-11, a minimum degree of symbolization has been added to the base image. This comprises the inclusion of a few interrupted black lines to depict the boundaries of the urban area. Water features such as lakes, rivers and canals have also been enhanced in black without the addition of names. However, the names of the main villages, villages and small settlements have been included in the map in black. It is noticeable that no edge enhancement techniques have been applied to enhance the roads, streets or any other linear features as was done for the Berlin 1:100,000 scale sheet [Map 23]. Nor have the TUB cartographers made any attempt to pick out or highlight the built-up areas or to classify vegetation. The interpretation task has been left entirely to the user and his skills, experience and local knowledge of the area in order to use the map. It seems that this space photomap has been produced quickly and cheaply as an experimental sheet from the TUB side to test the potential of KFA-1000 photography for image mapping at 1:50,000 scale. It is noticeably less sharp than the two image maps (31 and 32) of the Ruhrgebiet and Berlin at the same scale produced from digital TM and SPOT imagery.

Map 29 (of **Laag, Somalia**) has also been produced in 1990 by the Technical University of Berlin (TUB). This image map is based upon images from Landsat-5 TM Bands 1, 2 and 3, together with SPOT data taken in panchromatic mode. By combining both types of data, this satellite image map has been produced at 1:50,000 scale. The background image is printed in natural colour. The sheet size of this map is 37 x 54.4 cm, and both geographical co-ordinates (via marginal ticks), and national co-ordinate system (using full grid lines) have been used to provide a locational reference.

Figure 6-20: A small window from the Laag, Somalia map at 1:50,000 scale.

In fact, this map provides a good representation of an undeveloped arid area where man-made features are few and the terrain is almost wholly a natural and undisturbed landscape. As can be seen in Figure 6-20, the background image itself represents the image details – in particular, the mountains, ridges, valleys, drainage patterns and sand dunes – quite successfully in a manner that is not possible with a traditional line map. Hence, this base image will interest many local users living in this area even without any cartographic additions. However, as can be noted from Table 6-11, a reasonable number of line and point symbols and names have been added to the image in black. This has been done to pick out and to represent roads (primary, secondary), car tracks and footpaths, villages and small settlements, isolated buildings, water supplies, mosques and quarries – which are the man-made (cultural) features that are so important to users in this type of area, but often cannot be detected on the satellite image itself.

Unfortunately, the cartographic design of the added symbols and names has not received the most appropriate treatment. In particular, the use of black symbols and names within the dark areas of the image, has made these point symbols and letters more or less invisible (Albertz and Tauch, 1994). This particular problem has been created through the occurrence of strong shadows in the mountainous area located in the south-western part of the image map. However, taken overall, this map would still appear to be very useful for many local users in the area where either other maps do not exist or, if they do, they are out-of-date. It has been of special interest to the author because of area's resemblance to certain mountainous areas in Libya.

Map 30 (of **St. Louis, Missouri**) is an ungridded geo-referenced image map has been produced digitally in 1990 in the form of a poster by the Intergraph Corporation. This image map does not carry any of the usual co-ordinate systems, and has been produced with a sheet size of 48.5 x 48.5cm. Both SPOT XS and SPOT Pan image data have been utilized to produce the background image of this particular space image map. The image processing components of Intergraph's MGE software package have been used to process these SPOT image data sets into a single colour image. The three spectral bands of XS image data with their 20-m ground pixel size were spectrally enhanced and spatially resampled to fit the 10-m Pan image data, which were edge enhanced with a Laplacian filter. The resampled XS images were then fused with the Pan images using IHS transformation techniques. A false-colour combination has been adopted for the background image.

As can be seen from Table 6-11, only a few lines and names have been added to the image. The few lines that have been included in the map depict interstate roads and state boundaries. Besides these, a very few names have been overprinted. They comprise those for two parks, the international airport and the Mississippi river where the text does not interfere with the background. As can be seen in Figure 6-21, unfortunately, the base image of this map is characterized by the quite strong red (false) colour that makes it difficult for users to discern the underlying image detail. Moreover, there seems to be no obvious basis for displaying the built-up area in two different colours – the one in blue-grey and the other in a light red. Furthermore, no attempt has been made to classify the vegetation or to pick out the water features that are present in this area. Also, no interpretation key has been provided to help the users. In addition, the representation of the interstate roads using strong yellow colour has not been too successful, since these lines quite dominate the map and resulted in a somewhat unbalanced final appearance of this image map. With all of this in mind, the author thinks this space image map has not been too well designed and, in fact, it appears to be a somewhat unfinished map product that would be difficult to use in actual practice. Perhaps Intergraph simply visualized this map as being an advertisement and marketing tool for its software – if so, then a good opportunity to produce a useful cartographic product has been missed, especially when a considerable time, effort and money has been spent on its production.

Figure 6-21: A small window from the St. Louis, Missouri USA map at 1:50,000 scale.

Map 31 (of **Ruhrgebiet, Germany**) has been produced in 1990 by the Technical University of Berlin (TUB). It is based on one Landsat TM scene and two SPOT Pan images. All three space images that have been used to produce this map, have been acquired on 1st May 1986.

This has avoided any problems that may occur as a result of time or seasonal changes. This image map has been produced digitally by utilizing the mosaicing and merging techniques developed by the Technical University of Berlin. These particular techniques are described and discussed in more detail by Tauch & Kähler (1988), Albertz et al (1987 and 1990). and Tauch & Scholten (1990). In the case of the Ruhrgebiet map, since a natural colour rendition was desired, the TM Band 1, 2 and 3 images were selected for the production process and enhanced by suitable digital image processing techniques. Since the selection of these three Bands has not provided good results for water areas and vegetation, additional information has been derived from the Band 4 and 5 images using a similar procedure to that which has been applied in the case of the 1:100,000 scale Berlin map (No. 23). This space image map is characterized by its large sheet size (70 x 100cm) that covers an area of 35 x 50km on the ground. It does not carry any of the usual gridded co-ordinate systems; instead only the geographical latitude and longitude of the four corners of the sheet are given within the marginal information.

As can be noted from Table 6-11, a medium level of cartographic symbolization and names has been added to the image. Water features such as lakes, rivers and canals have been enhanced via the appropriate mask using a black colour with no names assigned to them. Moreover, the names of towns, main villages and villages have been overprinted in black. Linear features are well enhanced in the background image. It appears that an edge enhancement technique has been applied to accentuate boundaries, edges, roads, streets, and other linear features all over the image (see Figure 6-22). Again, this space image map has been produced to test the merging of TM and SPOT Pan imagery for image mapping at 1:50,000 scale in a highly developed area. It can be useful for many local map users who have sufficient knowledge of the area, but it will be less useful for other people such as visitors who are unfamiliar with the area. They need the additional information normally conveyed through the symbols and names provided by cartographers in order to have a really useful and understandable map.

Figure 6-22: A small window from the Ruhrgebiet , Germany map at 1:50,000 scale.

Map 32 (of **Berlin-Potsdam, Germany**) has been produced digitally in 1991 also by the Technical University of Berlin (TUB). It is based on a single Landsat TM scene acquired in 1986 and two SPOT Pan Images taken in 1990. This space image map has been produced using natural colour for its background image. Its large format size (80 x 100cm) covers an area of 40 x 50km on the ground. No gridded co-ordinate systems have been incorporated in the map; however, the geographical latitude and longitude values of the four corners of the map have been provided within the marginal information.

In fact, although the Berlin-Potsdam map covers a different area in Germany to that of the Ruhrgebiet map, they are, to a large extent, similar in terms of the type of space image data used, the method of production and in the cartographic treatment that has been applied. Thus, there is no need to repeat what already has been discussed above. Instead, only the differences between these two maps will be discussed in this section. By inspecting both maps, it has been noted that the main built-up area in Map 32 is darker than the well enhanced one in Map 31. It appears that less attention has been paid to the enhancement of its built-up area. As a result, roads, streets, and the boundary edges of fields are much less well portrayed. However, particularly in the rural area of Berlin map, it appears that the merging of SPOT Pan & Landsat TM images together with the application of special filtering techniques have provided a good quality image of this area (see Figure 6-23).

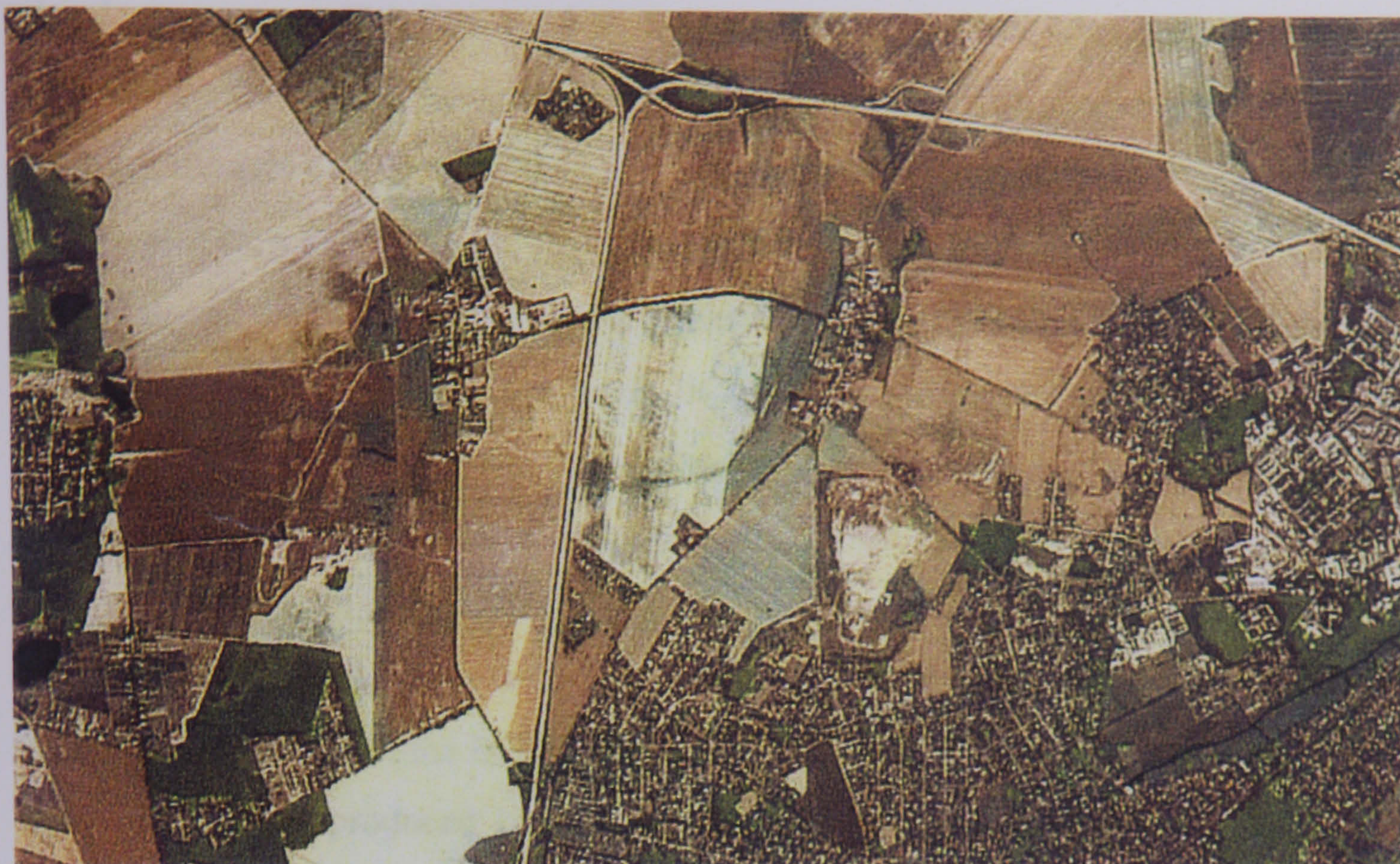


Figure 6-23: A small window from the Berlin-Potsdam, Germany map at 1:50,000 scale.

As can be seen from Table 6-11, again a medium level of symbolization and annotation has been added to the image. The TUB cartographers have picked out the water features and enhanced them using a black colour. Furthermore, white names have been overprinted on the larger (black) water bodies. Names have also been provided in different sizes using black for towns and the main villages. Although the cartographers did not pick out or classify any of the vegetation, these features are better enhanced and can be easily distinguished. Indeed, this map would be useful to many local users who live in the area, but perhaps not to visitors.

Map 33 of **Stockholm, Sweden** has been produced digitally in 1992 by SSC Satellitbild using SPOT Pan & SPOT XS imagery. This map covers a highly developed area in Sweden that comprises built-up areas, roads and railways, and an extensive variety of vegetation and water features. It has been produced as a poster using simulated natural colour and has a sheet size of 50 x 70cm. This map does not carry any of the co-ordinate systems that are normally used as locational references – which, for a Swedish map, seems most unusual.

As can be seen from Table 6-11, only names and simple lines to represent the roads and railways in this area have been added to the map. White is the only colour that has been used for the added line symbols and names. Unfortunately, this colour with its high contrast compared with the background coloured image tends to dominate the map and unbalance its visual appearance. This has resulted in coarse and poorly designed roads and railways. It appears that the SSC Satellitbild cartographers did not pay attention to this aspect and apply a more appropriate cartographic treatment when they designed this map. Furthermore no legend or interpretation key has been provided. In the author's opinion, this map has been poorly designed, and the main purpose for its production appears to be to simply show the Stockholm area using SPOT imagery. In a sense, it appears to be more an advertisement for SPOT imagery to be placed on a wall than the useful map that it could have been – in this case, it suffers from some of the same defects as the Intergraph map of St. Louis (Map 30).

Map 34 of **Orissaare, Estonia** has been produced in 1994 by the SSC Satellitbild in Sweden. After the withdrawal of the Baltic States from the Soviet Union, the only existing topographic maps were those produced by the former Soviet mapping authorities. These maps were erroneous and old, and the availablity of an up-to-date topographic map series is crucial for any country. Using conventional mapping technology based on aerial photography, the Baltic States would not have been able to obtain this basic coverage for many years. As reported by Klang (1996), the first contacts between the Baltic States and the Swedish space mapping company (SSC Satellitbild) were established in the early 1990s. Initially the Baltic States' aim was to use satellite image data to carry out environmental monitoring and natural resource mapping. However further investigations showed that the most urgent need in each of the three countries was for topographic base maps on a scale of 1:50,000. Over a period of 24-30 months, a new map series was produced based on SPOT ortho-images.

The maps have been produced on the basis of a common new geodetic datum and projection that is specific for all three Baltic States. A digital topographic data base was compiled using a combination of SPOT Pan & XS scenes, photogrammetric data, existing maps and other available data. The positions of the ground control points (GCPs) used for the geometric corrections and geo-referencing have been measured with the Global Positioning System (GPS). A digital terrain model (DTM) has also been created by digitizing the contours shown on the old Soviet maps and deriving the required elevation values. These were then used to correct up the relief displacements that were present in the SPOT images. The background space image has been printed in a green colour with a sheet size of 52 x 52 cm. Three co-ordinate systems – geographic (marginal & body ticks), UTM (marginal ticks) and the national co-ordinate system in the form of full grid – have been superimposed on the map.

Figure 6-24: A small window from the Orissare, Estonia map at 1:50,000 scale.

As can be seen from Table 6-11, a maximum level of point, line and area symbols has been added to the map from other sources to represent boundaries, roads, vegetation, water features, etc. Names have also been superimposed in black and blue over the background space images. The SSC Satellitbild cartographers have really made an intensive effort to pick out, classify and highlight built-up areas; water bodies; agricultural land; forest and grass lands, etc. Relief has been depicted by contours and spot heights – though this data has come from the existing Russian military maps. As can be seen from Figure 6-24, although the cartographers concerned with the production of this map have obviously spent a considerable time in interpreting, classifying and designing these topographic features to aid the use of this map, in the author's opinion, the resulting image map is crowded, unbalanced and unsatisfactorly designed. In particular, the selection of the overall green colour for the background image is unsuccessful since it reduces the contrast and legibility of many of the symbols and names. Furthermore, the selection of the boundary and road line forms and colours has not been too satisfactory and, indeed these may well confuse the user of the map. Overall, this map represents only a single sheet of the Estonian national map series that covers the entire country. The maps in this series carry a great deal of information that will certainly be useful for developing, planning and scientific projects. But the maps do not really reach the same high standard of cartographic representation that is found in the well-known Swedish

1:10,000 and 1:20,000 scale national orthophotomap series. Whether the considerable difference in scale of the 1:50,000 scale map has had a negative influence on the cartographic representation is a possibility as has the fact that the larger scale Swedish maps have a much higher resolution background derived from aerial photography.

As discussed above, seven general-purpose topographic maps at 1:50,000 scale have been discussed and systematically analyzed. These maps vary greatly in terms of the amount of symbolization and annotation added to their image background. Many of these maps suffer from the lack of an appropriate cartographic treatment and representation. Indeed on many of them, only limited attempts have been made to interpret, classify or highlight the various area features to ease the interpretation task for the user. But there are several reasonably successful examples – in the author's opinion, the maps of Slieve Bloom (Map 27), Laag (Map 29) and Orissaare (Map 34) all give pointers as to how a successful space image design could be produced for a 1:50,000 scale topographic map series.

6.3.4.4 Summary Regarding the 1:50,000 Scale Space Image Maps

In general, the production of space image maps at 1:50,000 scale only really began with the availability of the higher resolution space imagery from SPOT and the Russian KFA-1000 photography. Moreover, the development of sophisticated digital image processing software packages and techniques at the time when these became available provided good quality images to be used as the background to these maps.

However, again, as can be seen from Table 6-11 and the examples reviewed in this Section, due to the rather limited ground resolution and the lack of visibility of detail on most of the satellite images, the maps produced at 1:50,000 scale all suffer from a deficiency in the small man-made (cultural) features. Obviously if they are to be included, then they have had to be obtained from other sources such as existing maps, aerial photos or field completion surveys. This does make these products more suitable for users, especially in developing countries, since often the man-made features are very few but vital since most of the terrain is a natural undeveloped landscape. However, acquiring all this additional, though vital, data adds considerably to the time, effort and cost required for the compilation and production of these maps.

Since the 1:50,000 scale is used for national topographic mapping in so many countries, they have really been of special interest in this analysis. However, taken overall, the results are somewhat disappointing. As discussed above, three of the maps (Nos. 35, 36 and 37) included in the review are simply image mosaics. Two more – the maps of St. Louis (Map 30) and Stockholm (Map 33) – have been produced by an image supplier (SSC Satellitbild) and a system supplier (Intergraph) respectively. In spite of the considerable effort and expense involved in their production, both have suffered from a quite limited and rather incomplete cartographic treatment. It would appear that marketing considerations have played a major part in their production: if so, then the chance has been missed to produce a really useful cartographic product. A further three maps – those of Leipzig (No. 28), Ruhrgebiet (No. 31) and Berlin-Potsdam (No. 32) – have been produced by TUB. All of these are concerned with coverage of some of the principal cities in Germany. While the space images used as background have been well produced using advanced image processing techniques, there has been a noticeable reluctance to add symbols, names, etc. – which, in a sense, highlights the problems of adding these features to image maps at this scale containing large areas of built-up land.

In the end, only three maps – those of Slieve Bloom, Ireland (No. 27), Laag, Somalia (No. 29) and Oressare, Estonia (No. 34) have had a really comprehensive cartographic treatment. The Slieve Bloom map is a special touristically-oriented sheet which is reasonably successful. The Estonian map is very interesting in that, of all of the maps that have been reviewed, it probably has had the most extensive cartographic treatment – carried out by a Swedish organisation. Given the Swedish experience in the successful production of photomaps over a 60 year period, one would have expected a rather better result. The final map – that of Somalia by TUB – is of special interest to the author in view of the similarity of the terrain to that of parts of Libya. While the use of the black colour for all the added detail is not really successful, this can be overcome – as indeed the TUB cartographers have shown in the other maps of Egypt that they have produced – as reviewed in previous Sections of this Chapter.

6.4 Conclusion

As can be observed from this review and analysis, a lot of experimental work has been carried out to improve the design and production of satellite image maps with a view to their adoption to form the whole or a part of a national series. However, it has to be said that, so far, with a few exceptions – such as the recent Baltic States series – this adoption has not taken place. It is perhaps a matter of debate as to whether or not this results from some fundamental shortcoming in satellite image maps in general or whether they have not yet been developed sufficiently to be adopted by a national mapping organisation. In the case of those countries with huge areas of desert and semi-arid land (such as Libya), the use of satellite image background would certainly allow the representation of the terrain in a way that no other map can achieve.

The maps that have been reviewed vary widely in scale, projection used, format and design, sensor and image type, etc. Their scales vary from 1:50,000 to 1:1,000,000 but the most common scales are 1:50,000; 1:100,000 and 1:250,000. In fact, the scale has a direct relationship with the ground resolution of the space image data that has been available and could be utilized to produce the space image maps. Furthermore they have been produced mainly for two rather different purposes – (i) general topographic mapping and (ii) land cover/land use mapping. It is noticeable that the latter group have mainly been produced at smaller scales. This is partly due to the requirement to use multi-spectral imagery (from MSS or TM) as the basis for land use/land cover maps: inherently this type of imagery will have a lower ground resolution.

The availability of high quality satellite image data in digital form, and the advancement of the digital image processing technology and techniques have made it possible to mosaic several scenes to form a sharp and seamless mosaic of a large area. This technology has also made it possible to enhance certain of the features contained in the image via enhancement and filtering techniques and hence to present and visualise these features in an optimal shape and form that was not possible with early photographic techniques. However, the production of this kind of map is still restricted to certain scales; this is due largely to the limitation of the image resolution. From several of the recent examples included in the analysis, it can be seen that the fusion or merging of multi-sensor image data can be an effective tool to improve the quality of satellite image maps by combining the high geometric resolution of SPOT panchromatic image data and colour information from Landsat TM image data or SPOT XS image data. Better results can be obtained if the IHS transformation has been used as part of the merging algorithm. However, good results will only be achieved if the actual geometric and radiometric characteristics of the space image data involved are fully considered and the flexibility of digital image processing techniques is fully used. Normally a great number of interactive operations and also substantial practical experience are required if this is to be successful.

The advantage of employing space images as part of the map is that they can be highly informative and provide information that cannot be given in the line map. Particularly, in certain types of topography, such as sand dunes, tidal flats, swampy areas and areas of complex woodland, even with the minimum level of annotation, the natural space image provides a superior representation and more information than is possible on the conventional line map. On the other hand, a general disadvantage of image maps is the fact that some users may find their interpretation difficult. Hence, it is desirable to combine the image with certain relevant features that are not visible on the image. These features need to be added through the use of cartographic symbolization, – most often in the form of point and line symbols. As this review and analysis has shown, is far from easy to combine the natural terrain image with such symbolization. Whereas the design of conventional (wholly symbolized) topographic maps is well established and they do not differ much from one country to another, this is far from being the case with space image maps. The biggest problem is of course that the addition of symbols and names will obscure or eliminate the background space image, so the placement of these symbols and names requires a high degree of skill and sensitivity on the part of the cartographers who are carrying out this task. Almost certainly, the final result will not please everyone.

Some of the analyzed maps have been produced specifically to show the land use/land cover of the area that they cover and far more effort has been put into their production by the cartographers concerned in order to ease interpretation and to provide users with additional valuable information. Of course, on this type of map, the emphasis is more on areal features, rather than point and line features. Zones of similar pattern, such as residential areas of different densities, can be delineated on the image. However it is often not possible to identify the type of land cover in detail directly from the image. For this, familiarity with the area and reference data in the form of field work, aerial photography, and maps are needed. Furthermore it is not always possible in undeveloped areas to draw lines and define areas of a particular homogeneous type – since the vegetation or forest will often change slowly over a considerable distance. This can be seen from the natural image itself and will certainly preclude the use of patches of colour with definite boundaries – which is the traditional solution used in areas of highly developed land with well defined fields, woodland, built-up areas. The recently developed solution of leaving the space image to show the natural vegetation without attempting to delineate boundaries and to supplement this by incorporating interpretation keys in the legend is a most interesting and innovative solution to this problem.

However where it is appropriate, e.g. in more developed areas, cartographers should make more effort to classify and identify water features, vegetation and other area features in order to help users using the image map. They should also pay special attention to the method of representing these features. The colours used with the overall background image have very strong influence on the readability of final image map. For example, the use of false-colour – which is popular among the remote sensing community – is seldom a successful choice for a general topographic map – e.g. that of St. Louis (Map 30). The strong red appearance of its background image has dominated its final appearance and decreased the contrast and legibility of the added symbols and names. In the author's opinion, the use of false-colour for the background image of a general topographic map must be avoided. Instead, natural colour should be adopted to give a real impression of the mapped area to the users. Even in the case of land use/land cover maps, the use of false-colour must be queried – the examples provided by the USGS land use/land cover maps show the difficulties that can arise in this respect.

In very general terms, it can be said that many of the space image maps included in this review and analysis have not achieved a good level of success in terms of their cartographic design and enhancement. Too often, this type of map has suffered from the lack of certain basic information such as names, contours, road classification, etc. which is needed for non-specialist users. However, as noted above, the application of space image maps is very useful in arid and semi-arid regions where most of the features are those of the physical landscape and there are few man-made details. Still, even in such areas, as the author has observed through this analysis, the cartographic design aspects of the image map have not always received an adequate treatment. The shortcomings include problems with contrast and those concerned with the integration of the cartographic elements (placement of names and symbols) with the complex background satellite image. All of these give enough reasons for continuing research to solve the design problems of the space image map. Besides these purely cartographic issues, image mapping requires more collaborative work between the map makers and the map users such as geologists, planners, etc. Regarding the content of the final map, each one of these groups has its own requirements that it wishes to see on the image map and obviously more efforts should be made to see if these can be reconciled and met. On the other hand, it has to be said that, in the specific matter of conducting research into the design of the space image maps that are suitable for use in the Libyan context, some excellent pointers to a successful design solution have been given by the examples produced at different scales by TUB – at 1:250,000 (Map 14); 1:100,000 (Map 22); and 1:50,000 (Maps 29, 31 and 32).

Further consideration of the basic elements of cartographic design with respect to space image mapping will follow in the next chapter.

CHAPTER 7: GENERAL CONSIDERATIONS OF CARTOGRAPHIC DESIGN WITH RESPECT TO IMAGE MAPPING

7.1 Introduction

In Chapter 6, a systematic analysis of a representative sample of existing space image maps has been carried out in some detail. These maps have been produced at a variety of scales, have been made for different purposes, and represent different areas in the world. In this chapter, the cartographic design aspects of image maps will be discussed from a more general and more conceptual point of view.

The design of any map has an effect upon its usefulness as well as its general acceptability. Space image maps are now being considered as an alternative to traditional topographic maps, reflecting the improved ground resolution of current satellite imagery. The space image provides a detailed representation of the terrain, which can be inexpensively printed in the form of a mosaic produced by techniques such as those described in the preceding chapter. Such images contain great deal of descriptive information about the terrain. However, cartographic enhancements in the form of conventional (point, line, and area) symbols and the addition of names, grid, marginal information, are necessary, both to aid the interpretation of the image and to add information that is not shown by the image.

The final design of any space image map will be influenced by various factors such as the terrain characteristics and the conditions existing in the area to be mapped, the scale and the availability of data. Technical considerations, such as the availability of the facilities needed for processing and reproduction will also play a part, as will economic factors such as the permitted number of printing colours. The purpose of the map, which will be reflected in the specification of its content, will also influence the design process, both in the treatment of the background image and the additional cartographic enhancement.

The legibility of the background image and any superimposed cartographic data are both matters of prime concern. A major problem can arise with the superimposition of symbolisation in that this will almost inevitably conceal or obscure parts of the underlying image, creating the paradox that attempts to enhance the interpretability and usefulness may actually result in a loss of information contained in the original image. In part, this reflects a general problem of topographic mapping – in attempting to provide information for a wide range of users, the specific needs of specialists such as geologists, vegetation experts, foresters or soil scientists may not be completely satisfied.

7.2 General Principles of Space Image Map Design

7.2.1 Introduction

Notwithstanding the different nature of the information that forms the basis of the image, the design of any space image map has to follow the same basic principles of cartographic design that are applied in conventional line map production. Shearer (1969) pointed this out with respect to orthophotomaps, and Abdallah (1980) noted that "*The design of the RBV image map has to follow basic cartographic principles. Legibility, both of detail and of the map as a whole, is of prime importance*". Dahlberg (1993) similarly stated that "*The general considerations involved in the design process of image maps are similar to those for other types of maps. They include map purpose, content, target audience, graphic appearance, format and user requirements, especially in relation to the level of costs involved. Further considerations focus on the graphic design and include image enhancements in the form of type, point, and line feature symbols, and area symbols. Additional considerations include format, layout and integration of components.*"

A major consideration must be that the information which must be added to the space image background must be represented clearly and effectively in order to be efficiently communicated and understood by the user. The cartographer has to solve the problem of providing definitive information through symbolised representation while, at the same moment, exploiting the descriptive capability of the space image and minimising the loss of information caused by the superimposition of the symbols.

7.2.2 Design Controls

Generally speaking, there are three main inter-related controls on the design of any image map. These are:

i) map purpose; ii) map scale; and iii) terrain characteristics.

(i) The **map purpose** will determine the need to include or emphasise any information of the map. Most cartographic authors, e.g. Keates (1989) and Robinson et al (1995), stress the important influence of map purpose on design. Robinson states "*The purpose for which a map is made is the essential determinant of its final form.*" Topographic maps, whether of conventional line form or orthophoto or ortho-image maps, are essentially multi-purpose. Hence no single item or class of features should dominate the map appearance.

(ii) The **map scale** must be chosen with in response to map purpose. The two factors are inextricably linked. Of course, with topographic maps, one is normally dealing with the production of map series at standard scales and the style of presentation, the classification and representation of features will change with scale. For example, the treatment of buildings and urban areas on line topographic series covering the same area, will be quite different at large (1:10,000), medium (1:50,000) and small (1:250,000) scales.

As mentioned in the previous chapters, due to the frequent lack of high spatial resolution and contrast, the effective production of current space image maps is restricted to medium scales (1: 50,000) and smaller, though this situation may change with the advent of higher resolution space imagery. As the image scale is reduced, details become more difficult to recognise.

At 1:50,000 scale, features such as roads, airports, main villages, quarries, etc. can be clearly identified on the better types of space image and there may be little requirement for cartographic annotation to simply **identify** such features. In most cases, the additions necessary for identification can be restricted to features such as isolated buildings or wells. On the other hand, when designing a general purpose space image map at 1:250,000 scale, the interpretability of the image and the extraction of information, particularly of man-made features, is inevitably more difficult and additional symbolisation to allow identification of features becomes a greater necessity.

(iii) The **terrain characteristics** of the mapped area will obviously influence the appearance of the space image but will also determine the nature and extent of the additional treatment required in the map design. Every region has a certain geographical character, over which the map designer really has no control and, particularly with topographic series where the maps can extend over areas with quite different terrain characteristics, this can raise problems in standardising the design. Even in countries that have broadly similar overall relief and climatic conditions, the differences between natural and culturally developed landscapes can be quite marked. These characteristics and differences will be reflected in the space imagery and, in turn, will impose different requirements on the treatment applied in the image mapping.

In arid and semi-arid regions, as typified by Libya, where the majority of the landscape is natural terrain, the image may be fully exploited to depict the physical features of such areas, arguably with much greater success than attempting to represent them by conventional symbols. However, where the natural details are obscured, for example by shadow, or where there is a need to emphasise the degree of differentiation between features, an element of cartographic enhancement will be required. In more developed areas, particularly with respect to urban areas, the design task will become more complex and demanding.

7.2.3 Map Content

In most mapping projects, the map purpose and the terrain character will determine the necessary content and these factors taken together will influence decisions as to the appropriate scale. In the case of topographic line mapping, the scales of series coverage will be pre-determined, and since the maps are multi-purpose, the content will reflect the classification and representation of the various cultural and natural features required at the chosen standard scales. A listing of the items necessary for inclusion at specific scales and the classifications required (e.g. of roads) will be the essential pre-requisite to the design of symbolisation for conventional line topographic maps.

In the case of image mapping a similar process will be necessary but with a somewhat different approach. The space image, of course, will be a common constituent at all scales. There will always be a requirement to include certain map elements that do not appear in the space image – names, contours and administrative boundaries are obvious examples. The cartographic treatment of **imaged** features will then depend on their ease of recognition and identification in the image and the perceived need to confirm their exact identity, to emphasise them or to differentiate them from similar image features.

7.2.4 Generalisation

Cartographic generalisation is a complex and often subjective matter, demanding considerable skill on the part of the cartographer. In line mapping, various aspects of generalisation can be identified, though, in practice, the execution of generalisation normally involves simultaneous consideration of several or all of these elements. Keates (1989) identifies selective omission, simplification, combination, exaggeration and displacement as the major elements of the generalisation process. In conventional (topographic) line mapping, the need for and the degree of generalisation increases as the scale (of derived mapping) decreases. This is reflected in a multiplicity of ways – the selective omission of minor tributaries; the simplification of the form of linear features or area outlines; the combination of individual buildings into block or area representations; the exaggeration, particularly of linear features such as roads beyond their true scale dimension and the associated displacement of adjacent features. The overall aim of the generalisation process is to clarify the representation whilst retaining an accurate portrayal of the character of individual features and the area as a whole.

In image maps, there are similar requirements for generalisation at reduced scales. However, the cartographer will always have to consider the image itself where the generalisation resulting from the scale reduction, for example from 1:50,000 to 1:250,000, will not be a planned and systematic process but will be the combined result of changing dimension in relation to image resolution. As mentioned above, the interpretation of the image is generally more difficult at smaller scales and the need for additional cartographic enhancement through the use of conventional symbolisation will increase. The inclusion of such symbolisation on the essentially un-generalised image may pose problems. For example, the treatment of a sinuous road or river will involve progressive simplification of the form on a line map. If a similar feature is to be symbolised on an image map, there may be conflict with the un-simplified, un-exaggerated image representation of the feature.

On the positive side, some aspects of generalisation may be easier in the case of image maps. The treatment of vegetation boundaries is a good example. On a line map, the placement of boundary lines demarcating dense woodland, open woodland and grassland is always problematical e.g. in basic topographic mapping carried out by photogrammetric plotting. The three classes of vegetation may be reduced to two – woodland and grassland – at smaller scales, in which case, does the boundary now combine dense and open woodland, open woodland and grassland or fall midway in a transition zone between the two extremes. In the image mapping situation, the variations in tone and texture will continue to illustrate this transition and there may be no requirement at all for the inclusion of (unrealistic) "hard" boundaries. The use of interpretation keys is an appropriate solution to deal with the lack of these "hard" boundaries appearing on the space image.

7.2.5 Visual Levels, Contrast and Harmony.

The cartographic designer aims to use the visual variables of symbol form, dimension and colour to create sufficient contrast between the visual representation of different features to allow the easy differentiation, recognition and identification of features both in isolation and in combination with other features and to allow an appreciation of the map when viewed as a whole. At the same time, these variables are exploited to create different visual levels of perception. For example, on topographic line maps, different classes of roads are frequently given different colour infill treatment and the casing weight and overall dimensions will also vary. The aim is to allow the simple recognition of roads (as opposed to other features) and to introduce a visual order into the representation so that major roads are more prominent than minor roads. At the same time, as a group, roads are normally considered more important than, for example, contours; hence thinner lines in a less strong colour (normally brown) are used to represent the latter. This introduces visual levels into the overall map image; as a group, roads will be more prominent visually than the contours, though these will still remain clearly visible and meaningful at closer inspection. These aspects of contrasting colour and dimension must not be over exploited. Some degree of visual harmony is still required so that the different map elements do not become visually disturbing or conflict unpleasantly with each other.

The exploitation of these design tools or elements is probably most difficult in the case of image mapping. The designer of a line map starts with a blank sheet of paper and the white paper background is always a factor in determining the required symbol dimensions and colours. Of course, area infills may result in varying colour backgrounds and the juxtaposition of different symbols will always influence their perception to some degree. However, in the image map, the designer will always have to deal with the varying tones of the background image. Additional symbolisation must contrast sufficiently with this, but, at the same time, it must not replace or visually dominate the image.

The treatment of names on the map is a prime example. On the line map, the majority of names will be in black, the colour deliberately chosen to have maximum contrast with white and hence optimum legibility. The cartographer is aware of the colour area tints which will be used – these are normally deliberately chosen (where appropriate) to be sufficiently light to allow black names to retain contrast and legibility at the small text dimensions which are employed. In the image map, the cartographer has no such control over the background appearance. The image will vary in tone between light and dark, and a sufficient density range has to be retained in the image to preserve the quality of its detail representation. Effectively the requirement is for maximum contrast in the image tones. A black name may thus fall unavoidably in a dark area, in an area of varying tones, or in an area of strong texture or pattern variations. All these situations will have a detrimental influence on the legibility of the name. Similar problems will arise with line and point symbols. Overprinted area colour tints will no longer have a consistent appearance but colours will be modified by the background tones. Pattern and textural infills will normally conflict with or be illegible on the varying background image and are hence ineffective.

It can be argued that similar problems may arise with the varying tones of hill shading, which is employed in many topographic map series. Here however the cartographer has a measure of control over the appearance of this (via the density range and contrast occuring within the shading) and the problem does not occur with the same order of severity. In the case of image maps, the cartographic designer is faced with many problems which do not occur on line maps, or which occur in extreme forms. At the same time, some of the symbolisation possibilities common on line maps (e.g. area tints, area patterns) may be quite ineffective on image maps.

7.2.6 The Skill and Expertise of the User

The skill level of the user is another factor over which the cartographer has little control. Map interpretation skills are highly variable from user to user, though it is expected that specialist groups will be skilled in the map use relevant to their particular discipline. As stated by many prominent cartographers, it is an impossible task for a map-maker to design a single (topographic) map that will fully satisfy all users. According to Wood (1972) " *It will never be possible to make a single map (even for fairly specific tasks) to suit everyone, because of the wide range of natural abilities, skill, experience, education, etc., within which the user* *might fall. Also the effects of interests, reactions and performance in map use situations. Therefore, the cartographer must compromise and produce something which will be intelligible to the highest percentage of the users."*

It is however very important to identify the main groups of intended users and the main purposes for which the map will be used

As discussed above, the fundamental nature of space image maps is quite different than that of conventional line maps, since they carry two quite different and distinct levels of information – the image background and the added symbolization and annotation. This leads to the need for the user to possess not only skills in reading conventional line maps but also to have some capability of image interpretation. Indeed, to carry out this image interpretation is not an easy job, since it requires a suitable reference level, knowledge about the area being covered by the map, and practical experience.

The image map users, in general, fall into two main groups – these are the specialist and non-specialist image map users. The specialist users include geologists, hydrologists, engineers, planners, soil scientists, geographers, etc. They have the skills and experience in interpreting images for their own particular purposes. In fact, these users may face fewer problems using image maps. Indeed, often they seem to prefer to use an image map with a minimum number of symbols and names to which they can then add their own information in order to create their own thematic map. As discussed previously in Chapter 6, this has led to the production of a substantial number of space image maps that are simply geo-referenced image mosaics with little enhancement or value added by cartographers – since often the demand from such specialists is to have as few interruptions or alterations to the image as possible.

On the other hand, it should be recognised that the majority of the general (non-specialist) users have limited skills and practical experience to perform image interpretation – a more detailed account about the subject of image interpretation has been given by Carter (1974) and Ryerson (1989). In fact, it is quite difficult, if not impossible, to teach the non-specialist users how to interpret the image part of the map. Hence, a considerable level of additional information needs to be provided to these users in order to help them to make use of the image map in an efficient manner. Thus, in the first place, the cartographer must carry out the interpretation task for them. So the relevant features (point, line and area) need to be identified, classified, and represented properly through variations in the form, dimension and colour of the added symbolization. However this is not easy to achieve. For land use/land cover mapping, for example, in these areas where one class slowly changes into the next, it is difficult for the cartographer to draw boundaries. In which case, the most appropriate treatment for such an area is to include typical small representative images in the legend to provide an interpretation key. However this then transfers the final interpretation task back to the user, albeit with some aids in the form of the key.

In this context, it is worth noting that, in the case of standard topographic line mapping produced from aerial photos, the basic image-interpretation is mainly carried out (i) by the operator of the photogrammetric instrument during the stereo-plotting phase involving feature extraction, and (ii) by the surveyor or topographer who carries out the field verification and completion. In this case, the cartographer is normally little involved in the interpretation and extraction of the features appearing in the images and often is solely concerned with the cartographic design and map production stages. This means that he is seldom involved in any image-interpretation.

In space image mapping, the photogrammetrist tends to be involved in a quite different way, in that he carries out the rectification of the imagery and removal of the relief displacements – often using automated or semi-automated techniques based on the use of a DEM – to produce an ortho-image which is then passed to the cartographer. Thus the interpretation of the space image with a view to identifying the features present in the image falls to the cartographer – besides his normal task of designing and producing the final image map.

7.3 Specific Problems of Image Map Design

In the preceding section, those factors involved in the design of image maps have been discussed in general terms. It is now proposed to examine some of the specific problems, that may arise in the treatment of the image itself and in the combination of the image with additional symbolisation.

7.3.1 Visual Contrast

Achieving sufficient visual contrast is the basic and most difficult problem facing the cartographer in designing image maps. The starting point in design is a highly detailed background image over the whole map area, from which white space (available in designing conventional line maps) is absent. The cartographer is faced with the problems of achieving legibility in the multi-tonal image itself, in the superimposed symbolisation and in the combination of both these elements.

7.3.2 Visual Contrast and Clarity in the Background Image

A sufficient level of contrast in the background image is essential. Likewise, the reproduction process must aim to retain the maximum sharpness and clarity in the image if it is to function satisfactorily as the major element in the map content. The tonal variations within the image and its sharpness, resolution and clarity are initially functions of the imaging system employed and the nature of the terrain surface itself. Thus the cartographer can have no influence over these factors. In some cases, the image will prove quite unsatisfactory, as is demonstrated by Figure 7.1 where the natural shadow in this hilly area gives a dark and undifferentiated image.

Figure 7-1: A small window from the Laag space image map in Somalia at 1:50.000 scale showing the problem of insufficient contrast (tonal variation) caused by shadow in this hilly area. The map fragment illustrated is virtually indecipherable. Note also that the black grid is almost invisible. (Map 29 in Chapter 6)

The maximum tonal range in the image will be retained if the image is printed in black. The use of other colours will often reduce the range of tonal variation, with inherently light colours such as yellow giving the minimum (and generally unsatisfactory) contrast. Paradoxically, the legibility of added symbolisation and names will be easiest to achieve when the image is in lighter colours. The choice of colour or colours to reproduce the image is thus critical to the overall appearance and success of the image map as is demonstrated in all the following examples, which deal with specific aspects of design.

7.3.3 The Legibility and Placement of Names

It is to be expected that all image maps will incorporate map names, regardless of other additions to the image. The legibility of names is thus a matter of considerable concern and a number of illustrations are given below to demonstrate some of the problems that can occur. The names of places and features are necessary to help define locations, especially in the form in which the local inhabitants know them. Descriptive names are also important in that they can be used to ease the interpretation of the satellite image. However the cartographer must take into account the fact that the inclusion of many names will interrupt or disturb the background image and add to the visual complexity of the overall map image. Names may obscure some important details. Thus the placement of names is critical, as indeed is the actual decision to include or discard a particular name.

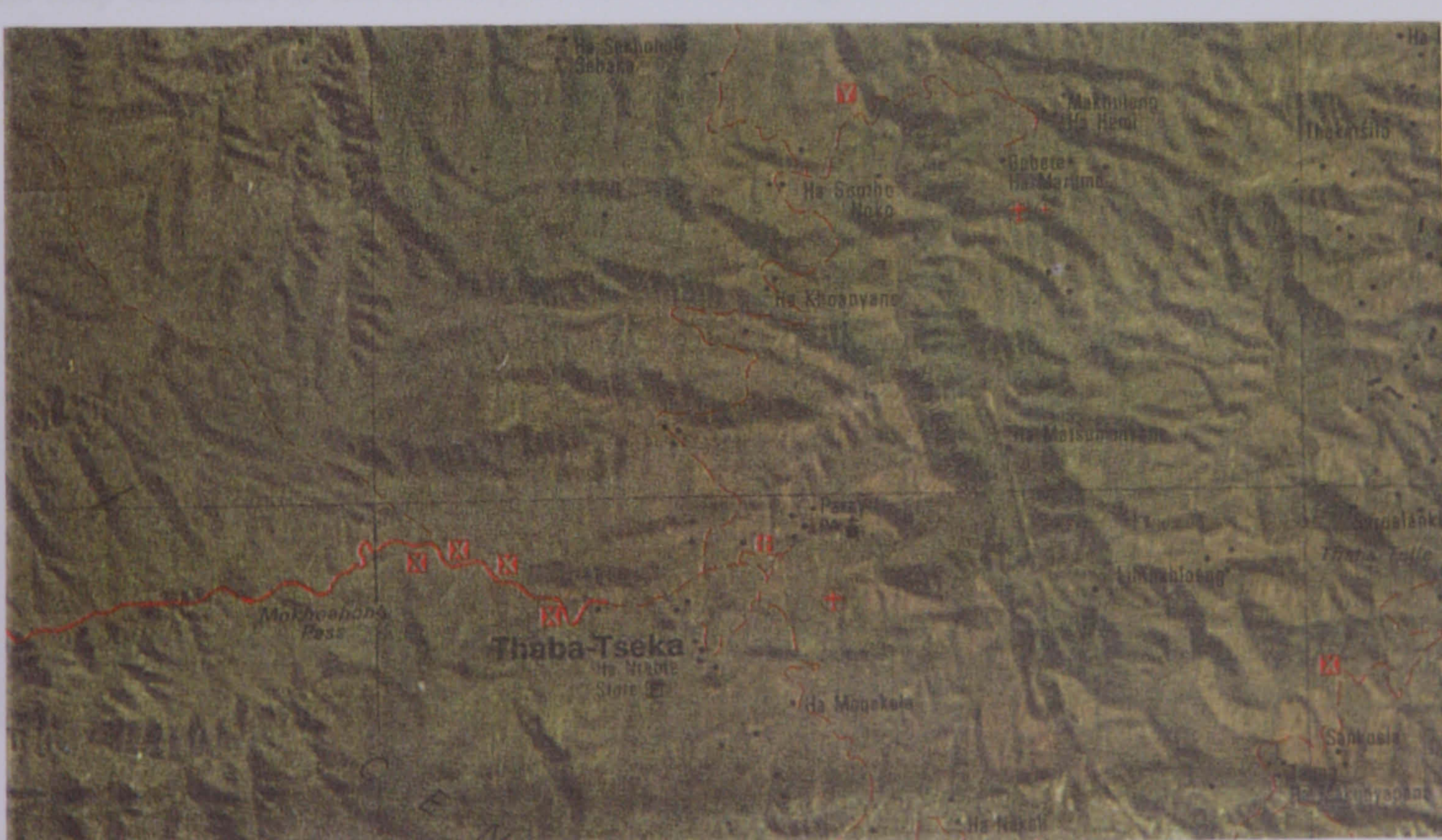


Figure 7.2: The black names shown against a green background image are difficult to read. While the dark green used for the image is quite successful in showing the nature of the terrain surface, there is insufficient contrast with the small dimension lettering used for the names. (Map 15 in Chapter 6)

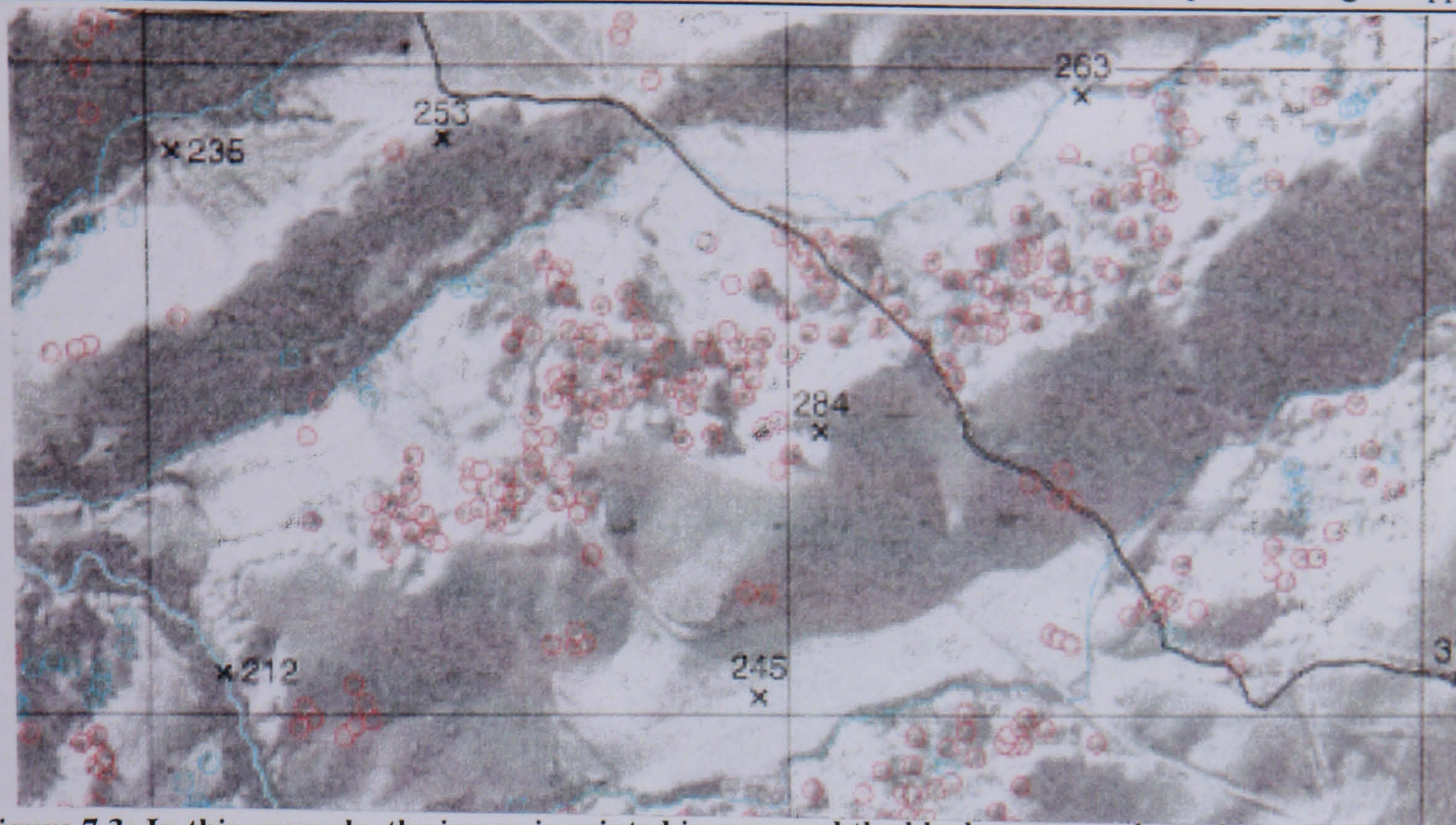


Figure 7.3: In this example, the image is printed in grey and the black names and numbers are more clearly visible. There is greater contrast between the lettering and image, but the sharpness and clarity of the image suffers through its reduced range of density. (Italy, 1994)

One possibility for the treatment of names on image maps is to create a hold-out mask of the names image, thus allowing the names to appear in white. While this technique may solve the problem of name legibility in the darker areas of the image, the legibility in lighter areas will of course suffer. Another possibility is to increase the dimension of the lettering beyond the sizes normally used on conventional maps. However this will have the disadvantage of adding to the problems of name placement since the names will occupy a greater amount of space on the map and there is the added problem that the larger letters may obscure still more details in the image.

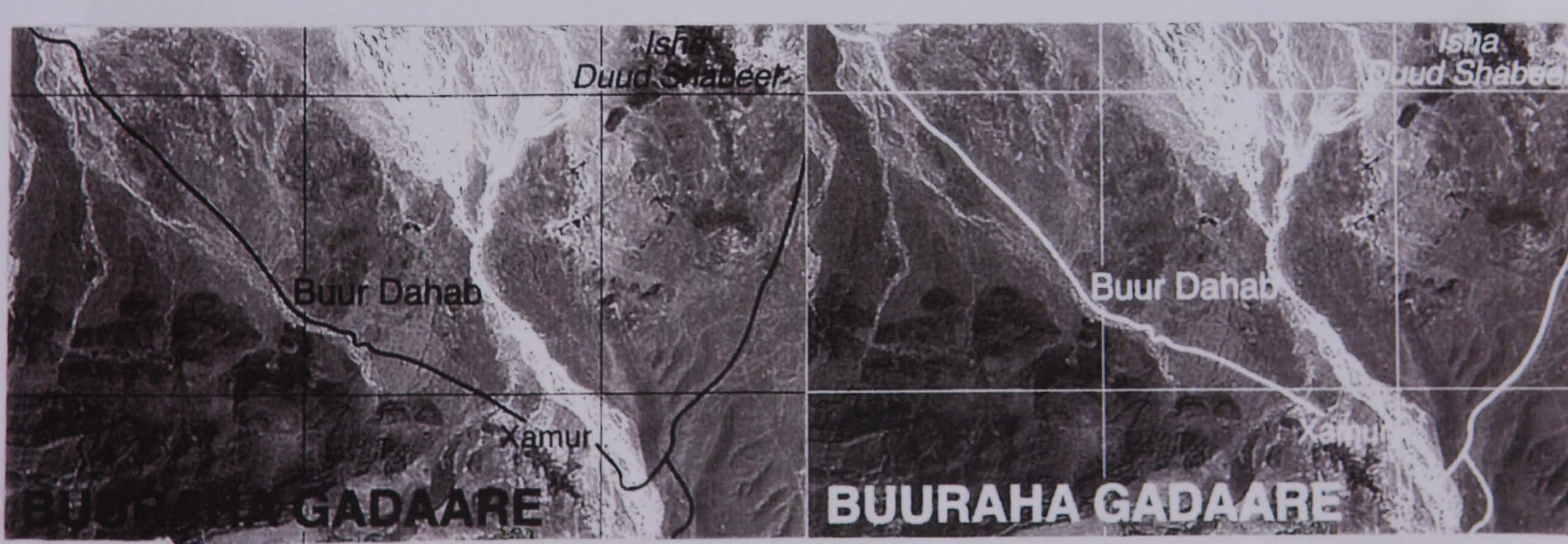


Figure 7-4: The names in this example are rendered in black and white, the image in both cases being reproduced identically in black. Neither solution can be regarded as satisfactory though the use of white names is rather more successful in this example. However, while the names in the centre and lower half of the example are reasonably clear, the name at the top left which falls over an area of mixed tones is illegible on both map fragments. (Map 29 in Chapter 6)

Figure 7-5: This fragment from the Stockholm space image map at 1:50,000 scale again illustrates the use of white lettering, this time on an image of an urban area with mixed and complex colours and tones. An attempt to improve the legibility by increasing the dimension and weight of the lettering is generally unsuccessful. (Map 33 in Chapter 6)

One commonly attempted solution to the problem of name legibility is to retain the use of black for lettering, but to introduce a "halo" in white around the name or around individual letters. The idea of course is that the black letters will always be separated from the background image by white, which should improve the contrast of the letters with the background. Two examples of this technique are demonstrated in Figures 7-6 and 7-7.

Figure 7-6: A fragment from the Bangladesh space image map demonstrates the use of white "halos" around names, line and point symbols. The various colours and tones together with the highly fragmented nature of the image make this less than successful. (Map 6 in Chapter 6)

Figure 7-7: A fragment from the Slieve Bloom Mountain space image map shows a more successful application of the white halo technique, here isolating individual letters. This is possible with the larger dimension of the text, which also aids the legibility. (Map 27 in Chapter 6)

Further problems may be introduced by the use of <u>dual lettering systems</u>, which is regarded as essential in some space image maps. For example, many maps of Arabic speaking countries employ both Arabic and English text in deference to the many non-Arabic speaking map users. This requirement effectively doubles the name placement and legibility problems.

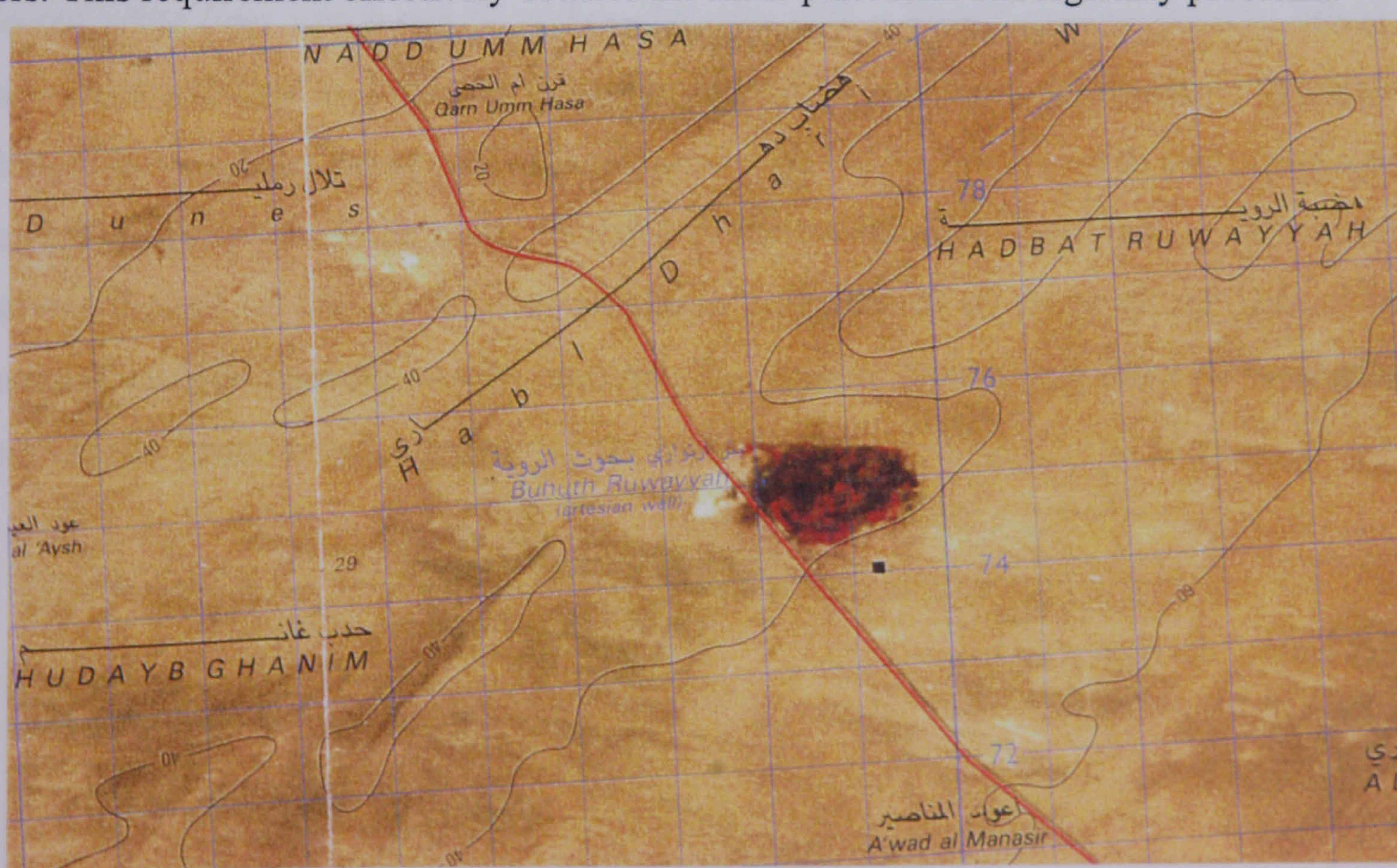


Figure 7-8: The use of a dual language lettering system on a fragment of the space image map of Dubai at 1:100,000 scale. (Map 20 in Chapter 6)

7.4 The Addition of Point Symbols.

Where features, which are considered essential to the map content, are too small to be resolved in the image, or have insufficient contrast with their surroundings, it will be necessary to represent these by point symbols. The problems that may be encountered and the solutions adopted are similar to those already discussed with respect to names.

7.5 The Addition of Line Symbols.

<u>Contour lines</u> are another conventional cartographic element appearing on virtually all topographic map series and are commonly required to show height information on image maps. On conventional line maps, the vertical interval for contouring is determined by the relation between the map scale and the overall elevation range and the typical slopes found in the area, the aim being to avoid touching contours in slopes of up to 45 degrees. Inevitably this means that contours are close together in steep slope areas. Typically a brown colour is used for contour representation, giving good definition without dominating the visual appearance of the map. Quite different factors have to be considered in the case of image maps. The brown colour is rarely appropriate when used against an image background and most image maps resort to the use of black or white. The visibility of such contours, as with names, thus depends on the background tones. As Petrie (1977) stated, *"Some producers have selected white lines which can be rather obtrusive with a higher contour density; others use black which will tend to disappear in darker areas of the photographic image."* There also is a danger that contours can appear to lie on quite a different visual plane to that of the satellite image and can appear to be quite unrelated to the background. Employment of the vertical intervals typical of line maps often results in concealment of much of the image; hence increased vertical intervals may be required. The contour interval may then be inadequate to represent the flatter terrain lying within the area of the map.

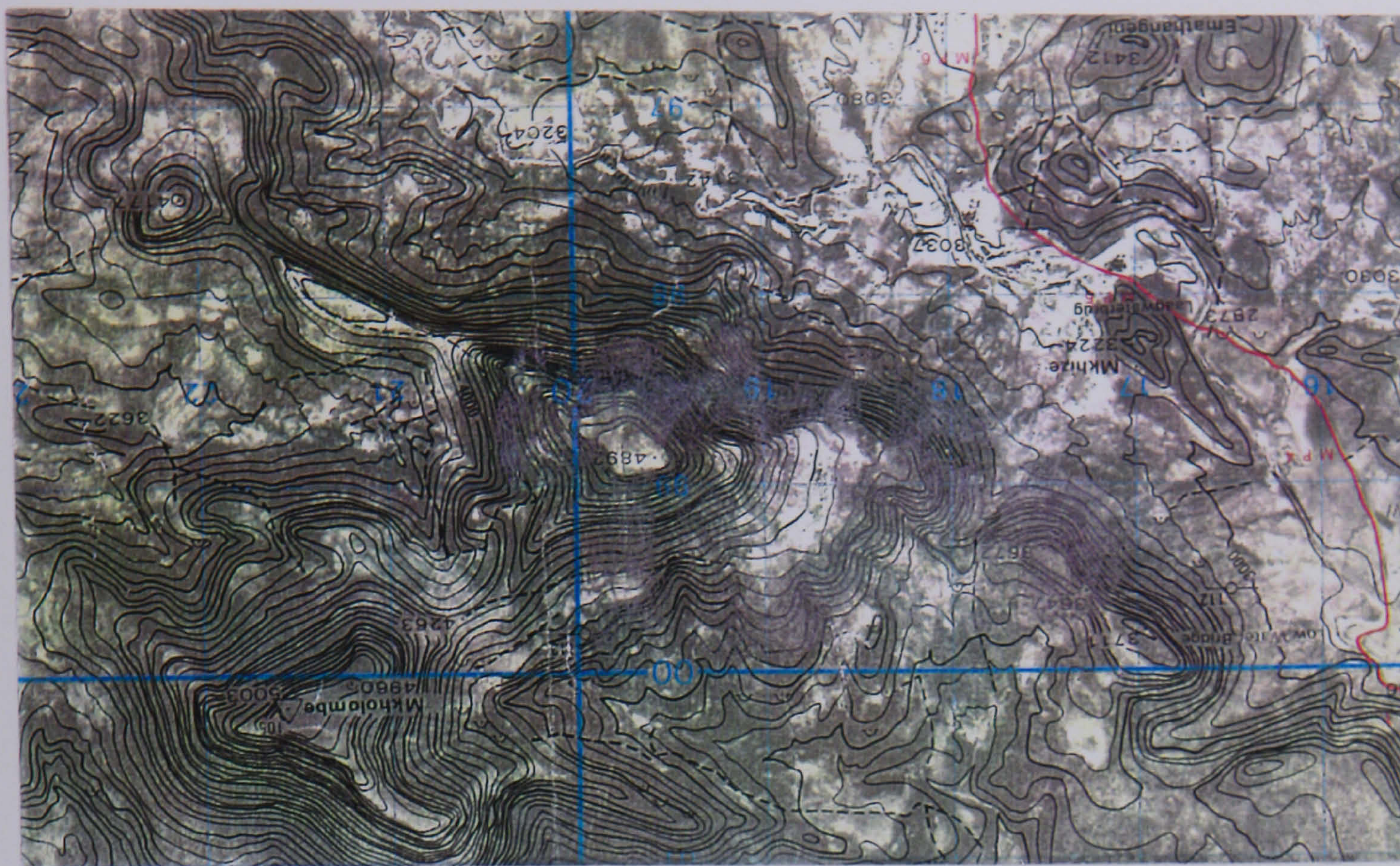


Figure 7-9: A fragment from the Weenen photomap at 1:50,000 scale. The vertical interval of 50m, which would be suitable for a line map, is inappropriate here. The closely spaced contours break up the image and render it illegible. While the black contours are quite clear on the image, the contours appear visually on a quite separate plane and do not appear to relate to the image (South Africa, 1969)

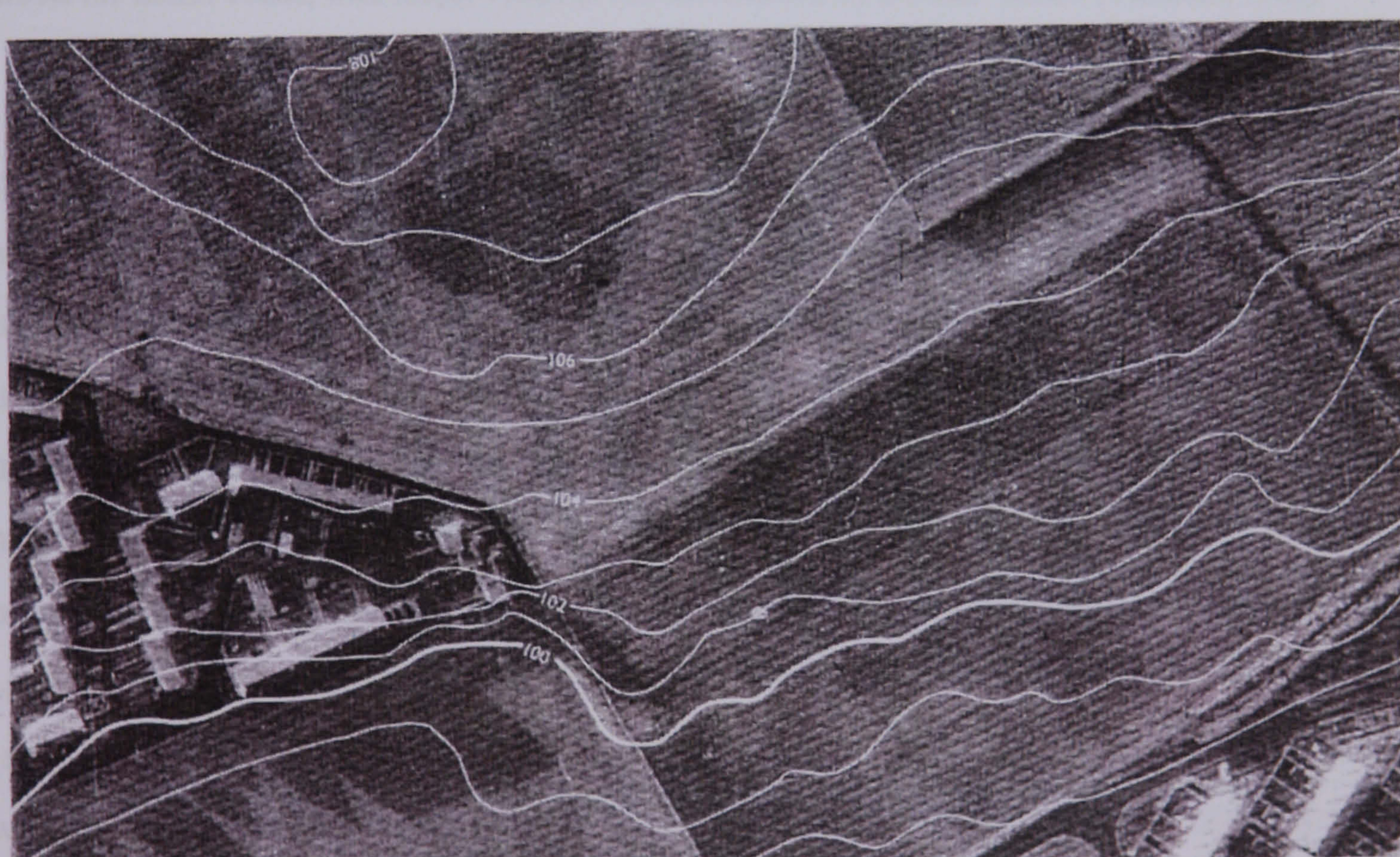


Figure 7-10: An example from an Ordnance Survey photomap illustrates the use of white contours, fragmented by the light tones of the buildings. (UK, 1959)

Other line symbols will be necessary to represent non-imaged features such as administrative boundaries or to enhance and classify features such as roads, railways and rivers. Examples appear on some of the earlier Figures. As with names, the use of white is one possibility.

Figure 7-11: A fragment from the A.M.S. Vietnam pictomap series demonstrates the use of white line symbols for minor roads, with major roads in red surrounded by a white "halo". (Vietnam, 1966)

In fact for most of the map users, roads are some of the most important features included in the map. Besides which, they normally have a physical appearance on the image. However, if a major tarred road does not have enough contrast with respect to its surroundings (e.g. in the case of fields or forest), this road might be undetectable or only partially visible on the space image. In such cases, line symbols will need to be used to depict non- or partially visible roads – and the solution that works in one area may not be successful in other areas. On the other hand, there are situations where a minor road which is far below the resolution of a sensor, can become visible through extreme high contrast. A typical example from Libya can be given – an oiled road, which is only 4 or 5 metres wide and crosses a highly reflecting area of sand in the desert, is clearly visible as a black "snake" against a light background even on lower resolution space images such as those from Landsat due to its high contrast with its surroundings. A further unusual feature that is present on space images in many developing countries is that minor roads can sometimes show up much more clearly than major roads. This is the case where a bulldozer or grader has cut out the road, which shows as a strong white line against the darker grass or bush vegetation. Whereas the dark surface of a tarred road gives little contrast against such backgrounds.

7.6 Area Symbolisation and Area Colour

The cartographer may have to consider different types of imagery as the starting point in the map design. With some digital image data (such as the Landsat TM images), it will be possible to reconstitute the natural colours of the terrain which can be very effective when included in the map. For example, as has been fully described in Section 6.3.4.2, the Slieve Bloom Mountain map (Figure 7.7) uses Bands 1, 2 and 3 of the Landsat TM image data to render a realistic image of the field pattern and heathlands of this area in (near) natural colour. A similar treatment is found on the Leipzig map (Figure 7.12). Where the user is familiar with the type of terrain portrayed, the use of natural colour can be very effective in representing the terrain in a readily interpretable manner and, with the exception of water surfaces, no additional treatment of area features may be required.

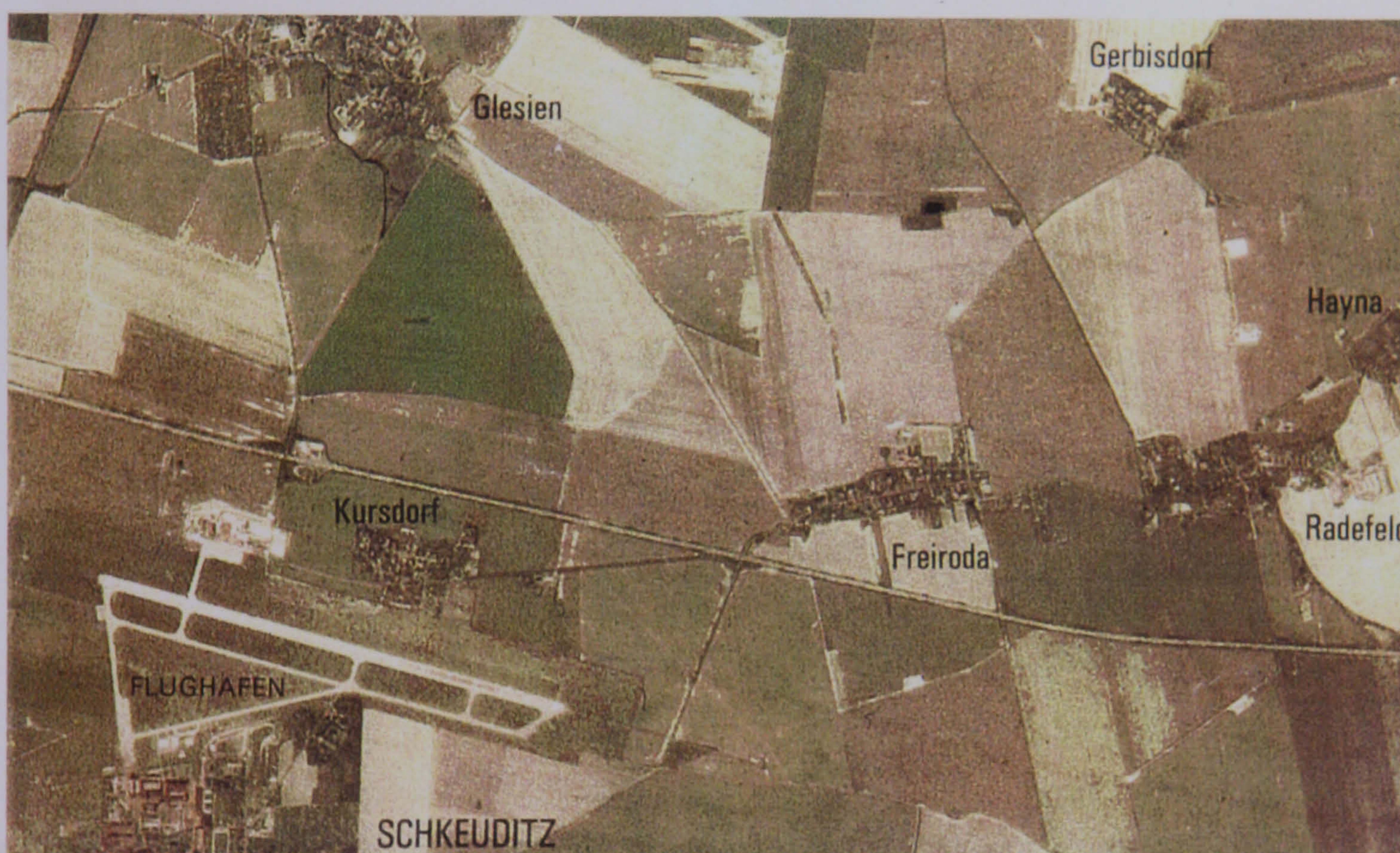


Figure 7-12: A sample from the Leipzig space image map at 1:50,000 scale showing the effective use of natural colour can be used for the background image. (Map 28 in Chapter 6)

In contrast to this, as discussed in Chapter 6, quite a number of space image maps have utilized false-colour for the image background, which has been printed in a mainly red colour. Almost invariably, this has resulted in a marked reduction in the image detail that can be discerned on the map. Unfortunately many in the remote sensing community appear to be addicted to the use of this type of false-colour representation of the terrain and this has been carried over to various of the maps analyzed in Chapter 6.

Panchromatic (monochrome) imagery, which gives better resolution than the colour or false-colour imagery, does not allow the automatic reconstitution of natural colour. If a colour treatment is considered desirable to aid the interpretation of area features in the image, one possibility is to isolate sections of the image through manual or digital masking and to print these in different colours. An example is shown in Figure 7-13, where urban, desert, scrub and cultivated areas in Khartoum (Map 12 in Chapter 6) have all been represented and printed in different colours. While the differentiation of these features is made simple by this technique, the hard edges and contrasting colours disturb the overall harmony of the map. The separation of the areas in this case was achieved by manual masking techniques. Even with more efficient digital methods, this type of representation would require considerable, time consuming effort with a doubtful final success.

Figure 7-13: A sample from the Khartoum space image map at 1:250,000 scale showing the use of colour to differentiate between area feature classes or types (Map 12 in Chapter 6)

The alternative is to overprint the monochrome (black) image with area tints in colour. Similar labour would be required and, in both cases, the integration of generalised boundaries to areas with the (un-generalised) satellite image is liable to cause problems.

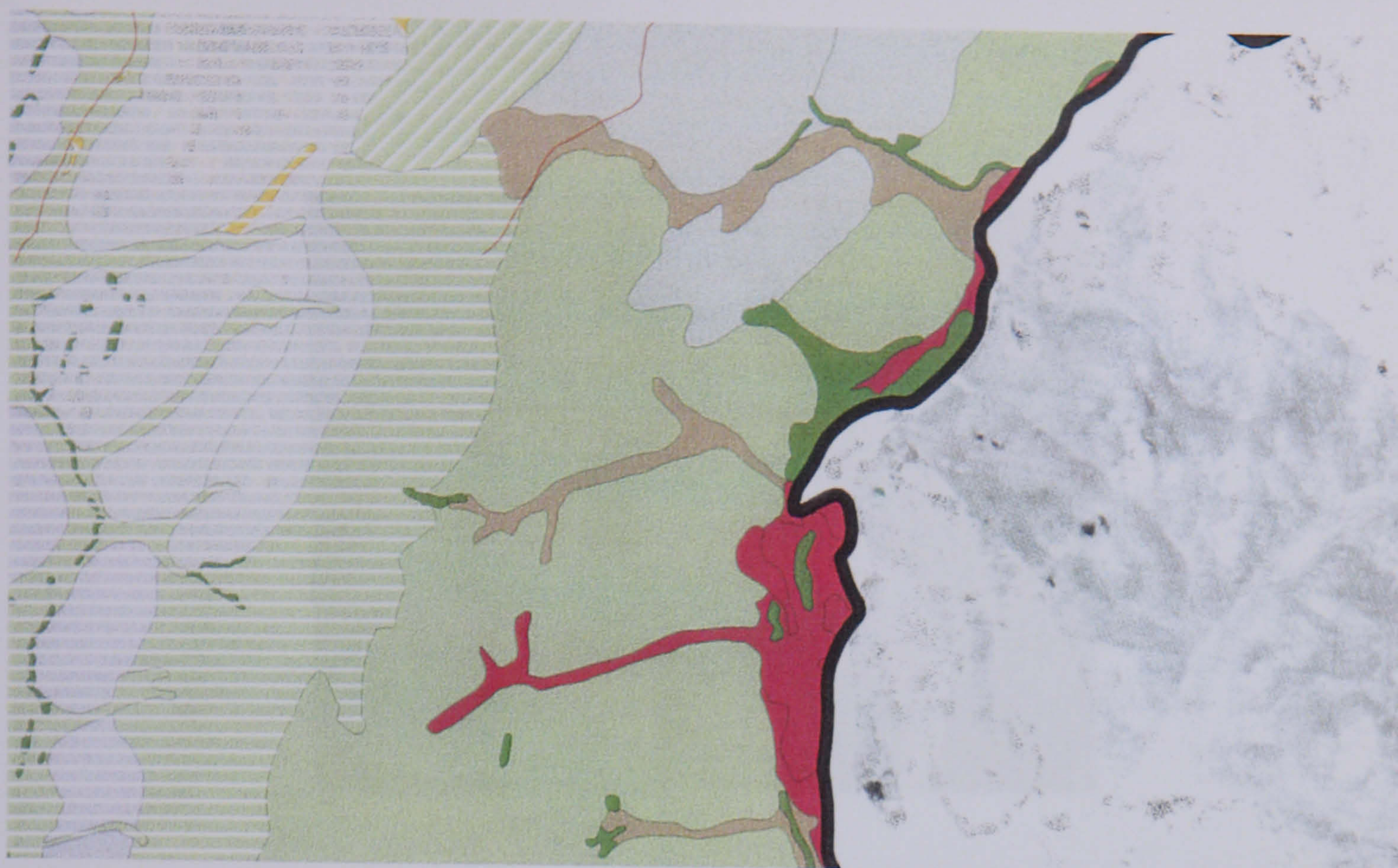


Figure 7-14 A sample from the Kagera space image map at 1:100,000 scale showing the use of area tints on monochrome base image. (Map 26 in Chapter 6)

7.7 Modification of the Image Tones and Colours (Image Processing Techniques)

Digital image processing algorithms may be employed as a means of improving some of the problems of overall lack of visual contrast, which still maintaining sufficient contrast in the image itself and, at the same time, allowing the addition of legible names and point and line symbols.

As has been reported by Albertz and Tauch (1994), a number of experiments have been carried out by the Technical University of Berlin to find an appropriate solution to this problem. The conclusion that has been reached is to retain the graphical elements (symbols and names) in black, but to try to improve their detection in dark areas. This can be achieved by applying digital image processing techniques through the conversion of the graphical data to a raster format which is identical to the background image data. From this, an unsharp mask of the graphical elements is generated by means of blurring filters. The inverted unsharp mask of the image is then added (thus the areas around the graphical symbols become lighter). Afterwards, the graphical data in black is merged with the raster image data. As illustrated in Figure 7-15, the use of this procedure shows that the recognisability of the graphical elements in dark areas has been improved while the degradation of the image has been kept to a minimum.

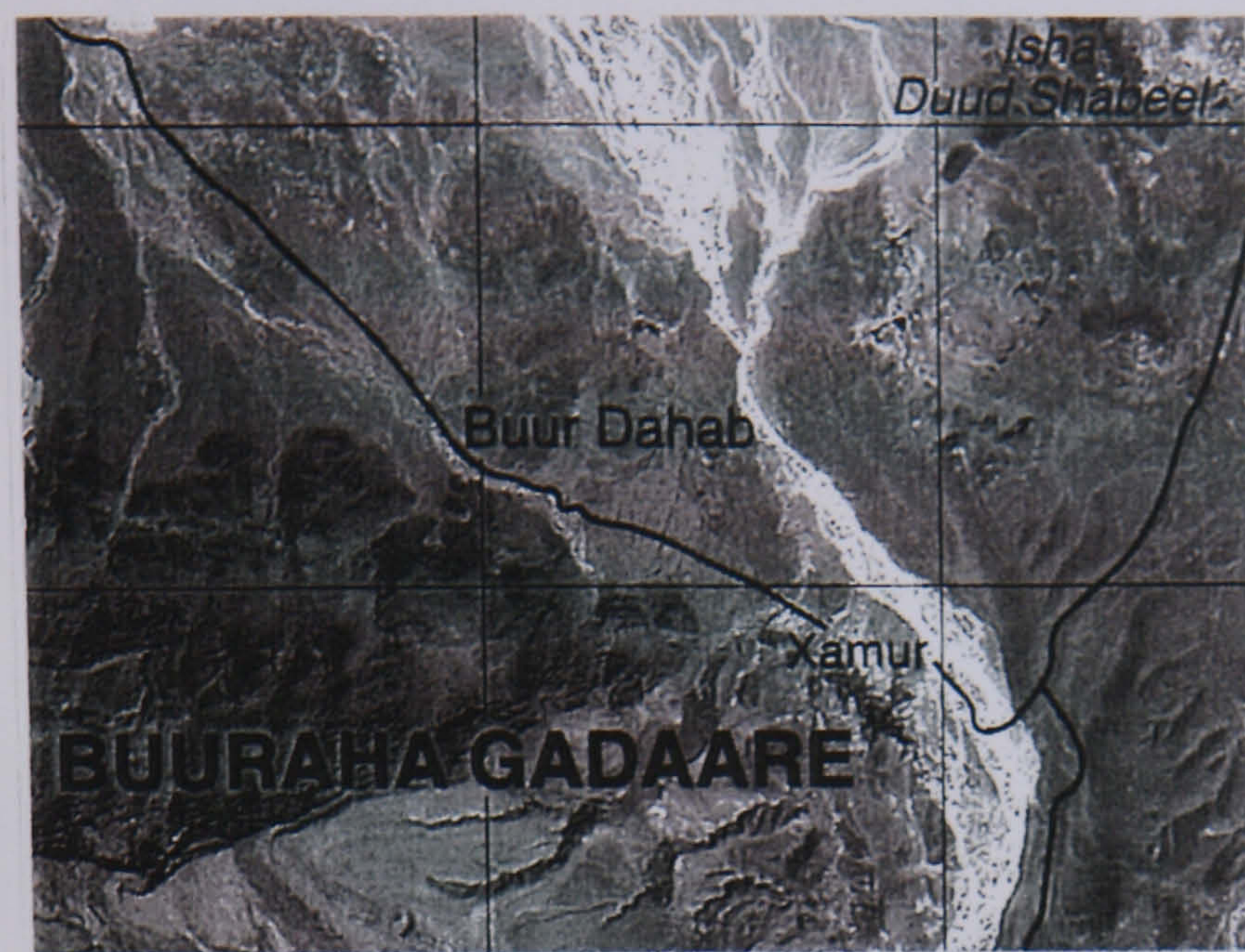


Figure 7-15: The integration of graphical elements in raster format into the space image (see text for explanation). Compare this image with Figure 7.4.

Lightening the overall tone of the satellite image background to the minimum sufficient to retain its own clarity is one possible solution. If it can be done successfully, then it would allow a much easier and finer treatment of the superimposed cartographic data. In turn, this would lead to a lightened and more aesthetically pleasing map. However this cannot always be done successfully if there is a great range of contrast with very dark and very light tones present in the image. If the dark tones are reduced to an appropriate level, then the lighter tones may disappear completely.

The satellite image of Aswan (Egypt) at 1:500,000 scale, produced by the Technical University of Berlin in 1993 is a good example (Figure 7-16). The background image has been rendered in the lightest tone possible whilst still retaining perceptible fine details in the image. This has in turn allowed the additional cartographic symbolisation to be given the minimum weight necessary to create a suitable contrast with the base image. The delicate treatment of the names and symbolisation has had the advantage of achieving sufficient visual contrast without crowding the image. The danger of concealing any important detail with bold lettering and symbols has also been minimised.

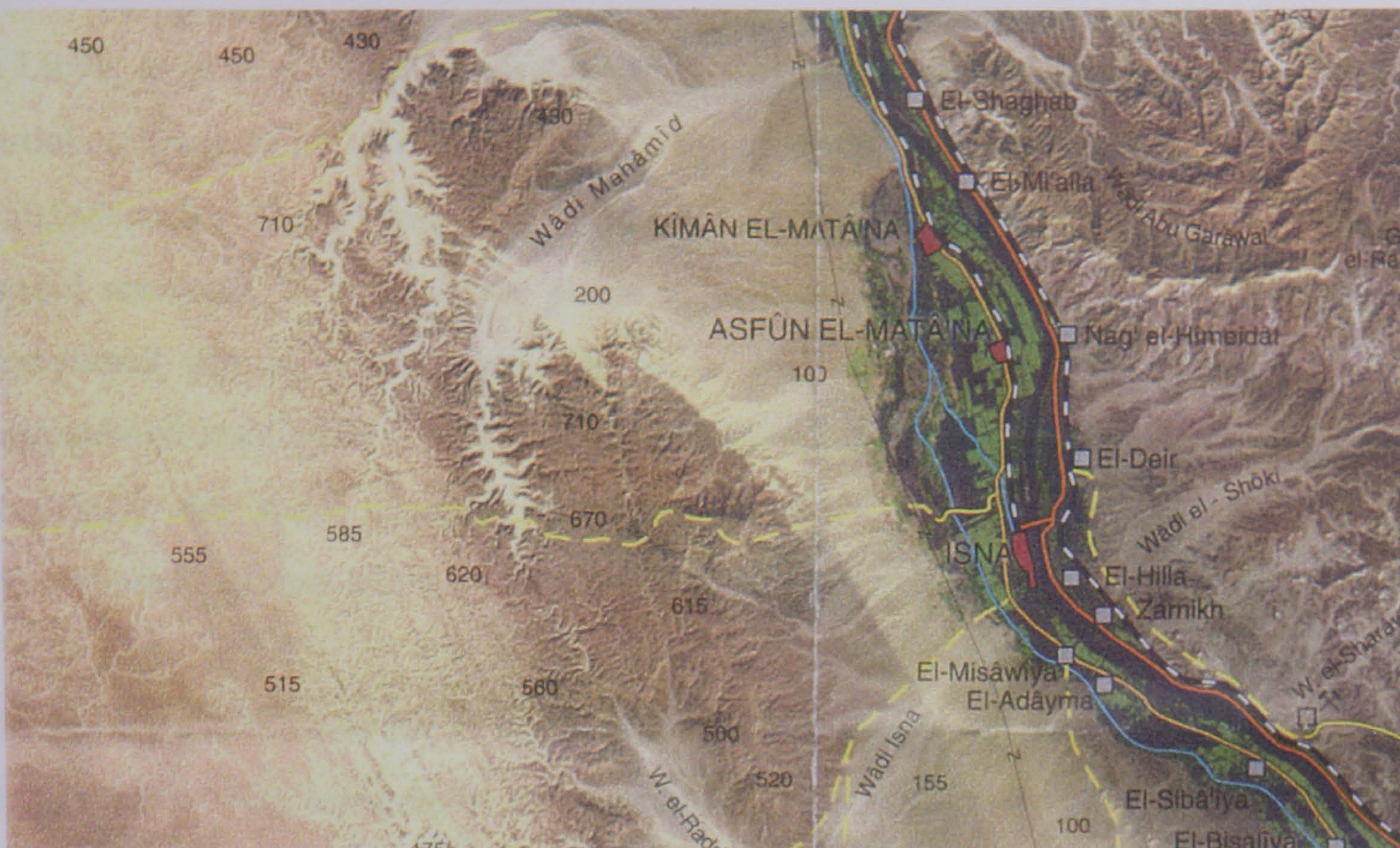


Figure 7-16: A small window from the Aswan space image map at 1:500,000 scale demonstrates the successful use of image lightening. (Map 7 in Chapter 6)

On the other hand, the space image map of Bangladesh (Figure7-17) at 1:500,000 scale shows how the presence of a dark image background decreases the clarity and legibility of the space image, and thus a much heavier treatment of the additional names and symbols is required. As a result, the map image is crowded and information appears to have been obscured.

Figure 7-17: A section from the space image map of Bangladesh at 1:500,000 scale shows how an underlying dark image can decrease the legibility of the superimposed data. In turn, a less subtle (compare with Figure 7-16) approach to the cartographic additions is needed to create contrast. (Map 6 in Chapter 6)

7.8 The Intention in this Project

In Libya, as in many other developing countries, there is an increasing need for complete or partial coverage of the country with general purpose topographic base maps at 1:250,000 and 1:50,000 scales. The primary aims of producing such maps are to provide an inventory of the natural resources, to assist in the planning and execution of development projects, and for recreational use in certain areas. Hence, a clear knowledge of the topography at each geographical location is a fundamental requirement that must be met by the final product. Potentially the space image map should provide both the required qualities of the conventional line map and the highly informative detail given by the space image.

The intention in the near future in Libya is that general purpose space image map series are to replace the existing topographic line map series at 1:250,000 and 1:50,000 scales, or to cover areas where no conventional line maps exist or where they are inaccurate or out-of-date. In carrying out the research needed to underpin the cartographic aspects of this very project, an attempt has been made to utilise SPOT (Pan) imagery for the production of experimental space image maps at 1:50,000 and 1:250,000 scales of a test area in North Libya (Misratah). The intention has been to concentrate on the cartographic design aspects of these image maps and to present the imagery in as clear and self-explanatory manner as possible. The aim has been to produce clear and legible space image maps with suitably enhanced cartographic additions.

7.9 Conclusion

In this Chapter, the general considerations of cartographic design with respect to image mapping have been discussed in some detail and examples showing some of the specific problems of image map design have been introduced. The overall strategy & general considerations for Libyan space image mapping will be discussed in the following Chapter.

CHAPTER 8: OVERALL STRATEGY & GENERAL CONSIDERATIONS FOR LIBYAN SPACE IMAGE MAPPING

8.1 Introduction

The previous six chapters (2 to 7) have given the background to the research project carried out by the author and have set out the framework within which the actual experimental work has been carried out. In Chapter 2, the status of mapping in Libya was reviewed, since this is the specific area for which the research work for a new space image map series has been carried out. This was followed by Chapter 3 which reviewed the general cartographic requirements for medium and small-scale topographic line and image maps. In Chapter 4, the characteristics of the different types of high resolution space photographic sensors and the topographic mapping potential of their photography have been given. In particular, attention has been focused on the high-resolution space photography produced by the Russian cameras and their mapping capabilities and potential use in the production of a space image map series. In Chapter 5, the various high resolution spaceborne scanner systems and imageries have been reviewed and again their capabilities have been analyzed in detail in the context of national topographic mapping programmes in general and their application to the mapping of Libya in particular. This was followed in Chapter 6 by a systematic analysis of existing space image maps with a review of their cartographic design aspects. In Chapter 7, general considerations of cartographic design with respect to image mapping were reviewed in some detail and from a more general viewpoint than those reviewed in Chapter 6. In total, these chapters have provided the background to space image mapping in general and to Libya in particular. The various analyses carried out within the chapters have also thrown a clear light on the cartographic problems associated with space image mapping. The remaining chapters of this dissertation will deal with the procedures adopted and the results obtained during the experimental part of this research work, including an analysis and evaluation of the results obtained.

In this Chapter, the overall strategy and general considerations that are involved in cartographic design of space image maps for Libya will be outlined and discussed. This will include the designs for two experimental space image maps at 1:50,000 and 1:250,000 scales as required for the proposed national series to cover Libya.

Although more than 90% of the surface area of Libya is mainly desert and relatively few man-made features exist on its terrain, the coastal fringe, where the majority of the Libyan population is concentrated, is highly developed. Thus it has an overwhelming importance in all aspects of Libyan life and, in a mapping context, this coastal area should certainly be covered by a general-purpose 1:50,000 scale topographic map series. However, in the author's opinion, there would be very limited value in attempting to cover the whole of Libya with 1:50,000 scale maps, since, particularly in the desert area, there are very few details of the terrain surface that would be shown on such a map series. Furthermore, an undertaking of this nature would require a significant amount of money and resources and would take a very long time to execute. Even if such a series were to be produced, it is difficult to envisage any large body of users for a national series at 1:50,000 scale. Thus, the obvious strategy would be to cover the highly developed coastal area with a 1:50,000 scale map series, whereas an image map series at 1:250,000 scale would be appropriate for the basic map coverage of the whole country.

The terrain of the developed coastal belt comprises a wide variety of the topographic features (both physical and cultural) that would normally be shown on small-scale topographic maps. The presence of this great variety of features presents a good opportunity to test and develop the representation of a large number of the categories and classes of features that should appear on space image maps at small scales. Therefore, in the author's opinion, it would be best to have a test area within the coastal fringe in order to carry out the design experiments of the proposed image map series of Libya at small-scales. Indeed, the Misratah area which has been chosen for the purpose is characterised by urban areas, water features, vegetation, forest, cultivated areas, semi arid terrain, desert, etc. that will allow the design and development of space image maps that cover the variety of terrain types that are likely to be encountered in Libya.

8.2 General Considerations

The aim of this project is to conduct research into and to devise and apply methods using SPOT Pan digital data and digital image processing techniques to produce space image maps of a test area in Libya. In this context, the analysis, development and evaluation of the cartographic design aspects of these space image maps forms a major component of the research. The reasons underlying the decision for the author and his organisation to carry out this research project are:

(i) Libya is a huge country and most of it comprises a desert landscape which would almost certainly be represented more effectively by producing space image maps rather than the traditional form of topographic line map.

(ii) The author's country was one of the first in the world to undertake a national space image map series at 1:250,000 scale (comprising 127 map sheets for the whole country). This series was produced largely manually using the techniques available at the time (in 1978). Although it had shortcomings in terms of its low ground resolution (Landsat MSS) images and is now out-of-date, it still proved to be very useful and has been utilized widely within the country. Thus consideration has to be given to producing a new series of space image maps using higher resolution imagery – since this would show more detail and there is a need for continuous updating given the rapid changes that have been taking place in the country.

(iii) As has been discussed in Chapter 6, most existing space image maps suffer from an absence of good cartographic design – they are largely lacking in annotation; in the use of appropriate symbols; and in the use of colour. In this way, many of the real problems inherent in the production of space image maps have been avoided – but at the price of producing an inferior product. Thus there is a need for research into a better cartographic design and specification before a new series can be recommended and authorized.

(iv) The other important reason is that most of the existing Libyan maps have been produced by American and European mapping agencies using technical staff who do not have sufficient local knowledge regarding the Libyan landscape. Furthermore, they do not know who the actual users of the maps would be or for what specific purposes they would be used for. There is therefore a need for local knowledge to be utilized in any future map production, besides building up the technical knowledge and expertise needed to produce maps within Libya.

(v) It must be said too that no consultation have ever been carried out by the Surveying Department of Libya, or indeed any other related organisations, to define the requirements of map users within the country. Besides which, no attempts have been made to involve the various map users in evaluating the contents and representation and final appearance of the maps produced in Libya. The author resolved to try and involve at least some potential users in the evaluation of the experimental maps produced through his research project.

(vi) The last reason is that those small-scale conventional topographic line maps that do exist in Libya suffer from a general lack of good cartographic treatment and representation. No colour has ever been employed to facilitate the classification of features. Instead, only black was used to show the different features (point, line and area) on those maps. Therefore, Libyan map users were not given sufficient help to differentiate easily between the different classes and, as the author can confirm, they had to consult continuously the legend of the map whenever they wanted to recognise or distinguish between features.

In summary, the main thrust of the research that has been conducted by the author has been into the cartographic design aspects of utilizing space imagery for national topographic mapping in Libya at both 1:50,000 and 1:250,000 scales. The general approach has been to mosaic individual SPOT Pan images taken at different times and under different conditions into a single seamless image to form a mosaic of the test area using digital image processing techniques and then to design and add symbols and text to produce a superior cartographic product. Research has also been conducted into the possibilities of a new visualisation technique to generate a 3-D stereoscopic image, covering part of the test area.

8.3 Overall Cartographic Treatment and Design

Any space image or mosaic offers a crowded but undifferentiated image of the terrain that it covers. At first inspection, it is very evident that image contains a great deal of detail. Unfortunately, this raw image will lack interpretability in the cartographic sense, and even experienced users will find it difficult to use and obtain value from it beyond a fairly low or rudimentary level. Indeed, without further cartographic treatment it may not even be very useful, since important features may be concealed by shadow. Furthermore, from the point of view of the map users, many of these important features could well be less obvious on the image than quite minor features through shortfalls in contrast or ground resolution. Thus additional cartographic treatment is necessary to bring some meaning and emphasis into the undifferentiated raw image. As was evident from the other space image maps at scales similar to those of the maps produced in this project (those that had been analysed in Chapter 6), the features requiring most emphasis will be roads, buildings, drainage features, relief and land cover/vegetation features.

Besides registering and enhancing the presence of certain specific features or classes of features that are present on the terrain surface, there must be a prior evaluation of the significance of the features that are contained in the imagery and the results of this evaluation presented to the user. For example, major roads must be identified and made more obvious than minor tracks which may in fact be more prominent in the image; built-up areas must be clearly differentiated from open land; differences in vegetation, cultivated land, orchard and forest that may (or may not) be apparent on the imagery should be given added emphasis. This means that aid must be given to the different map users in order to allow them to recognise quickly the most important topographic features that are present in the terrain area covered by the map. Indeed, without this cartographic help, these features might be difficult to separate from the wealth of other detail contained in the space image. Yet, at the same time, the cartographer has to retain as far as possible the detail given by the space image that will never appear on a line map. Moreover the cartographer needs always to bear in mind that the features requiring emphasis will naturally depend on the map specification or the intended use, and will also be dependent on the map scale and the characteristics of the terrain to be covered by the map. Thus the design and production of space image maps poses a number of challenges to cartographic designers beyond those posed by line maps.

From this discussion, it can be seen that the scale and purpose of the map and the nature of the terrain to be covered by map are always important factors in image map design. Other factors such as the cartographic education, experience, skills and local knowledge of the designer and the matter of having access to suitable tools will also be helpful in achieving a successful map design. Indeed, time, familiarity with appropriate production methods and the availability of adequate financial resources and facilities are necessary elements in designing any good quality map, whether from space imagery or from other types of data.

8.3.1 The Need for Cartographic Treatment

(i) It is often necessary to identify and define particular linear features (e.g. roads) or other features that are ill-defined due to shadow or are obscured by vegetation. Thus a way of enhancing ill-defined detail, or of completing missing detail, must be found, e.g. through the application of ground or field completion procedures. To a large extent, this process will concern only the man-made (cultural) features, since, in general terms, natural (physical) features have a much better representation on the space image than on any symbolised conventional map. Thus, apart from hydrographic features, the need for field completion and the addition of further value to the map, resulting in the requirement for sophisticated cartographic treatment mainly applies to the cultural landscape.

(ii) Regardless of the method adopted for the production of space image maps, one can say that a major difficulty comes in the choice and number of separate landscape categories together with the definition and determination of their boundaries. The number of separate categories that will be defined depends largely on the intended use (i.e. the function) and scale of the map and the nature of the terrain surface to be covered by the map. In the simplest case, water surfaces should be separated from land areas, which in turn may be separated into built-up and non-built-up areas. This is rather straightforward practice, but, if further categories are required, the situation is more difficult. Theoretically, it is possible to divide open areas on the basis of their land use or land cover into arable, pasture, etc. In conventional mapping, simplification and omission can be applied to present a generalised distribution of such categories. However the space image cannot be 'generalised' in this manner, one cannot discard the image or make it go away. In situations where the boundaries between different zones or categories are definite, the problem becomes relatively simple to deal with. But there can be no adequate solution to the more common situation where changes occur gradually and categories merge into each other with no definite boundary line.

(iii) On the other hand, the representation of such categories exploiting the natural image will almost certainly be more "truthful" than the generalised representation used in conventional line mapping. Indeed, providing that the user will be given help by the cartographer in carrying out the interpretation of these features, the major areal categories will be relatively easily recognised. This can then be followed logically by a more detailed interpretation, perhaps aided by an image key. Using suitable cartographic treatment, much value can be added to the image map in this way. Thus, for instance, built-up areas can be clearly differentiated from open land and the differences between cultivated areas and orchard and forest may be given added emphasis. The consequences of all of this help to users, should provide quick recognition of the most important area features which might otherwise not be easy to discriminate from one another on the space image. In the past, this differentiation has been achieved through the addition of different colours to the different area classes. This requires a prior detailed interpretation of the photographic or space image by the cartographer. These are skills that are new to most cartographers involved in topographic mapping who have become accustomed to receiving data that has already been interpreted and classified by the field surveyors or photogrammetrists who have carried out the data collection.

(iv) Prior to the introduction of computer-based technique, the actual implementation of these coloured areas on the final map was usually achieved by colour separation through the use of manual masking techniques. Photo-mechanical masks were prepared for each area needing to be printed in a separate colour, e.g. built-up areas, cultivated land, forest, etc. However, the number of separate masks would often be controlled by financial considerations, both from the printing aspect (the number of separate plates allowable), and the time needed to prepare the masks and to combine them to create a separate film or plate. Nowadays, with the availability of advanced software packages and more flexible techniques for image processing and digital mapping, the task of achieving the required colour separation and combinations is much easier and faster to implement and, in turn, is cheaper. Furthermore, a great advantage of using the digital technique is that mistakes can be edited or changes made much more quickly (often within couple of minutes) as compared with manual masking techniques.

8.4 Symbolisation

There are no fixed criteria to define the kind and amount of overprinted symbolisation and annotation to be shown on a space image map. Obviously, the use of extensive symbolisation and overprinting on an image map would tend to negate the advantages of having an image-based map product, as well as limiting its intended effectiveness by obscuring the image details. In such a situation, some degree of cartographic judgement must be exercised for each area to be covered within the map. The minimum level of symbolisation and annotation should include names, grids, and boundaries. Then, depending on the area concerned and the intended map use, considerations should be given to highlighting major transportation routes, particularly in an area where they are partially concealed by vegetation. The over printing of elevation information depends, of course, entirely on the intended use of the map and the nature of the terrain (whether hilly or flat), which controls the number of contours must be overprinted. Again this is a very definite and critical issue that needs to be resolved in this particular area – since the presence of a large number of closely spaced contours will obscure the background image and the information on the land cover that it contains. This matter will be discussed in more detail later in this chapter.

A satisfactory outcome from the digital image processing of the space image used as the background for the map is another necessity. The background should not be too dark or too light, since this may affect the clarity of the image detail and the clarity, legibility and contrast of added symbolisation and names.

Extensive and thoughtful use of the basic graphic variables (of form, dimension and colour) will also have a most significant influence on the symbols used in image map design, since these will facilitate the classification of features and bring more meaning to the image map. Exaggeration from true size is a common practice in medium- and small-scale mapping, but over-exaggeration of symbols must be avoided, especially on image maps – since they will then dominate the map and disturb the visual balance and final appearance of the final map product.

8.5 Text and Lettering

The inclusion of names and text is an integral part of the overall map design. Furthermore, because of the important functional role of the lettering and its impact on the final appearance of the map, the actual choices of the size and form of the fonts to be used must be carefully considered. Wrongly specified or poorly designed lettering can confuse the map user instead of helping him and, if poorly positioned, it can interfere with the other detail present on the map. Hence, it cannot be treated in isolation, nor treated lightly when designing any type of map. However, in many ways, this matter even more critical in image maps since inevitably it will eliminate or obscure some of the detail of the background image. As stated by Al-Amri (1994) "......., the cartographer must bear in mind not only the characteristics, scale, purpose and the intended user of the map when selecting, designing and employing lettering, but also the characteristics, variables and objectives of the map lettering itself.". In other words, the cartographer should always be able to make full use of the variations that are available to design and implement map typography that emphasises and maintains the quality of graphic details, eases interpretation and enhances the role of the map as a means of representation.

8.5.1 The Dual Language Systems Used on Libyan Topographic Line Maps

The use of two languages – Arabic and English – and the two corresponding systems of lettering has been adopted on existing Libyan topographic line maps (Figure 8-1). Arabic is, of course, the mother tongue and the official language of the country, whereas English is used widely as a commercial and scientific language. It is quite evident that the inclusion of

English names and text along with Arabic on Libyan maps is not intended for the main body of map users – who are Arabic speaking. But numerous foreigners work in Libya, especially in the oil industry, and their needs have to be considered also – especially since most of them use maps in their day-to-day professional activities. The main advantage of using the two different language and lettering systems simultaneously on a single sheet is to serve the needs of users from the two quite different cultural backgrounds. This means that a single map sheet containing the two systems of lettering can be used by different users rather than having to produce two separate map series with different lettering being used on each sheet to meet the needs of each specific group. However, employing English together with Arabic language and lettering cannot be achieved without creating problems in terms of the design, production and use of the resulting maps. In particular, the inclusion of English in Libyan maps may cause confusion to the local Arabic-speaking users, especially those (the majority) who are unfamiliar with the English language.

Generally, even when dealing with only one language and a single lettering system, the cost of the material involved in the process and the effort and time spent by the cartographer to select, specify, produce, arrange and place different types of names must be considered. As stated by Robinson (1984), some cartographers consider that the selection and placement of names on maps are matters that are difficult to deal with. Indeed, they call them a 'necessary evil' because they have a tendency to crowd the map and complicate the terrain representation. But a map without names cannot be called a map! If the case is difficult with names and lettering in one language, then the situation will be far more difficult when two sets of names and two quite different lettering systems have to be applied on one single sheet. The use of dual languages and dual lettering systems means (i) at least doubling the time, effort and cost involved; (ii) requires that more space be occupied on the map; and (iii) also means that the cartographer who is undertaking the work must have sufficient knowledge about the rules and characteristics of the two languages and lettering systems. Using two different versions of lettering will increase the chances of conflict between names and other symbols and between names themselves.

The brief discussion that has been given above – about the dual languages and dual lettering systems used on Libyan topographic line maps – has been introduced to give a general idea about the advantages and the problems that the use of dual systems can cause. A further and much more detailed account about the use of dual languages and lettering systems on maps –

in this case English and Arabic – has been given by Al-Amri (1994) and Al-Amri & Forrest (1997).

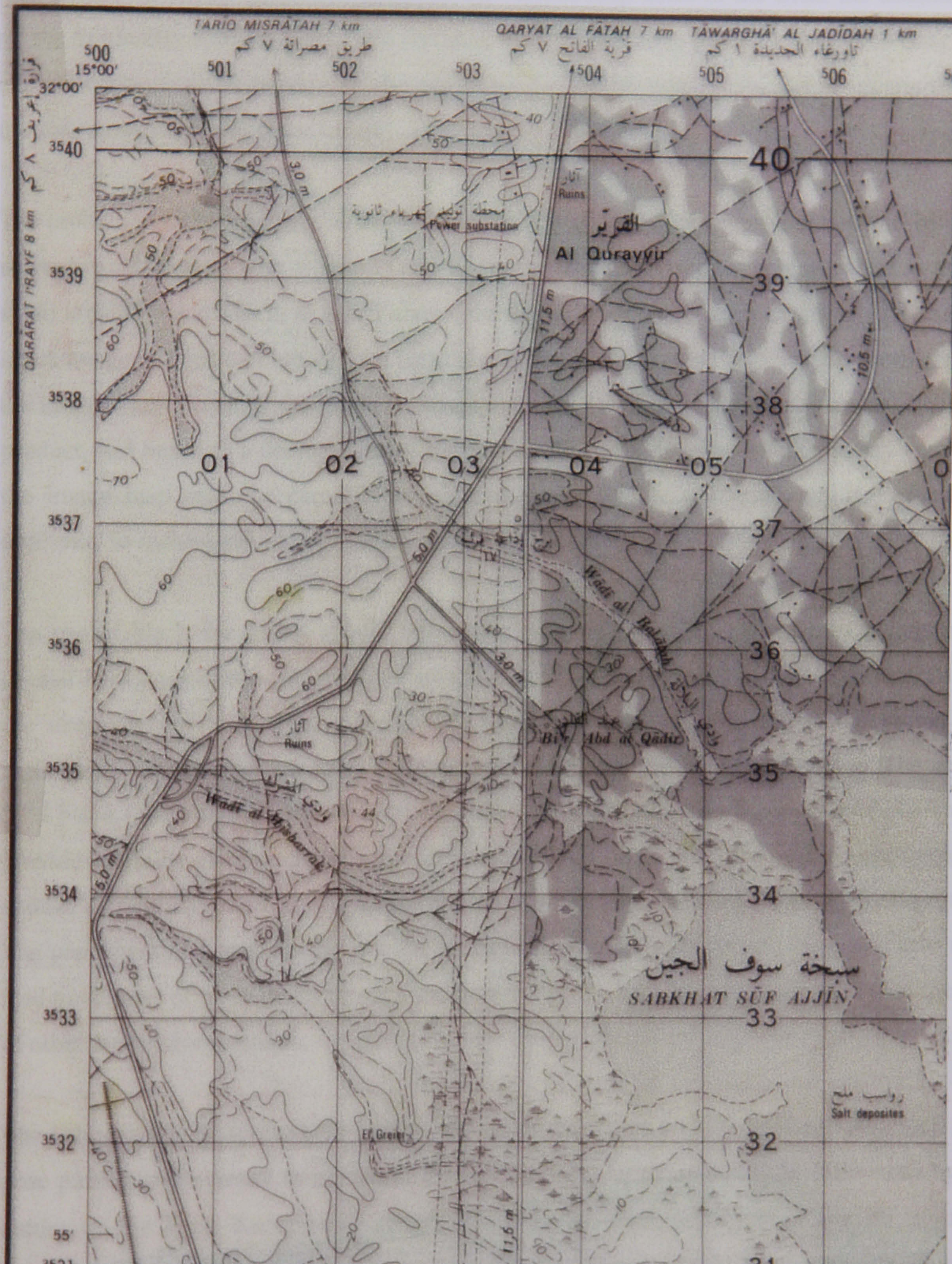


Figure 8-1: A small window showing the dual language systems used on a topographic map (at 1:50,000 scale) that has been produced by the SDL.

8.5.2 Names and Text and Image Mapping

Particularly in image mapping, while the space imagery provides much of the detailed locational information about the terrain to the various map users in the field, the addition of names to identify specific places and features, whose location is given by the space image, is of course a necessity. Furthermore, the additional descriptive names can, almost invariably aid the interpretation of the space image.

The problems of the legibility of the text and the actual name placement increase and become more difficult to deal with wherever and whenever it is necessary to include names within a small area. Besides which, as noted above, the legibility of names against the highly detailed space image background has its own particular difficulties in image map design. Furthermore, the inclusion of too many names on an image map will inevitably lead to an overcrowded map product, and hence to a decrease in legibility. Therefore, the decision to include any name on the image map must be carefully considered, and only the minimum number of names necessary to make good use of the map should be added.

The use of black for names should be avoided whenever possible, since it may impart an overall heavy appearance to the final image map. The cartographer should always consider the alternative of exploiting other lighter colours for names, especially since often the legibility of these names has to be achieved against a black and white tonal image. The use of 50% black (grey) or light brown is another alternative that needs to be considered. This may provide legibility without the heavy appearance of full black. The use of drop-out-masks is another possibility, in which the names appear as white letters against the image background. The placement of names against a white space is also possible. However, these practices may lead to the loss of more detail through the removal of the background image data than the use of other alternative methods.

The cartographer must also bear in mind that each small area making up the overall map may pose particular problems. In particular, name placement must invariably be influenced by the nature of the local background image, since, in the real world, these can be no fully homogeneous background. For this reason, particular attention must be given to the lettering style and weight being used, not only according to the order of importance of a particular name, but also with regard to its particular situation on the image map. The nature and appearance of the immediate surroundings (in terms of the other map elements) will also affect the actual placement of names. The name should be placed that such it causes a minimum obscuring of the image detail while, at the same moment, the relation of the name to the feature named should be evident. Hence, it may be difficult, if not impossible, to achieve a standard lettering specification that can be used for the whole of an image map series. Instead it may be more effective and necessary to specify the lettering style in relation to the nature of the terrain. This means that, as far as names are concerned, each particular group of sheets in the overall image map series, that cover similar terrain, may need to be treated separately.

In map design, the adoption of different type designs, and of variations within one design should be related to the organisation of the image, and particularly to the classification that has been adopted. Variation in font style and form helps to reinforce the contrast between symbols. Conventionally, for example, there is usually a major distinction in the map between physical and cultural (man-made) objects and in the colours used to represent such features. As a result, the names in these main groups should be presented in contrasting typefaces in image maps, in much the same manner as is done for line maps.

The use of serif and sanserif faces; upright and italic forms; bold or normal weights; and the upper and lower case forms of the letters provides a sufficient visual distinction which may be exploited for the distinction between the different categories of information. Moreover, the variables of size and weight can also be used to indicate the importance of the feature named. However, the effect of using names with different sizes and weight on the background image should be carefully considered before a final decision as to the choice is made.

8.5.2.1 Dual Language Names & Text on the Proposed Libyan Space Image Maps

In the Libyan context, the intention is, in the near future, to replace the existing topographic line map series at 1:50,000 and 1:250,000 scales with image maps at the same scales based on the use of space imagery. If not for the whole series, then, at the very least, this solution is likely to be adopted and implemented in those areas where most of the terrain is a non-vegetated physical landscape with few or no cultural (man-made) features. If this is the case, then one can argue why not using similar lettering systems to those adopted in Libyan topographic line maps? Especially, when the rapid and continuous development of Libya means that most construction and mining and oil and gas exploration projects that rely heavily on maps will be carried out by companies with English speaking staff. Since maps that are produced using both Arabic and English languages can be used internationally, then the use of English, along with Arabic, is a necessary requirement on these new types of space image maps. This will certainly influence the contents and, in turn, the design of these maps.

As discussed previously (in Sections 8.5 and 8.5.1) for line maps and (in Section 8.5.2) for image maps, in image mapping in particular, the simultaneous use of two different versions of names and blocks of text will increase the potential for conflict and make the situation more complicated, since the inclusion of more names will hide more important details and make the map appearance more crowded. The problems of conflict and the limitations of the available space mean that some names will have to be sacrificed in order to leave room for others. The problems of legibility, clarity and achieving sufficient contrast against the detailed tonal image will be far greater. An important question is which language system should be given more emphasis or priority? In the author's opinion, the answer to this question is always a matter of cartographic judgement. The scale, purpose and the terrain conditions as shown by the space image will always influence the decision to whether one or two language systems should be used. This might mean that, in certain specific desert areas with no man-made objects, it will be easier to use dual language systems. In other areas that contain a considerable number of man-made features, the other possibility is to emphasise the Arabic names and text and provide more English explanations. Of course, Arabic names will facilitate the map reading process for Arabic-speaking users but can also be difficult for foreigners to understand. Since the map is intended to serve both groups of users, a glossary of terms with an appropriate translation to English could be considered for inclusion in the marginal information. In which case, English-speaking users must frequently refer to marginal information to find out what is the English version of any name shown on the image map. Whether this possibility is feasible or practical to implement will no doubt be open to debate and will need detailed testing.

8.6 Relief Representation

Somehow the space image map as a topographic reference document must attempt to represent the terrain relief in an adequate manner in order to satisfy the requirements of the various map users. Contours and spot heights have been commonly used to indicate relief on this type of map product. It must be said that spot heights in the form of a grid, e.g. generated from a DEM, are a less suitable method to be used in the case of space images. In particular, the need to accommodate a large number of numerical elevation values that will obscure the background space image makes it an unpromising method in the context of space image maps. Thus contours are by far the more suitable method of relief depiction for image maps. However there are certain specific problems that have to be solved with every space image map. Obviously, if such an image map includes contours, there is, particularly in hilly areas, the problem of the contours to intruding and interrupting this natural image of the terrain. In other words, if there are too many contours, set too close to one other, as is the case in hilly areas, they will conceal and break up the background image. So, in certain situations, there may be a need to consider the selection of a fairly wide contour interval in order to provide an acceptable density of contours in such areas. However this will result in a lack of information in the flatter areas. Since the background of the experimental space image maps at 1:50,000 and 1:250,000 scales have been produced by the author using monochrome (black and white) image, the important question also arises as to which colour should be adopted for the contour lines. As described in Chapter 7, some designers have selected white lines. However these can be rather obtrusive with a higher contour density. Others have used black lines that may disappear entirely in the darker areas of the space image. The use of the other colours (brown, red) used in conventional line maps is often unsuccessful when used against a black and white space image background. From this discussion, it can be seen that contours really do require careful treatment if they are not to dominate the image map. They must be carefully designed to blend with the terrain as shown on the space image.

As can be seen from this discussion, in the author's opinion, the problem of representing contour lines on space image maps, particularly on a black and white image, is much more complicated than cartographers might expect. The tonal variations of the background image and the colours added to represent built-up areas, cultivated lands, orchard and forests make the problem of contour representation particularly difficult to solve. Sometimes, there is no straightforward or unique solution that can resolve the matter. For example, heavy black lines for contours provides a poor result, since they either disappear in dark areas or they appear to float above the terrain, and appear to bear little or no relation to it. However, the use of white contours is another possibility, but over-exaggeration of the line width must be avoided and the lines should be kept as fine as possible. Although white lines do blend in better with the terrain and seem to integrate well with the space image, the problem is that they become invisible in light areas.

8.7 Projection of the Small-Scale Space Image Maps of Libya

All Libyan topographic maps at the 1:50,000 and 1:250.000 scales are based on the Universal Transverse Mercator (UTM) projection and all carry the full UTM grid lines. This solution was adopted because the UTM projection is conformal, which means that features drawn on the maps retain their true shape, and, in a given area, the scale of the map is constant in all directions. Thus the distortion that is inevitable when a curved surface is projected into a flat surface is kept within reasonable limits. Of course, it must also be said that the influence of the American Army Map Service [later the Defence Mapping Agency (DMA) and now National Imaging Agency (NIMA)] that undertook much of the original mapping was very strong, and, since it had adopted the UTM projection as its standard for world-wide mapping, it was also used for its Libyan mapping project However it now has a wide currency elsewhere.

Thus for the new small-scale image map series of Libya, it will be quite suitable for these to be produced on the same projection (i.e. the UTM) as that used on the conventional line maps of this country that have been produced at 1:50,000 and 1:250,000 scales. In this situation, the 1:50,000 scale image map should carry a full UTM 5,000-metre grid, while a full 25,000-metre UTM grid should be used in the 1:250,000 scale image map series. An appropriate selection of suitable grid lines with good intervals should not disturb the background image or the other elements on the map. As described in Chapter 6, most existing space image maps at medium- and small-scale use a grid as the major reference system, even though graticule positions may be shown in the map border via marginal ticks. Often the boundaries of the sheets in a topographic map series are likely to be arranged on the basis of a grid lines – though some smaller scale maps employ graticule (latitude and longitude) lines to define the boundaries of the coverage of each individual sheet. Obviously, the inclusion of a precise grid is essential, since this will help the intended users to define the location of features shown on these maps in a commonly used reference system. For the experimental image maps at 1:50,000 and 1:250,000 scales to be produced by the author, both the UTM grid and graticule showing geographical latitude and longitude should be included.

8.8 Size of the Space Image Maps

There is no universal standard for the map size used in 1:50,000 & 1:250,000 scale topographic map series. However, the sheet size that is adopted can influence both the production process and the actual use of the map. Maps produced in larger sheet sizes are not easy to handle in the field, while the adoption of a small sheet size requires more sheets to cover the area and adds considerably to the cost of producing the whole topographic map series. Consequently, the map user would have to purchase many more maps to cover his desired area. Largely, the decision about sheet size depends very much on the overall terrain area to be covered by the map series and its size and shape and the level of detail required. In this context, the optimum size for efficient image map production is also a consideration.

Because of the need to maintain the design and production of the experimental map within a reasonable cost limit, its general arrangement and format has been adjusted to that of a single side-printing sheet. Its size has been maintained under the limits of those printing formats that are commonly available and used in Libya and considering the users' point of view that the size should be manageable both in the office and in the field. Therefore, for the new small-scale image map series, it has been decided to use the same rectangular formats or sheet sizes that have been used in the existing 1:50,000 and 1:250,000 scale topographic line map series produced by the Surveying Department of Libya. The main reason for the adoption of the same sheet size was that these maps had been well received by the actual map users who have reported that they did not face any difficulties when using them either in the office or in the field.

8.9 Conclusion

Taking into account the overall strategy and the various general considerations that have been described and discussed in this chapter, the new image map series at 1:50,000 and 1:250,000 scales should certainly be more effective than any conventional line mapping approach in displaying the Libyan terrain surface – particularly in the huge area of desert and semi-desert that are characterised by a very low level of man-made objects. Furthermore, in this situation, only the coastal area should be covered by the 1:50,000 scale image maps, while the 1:250,000 scale space image maps are more appropriate for a national series covering the whole of Libya.

Factors such as scale, purpose of the map and the nature of the terrain strongly influence the level of detail that can be effectively incorporated and the method of representation. Therefore, in the author's opinion, it may well be that no standard or single specification can or should be adopted for the whole image map series of Libya as is the case in conventional line mapping. However, this could be a rather controversial matter and a strong case would have to be made for its adoption. Other factors, such as the cartographic education, practical experience, skills and the familiarity with the map production process of the SDL staff and the financial resources and facilities that are available to the map maker will also be significant in deciding the exact form and specification that will be adopted for the proposed space image map series for Libya.

The appropriate and imaginative use of the graphic variables (form, dimension, and colour) should enable the cartographer to produce more successful space image maps (in terms of their terrain representation) than many of those that have been produced up till now. In particular, the use of appropriate colours with point, line, area symbols can be considered to be the key for achieving a good contrast against the background space image. Nonetheless, factors such as the type of features being represented (e.g. water features which are generally represented by using blue colour symbols) and the size, shape importance of the symbols being used will play a significant role in the selection of colours used and in the decision as to whether these colours should be solids or tints.

The materials, systems and experimental procedures available and utilized in the author's research project will be discussed in some detail in the next Chapter (9).

CHAPTER 9: THE ACTUAL IMAGERY, MATERIALS, SYSTEMS AND EXPERIMENTAL PROCEDURES ADOPTED IN THE PROJECT

9.1 Introduction

In the previous chapter, the overall strategy and the general considerations regarding the potential of space image mapping of Libya have been described and discussed in some detail. In this chapter, the actual imagery, materials and systems that were required for the different stages of this research work will first be given. Afterwards the experimental procedures adopted in this project will be described and explained in some detail.

9.2 Strategy and Experimental Requirements

As discussed in Chapter 6, the first step was to precede the actual experimental work of the current research project by a review and systematic analysis of the cartographic design aspects of 37 space image maps that have been collected for this project. In fact, they present the experimental and publication work of a 30 year period and cover different areas of the world. This study was undertaken by the author to highlight the problems that are hindering space image map design and to ensure that these problems were properly identified and understood before undertaking the research and devising solutions to these design problems. Also it allowed the author to devise a strategy that allowed him to attack these problem in a systematic fashion in order to find the most appropriate solutions.

(1) In the **first stage**, the procedures that have been employed have followed conventional lines making use of SPOT Pan image data in digital form. This has involved the application of digital image processing techniques to match the adjacent images covering the test area both in terms of their geometry and image intensities. These processed images have been used to produce a seamless mosaic of the area and ensure that the boundaries between the different component images are not apparent to the user. Although the digital image processing procedures that have been used for mosaic production are somewhat similar to some of those reported by other researchers in Chapter 6, there are differences, among which are the following:

(i) the digital image processing software packages used;

(ii) the quality of the SPOT Pan images utilized:

(iii) the location of the test area; and

(iv) the number of ground control points (GCPs) used with each SPOT scene.

(2) During the **second stage**, a great deal of attention has been paid to the cartographic design aspects which were required. In particular, much experimental work has been carried out into the design of the symbols, text, lines, etc. that were to be used as overlays on the space background image. This, of course, included the effective use of colour in order to enhance this information on the final maps. These activities have been accomplished through the adoption of digital cartographic processing techniques which include the generation, placement and combination of cartographic elements such as co-ordinate systems, symbols, names, etc. using computer-based (digital) methods.

(3) The methodology and procedures that have then been used in the **third stage** for the actual planning of the map content and obtaining the necessary information – including the compilation of the topographic data required for the space image maps at 1:50,000 & 1:250,000 scales – have followed the same general lines used by other researchers in this field. Thus the specifications of the map content for each of the desired scales have first been determined. These have been followed by the visual interpretation and feature extraction required to obtain the necessary topographic information from the SPOT Pan images. In addition to these activities, information that could not be derived directly from the SPOT Pan imagery was obtained from external sources – such as aerial photography and existing topographic line maps of the test area – using both conventional and digital methods.

(4) In any mapping project, once the information that has needed to be shown on a map has been collected, properly categorized and classified, the next step – in this case, **the fourth stage** – is the planning of the graphic representation of the information, an activity usually known as cartographic design. In the author's opinion, the overall strategy that has been adopted for the task is somewhat unique and different to those reported in Chapter 6. For the cartographic design of the new space image map series, a systematic approach has been followed in the present project. In particular, it was felt that the different symbols have to be clearly distinguishable from one other. This has been achieved through the creation of alternative versions of the graphic symbols (i.e. the point, line and area symbols) in terms of their form, dimension and colour. This was necessary to ensure a proper graphical treatment of all the various aspects involved in space image map design and thus to reach the most appropriate solution regarding the representation of the different features required on the image map. In fact, this systematic approach has allowed the author to attack the problem with a great deal of confidence and creativity. At this stage, the evaluation of these alternatives to select the most appropriate form, dimension and colour of each of the image map elements has been carried out by the author based on his own cartographic background, education and experience.

(5) The application of these procedures has been followed by the production of experimental space image maps at 1:50,000 & 1:250,000 scales for the test area that are of a good design quality.

(6) Part of the design strategy has also been to design and execute a test among a group of 20 to 30 map users to examine and evaluate the design quality of the space image map samples that have been produced in the current research project.

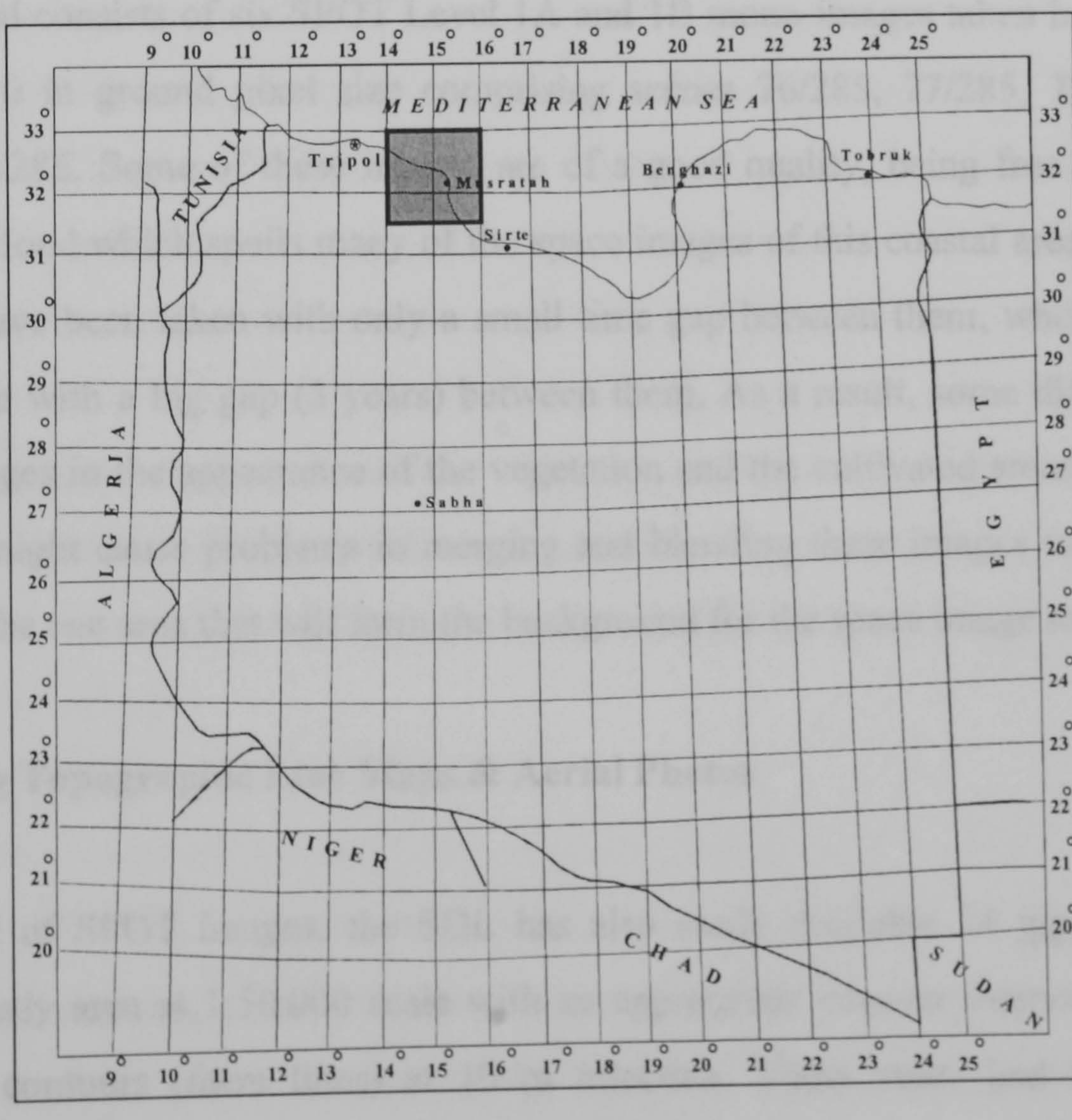


Figure 9-1: The location of the test area

9.2.1 Test Area

The test area that has been selected covers the Misratah region in north Libya, which gives a sufficient variety of terrain types, e.g. urban areas, water features, vegetation, forest, cultivated areas, desert, etc. to ensure that it takes in many of those that occur in the Libyan landscape. This area is located on the Mediterranean coast, east of the capital, Tripoli, extending between latitude 31° 30′ and 33° 00′ and longitude 14° 00′ and 16° 00′ – see Figure 9-1.

9.2.2 Test Material

Considerable efforts have been made and a large sum of money has been spent by the Surveying Department of Libya (SDL) to make available the material required to carry out the research project and produce the experimental examples of the space image maps at 1:50,000 and 1:250,000 scales.

9.2.2.1 SPOT Pan Images

The test material consists of six SPOT Level 1A and 1B mono-images taken in panchromatic mode with a 10 m ground pixel size comprising scenes 76/285, 77/285, 78/285, 76/286, 77/286, and 78/286. Some of these images are of a good quality, being free from the dust, haze, and thin cloud which spoils many of the space images of this coastal area. A number of these images have been taken with only a small time gap between them, whereas the others have been taken with a big gap (3 years) between them. As a result, some difficulties could arise from changes in the appearance of the vegetation and the cultivated areas over this time period. These might cause problems in merging and blending these images together to form the mosaic for the test area that will form the background for the space image maps.

9.2.2.2 Existing Topographic Line Maps & Aerial Photos

Besides the set of SPOT images, the SDL has also made available 24 topographic maps covering the study area at 1:50,000 scale with an appropriate contour interval of 20 m and supplementary contours (form lines) at 10 m intervals. These maps had been produced originally by the U.S. Army Map Service (AMS) in 1962 using aerial photogrammetric methods and then up-dated in 1979 by POLSERVICE-GEOKART, Poland, from aerial photographs taken at 1:20,000 scale in 1976. The writer spent a one-month period in the SDL cartographic laboratory in Tripoli copying these topographic maps from the original films using photo-mechanical methods to make them available on stable films for use in Glasgow.

SDL has also provided the writer with the complete coverage of 800 aerial photographs taken at 1:40,000 scale for the test area. These aerial photographs had been taken in 1989 and could be used as an additional source for interpretation and information extraction. To supplement this information, the author also spent some time visiting the area to become familiar with its main features.

9.2.3 Hardware and Software Packages Used in the Project

The Topographic Science Department has made the appropriate computing facilities available, including the hardware and software systems that were needed to carry out the various experimental parts of the research project.

9.2.3.1 Hardware

For the purpose of this research project, the author was provided with a PC equipped with a 133 Mhz Pentium I processor and fitted with 32 MBytes RAM and 2 GBytes of hard disk. Later, 4 Gbytes more hard disk storage was added at the request of the author in order to accommodate the large image data sets that were being used. Besides these facilities, Hewlett-Packard DeskJet 850C, EPSON Stylus 1520 and ENCAD Novajet II inkjet colour printers were available in the Department and have been used extensively during the cartographic design experiments undertaken during this research project.

9.2.3.2 Software Packages

Most use has been made of two software packages (EASI/PACE & ACE) that have been produced by a Canadian company named PCI. EASI/PACE is a sophisticated image processing software package that has been used mainly for the geometric corrections and radiometric enhancements of the imagery and for the production of the mosaic of the test area. Whereas ACE is a digital cartographic package that has been designed specifically for use with the output from the EASI/PACE system and has been employed on the cartographic design and production of the two experimental space image maps at 1:50,000 & 1:250,000 scales. The Topographic Science Department has provided these systems to the author specifically for this project.

In addition to the main software packages – EASI/PACE and ACE – used in this research project, supplementary software packages were needed to carry out certain other specific image processing and graphic tasks that could not be executed on the two main systems. These included CorelDraw and Adobe Photoshop. Other small programs from the Department's software library were also needed to carry out digitising (MAPDATA), vector plotting (VECTOR) and certain format transformations (using a small FORTRAN program).

A more detailed account about the EASI/PACE and ACE system characteristics has been given in Appendix I.

9.3 Necessary Pre-Requisite to the Experimental Work

Prior to starting the experimental work, the author spent a considerable time training himself on the two main software systems (PCI EASI/PACE and ACE) that would be required for the production of the space image maps. This was followed by the production of the space image background as a necessary pre-requisite to the experimental work. In this respect, well known routines, that are available in most commercially produced packages, have been used to produce the required space image mosaic that formed the bases of the experimental space image maps at 1:50,000 & 1:250,000 scales for the Misratah test area. The production of the space image mosaic using the EASI/PACE software system comprised the following steps:

(i) The pre-processing and the preparation of the original SPOT Pan data for further operations was carried out first of all.

(ii) Radiometric enhancements were then employed to improve the appearance of the SPOT Pan images for image-interpretation and feature extraction.

(iii) Next rectification and resampling were carried out to compensate for all the displacements and distortions introduced by the sensor system attitude changes, altitude changes and overall tilt so that the corrected images had the geometric integrity of a map. These distortions were corrected through the use of ground control points (**GCPs**).

(iv) Radiometric matching & mosaicing were then carried out in such a way that the geometric and radiometric differences between the adjacent images were minimized or disappeared.

(v) Finally post-processing techniques were applied after the mosaicing operation in order to optimise the background image data for the purpose of producing the experimental maps.

After finishing all these operations, the image mosaic of the project area was ready for the further experimental work.

9.4 Experimental Procedures

As outlined above, this experimental work has been designed to be carried out in the form of four separate experiments:

(i) The planning of the content and the actual acquisition of the information required for the production of the image maps at 1:50,000 & 1:250,000 scales;

(ii) The cartographic design and production of the space image maps at 1:50,000 & 1:250,000 scales;

(iii) The test carried out to evaluate the user reaction to the experimental space image maps; and

The approach and the procedures used in each of these experiments will be outlined below.

9.4.1 Planning of the Content and the Acquisition of the Required Information

Generally speaking, any mapping project starts with the planning of the content and acquisition of the information needed for the sample maps – in this case, those of the Misratah area at 1:50,000 & 1:250,000 scales. The procedure that was adopted for this operation was as follows:

i) the definition of the basic parameters;

ii) the detailed specification of the map content;

iii) tests to establish the extent to which image-interpretation and feature extraction could be used to obtain the required topographic information from the SPOT Pan satellite images using visual interpretation techniques; and

iv) specifying the additional information that would have to be obtained from external sources and the methods needed to acquire this information.

(i) The basic parameters: The plan was to produce experimental space image maps at 1:50,000 and 1:250,000 scales for the Misratah test area. The intention behind this is to investigate the feasibility of producing a new national image map series of Libya to meet the needs of the different governmental Departments, universities, oil companies, military forces, etc. within the country. The demands by these different groups of users for maps either in printed or in digital form, and their particular needs in terms of map scale and map content, will of course influence the development of every Libyan national map series. These mapping programmes are completely funded by the Libyan government, and unlike certain highly developed and densely populated European countries, there is no prospect of them generating enough income to cover the cost of their production. The purpose of the experimental space image maps was seen therefore as being the production of general-purpose topographic maps designed to meet the general needs of the user community rather than the very specific needs of a particular group of users. On this basis, the relevant features for each scale have been selected to meet these general-purpose requirements. In this context, the scale of each map has, to a large extent, determined the information level and the size of the individual features that have to be included.

(ii) Map content specifications: The experimental space image maps should contain an appropriate level of detail about both the physical and cultural features that exist in the area of interest. Generally, the map content of the experimental maps has been controlled by (i) the user requirement, (ii) the scale of the space image map that will be produced, and (iii) the ground resolution of the SPOT Pan imagery that has been used as the base of the map. Besides which, with a space image map, one does not have the freedom to add too many symbols to the background image in case they obscure important details. The map content specification is the first step that must undertaken in any map design process, and it has to be specified before any image interpretation or symbol design can be carried out. In the author's opinion, a full-scale survey of user requirements should have been carried out previously by his Department in Libya. Unfortunately, in the present project, due to difficulties in terms of the cost, time and complication of the process, this kind of survey had not been carried out. Hence the solution was to base the specification solely on the author's past experience gained during the 10 year period of his work at SDL.

The first step was therefore to define which specific features should be included at the two different scales – 1:50,000 and 1:250,000 scales – at which the experimental space image maps of Misratah area are going to be produced. To this end, the SDL topographic line maps at 1:50,000 scale have been consulted to help specify the features that should be included in the space image maps to meet the main requirements of the different users. Also it was possible to gain some further ideas about the features that needed to be included in the map from inspection of the space image maps at the same scale among those analyzed in Chapter 6 – more especially those covering arid and semi-arid areas. With all these different considerations in mind, the author has had to make a compromise and has included a medium level of features which have been translated into the map content technical specifications.

Once the important features that – from the users point of view – needed to be included in the map have been selected, then these features can be placed in categories or classes. In the case of the present project, seven main information categories – comprising boundaries, roads, water features, other cultural features, vegetation, other area features and relief – have been defined. They present the major elements of the physical topography and the cultural landscape, and, in turn, each of these categories has been sub-divided into several sub-categories.

(iii) Image interpretation and feature extraction: Quite a number of the specified features can be extracted directly from the SPOT Pan images, but, partly due to the lack of higher ground resolution and contrast, the rest can only be provided from additional sources of topographic data such as aerial photos, existing topographic maps and field completion operations. In this project, for the actual image interpretation and feature extraction, monoscopic SPOT Pan images have been used. For this task, visual interpretation techniques have been used by the author to identify quite a large number of the specified features that needed to be included in the space image maps of Misratah area. First, the SPOT Pan scene has been displayed on the screen of the monitor using the Image Works program of the EASI/PACE software. As discussed previously, the zooming and full resolution viewing facilities that are available within the Image Works module have been used extensively for this purpose. These facilities allowed the author to carry out a detailed visual interpretation of the images and to extract as many of the specific features as possible. Of course, the aerial photos and topographic line maps of the project area have also been available as collateral information sources and have been consulted for verification purposes. The results of this procedure will be discussed fully in Chapter 11.

(iv) External sources and the methods used to acquire additional information: The topographic data that could not be derived directly from the SPOT Pan imagery has been obtained from external sources:

- *Additional image data*: Using visual image interpretation techniques, additional topographic data has been derived partly from the SPOT multi-spectral (XS) imagery of the same area, and partly from the stereo aerial photographs taken at 1:40,000 scale for the test area. In particular, these sources have allowed the more precise delineation of the limits of some of the large urban areas to be carried out in relation to other identifiable features. The aerial photographs have been also used to locate some of the more important tracks that are present in the area, these being partially absent in the SPOT Pan mosaic.
- *Existing maps*: Existing maps of the test area at 1:50,000 scale were available and have also been used to determine the positions of certain villages and individual buildings that were too small and lacking in contrast with their surroundings to show up in the SPOT Pan imagery. They also showed the location and alignment of certain other topographic objects as well as providing names and terrain heights that could be incorporated in the experimental maps. The required topographic information has been compiled from existing maps using a conventional analogue approach. A CalComp 9100 digitising table and the MAPDATA software package have been used for the digitising of some linear features, contours, some tracks and trails. In order to transfer these digitised data so that they could be used in the ACE software on top of the space image background, each set of digitised data had to be saved as an ASCII file. Then using a small FORTRAN program that is available in the Department of Topographic Science, the ASCII file was converted into the format of an ARC/INFO ungenerated (UNG) file. This file type is supported by ACE, and using it, the digitized data could then be imported to the main image map file.

9.4.2 Cartographic Design and Production

A great deal of attention has been focused on the cartographic design aspects of the project. To accomplish this, the following activities have been carried out.

9.4.2.1 Symbol Design

After the content of each space image map (at the 1:50,000 and 1:250,000 scales) had been acquired and edited, the next step was the design of the symbols. The use of symbols is essential to express the reality of the objects existing on the ground in an abstract way on the map. Each different item of geographic information becomes a point, a line, or an area characterised by a certain size, shape, and colour. Obviously, the design of each individual symbol plays a vital role in the total space image map design. From previous experience, the author considers symbol design to be one of the most difficult aspects of map design to comprehend and to be successful at. This aspect must be handled with a great deal of care. It needs a full knowledge and understanding both of the cartographic design process and of the technical production methods available to produce the final map.

As already mentioned briefly in Section 9.3, the author has followed what he considers to be a systematic approach to design the symbols of the different individual point, line, and area features contained in the maps. The graphic variables (of form, dimension and colour) of the point, line, and area symbols used to represent the image map features have been utilized to the maximum extent possible. To reach the optimum symbol design and to test the integration of the symbol with the background image, alternatives for each designed symbol have been produced. Initially, the author has designed three different graphical forms for each individual symbol that should be included in these space image maps. For these symbol design experiments, the decision was taken to work with A4 size portions of the black and white background space images. Three alternative experimental designs – with variations in the form, dimension and colour – have been produced for each individual symbol. Each category or group of features (e.g. water features) that have certain characteristics in common were superimposed together on the portions of the space image. The alternatives in terms of their form, dimension and colour have been tested and evaluated by the author until a good symbol design has been found. These experiments have been carried out twice – once for the design of the symbols required for the space image map at 1:50,000 scale, and then a second time for the 1:250,000 scale map symbols. Since each symbol or category of features has been tested individually, the design of these symbols was not final and changes did take place later on when all the symbols of the map were put together to produce the whole sheet of the space image map.

9.4.2.2 The Combination of the Different Elements of the Misratah Space Image Maps

During this stage of the space image map design, the author was dealing with the overall design incorporating all the elements of the space image maps. Thus all the point, line and area symbols were superimposed together on the background image to test their design quality in terms of their form, dimension and colour. Other elements such as grids, text, marginal information, etc. were also included at this stage. Three alternative versions of the space image maps have been produced for each scale in order to reach an optimal solution in the design of these image map products. In fact, taken overall, extensive experimental work has been carried out by the author to test and evaluate all the individual elements of the map. A final design solution was then selected for each of the experimental space image maps at 1:50,000 and 1:250,000 scales. In turn, this led to the establishment of the final design specifications for the experimental space image maps of the Misratah area.

9.4.2.3 Cartographic Data Processing

For the cartographic data processing carried out in this project, those procedures that have been applied at 1:50,000 scale are largely those that have also been applied at 1:250,000 scale. So these processing procedures will be discussed together as follows:

(i) Graphical element generation and representation: This step in the cartographic processing was concerned with the actual creation and representation of the various point, line and area features that were involved in the design and production of the experimental space image maps. Using the ACE software, the extensive series of operations involved in the creation of the point, line and area symbols with their alternative forms, dimensions and colours were carried out. These operations started with the creation of the **Map Header** file, within which, the desired map scale was specified, and was followed by the **.rst** file creation.

(ii) The RepCode Setup Table (RST) creation: All the different classes of features such as boundaries, roads, water features, cultural features, vegetation, and so on, were given a **RepCode** group number to differentiate one from another. Roads have been classified into highways, main paved roads, secondary paved roads, unpaved roads and tracks. Each individual symbol was specified precisely in terms of its form, dimension and colour. All the resulting **RepCodes** were stored in the file named **RepCode Setup Table** (RST).

(iii) The actual symbol and text generation has been undertaken as follows:

- Point symbol generation: This step started the actual process of generating the point symbols that had been designed and specified by the author during the previous stage of the experimental work. Some simple geometric point symbols such as circles, squares, and rectangles were already available in the ACE library. Thus the present author was able to use them in designing his own symbols. However, a considerable number of point symbols had to be drawn from scratch using the **Symbol Editor** tools available in ACE. After having been created, these point symbols were then stored for further applications.

- Linear feature generation: All of the different types of lines (e.g. solid, dashed, dotted) that were available in the ACE library have been employed to represent the different linear features – e.g. the different classes of roads, the contours, coastline, and grids involved in this work. As discussed above, the form, dimension, and colour had already been specified to meet the desirable specifications at a particular scale. Using the priority facility in ACE, each colour was also given a priority number to allow them to be superimposed one on top of the other in the final form of the map. As an example, highways have been treated in this way.
- Area feature generation: In fact, these are some of the most difficult features to represent in a satisfactory manner in image map design and production and must be handled carefully. Most of the previous work that has been done by others have represented these features through the use of solid polygon or/and patterns, which are artificial additions that disturb the natural image. In this project, transparent polygons with different colours and opacity have been employed to represent the different area features such as cultivated area, forest, and sabkhah.
- Text generation: The addition of text on image maps is of course, a necessity to identify places and certain definite features whose actual location and form are supplied by the imagery. The addition of text also has the purpose of aiding the interpretation of less well-defined features. From the ACE library of fonts, different types of geographical features (e.g. the physical and man-made features) were given different types of text representation in terms of their fonts, dimensions, and colour. Each name for an individual feature has been given a **RepCode** and its style, size, and colour was specified and saved in the **RST** file. The legibility and actual placement of names against the highly detailed image background is a serious problem in all image mapping. Since the inclusion of too many names would lead to an overcrowded image and hence the overall

legibility of the map would be decreased, the author selected the names very carefully and only the minimum number of names necessary to make good use of the image map were included.

- Other feature generation: Features such as grids, scale bar, title, etc. were created using the **Surround** tools available within the ACE software.

As described previously, the compilation of the topographic data from the SPOT Pan images has been carried out using on-screen digitising techniques and the data was then combined with the point and line features digitised from existing topographic maps at 1:50,000 scale, and integrated to produce the final data set.

9.4.2.4 Printing

Producing maps would not be useful without the ability to print them in hard copy form in order to ensure both their correctness and their widespread distribution to users. So printing is an important process to any cartographer, enabling him to produce a hard copy (i.e. on paper or film) of his map for checking or publication purposes. The printing of digital map data can be achieved using:

(i) Small format inkjet printing: This was the process of printing direct to paper, which was achieved initially on an A4-sized Hewlett-Packard DeskJet 850C inkjet raster printer and latterly on A3-sized Epson Stylus 1520 inkjet printer. A great number of printed copies were generated and output in colour during the experimental design stages as a means of checking symbol design; the integration of the symbols and the background image; name placement; etc. Although the output maps generated from these devices were limited in terms of format and colour appearance, they did however provide a relatively inexpensive and acceptable option for printing the numerous proofs that are required during the different stages of image map design and production. ACE software supports both printers and allows the cartographer to set-up the specific printer. To print a map, ACE simply transfers the map directly to a file ready for printing, then this file has to be copied to the particular printer concerned using a specific DOS command.

(ii) Large format inkjet printing: On completion of the data capture process and the creation of the digital files of the experimental maps, the next stage of the printing process to be undertaken was to produce a proof in colour of the final experimental maps directly on paper by means of a large format Novajet raster inkjet plotter. This was produced for the purpose of checking all map elements; the completeness and correctness of the content; the registration of the map features relative to each other, and as means of examining the success of the design and layout; etc. Errors found at this stage can then be corrected before sending the map data for final printing.

(iii) Film writing and final printing: To retain the intrinsic resolution of the original images, particularly for image maps, a high resolution film plotter needs to be used to generate a continuous-tone negative or positive film image. Films can be written using the following types of plotter:

- Small format film writers: These film writers only allow a limited format size of negative film images to be produced (typically 10 x 12 inch), but at a very high resolution (e.g. 2,500 dpi). Then from these negatives, high quality enlargements of the final image map can be produced by projection on to photographic film or paper. The final enlargement process can be achieved using a conventional high quality photographic enlarger. However this process is really only suitable for the production of a few very high quality colour photographic prints.
- Large format film writers: The alternative is to use one of the large format film plotters that are available in the market. They can produce the stable film negatives or positives at very high resolution (up to 4,000 dpi) required as colour separations to produce the plates for printing colour image maps, using offset litho teqniques. In fact, as reported by Petrie (1997), the Barco LithoSetter even allows the direct production of printing plates from the digital image map data.

In this project, the final experimental maps were produced using the photographic printing method. This method of printing is recommended whenever the required number of printed copies is limited to few copies – as was the case in this current project. Fortunately the materials have become relatively cheaper than they used to be, and the availability of automatic colour processing technology made the application of this method more practicable. As a result of all the previous operations, two final digital data files, one for each scale, were generated. Using a small format (12 x 10 inch) film writer that has been mentioned above, two negative film images have been produced for the experimental image maps of Misratah area. Through the use of a high quality photographic enlarger, enlargements of the final experimental maps have been produced on photographic paper.

9.4.3 The User Test

For the evaluation of the cartographic design aspects of the experimental space image maps, a user test has been prepared by the author and distributed to 20 to 30 graduate students. These students all live in Glasgow but come from various countries in North Africa and the Middle East that have similar terrain characteristics to those experienced in Libya. The main areas of this test are:

(i) the background image quality,

(ii) whether the contents of the experimental maps are sufficient or not, and

(iii) the cartographic design and final appearance of the experimental maps.

9.5 Conclusion

In this Chapter, the overall strategy and the actual materials, systems and procedures adopted and used in the cartographic design experiments to produce a space image map for a test area in Libya have been discussed. Some of the methods adopted in the present research are similar to those discussed in Chapter 6. However, there are some differences, especially in terms of the extensive experiments have been carried out in order to select or reach the most appropriate design for both the individual components and the final experimental maps. This has been accomplished through the adoption of a systematic approach of cartographic design and symbol generation, with the generation and evaluation of a number of alternatives before the final design was decided upon.

In the next Chapter, the production of the space background image as a necessary pre-requisite to the experimental work will be presented and discussed in some detail. This will include pre-processing, radiometric enhancements, rectification and resampling, and the mosaicing of several SPOT Pan images using a number of well known image processing techniques.

CHAPTER 10: THE PRODUCTION OF THE SPACE IMAGE MOSAIC FOR THE PROJECT AREA

10.1 Introduction

In the previous chapter, the overall strategy and the materials, systems and procedures adopted and used for the author's experimental work have been presented and discussed. In this chapter, the steps – which involve radiometric enhancements, geometric corrections and mosaicing – used in the production of the space image mosaic for the test area will be covered in more detail. For this task, the author has used the set of SPOT Pan imagery, comprising four Level 1A and two Level 1B images, taken over the Misratah region in north Libya. These have been used to produce the background mosaic for the test area that was required as the basis for the image maps before superimposing any cartographic symbology. For this operation, a modern approach has been adopted that is based entirely on the use of digital image processing techniques. The PCI EASI/PACE software system could be used to execute almost all the various aspects involved in producing the background mosaic for the Misratah test area. The diagram shown in Figure 10-1 shows these steps. Each of these stages will be described in more detail in the following sections.

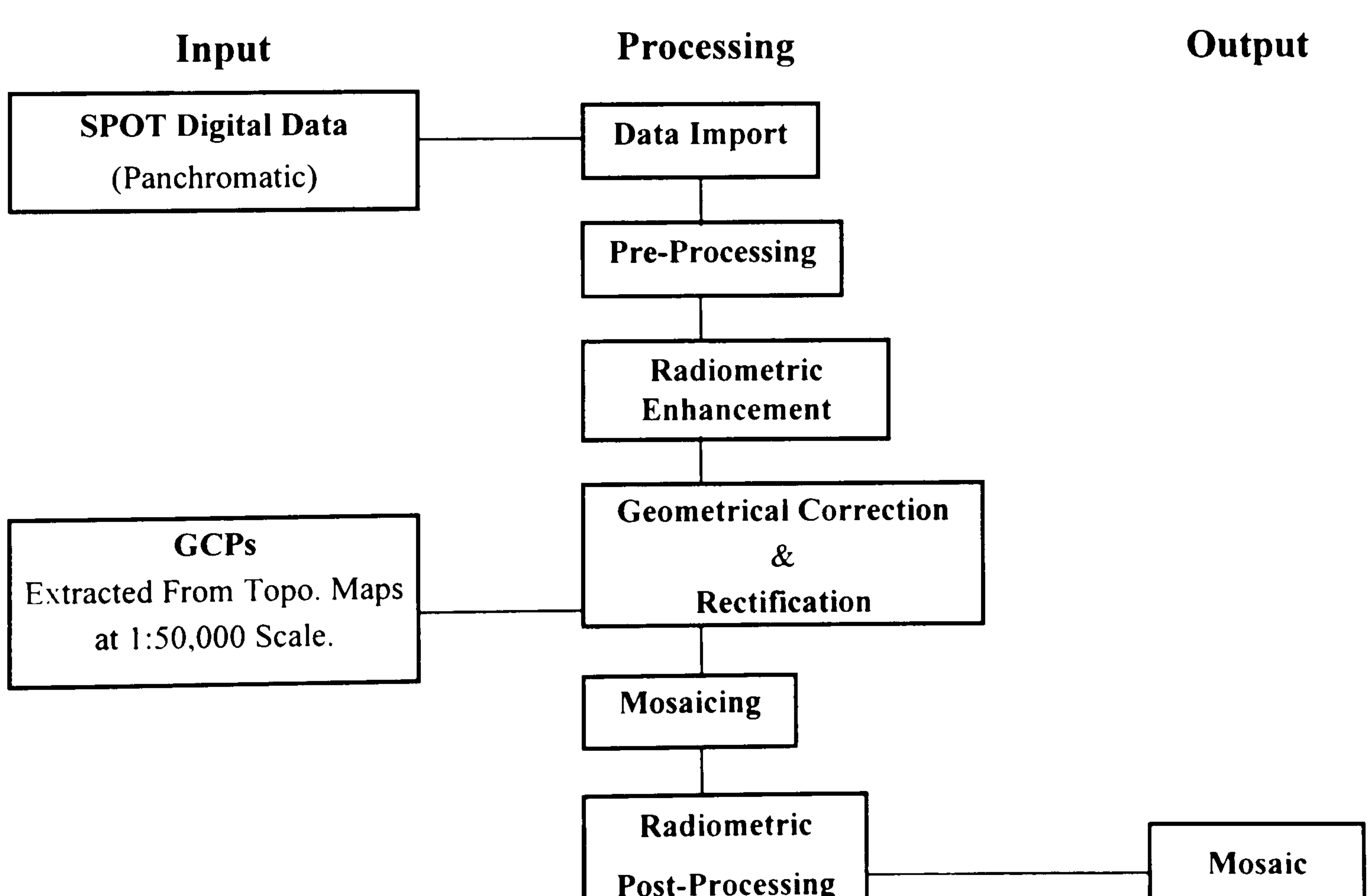


Figure 10-1: The steps involved in the production of the space image mosaic

10.2 Data Import

This was the first step in the overall procedure. As mentioned in Chapter 9, the SPOT Pan images had been collected at various times during the period 1986-1989. In 1994/95, when the present research work commenced, the choice of SPOT panchromatic imagery (with its ground pixel size of 10 m) for the research into the cartographic aspects of space image maps was most appropriate. At that time, the Indian IRS-1C imagery was not even in existence, while the ground resolution of the Landsat TM imagery was much poorer (30 m ground pixel size v. 10 m) than that of the SPOT Pan imagery. However, at the beginning of the project, the SPOT scenes of the project area were not made available to the author due to difficulties in Libya. This lost a great deal of time and, indeed later, the author had to go back to Libya and bring the image data back with him personally. These SPOT Pan scenes had all been recorded on optical disks in an ERDAS format. It was difficult to read these data since the optical disk drives used to record them in Libya are of an older type that very few people in the UK still use. Finally, the Chemistry Department at the University of Glasgow solved part of the problem and managed to read some of the data and transfer it on to CD-ROMs. For the rest of the data, quarter-inch wide data cartridges had been sent to the author. These cartridges could be read and their data was also transferred on to CD-ROMs by the Computing Service at the University. These transfers on to CD-ROMs allowed the data to be read into the author's PC.

As far as the PCI EASI/PACE package is concerned, before any image processing could be undertaken, the imported SPOT image data had to be re-formatted into **PCIDISK** (pix) format. This task was accomplished using the **FIMPOT** routine that is available among the PACE programs of EASI/PACE. This task had to be carried out for each SPOT scene individually.

10.3 Pre-Processing

Image pre-processing refers to the initial processing of the raw data as received from the imaging sensor mounted on the satellite platform. This raw data may contain flaws or deficiencies. The removal of these flaws and the correction of the deficiencies that exist in the space image data is called pre-processing. The purpose of this step is to prepare the original data for further processing operations. It has both a radiometric and a geometric aspect. The purpose of the radiometric pre-processing is to correct the various shortcomings in the SPOT image data resulting from the effects of atmospheric absorption; from the effects of cloud cover both directly and as ground shadows; by the less than optimal operation of the scanner system used to collect the data; etc. Each SPOT scene covering the map area had to undergo radiometric pre-processing prior to any geometric correction and rectification, since some of the radiometric pre-processing operations require the use of the original raw data and image geometry. The geometrical pre-processing involves the compensation of certain scanner system and spacecraft effects (e.g. scan skew, panoramic distortions, spacecraft velocity, Earth curvature, etc.) on the digital image data that had been received from the SPOT satellite. Nowadays the receiving stations do much of this type of pre-processing, but for four of the SPOT Libyan image data sets, this was a necessary preliminary operation. However, these operations were only required for the Level 1A SPOT Pan images, since the Level 1B images had already been pre-processed and rectified.

10.3.1 Radiometric Pre-Processing

Even when some of the corrections have been carried out at the ground receiving stations, there is still a need for further pre-processing to get rid of the residual noise or any other artefacts that may still be present in the image data. Each SPOT Pan image in the Misratah map area underwent radiometric pre-processing before any geometrical rectification and resampling was undertaken. So, after importing the SPOT scenes and transforming them to **PCIDISK** (pix) format, the author displayed each image using the Image Works module that is available within EASI/PACE. By viewing and inspecting these images very carefully, it was found that two radiometric techniques (line drop replacement and cloud substitution) had to be applied to some of the images.

10.3.1.1 Line Drop Correction

Missing line or line drop is caused by the temporary electrical malfunction of the sensor during the data acquisition process. This kind of problem can also occur at the ground receiving station if a temporary failure happens there. Whatever the cause, this results in the grey level value being either 0 or 255 for a complete line. It is obvious that there is no way to restore the real data, which have never been acquired. The only possible solution to this problem is to estimate the grey level values for each pixel in the missing lines from the values that are present in those scan lines located above and below the missing values.

In this project, the missing lines were replaced using the **LRP** (Line Drop Replacement) routine that is available among the PACE programs of the EASI/PACE software system. This routine performs the replacement of damaged lines in images where either several adjacent pixels or an entire line are missing or noticeably defective. Lines may be replaced with the line above, the line below, or the mean of the line above and below. The first two options (the use of the line above and line below) of the LRP routine have been applied to correct the SPOT scene 77/286. Both the uncorrected image and the corrected images are shown in Figures 10-2 and 10-3 respectively.

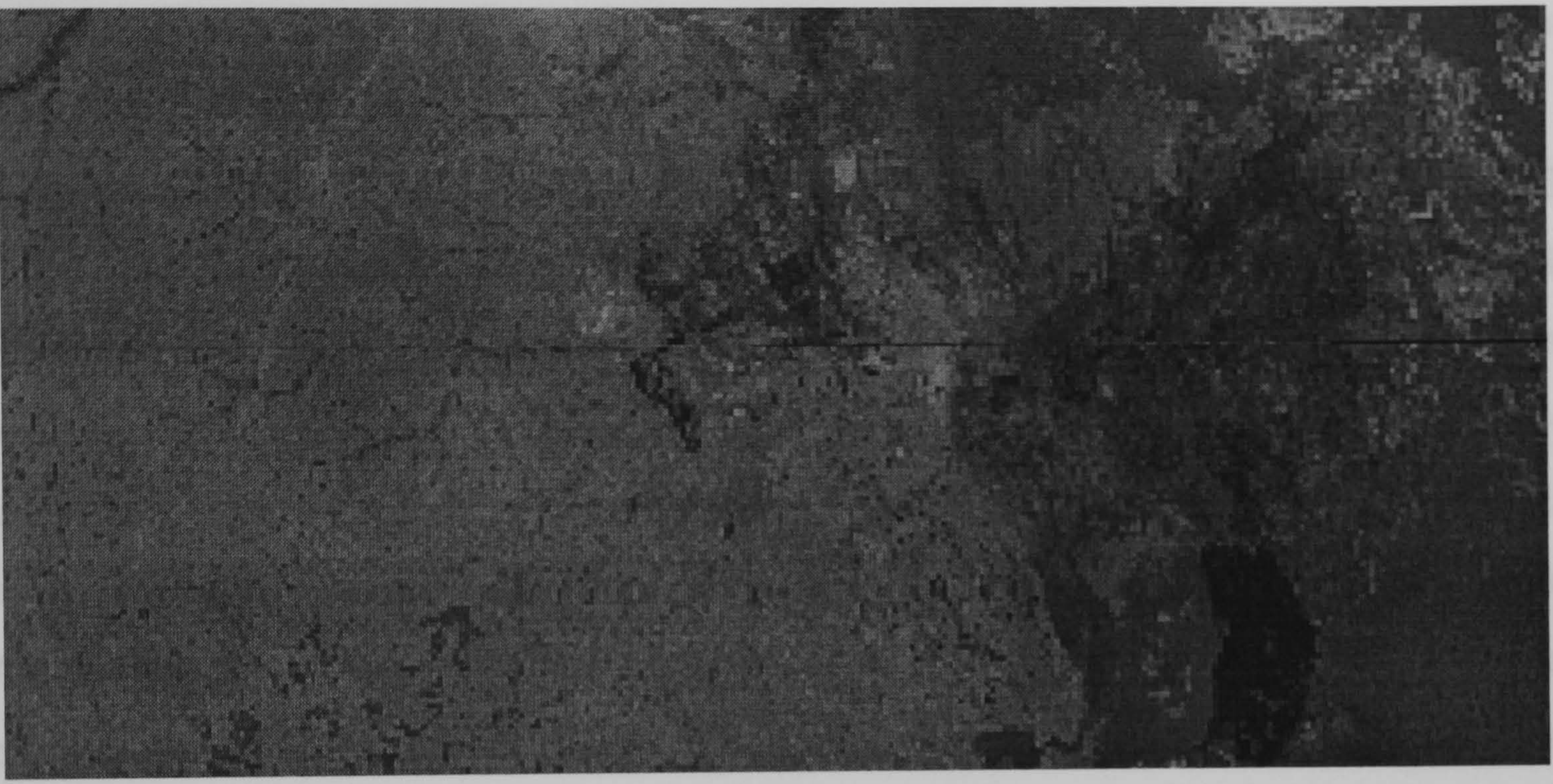


Figure 10-2: Part of scene 77/286 with the missing line.

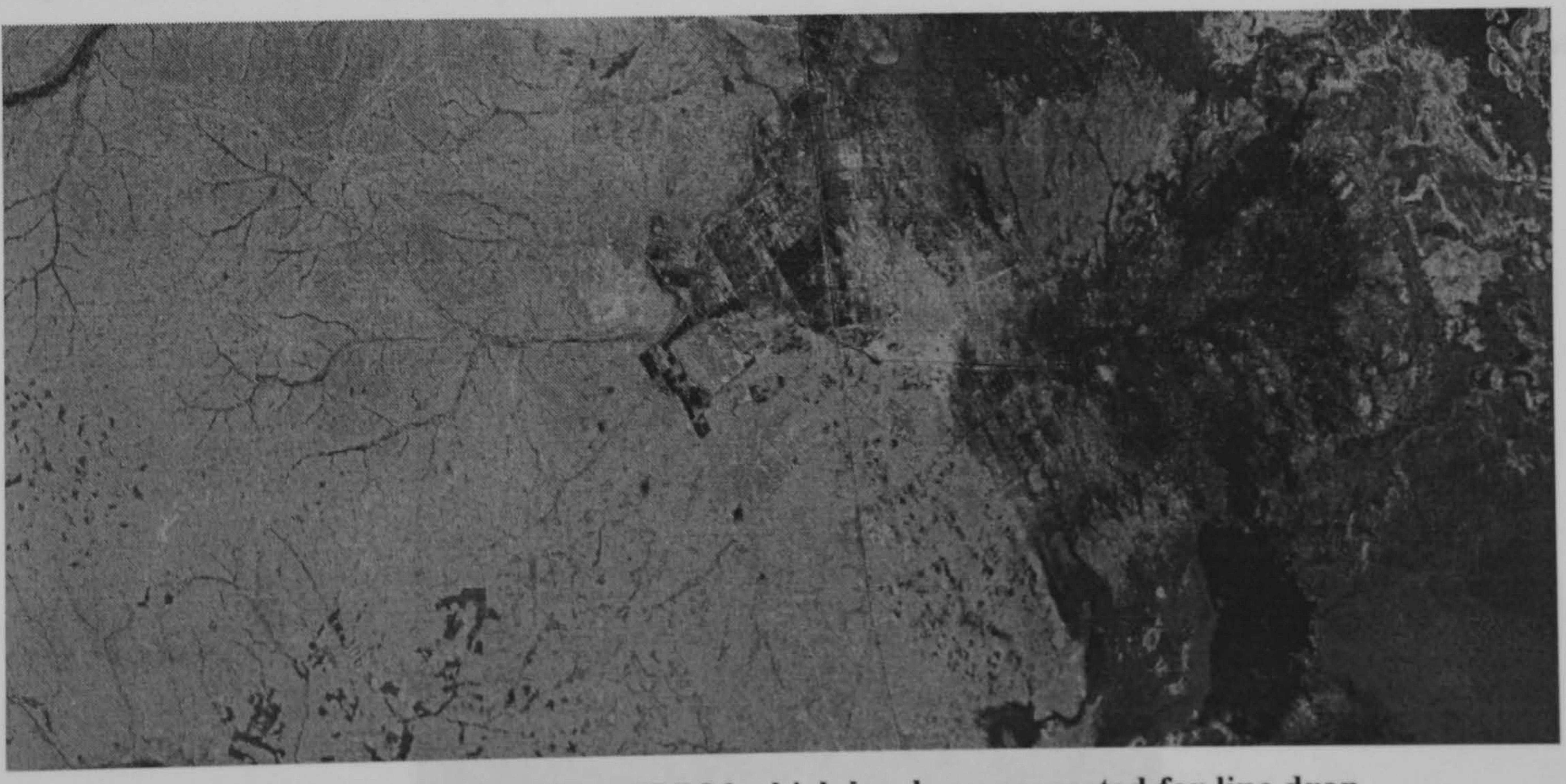


Figure 10-3: Part of scene 77/286 which has been corrected for line drop.

10.3.1.2 Cloud Substitution

On many occasions, clouds or cloud shadows, industrial smoke or other similar effects can influence space image data in a negative fashion. If other space image data is available for the same region, it is possible to eliminate the area of poor quality data by partial substitution of the other data. In particular, for space image map production purposes, any cloud covered parts of the image may have to be substituted by image data from other space scenes acquired on different dates. In order to do so, the scenes concerned must first be transformed on to a common geometric reference system (e.g. UTM) before any substitution can be carried out.

In the case of the SPOT Pan data covering the test area, scene 76/285 was disturbed by clouds. Fortunately, another SPOT scene was available which covered the same area. This had been acquired at a different time, but luckily the area concerned did not show any major differences to that of the main scene. For the cloud substitution operation, a lot of processing steps and interactive control procedures had to be carried out. In fact, two software packages had to be used for the purpose – EASI/PACE for the image rectification and radiometric adjustment and Adobe Photoshop for the interactive control procedures involving the selection, copying and pasting of the images. The method was rather time consuming because of the need for a high degree of interactive control of the process by the operator. However, for the production of high quality space image maps, the elimination of these cloud-affected areas was quite essential. Figure 10-4 presents a part of SPOT scene 76/285 with the cloud cover, while Figure 10-5 shows the same image with the cloud effects removed.

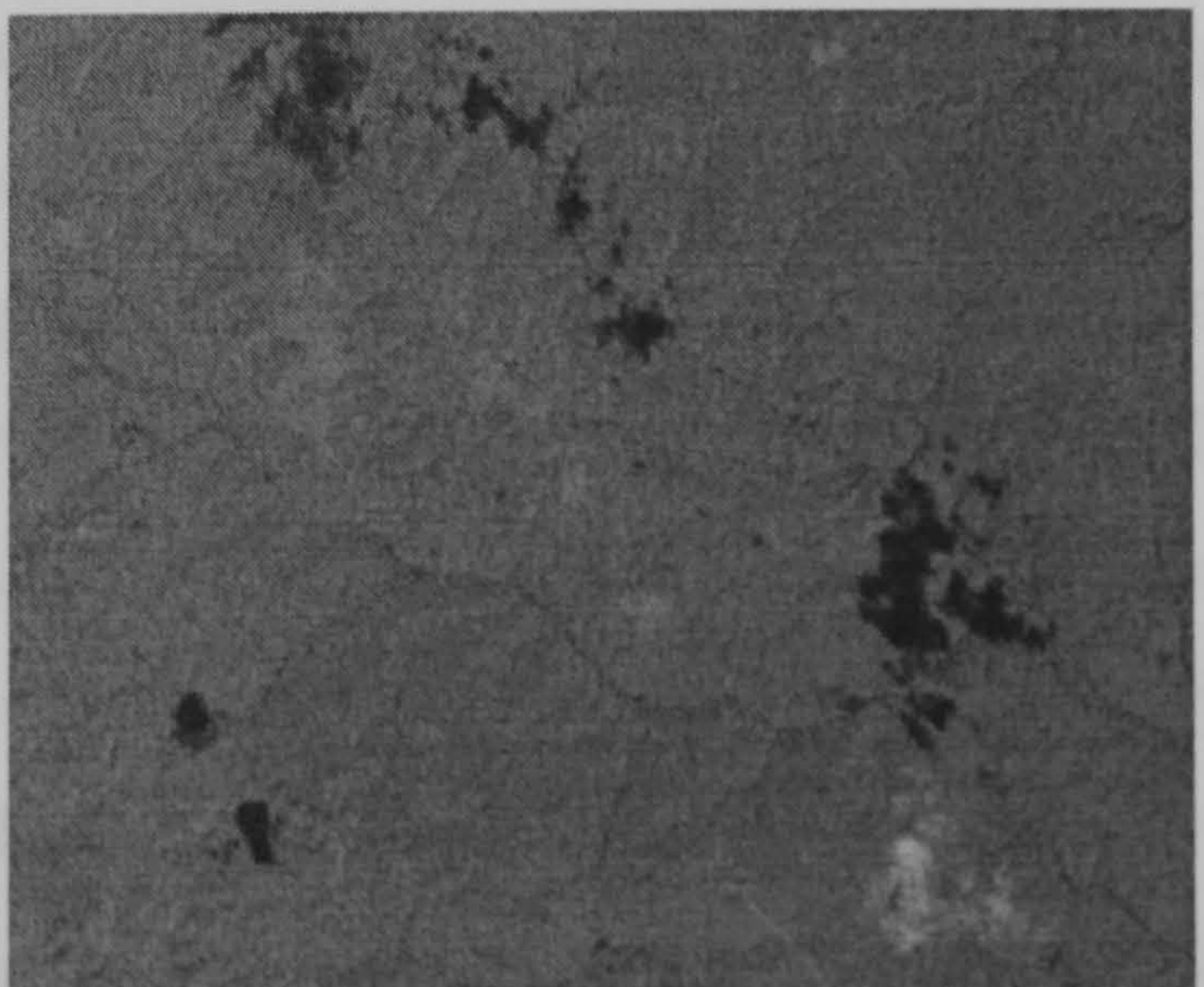


Figure 10-4: Part of scene 76/285 showing the cloud coverage.

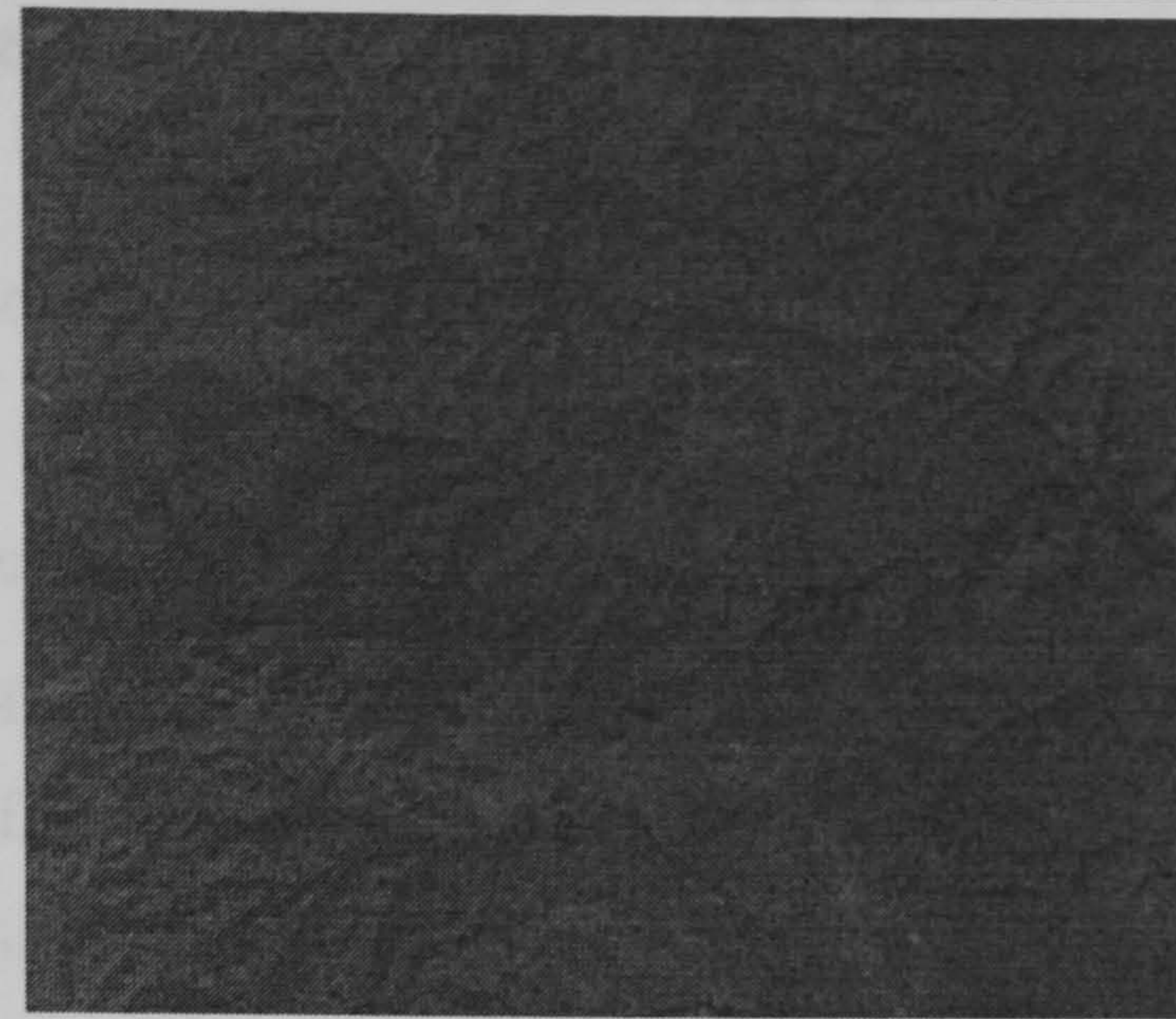


Figure 10-5: Part of scene 76/285 after the application of the cloud substitution procedure

10.4 Radiometric Enhancement

One of the good reasons for producing space image maps that they are graphic documents in which the background images provide a great deal of the required topographic information. However, in most cases, the raw data does not allow a clear distinction between different features due to the lack of contrast between them. Many space sensors and image display devices operate over a range of 256 (0 to 255) grey level values. However the raw data in a single image rarely extends over the whole of this range. Hence, the main goal of image enhancement is to improve its visual impact by increasing the contrast – which is the apparent distinction between the features in the image. Increasing the contrast of a scene, for example, may bring out specific differences in vegetation and soil types.

As Jensen (1986) reported, raw data brightness values in space images usually range between 10 to 50. Therefore, to produce a space image map of a good final legibility and appearance, image enhancement procedures must be applied, since they improve the appearance of the image and make it easier to analyze and interpret. On the SPOT Pan images used in the present work, the raw data brightness values (BVs) ranged approximately between 40 and 120 on an 8-bit grey value scale, i.e. they only occupied 80 of the available 256 BVs. So only a small part (roughly one-third) of the available range was actually being used. Therefore, a certain amount of enhancement was required. In this project, two image enhancement routines – contrast enhancement and edge enhancement – were used for the purpose.

10.4.1 Contrast Enhancement

The contrast enhancement operation can be executed using EASI/PACE, employing either the routines available within the Image Works module or those available within PACE. In fact, the Image Contrast Stretch (**STR**) program that is available within PACE has been used to generate a suitable Lookup Table (**LUT**) to perform the contrast stretching of the image data available in the database file. The setting of the appropriate factors in the LUT is made by the operator. The program will then physically pass all the image data through the Lookup Table (**LUT**) and write it back to disk. Of course, in the present work, this operation has had to be applied individually to each of the SPOT scenes that has been used in the production of the space image mosaic. The output was a contrast enhanced image of each individual scene that could be used further for mosaicing purposes.

10.4.2 Edge Enhancement

Edge enhancement is a filtering technique that is applied to emphasise the boundaries and edges of local features that are present in the images. In this project, a high pass Laplacian filter has been used to produce both a general emphasis of the linear features that are present in the landscape and to highlight those lines with specific directions.

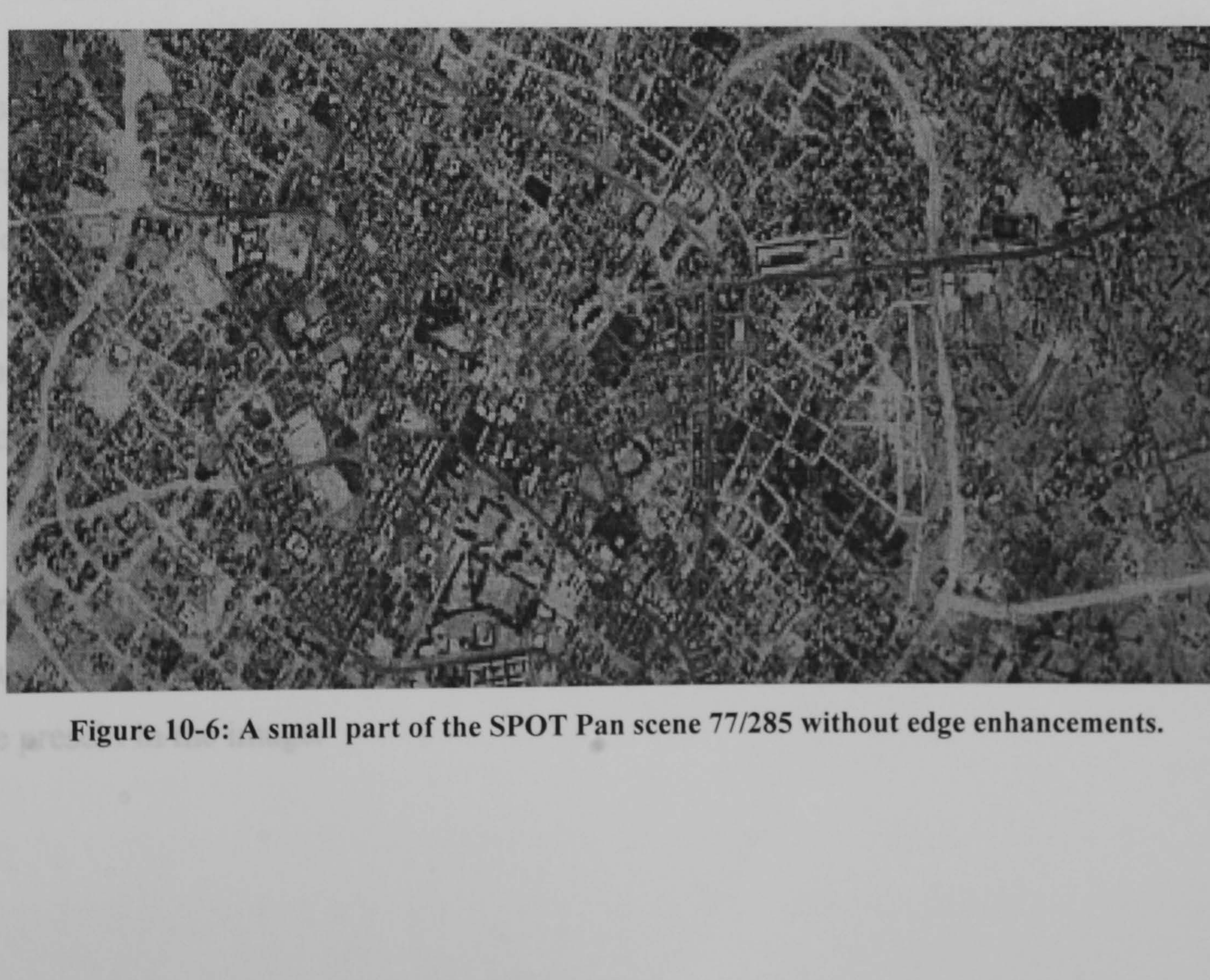


Figure 10-6: A small part of the SPOT Pan scene 77/285 without edge enhancements.

Figure 10-7: The same part of the SPOT Pan scene 77/285 with edge enhancements.

The **FSHARP** (sharpening filter) routine that is available among the PACE programs of the EASI/PACE package has been used for the edge enhancement procedure carried out on each of the SPOT Pan scenes. The program computes the result of processing the image using a high-pass differential edge detection filter and then adds this result back to the original image to produce the final edge enhanced image. Essentially this program uses a subtractive smoothing method to sharpen the image. First, an averaging filter was applied to the image. The averaged image retained all the low spatial frequency information but had its high frequency features (edges and lines) attenuated. Consequently, the averaged image was subtracted from its original so that only the high-frequency information was remaining. After the edges were determined in this manner, the difference image was added back to the original to produce the edge enhanced image. The resultant image then exhibited clearer high frequency detail. Figure 10-6 shows a small part of the original SPOT Pan scene 77/285 without edge enhancement, while Figure 10-7 illustrates the same part of the SPOT Pan scene after the application of the edge enhancement technique.

After applying the edge enhancement to each SPOT Pan image, the contrast stretch technique has also been applied. This was necessary since the spatial filtering decreased the grey level range present in the image.

10.5 Geometric Correction and Rectification

Raw digital images obtained from space sensors including SPOT cannot be used directly in a space image map, unless they are geometrically corrected and transformed to the ground co-ordinate system of a selected map projection. The aim of geometric correction is to correct and compensate for the inherent (systematic and non-systematic) geometric distortions and the displacements introduced to the image at the time of data acquisition. As stated by Sabins (1978), non-systematic distortions are caused by the instability of the satellite and therefore they are not constant and are not predictable. Whereas, systematic distortions are constant and can be predicted in advance – examples are scan skew, scanner distortion, and variations in scanner mirror velocity.

10.5.1 Correction of Geometric Distortions and Displacements

Two different stages can be identified in the correction of the geometric distortions and displacements that are present in the SPOT images.

(i) Geometric pre-processing deals with the correction of those systematic geometric distortions whose causes are known and can be modeled by suitable algorithms. These include the effects of Earth rotation, panoramic effects, the sampling delay, the scan skew, etc. Normally most of these defects have already been corrected optimally by the ground receiving stations.

(ii) On the other hand, geometric processing deals with the correction of the non-systematic geometric errors. These can only be corrected through the use of ground control points (GCPs). Examples of these include sensor system attitude changes (roll, pitch and yaw), altitude changes, overall tilt.

The purpose of applying geometric corrections is to compensate for all the distortions and displacements introduced by the above mentioned factors so that the corrected image will have, as far as possible, the geometric integrity of a map.

10.5.1.1 Rectification

This is the process by which the geometry of an image is made to correspond to that of the map. It will not, however, remove the topographic relief displacements that are present in the images. As described previously, it is the process of removing certain geometric displacements that are present in the image – in particular, those caused by the overall tilt and the changes in altitude and attitude occurring during the time of data acquisition. The procedures used to rectify these errors involve the use of GCPs. Based on the collected GCPs data, each SPOT Pan scene can be rectified and transformed into the desired map projection using 2-D polynomials. A resampling step is then followed to determine the brightness values at the intersection points of the transformed grid through an interpolation of the surrounding brightness values of the pixels in the original non-rectified image.

In the case of the present research work, since much of the test area is nearly flat, the relief displacements are very small and can be neglected. As mentioned previously in Section 9.3.2.1, four Level 1A and two Level 1B SPOT images (see Table 10-1) taken in panchromatic mode have been used for the current research work. In the case of SPOT Level 1A images, only the detector normalization is performed at the ground receiving station using a linear model that equalizes the differences in sensitivity between individual CCD detectors. This means that no geometric corrections have been applied. A SPOT Level 1B image also incorporates the radiometric corrections mentioned above for the Level 1A images, but, in addition, geometric corrections are applied which take into account the systematic distortions due to Earth rotation and curvature, sensor viewing angle and desmearing. Valadan Zoej and Petrie (1998) have given more details regarding the basic characteristics of SPOT Level 1A and Level 1B images and the methods that can be used for their rectification.

SPOT Pan Scene No.	76/285	77/285	78/285	76/286	77/286	78/286
Level	1A	1B	1B	1A	1A	1A
Viewing Angle	-21.8°	-13.0°	-10.4°	+25.1°	+22.0°	-10.4°

Table 10-1: Level 1A and 1B SPOT Scenes Used in the Research Project.

As can be seen from Table 10.1, none of the SPOT Level 1A and Level 1B images for the project area were truly vertical: all have been taken with substantial but different viewing angles. This resulted in the need to rectify the four Level 1A SPOT images and remove the tilt, since this type of SPOT image data has no correction for tilt, Earth rotation, etc. Whereas these matters had already been taken care of by the data supplier in the case of the two SPOT

Level 1B images. However, although each of the SPOT Level 1B images had been partially rectified at the ground station to remove the large tilt caused by the sensor viewing angle, it was still necessary to rectify these SPOT images using a two-dimensional polynomial transformation in combination with the known co-ordinates of GCPs to remove the small tilts caused by the changes in attitude of the spacecraft during the acquisition of these images.

As noted above, in order to carry out the rectification operation, a number of ground control points (GCPs) are required. These also provide a geodetic reference to the images. These GCPs are well-defined features with known positions, identifiable on the images as well as on the map. They are best obtained through geodetic measurements in the field or through extraction from existing large-scale topographic maps – if these maps are of sufficient accuracy. However, in this project, since no other source was available, the GCPs were scaled from the existing SDL topographic maps at 1:50,000 scale covering the project area. The author took a great deal of care to avoid errors in the identification of the GCPs and in the measurement of their co-ordinates on the map. The process comprised three steps as follows:

(i) *Selection and identification*: GCPs were selected that were well distributed over the area of each image. Others were located along the border of the area of the interest to avoid extrapolation during rectification. Most of the GCPs selected by the author were man-made features such as road intersections, highway crossings and well defined points located on bridges, dams, or buildings. The locations of the GCPs and check points were identified visually both on the map and on the image. Enlargements of the SPOT images (using zooming) on the monitor screen of the PC running the EASI/PACE system have been used to carry out the precise location and identification of the points on the image and to ensure the accuracy of the rectification. Also a number of additional points were selected and these have been used as check points to test and evaluate the results of the rectification operation.

(ii) *Measurement of the image co-ordinates of the selected ground control points (GCPs)*: This was done interactively using the facilities of the GCPWorks module of the EASI/PACE software.

(iii) *Measurement of the geodetic co-ordinates*: The features selected as GCPs were identified precisely on the topographic map, then their geodetic co-ordinates were extracted by precise cartometric measurements.

10.5.1.2 Two-Dimensional Polynomial Transformation

This type of transformation has been widely used for space image rectification. The method makes use of a general 2-D transformation function that establishes the relation between two plane co-ordinate systems – those of the SPOT image and the maps – using polynomials. With the assumption of small relief variations and consideration of the fact that these images were taken from an orbital altitude of 832km, the SPOT Pan images can readily be rectified and transformed and fitted into the desired map projection using a two-dimensional polynomial transformation in combination with the known co-ordinate values of the ground control points (GCPs). The procedure requires that the measured image co-ordinates be fitted to the known terrain co-ordinates of the GCPs. The coefficients of the polynomial transformation are then determined using a comparison between the measured image co-ordinates and the known ground control point co-ordinates. Normally, a least squares procedure will be used with the solution – since usually there are more GCPs available than are necessary to determine the transformation parameters contained in the polynomial equations. The option of choosing the order of the polynomials in a particular image transformation depends on the degree of accuracy, the number of GCPs needed to achieve this accuracy required, and the computational facilities available (El-Niweiri, 1988).

Obviously, the higher the order of the polynomial, the more GCPs and the greater the computer processing time required. The disadvantage of using polynomials is that the model from which the coefficients have been computed may fit well at the control points, but it may deviate strongly elswhere in the image due to the unpredictable effects of the higher order terms. The subject of polynomial transformation is well explained by Wong (1975), Konecny (1976), El-Niweiri (1988), and Petrie and El-Niweiri (1994).

In the current project, a third order polynomial function was used which takes the form of the following sets of simultaneous equations.

$$X_1 = a_0 + a_1x_1 + a_2y_1 + a_3x_1y_1 + a_4x_1^2 + a_5y_1^2 + a_6x_1^2y_1 + a_7x_1y_1^2 + a_8x_1^3 + a_9y_1^3$$

$$\vdots \qquad \vdots$$

$$X_n = a_0 + a_1x_n + a_2y_n + a_3x_ny_n + a_4x_n^2 + a_5y_n^2 + a_6x_n^2y_n + a_7x_ny_n^2 + a_8x_n^3 + a_9y_n^3$$

$$(10.1)$$

$$Y_1 = b_0 + b_1x_1 + b_2y_1 + b_3x_1y_1 + b_4x_1^2 + b_5y_1^2 + b_6x_1^2y_1 + b_7x_1y_1^2 + b_8x_1^3 + b_9y_1^3$$

$$\vdots \qquad \vdots$$

$$Y_n = b_0 + b_1x_n + b_2y_n + b_3x_ny_n + b_4x_n^2 + b_5y_n^2 + b_6x_n^2y_n + b_7x_ny_n^2 + b_8x_n^3 + b_9y_n^3$$

where

(X_n, Y_n) are the co-ordinates of the points taken from the map,

(x_n, y_n) are the co-ordinates of the corresponding points on the image,

(a_i, b_i) are the polynomial coefficients.

In this project, the method that has been used first treated each SPOT Pan image individually, i.e. the transformation parameters for each scene were determined separately in the first instance. Subsequently the transformed images were matched together to form the mosaic. From Table 10-1, it can be seen that a total of 159 control points has been used to rectify the six SPOT Pan scenes covering the project area – with 22 to 30 GCPs available for each image compared with the minimum of 10 points needed to compute the values of the coefficients in the third-order polynomial. A total of 113 additional check points (see Table 10-2) that were different to the control points have also been used to test and evaluate these results.

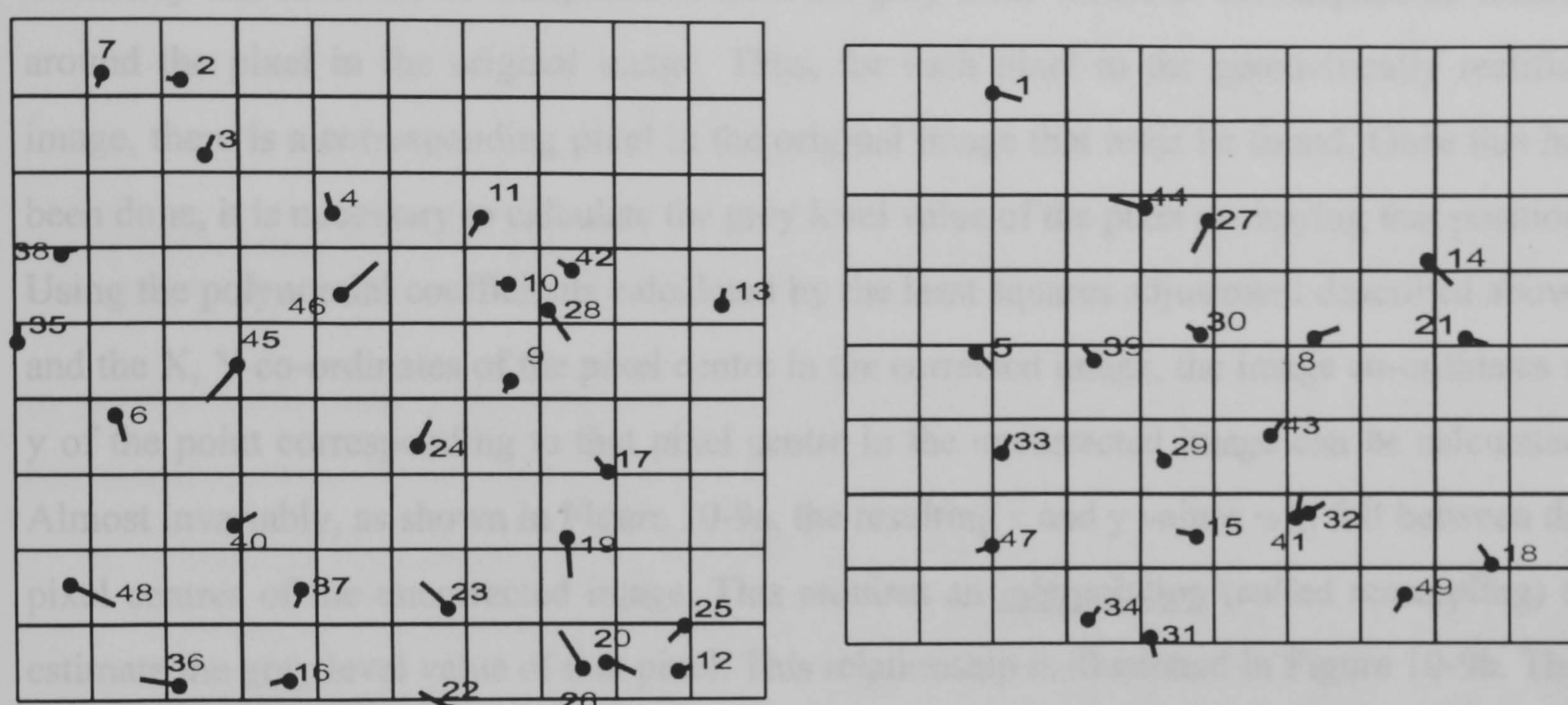
SPOT Pan Scene No.	76/285	77/285	78/285	76/286	77/286	78/286	Total
Number of Control Points	29	26	22	30	29	27	159
Number of Check Points	20	15	17	25	23	23	113

Table 10-2: The Number of Control and Check Points Collected in each SPOT Pan Scene.

This transformation and rectification procedure was carried out using the GCP Works module within the EASI/PACE software. After introducing the GCPs required for each SPOT Pan image, the program carried out the least squares adjustment and produced the values of the coefficients of the polynomial terms; the residual errors at each individual point; and the root mean square error (RMSE) of the residuals. For the six individual images, a range of RMSE values of between ±1.30 to ±1.43 pixel (±13.0 to ±14.3 m) has been obtained at the control points, see Table 10-3.

SPOT Pan Scene No.	76/285	77/285	78/285	76/286	77/286	78/286
Total RMSE at GCPs	±1.08	±1.14	±1.03	±1.10	±1.18	±1.10
Total RMSE at Check Points	±1.25	±1.08	±1.23	±1.13	±1.30	±1.25

Table 10-3: The Overall RMSE Values (in Pixels) for the GCPs and Check Points of the Six SPOT Pan Scenes.



GCPs **Check Points**

Figure 10-8: Vector plot of the X and Y errors at the control points and check points for the SPOT Pan scene 76/285. Green = Control Point ; Red = Check Point

It is significant that, for these six scenes, RMSE values of ±1.03 to ±1.30 pixel (±10.30 to ±13.00 m) for the independent check points have been obtained – see Table 10-3. The required planimetric accuracy of the well-defined features of topographic maps is ±0.3mm which equals ±15m at 1:50,000 scale. Thus the rectified images met this requirement.

The residual errors at each of the control points and check points have been plotted out in the form of a vector diagram for each individual image using a program **(VECTOR)** that has been written in the BASIC language by Mr. Shearer of the Department. The resulting vector plot gives an immediate graphical display of the error pattern either on the computer screen or in hard copy (paper) form. The plot of the errors as vectors gives an immediate view of the characteristics of the error pattern, i.e. whether it is systematic or random. As can be seen in Figure 10-8, the plot of the planimetric errors in the form of vectors at each control and check point in the SPOT Pan scene 76/285 shows that the residual errors were random in extent and direction and that the final results were not affected by systematic errors. Similar patterns were observed with the other scenes.

10.5.1.3 Resampling

The last phase of the procedure of geometric correction involves resampling where, for each pixel of the geometrically corrected image, there must be an associated grey level value. Generally this involves an interpolation from the grey level values of the neighbours located around the pixel in the original image. Thus, for each pixel in the geometrically rectified image, there is a corresponding pixel in the original image that must be found. Once this has been done, it is necessary to calculate the grey level value of the pixel occupying that position. Using the polynomial coefficients calculated by the least squares adjustment described above, and the X, Y co-ordinates of the pixel centre in the corrected image, the image co-ordinates x, y of the point corresponding to that pixel centre in the uncorrected image can be calculated. Almost invariably, as shown in Figure 10-9a, the resulting x and y values will fall between the pixel centres of the uncorrected image. This requires an interpolation (called resampling) to estimate the grey level value of that pixel. This relationship is illustrated in Figure 10-9b. This diagram shows the geometrically correct output matrix of cells (given by solid lines) superimposed over the original, distorted matrix of image pixels (given by dashed lines).

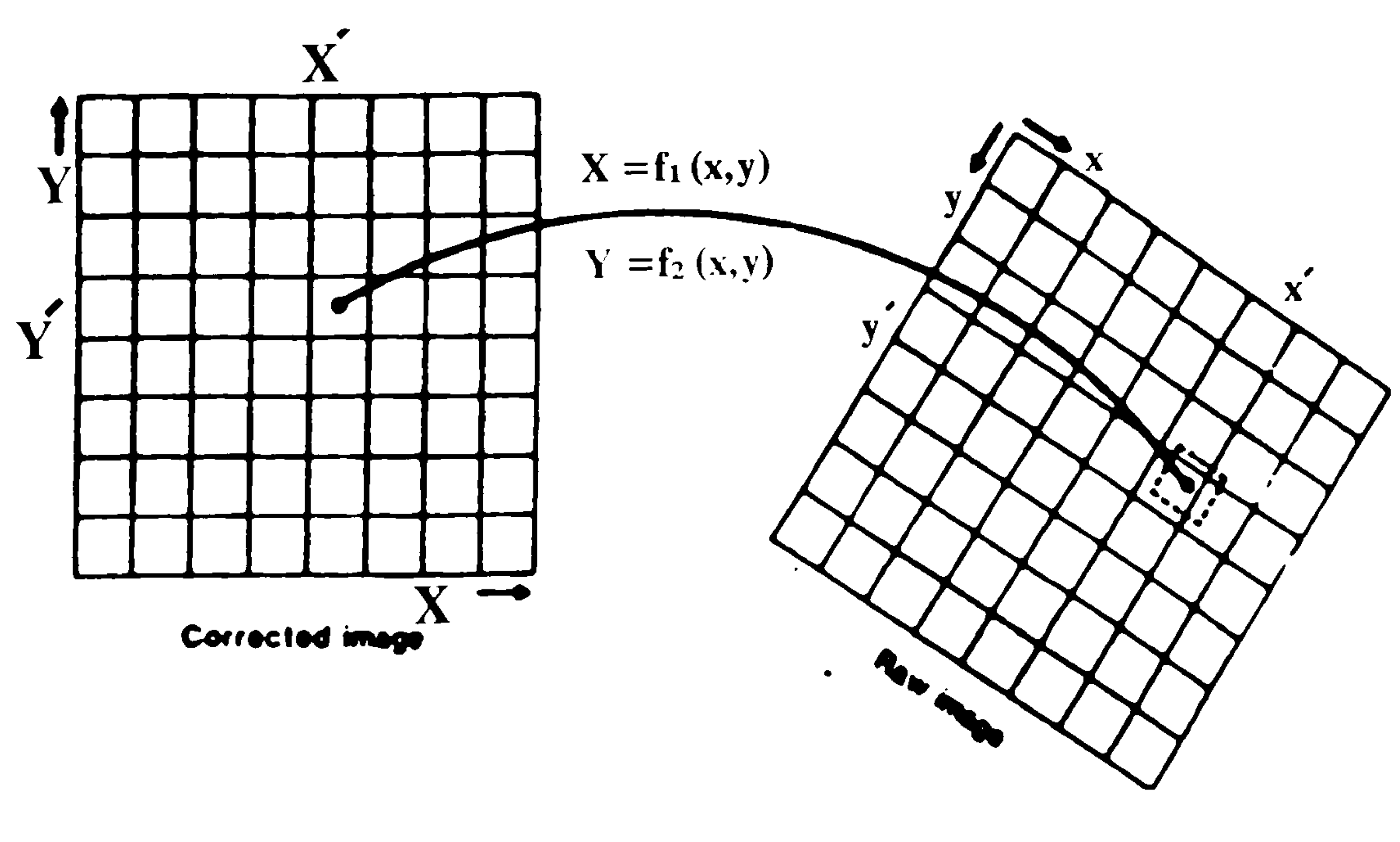


Figure 10-9a: Resampling the digital image

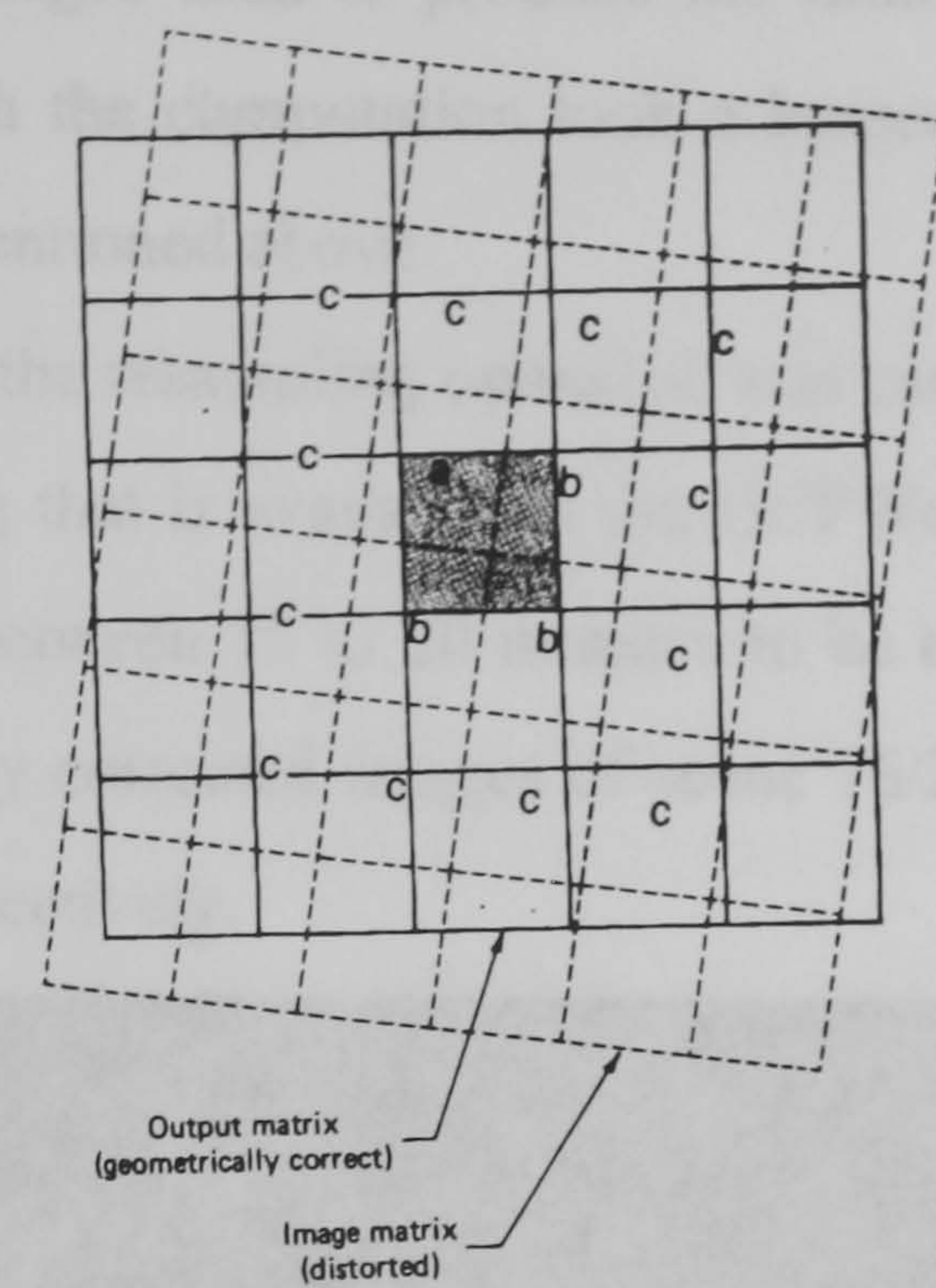


Figure 10-9b: The matrix of geometrically correct output pixels superimposed on the original matrix of (distorted) input pixels.

In practice, this resampling process is normally executed by one or other of the three commonly used methods – nearest neighbour, bi-linear interpolation or cubic convolution.

(i) Nearest neighbour resampling uses the grey level value of the closest input pixel as the output pixel value. The grey level value of whichever pixel has its centre nearest the calculated point in the image is used as the value in the rectified image. This is the simplest and fastest method and offers the advantage of retaining the original data. In other words, the output grey level values are the original grey level input values. The disadvantage of this algorithm is that the image that is produced has a quite rough and jagged appearance relative to the original uncorrected data.

(ii) The bi-linear interpolation technique calculates the distance-weighted average of the grey level values of the four nearest pixels in the uncorrected image. This algorithm generates an output image that has a smoother appearance, but obviously the time required for the computation is greater than that needed for the nearest neighbor method.

(iii) With the cubic convolution method of resampling, the new grey level value is computed taking into account the values contained in the 16 nearest pixels in the input image. The cubic convolution procedure uses the grey level values of the pixels in a 4 by 4 pixel window to calculate the output value using a cubic function. Cubic convolution is considered to be the best for image mapping purposes, since it smooths out the blocky pixel structure of the original data without an appreciable loss of form or contrast. For this reason, this method of resampling has been adopted and applied to those SPOT (Pan) images used to produce the final mosaic of the test area in this project – even though the computation took a longer time when compared with the other two methods mentioned above.

In the present research work, the resampling operation was carried out through the adoption of the cubic convolution routine that is available in the GCPWorks module of the EASI/PACE software. The process took between 15 to 20 minutes to be executed for a single scene. The uncorrected and geometrically corrected images of scene 76/285 are included as examples in Figures 10-10 and 10-11 respectively.

Figure 10-10: Uncorrected SPOT Pan image 76/285

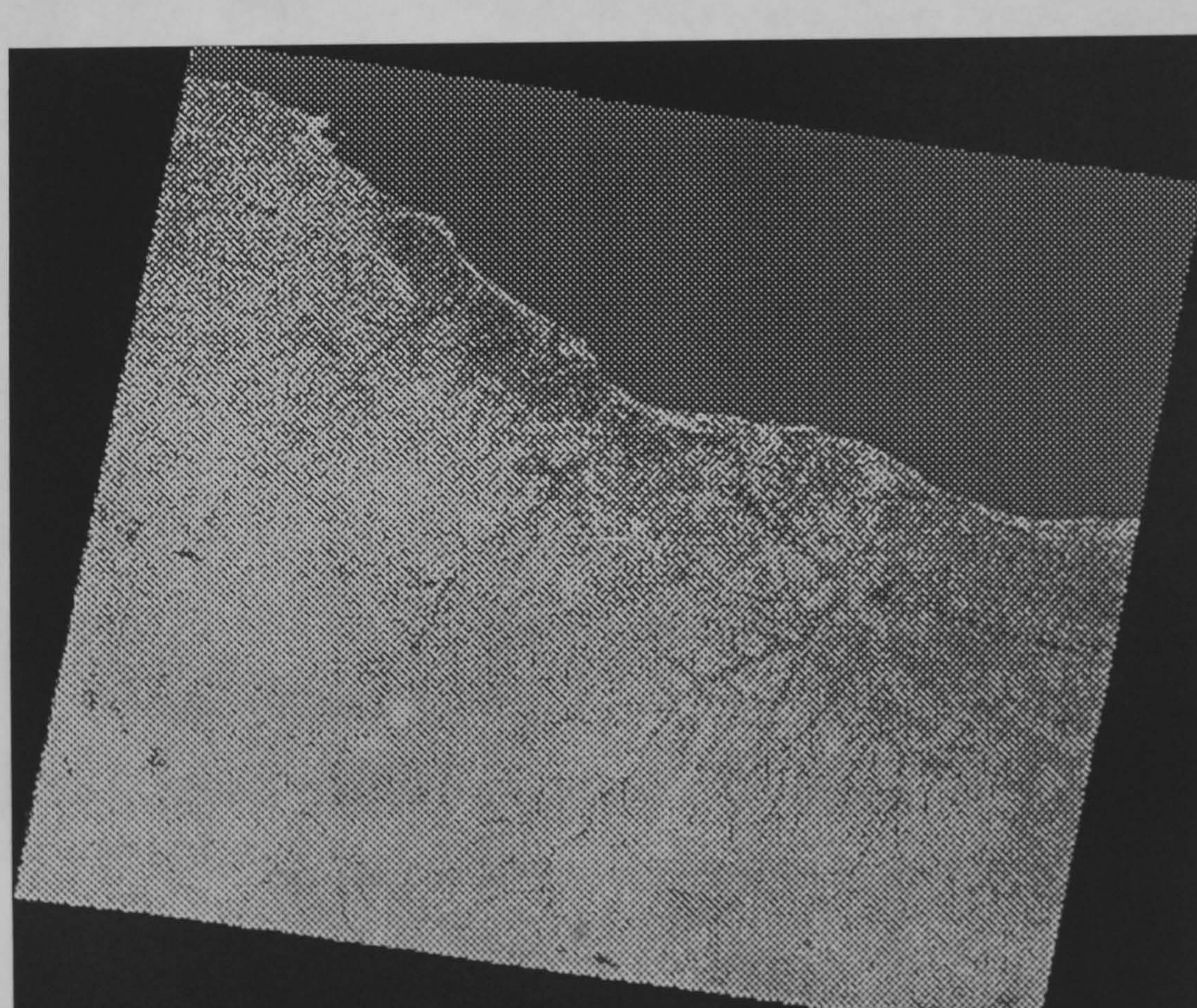


Figure 10-11: Geometrically corrected SPOT Pan image 76/285

10.6 Mosaicing

After the geometric correction of the individual SPOT scenes had been completed, the SPOT images were ready for digital mosaicing. This is an essential feature of space image map production, especially for one that is to be produced at 1:250,000 scale where several scenes have to be mosaiced together in order to fit the coverage requirements of a single map sheet. Furthermore this mosaicing must be carried out in such a way that any geometric and radiometric differences between the adjacent images should disappear. Using the mosaicing program available in the GCP Works module of EASI/PACE, one SPOT scene was considered to be the master image while the others were regarded as slaves that were to be fitted to this master. The first step was the determination of the cut lines defining the area of each individual image that was to be used in the mosaic. Using the interactive image display system, the join line in the overlapping area of the two images was defined by interactive pointing on the screen. Each new scene was then introduced one at a time as the slave to be fitted to the master.

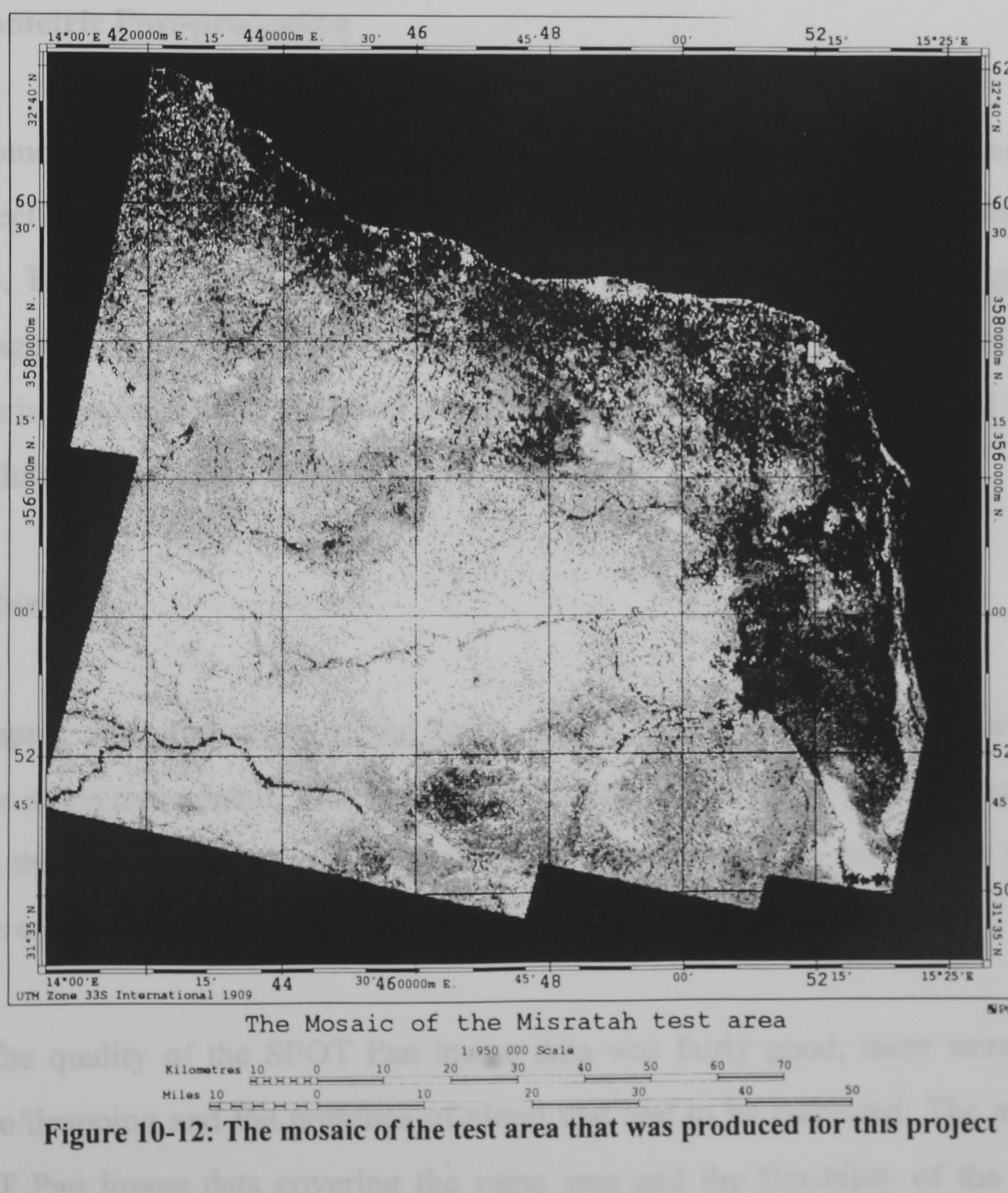


Figure 10-12: The mosaic of the test area that was produced for this project

For each scene, the image edge was smoothed digitally using histogram equalization. Before applying any final processing to produce the mosaic, an overall histogram matching technique needed to be applied. Applying this procedure, the data contained in each individual image was converted into a homogenous grey scale that was used for the whole of the mosaic. This mosaicing operation blended the several arbitrarily shaped images together to form a single large, radiometrically-balanced image mosaic so that the boundaries between the original images could not easily be seen. Feathering was also performed along the boundaries and overlaps between uncorrected images, making the seams virtually unnoticeable. Using the whole procedure of rectification and mosaicing, it took a very considerable time to achieve a satisfactory result that could act as the basis for the production of the experimental space image maps. As can be seen in Figure 10-12, the final result was a seamless, geo-coded SPOT Pan image mosaic of the project area ready for cartographic processing and image map production.

10.7 Radiometric Post-processing

Some radiometric enhancement techniques have also been applied after mosaicing the images of the project area in order to optimise the data for the specific purpose of producing a space image map. These included a linear contrast stretch and a brightness enhancement that made optimal usage of the 256 grey level values. This has been applied to the mosaic of the test area through the interactive use of the linear contrast enhancement routines contained in the Image Works module of EASI/PACE.

10.8 Conclusion

In this chapter, the production of the space image mosaic for the project area has been discussed in some more detail. This involved the extensive use of the digital image processing techniques that are available in the EASI/PACE software. These have been used for the radiometric enhancement, geometric correction and mosaicing of the images.

Although the quality of the SPOT Pan image data was fairly good, there were some flaws such as line dropping and the presence of cloud that had to be corrected. The availability of other SPOT Pan image data covering the same area and the flexibility of the EASI/PACE software helped to overcome the problems of cloud cover. Other radiometric enhancement techniques – such as contrast stretching and edge enhancement – have also been used extensively. They were of great help in producing better quality images that could be used for the production of the image mosaic of the project area.

One of the advantages of using the Misratah area is that the SPOT Pan images used in this project were not affected by relief displacements to any large extent, since the test area is relatively flat. Each of the six SPOT Pan images was rectified and transformed into the desired map projection using a 2-D polynomial transformation. In turn, all of these images have been mosaiced and the final product was a seamless homogeneous image mosaic of the Misratah area [Figure 10-12] that also met the accuracy criteria for 1:50,000 scale maps.

In Chapter 11, the planning of the content and the actual acquisition of the information required for the production of the image maps at 1:50,000 & 1:250,000 scales will be discussed in some detail.

CHAPTER 11: PLANNING OF THE CONTENT AND THE ACTUAL ACQUISITION OF THE INFORMATION REQUIRED FOR IMAGE MAPS AT 1:50,000 & 1:250,000 SCALES

11.1 Introduction

In the previous chapter, the radiometric, geometric and mosaicing steps that were needed to produce the background image mosaic of the project area have been described and discussed. In this chapter, the specifications for the content of the sample maps of Libya at the scales of 1:50,000 and 1:250,000 will first be established. Afterwards the image-interpretation and feature extraction carried out to obtain the required topographic information from the SPOT (Pan) satellite images using visual interpretation techniques will be described and explained. This has included a comparative test concerning the detail that can be extracted from SPOT images and aerial photographs of the same area. Finally, the additional information that needs to be added from external sources and the methods used to acquire these topographic details will also be described in some detail.

11.2 Map Content Specifications

General purpose image maps are designed to inform users about topographic features and their distribution in the area of interest. Indeed, map content is the very first factor that has to be considered in the image map design process, and it has to be established and defined before any interpretation or symbol design can take place. In this project, the first requirement was to establish the right relationship between the map content, the geographical area to be covered by the image map, and the scale and format of the map. As has been mentioned in Chapter 7, the definition of the map content is closely related to the purpose of the map and the user's requirements. It can be stated that an image map is constructed to meet either present or anticipated requirements: thus the map content should be strongly influenced by these needs. A full-scale survey of user requirements should be carried out. Unfortunately, in the case of the current project, this survey was not possible because of the cost, time and complication of the process. Instead, an alternative approach was adopted based solely on the author's past experience obtained during the period of his work at SDL.

In fact, the main users of the satellite image maps at 1:50.000 and 1:250.000 scales will be military personnel, geologists, geographers, surveyors, agriculturists. foresters, city planners. etc. The wishes of these different map users have then to be translated into the actual content to be included in the map and the technical specifications regarding the different features that make up the content. In practice, the nature of the image map will not allow the map maker to add too much information to satisfy the specific needs of each of these individual groups of map users; adding a great number of symbols, names, grids and contours would obscure the image and, as a result, the clarity of the map would suffer. Hence, a compromise must be reached regarding content. In fact, only the common basic requirements of the above mentioned map users can be met in order to design a general purpose image map that is satisfactory from a cartographic point of view and will still be acceptable to all the potential users.

11.2.1 Features to be Included in the Space Image Map

At this stage, those specific features that need to be included in the 1:50.000 and 1:250.000 scale maps must be defined and specified. In general terms, of course, the user requirements and the scale at which the map is going to be produced will control this task. In more particular terms, since, as noted previously, no full-scale survey of user requirements has been carried out, the selection and specification of the features to be included in the two experimental maps was based mainly on the author's background and experience. In fact, some further guidance as to the features that needed to be included in the experimental space image maps of Misratah area was gained:

i) from consulting the conventional topographic line maps at 1:50,000 scale which have been produced in 1979 by the Survey Department of Libya (SDL); and

ii) from the inspection of the space image maps at 1:50.000 and 1:250.000 scales among those reviewed and analyzed in Chapter 6, in particular, those space image maps that have been produced by the Technical University of Berlin (TUB) for arid and semi-arid areas.

Based on his own personal experience and all these very helpful ideas, the author made the appropriate compromises regarding content and defined a medium level or number of features. Afterwards these have been listed and placed into classes or categories (see Tables 11-1) for the 1:50,000 and 1:250,000 scale space image maps respectively. Only these listed features need to be found on the image. Thus to be sure that the interpreter does not waste time searching for features that are not to be portrayed on the map, he must be fully aware of the content specifications and the criteria for their inclusion in the map. These have been included in Table 11-1 and have formed the basis for the image interpretation and feature extraction that have been carried out using the SPOT image data.

For many users (e.g. military officers, geologists, etc.), contours are a completely necessary part of the map and must be included in 1:250,000 scale maps. Unfortunately, as can be seen from Table 11-1, contours have been omitted from the 1:250,000 scale maps, since the existing topographic maps at this scale were not available for this research project. Of course, these contour lines could have been obtained by digitising the 24 topographic map sheets at 1:50,000 scale that cover the whole of the test area. These contours could then have been merged together and reduced to 1:250,000 scale in order to be available for inclusion on the space image map of Libya at this scale. However, this solution has been avoided since there was no time available to undertake such a time-consuming operation. Only the contours of a single 1:50,000 scale sheet were digitized and included on the experimental image map of the Misratah area at that scale.

11.3 Image Interpretation and Feature Extraction

As described by Tait (1970) and by Essadiki (1987), image information can be classified under two main headings as follows:

i) Metric information that deals mainly with the exact location of an object, and the measurement of its linear dimensions (e.g. distances, angles, etc.).

ii) Attribute information, which relates to the nature of objects and their identification.

It is clear that the use of image interpretation techniques can help the cartographer to establish the nature of objects recorded on images, and can therefore be defined as the main process by which the attribute information required for the compilation of an image map may be extracted from space images. In practice, sometimes image interpretation may only help the identification of an object on the space image – in such cases, field completion may be needed to confirm this identification. Moreover, the space image does not contain all the attribute information needed for the compilation of an image map; e.g. names, boundaries and the exact nature of buildings are typical examples of attribute information that are not visible on a space image. Thus, although the space image is a vital source, it cannot be considered as the source of this kind of information – which will have to be acquired from another source.

Categories	Features	Identification Criteria & Characteristics
Boundaries	- International * - Provincial *	- Invisible linear features since they have no physical appearance on the ground.
Roads	- Highways *	- Linear features, dual carriageway roads surfaced with asphalt, up to 20m wide characterised by dark tonal appearance.
	- Main Paved Roads *	- Linear features of single carriageway roads surfaced with asphalt, from 8m to 12m wide and characterised by dark tonal appearance.
	- Secondary Paved Roads *	- Linear features of single carriageway roads surfaced with asphalt, from 4m to 6m wide.
	- Unpaved Roads *	- Linear features created by bulldozer or grader (unsurfaced) and characterised by very light tonal appearance.
	- Tracks *	- Narrow linear features created by repeated passage of vehicles over the ground, and characterised by very light tonal appearance.
Water Features	- Sea *	- Large size areal feature, located in the north, characterised by smooth texture and very dark tonal appearance.
	- Coastline *	- It is the borderline between land and sea.
	- Water Body *	- Irregular shaped medium or small areal feature characterised by smooth texture and very dark tonal appearance.
	- Wadis *	- Dry stream channels that form the natural drainage system (having a dendritic form) and vary greatly in form and size.
	- Spring *	- Very small point feature that can only be identified if its location is known; in such a case, local knowledge and experience is needed.
	- Well*	- Vertical shaft that appears as a circle on the ground surface and is very small in size.
	- Water Tower	- A circular or rectangular water tank built above the ground and small in size. Its shadow helps to identify it.
Cultural Features	- Town *	- Large areal feature with street patterns visible, often with a mottled grey tonal appearance, and associated with features such as buildings, roads, etc.
	- Small Town	- Appears the same as the town but smaller in size.
	- Main Village *	- Small size areal feature associated with houses, schools, roads and road intersections. Characterised by mottled grey tonal appearance.
	- Village *	- Small, mottled and grey tonal appearance, often comprising a number of isolated and scattered buildings which are quite small and not organised in a regular pattern.
	- Settlement *	- Smaller than a village with only very few buildings and usually located in the southern part of the area.
	- Isolated Building *	- Very small, rectangular or square in shape with a flat roof, appears as a white block.
	- School	- It can be identified having regard to its shape, size and location. Sometimes it can be recognised with the help of other features such as roads or tracks leading to it.
	- Mosque	- A religious building for Moslems identified by the design of the dome-shaped roof and its orientation towards Mecca instead of conforming to the local street pattern.

	- Church	- A religious building for Christians characterised by the V-shaped roof.
	- Cemetery *	- Areal features with smooth texture and light grey appearance. Surrounding buildings provide recognisable shape and pattern that can help to identify large cemeteries.
	- Shrine *	- A religious building with similar shape to that of mosque but smaller in size.
	- Airport, Airfield *	- The shape of its runway and other associated features such as buildings, aeroplanes and roads can identify it.
	- Bridge	- Shape, shadow and association with roads can help to identify bridges.
	- Dam	- Its shape, location and its association with watercourses identify it. The high reflection of the concrete appears in a light grey tone.
	-Dam with Road	- Wide linear feature that appears dark in the middle and with light grey outside where the concrete supports the road.
	- Quarry *	- Appears with mottled texture and light grey tone and can be identified by its location – if local knowledge and maps are available.
	- Ruins *	- Very small size historical buildings that can only be identified with the help of maps.
	- Monument	- Very small size cultural building that can only be identified with the help of maps.
	-TV Tower	- Very small in size; the shape, height and shadow can give a clue to its identification.
Vegetation Features	- Cultivated Area *	- Characterised by regularly shaped fields, some of these fields appear dark and some appear grey: it depends on the growing season and harvest stage.
	- Orchard *	- Areal features of uniformly spaced rows of trees that give the appearance of a grid-pattern characterised by grey tonal appearance.
	- Forest *	- In natural forest, trees are distributed randomly. Forest is often characterised by its mottled texture and dark tonal appearance.
	- Palm Tree	- Shape, row pattern, height and shadow can give clues to their identification.
	- Olive Tree	- Shape and row pattern is very helpful to identify olive tree areas.
	- Fallow Land	- Medium texture and grey tonal appearance due to the high reflectance of the soil.
Other Area Features [LandForms]	- Sabkhah *	- Smooth to medium texture with dark tone appearance. Its location near the coast helps its identification.
	- Hummock and Ridges *	- Their shape, location near the coast, rough texture and grey tonal appearance can identify them.
	- Sand Hummock with Low Growth *	- Characterised by rough texture and gray to medium dark tonal appearance.
Relief Features	- Contours - Spot Height *	- Invisible linear and point features since they have no physical appearance on the ground.

Table 11-1: Content specification of major topographic features (Misratah image maps at 1:50,000 and 1:250,000 scale). Only those features marked with asterisk (*) are included in the 1:250,000 scale map.

The main purpose of the image interpretation process is to obtain and extract the maximum possible information about those features that need to be included in the map. However, the amount of attribute information that can actually be extracted from an image depends upon three major interdependent factors – resolution, scale, and contrast. The ground resolution is one of the main limiting factors in detecting and identifying objects. Accordingly, any image product is limited by the spatial resolution of the sensor. In the case of this project work, the ground pixel size of the SPOT (Pan) imagery used is 10m: the ground resolution is more like 15 to 18m. The scale of the actual images (which is closely related to the ground resolution) is another limiting factor that determines the minimum size that is directly discernible and limits the amount of detail that may be recognised. The contrast of the object with its surroundings is also a limiting factor: to a considerable extent, it determines the effectiveness with which the various features that are present on the ground can be detected and identified.

According to Konecny et al (1982), in order to detect and identify topographic features for topographic mapping at 1:50,000 scale, a pixel size of at least 3 metres for monoscopic imaging or a pixel size of 6 metres for stereoscopic viewing is required for a single building to be discerned and mapped. However it is immediately obvious that the SPOT imagery does not have the ground resolution that would allow the detection and identification of such small objects. For example, an individual building may be a most important feature, especially in a remote or desert area. In which case, it is one of the most critical features in the identification process, yet frequently it cannot be seen on a SPOT image. In the case of the interpretation of other larger areal features, including cultivated areas or vegetation and forest, and large linear features such as roads or wadis, this pixel size requirement can be slightly relaxed – especially a strong contrast between the features and their background. Doyle (1984) also noted that the reliable identification of many cultural features, such as the roads, railways, and building that are usually displayed on maps at different scales, needs a ground resolution of 2 to 3 m/lp or better than 1 to 2 m/pixel. Obviously, if the sensor used for image mapping does not meet the resolution requirements (as is the case with the SPOT images of Misratah), many cultural features will not be adequately compiled or represented unless they are derived from field completion using ground survey methods or from other source material. In which case, problems can arise in incorporating this additional data and merging it in a satisfactory way with the space image data.

11.3.1 Visual Interpretation

Since automated feature extraction is only in its infancy and is not an operational technique, visual interpretation is the technique that has been used by the image-interpreter (in this case, the author), for extracting the required information from the SPOT imagery. An understanding of the image forming process and a knowledge of the different features likely to occur in the area are both necessary for extracting this information. Furthermore, the skill of extracting information from space images is something that is only developed through experience. Moreover, the interpreter has always to bear in mind that the use of collateral material (e.g. existing maps) and an appropriate field completion will be also needed to achieve a good result.

For the purpose of the feature extraction carried out during the current project, the SPOT panchromatic image background (mosaic) of the Misratah region was enlarged to appear on the screen of the monitor at 1:50,000 scale. As discussed above, the SPOT panchromatic image background could only be considered to a certain limited extent as the primary source for providing the information content and features that had to be extracted having regard to the scale of the desired satellite image map. Given the limitations of the 10m ground pixel size, feature identification was dependent to a large extent on the tonal differences and contrast between individual features and their background reflectance. The identification of features was also reliant on the author's knowledge of the area. In this particular case, this was at a good level of familiarity. The decisions about the objects to be detected and identified on the image were then made on the basis of the specified content of the 1:50,000 and 1:250,000 scale maps of Misratah as listed on Table 11-1.

The monoscopic SPOT (Pan) images (Figure 11-1) that have been used in this project are of a good quality in visual and radiometric terms. A detailed interpretation and feature extraction has been carried out visually by the author using the enlarged digital images displayed on the screen of the monitor and certain other additional sources – mainly the 1:50,000 scale topographic line maps and aerial photos at 1:40,000 scale of the test area.

Visual interpretation techniques have also been carried out using the stereo-pairs of aerial photos (Figure 11-2) at 1:40,000 scale taken over Misratah test area in 1989. This was done both to confirm the identity of some objects and to extract those missing features that could not be obtained from the SPOT Pan image. The other important reason for carrying out such an interpretation was to carry out some experimental tests comparing the amount of information content that could be extracted from the SPOT Pan image with the information that could be obtained from the aerial photographs of the same area.

For the Misratah test area, the occurrence of each type of feature on the SPOT Pan image was compared with its occurrence both on the 1:50,000 scale map (Figure 11-3) and on the contemporary aerial photos. Since these features can be point, line or area features, their occurrence was estimated as follows:

i) In the case of point features, the ratio of the number of features or objects occurring on the SPOT Pan image to the corresponding number that were present on the map and photographs provided a percentage figure that has been referred to in many places below.

ii) For linear features, the estimation of the percentage was carried out by comparing the length of the features in a particular class (e.g. main paved roads) digitized on the screen from the SPOT Pan image with the total length of the corresponding features derived from the map and the aerial photographs, again computing a percentage figure.

iii) With the areal features, an estimate was made of the percentage area digitized on the screen from the SPOT Pan image against the corresponding data derived from the map and aerial photos.

In fact, the main interest here lies in the amount of information that can be extracted from these SPOT images in comparison with that obtained from the aerial photos of the same terrain. The results of this work are discussed in the following sections.

Figure 11-1: A small part of the SPOT Pan Image at 1:50,000 scale taken over Misratah area.

Figure 11-2: An aerial photograph at 1:40,000 scale of the same area that has been covered by the small part of the SPOT Pan image in Figure 11-1.

Figure 11-3: The existing topographic map at 1:50,000 scale of the same area.

11.3.2 Results of the Interpretation of the Misratah SPOT (Pan) images.

As noted above, for the actual interpretation task. in order to identify a large number of the specified features that needed to be included in the experimental maps of Misratah area. the author has used visual interpretation techniques. The SPOT Pan scene has been displayed on the monitor screen of the author's PC using the Image Works module of the EASI/PACE software. The zooming and full resolution viewing facilities that are available within the Image Works module allowed the author to carry out the detailed visual interpretation of the images and to extract as many specific features as possible.

Many of linear, point and area features were detected and identified without any difficulties arising. The most difficult part of the image interpretation lay in recognising those objects that are unknown, obscured or are too small in size to be distinguished. For these reasons. additional collateral information had to be derived from aerial photographs and existing maps of the area to aid the identification of the features. Those features that could be detected and identified were then extracted using on-screen digitising for the production of image maps of the Misratah area at both the 1:250.000 and 1:50,000 scales.

As set out in Table 11-1. the features that have been listed for visual interpretation fell into six groups or categories. These are:

(i) roads;
(ii) water features;
(iii) cultural features;
(iv) vegetation features;
(v) other area features (land forms); and
(vi) relief features.

1) Roads:

In the Misratah project area. these features include highways. main paved roads. secondary paved roads. unpaved roads and tracks.

i) Highways: These are dual carriageway roads that are surfaced with asphalt and are up to 20 metres wide. They extend from the north-western part to the north-eastern corner of the test area. All of these roads were easily detected, identified and classified on the SPOT images. Compared to the existing 1:50,000 scale topographic maps and the 1:40,000 scale aerial photographs, overall 100% of these linear features were successfully detected, identified and interpreted on the SPOT Pan images.

ii) Main Paved Roads: Those are single carriageway roads that are also surfaced with asphalt and are 8m to 12m wide. These roads come second in their importance as communication lines. Again, overall 100% of these features were correctly detected, identified and interpreted on the SPOT Pan images.

iii) Secondary Paved Roads: These are single carriageway roads that are paved with asphalt and are 4m to 6m wide. In this project area, mostly they run parallel to cultivated areas or traverse such areas. Once again, they were easily located on the SPOT images and an overall 100% of these features could be detected, interpreted and identified.

iv) Unpaved Roads: These unpaved roads have been created deliberately by a bulldozer or grader. Because of their low contrast with their surroundings in some places, only an overall 70% of them were detected, interpreted and identified.

iv) Tracks: These features are very important in semi-arid regions; indeed sometimes they are the only means of communication. They are mostly located in the southern part of the test area. All of them are essentially unsurfaced tracks. A few have been scraped out from the underlying material, but mostly they have been created by the repeated passage of vehicles over the ground. Some of these tracks act as the boundaries between the different cultivated areas. Because of the high contrast existing between these cultivated areas, these particular tracks could be easily detected and identified. However, in the southern part of the image, according to the SDL topographic maps, there are many major or minor tracks that traverse the dry stream channels (wadis) and connect the scattered small villages. In fact, it was very difficult to detect these tracks on the SPOT images since they traverse the highly reflective sandy beds of the wadis. Therefore the contrast between these tracks and their surroundings was often negligible and indeed most of these features could not be found, even with the help of the SDL topographic maps.

v)

(2) Cultural Features:

This group of features includes built-up areas, smaller towns, main villages, villages, settlements, isolated buildings, quarries, ruins, cemeteries, shrines, airfields and airports.

i) Built-up areas: In the Misratah test area, the populated areas comprise three large towns (Misratah, Al-Khums, and Zliten) and a number of small towns, main villages, villages, and scattered settlements. These large towns contain residential, commercial, and industrial areas intermingled together. The buildings in the older parts of these towns are built from local earth, mud, and bricks, whereas the buildings in the newer parts are constructed from stone and concrete. The main densely built-up areas could be detected on the image, when using the digital image on the screen. This is due to the very different reflectance of these features with respect to their background. It is worth mentioning however that, having their positions shown on the existing topographic maps helped to a great extent in their location and identification.

Inspecting next the smaller-sized built-up areas such as the small towns, main villages and small villages that are present in the Misratah test area, it was obvious that the predominant material that has been used in the construction of the buildings is mud made from the local earth. The detection, identification and delineation of the small towns and main villages was easier than that required for the small villages. As the village size gets smaller, detection of the built-up areas and their limits becomes more and more difficult. Especially in the villages, many of these buildings are quite small in size and are not organised in a regular pattern; instead they often comprise a number of isolated and scattered buildings. In the southern part of the test area, which mostly comprises bare areas, the detection of the small villages proved to be impossible because of their lack of contrast with their surroundings and, to a certain extent, due to the small size and the irregular shapes of the buildings. Furthermore, none of the individual public buildings, including schools, mosques, churches, and factories could be identified.

ii) Quarries: In the project area, only six quarries were found in the north-western part of the area. Thus overall, 75% of the quarries in the area were detected and identified. Indeed the author's familiarity and detailed knowledge of the area were of great help in achieving such a high rate of success.

iii) Ruins: Lots of ruins are present in the Misratah test area, but, once again, they are quite small in size. These features are included in the map content specification, but they could not be detected on the SPOT (Pan) images.

iv) Airfields: Only one airport exists in the project area. This is the internal airport located at Misratah that is used for domestic flights only. However its runway is very long, wide and hard surfaced. This could be detected and identified easily on the imagery.

v) Cemeteries: In the Misratah area, only those large cemeteries that are surrounded by buildings to provide a recognisable shape and pattern could be detected. Even when this can be achieved, it was difficult to identify them without the aid of the existing maps. Detection or delineation of any other cemetery was impossible using the SPOT Pan images.

vi) Shrines: Since these religious shrines are associated with holy persons and people in the area visit them regularly, it is necessary to show them on the image maps of Libya. However, due to their small size and the character of the material used in their construction, there is no way to detect these shrines on the imagery. Their location must be provided from existing topographic maps or through field completion.

The other cultural features such as bridges, dams, water towers, etc. that will normally appear on topographic maps at 1:50,000 and 1:250,000 scale are too small to be detected on the SPOT imagery. Again their location needs to be derived from some other sources.

3) Water Features:

The water features that need to be included in the 1:50,000 and 1:250,000 space image maps of Libya comprise water bodies, wadis, wells and springs.

i) Water Bodies: The sea covers about 20% of the whole area. No other large water bodies are present in the test area. Instead some small seasonal water bodies are found in this area, but, due to their small size, they could not be seen on the SPOT images.

ii) Wadis: There are a great number of these dry stream channels in the Misratah area. They form the natural drainage system that takes the rainwater down to the sea. These wadis vary greatly in size and form, but their detection and identification were quite easy on the SPOT Pan imagery.

v) Wells and Springs: Many wells and a few springs exist in the test area. However they are very small in size and it was impossible for these features to be detected on the SPOT Pan images.

4) Vegetation:

Two types of vegetation (cultivated areas and forest) dominate the test area and must be shown on the 1:50,000 and 1:250,000 scale image maps of the project area. Obviously, from close examination of the SPOT (Pan) images, there is also a ground cover of natural vegetation with scattered low trees and bushes but it is one that is very hard to define and to represent. Again field completion is required to identify the nature of this ground cover and to find a way of establishing the limits of the vegetation.

i) Cultivated areas: There are many small areas of cultivated land and several agricultural projects with large regularly-shaped fields that are quite distinctive and easy to recognise. Most of the time, cultivated areas have a high contrast when seen against uncultivated land. In addition to the large geometrically shaped fields and agricultural projects, there are also some scattered small fields with irregular shapes that represent the old traditional ways of cultivation in the area. Mostly these small fields could be seen easily on the SPOT Pan images, though some could not.

ii) Forest: Both natural and planted forest areas are present in the test area and, mostly, they could easily be identified on the images. However, sometimes, it is difficult to identify forests, in which case, either other information sources or ground inspection are needed to differentiate them from other areas having a different vegetation cover.

5) **Other Area Features (Land Forms):**

These features include sabkhahs (salt marshes). hummocks and ridges. and sand hummocks with a low vegetation growth. They dominate a large part of the terrain and could be detected on the imagery. However either field completion or additional sources such as topographic maps and aerial photos are necessary in order to differentiate between these three different types of features.

6) **Relief Features:**

The test area is nearly flat and did not contain much in the way of special relief forms. However, on the 1:50,000 scale map on which the test area falls, the relief features were shown using contours and spot heights.

The results of the identification and feature extraction test of the SPOT (Pan) images over the Misratah test area are summarized in Table 11-2.

Category	Features	SPOT Pan	Air Photos
Roads	-Highways	100	100
	-Main Paved Roads	100	100
	-Secondary Paved Roads	100	100
	-Unpaved Roads	80	100
	-Tracks	60	100
Other Cultural Features	-Towns	90	100
	-Main Villages	70	100
	-Villages	50	100
	-Settlements	30	100
	-Isolated Buildings	20	100
	-Quarries	75	100
	-Ruins	20	70
	-Cemeteries	20	50
	-Shrines	0	70
	-Airports	100	100
Water Features	-Water Bodies	100	100
	-Wadis	80	100
	-Wells	0	0
	-Springs	0	100
Vegetation Features	-Cultivated Areas	90	100
	-Forest	100	100
	-Scattered Trees	40	50
Other Area Features (Land Forms)	-Sabkhahs	70	100
	-Hummocks and Ridges	70	100
	-Sand Hummocks with Low	70	100

Table 11-2: The Results of the Interpretation and Feature Extraction from the Misratah SPOT (Pan) Images and Aerial Photographs, Expressed as Percentages, in Comparison with the Data Shown on the Existing Topographic Maps.

11.3.3 Results of the Interpretation of the Misratah Aerial Photos at 1:40,000 scale

Since the use of medium-scale (1:40,000 scale) aerial photography taken with super-wide-angle cameras (e.g. the Wild RC-10 camera) is the method currently employed for the compilation of 1:50,000 scale topographic line mapping in Libya, interpretation from aerial photographs was carried out visually over the Misratah area for comparative purposes. It was also done to locate those unknown or missing features that could not be found on the SPOT Pan images. It was obvious immediately that the ground resolution of these aerial photos is very high – at 40 lp/mm, it is 1m (at 1:40,000 scale). This means that, in terms of ground resolution, the aerial photographs used in this interpretation are very much better than the SPOT Pan images.

As mentioned previously, for this project, stereo-pairs of aerial photographs at 1:40,000 scale taken in 1989 and covering the test area of Misratah have been made available by SDL. Hard copies printed on paper of these aerial photos were interpreted under a mirror stereoscope available in the Topographic Science Department at the University of Glasgow. Once again, visual interpretation techniques have been carried out to extract those specific features that are required for the experimental space image maps. In this case, the same groups of features that have been listed for interpretation from SPOT Pan images have also been extracted from the aerial photographs. The results were as follows:

(1) Roads:

This group or category includes features such as highways; main paved roads; secondary paved roads, unpaved roads and tracks. All of the highways, main paved roads, secondary paved roads and unpaved roads were easily identified to the 100% level in the 1:40,000 scale aerial photography. Tracks were quite numerous in the southern part of the test area. However, using the 1:40,000 scale photographs, again there was 100% completeness, though, in places, this was only achieved with some difficulty.

(2) Cultural Features:

Features falling under this category include areal features such as built-up areas and point features such as schools, mosques, churches, isolated buildings, etc.

(i) Built-up areas: In the Misratah area, the roofing material of 50% of the buildings is mostly high reflective concrete. Thus their location and distribution on the 1:40,000 scale photographs was easily identified since they appeared as small but prominent white blocks. However the building materials used in some parts of the towns and villages had less reflectance against the background soil or vegetation. But still all the buildings could be identified fairly clearly. Sometimes they could be identified with the help of other features such as the tracks leading to them, etc. However, with mosques and shrines, although the individual buildings can be easily identified because of their orientation towards Mecca instead of conforming to the local street pattern, it is very difficult to confirm whether a particular building is a mosque or shrine without local knowledge or the use of existing maps of the area. On the other hand, because of their shape, size and location, a large number of the schools in the area were identified on the photographs.

(ii) Quarries: All the quarries that exist in the area were identified; i.e. 100% identification was achieved on the photographs.

(iii) Cemeteries: They could be identified on the photographs only with the help of the existing maps of the area.

(iv) Airport and Airfields: The only airport present in the area was identified quite easily on the photos.

(vi) Other Small Cultural Features: These include bridges, roundabouts, dams, ruins, monuments and T.V. towers. About 85% of the bridges, roundabouts and dams were successfully identified on the aerial photographs. Whereas, it was quite difficult to locate and identify ruins, monuments or T.V. towers without consulting the maps.

(3) Water Features:

Most of the water features that are shown on the 1:50,000 scale topographic maps are seasonal. Apart from the sea, there are no large water bodies in the test area.

i) Water Bodies: These are quite small in size but still almost 100% of these features could be identified and correctly interpreted from the photographs.

ii) Wadis: All of these dry stream channels could be identified on the photographs.

iii) Wells and Springs: Although there are a large number of wells in the test area, it was not possible to identify any of them on the photographs. On the other hand, only a single spring is present in the area of Misratah. It is called *Ain Kaam* and is located in the east of Zliten city. Its water course helped the author to identify this spring on the aerial photographs.

(4) Vegetation:

As mentioned earlier, part of the vegetation comprises cultivated areas and forests. These features could be identified and their boundaries delineated correctly from the aerial photographs of the project area. This area has more farms and plantations than natural vegetation and forests. Where they existed, they could be identified quite clearly and their extent delineated with some confidence. However the areas of natural vegetation of small stunted trees and bushes were difficult to interpret and to delineate.

(5) Other Area Features (Land Forms):

Features such as sabkhahs (salt marshes), hummocks and ridges, and sand hummocks with low vegetation growth dominate the north-eastern part of the test area. These areal features could be identified on the aerial photographs, but still some field completion is needed in order to differentiate and delineate the boundaries between them.

(6) Relief Features:

Since the area is characterised by relatively flat terrain with a very small number of tiny sand dunes occurring in the northern part of the area, only contours and spot heights were specified to be included in the experimental maps to represent relief features.

The interpretation results from the 1:40,000 scale aerial photographs of the test area of Misratah are summarised in Table 11-2.

11.3.4 Overall Experience and Observations

From the interpretation of the SPOT Pan images, it seems that a considerable number of features can be detected and identified on the digital imagery. Thus, for example, information can be obtained about roads, water features and large built-up areas. For these feature classes, the overall amount of data that could be extracted was reasonably satisfactory. This resulted in part from the good quality of the digital images and also resulted from the fact that the interpreter was familiar with the project area. However another general observation may be made is that many point features such as individual buildings, wells, ruins, mosques, etc. are quite small in size and cannot be identified on the SPOT Pan imagery. Much difficulty was also experienced with smaller settlements and tracks and with the definition of the boundaries of distinctive types of landforms. Overall an estimated 70% of the features that need to be included in the 1:50,000 scale topographic maps can be obtained from SPOT Pan images. This means that quite extensive field completion is needed in order to derive the 30% of features that cannot be extracted directly from the SPOT Pan images.

The superiority of the interpretation using 1:40,000 scale aerial photographs in terms of their very high geometric resolution (1m) is immediately apparent to the user, even on an initial inspection of the photographs. This was confirmed by the very high percentage figures (see Table 11-2) that were achieved for almost all the specific feature classes that needed to be included in the experimental space image map at 1:50,000 scale. Of course, data compiled from aerial photographs will still require some field completion, since some of the smallest objects or features such as wells, bridges, footpaths, etc. could still not be detected and interpreted with any degree of confidence on the photos. Nevertheless, the amount of work involved in the subsequent field completion is quite small compared with that required with the SPOT Pan images. In addition, the whole operation of the interpretation using aerial photographs is much more comfortable for the eyes of the interpreter than that of interpreting SPOT Pan images. Besides which, the 3-D stereoscopic display of the aerial photographs under the mirror stereoscope allowed the interpreter to identify the features more easily and in more detail than those displayed in 2-D – which was the case with the SPOT Pan images

11.4 Interpretation Results of Other Comparable Tests

Similar tests comparing the information which can be extracted from SPOT images with that from small-scale aerial photographs have also been undertaken in Australia, Uganda, Zimbabwe and Tanzania.

(i) In Australia, as reported by Manning and Evans (1988), tests have been conducted using 26 stereo-models of aerial photography of a rural and mining area in central Queensland. These stereo-models were set up and measured on a digitized Kern PG-2 instrument interfaced to an Automap digital mapping system. The scale of the super-wide-angle photographs was 1:80,000, while that of the map was 1:50,000. Hard-copy SPOT Pan stereo-images at 1:400,000 scale with a base:height ratio of 0.8 were also measured in a Zeiss Oberkochen Planicomp C100 analytical plotter for the same area. In these tests, the two sets of data were then compared both with each other and with the existing maps of the test area. This comparison revealed that only 70% of the linear features and 36% of point features could be identified from the SPOT Pan images. While 90% of the linear features and 97% of the point features were identified on the aerial photographs. In this work, field checks were carried out to pick up missing features.

(ii) During his master's degree project at the University of Glasgow, Kajumbula (1992) of the Ugandan Department of Lands & Surveys carried out comparative tests of space images and 1:30,000 scale aerial photographs of the Mabira forest area. He found that the many communication and settlement features that were missing from the SPOT Pan images could, in fact, be extracted from the aerial photographs and plotted using conventional analogue stereo-plotters or digital monoplotting techniques.

(iii) For Zimbabwe, other similar comparative tests have been carried out by Buka (1992) at the University of Glasgow using SPOT Pan images and 1:65,000 scale aerial photographs. He concluded that the 1:65,000 scale aerial photographs are of much higher quality than any space images available at that time. In this case, the ground resolution of such photography is about 1.5m. This gave a decisive edge to the aerial photography as compared with the SPOT Pan imagery with its 10m pixel size. Another advantage is that the aerial photographs could readily be interpreted and plotted using the stereo-plotting facilities that were already available in the

Department of the Surveyor-General (DSG) and are very familiar to the existing staff. A similar situation exists in the SDL.

(iv) For Tanzania and the surrounding countries, an even more extensive series of tests comparing the information content that can be extracted from SPOT images with that from small-scale aerial photographs were also carried out in Glasgow by Liwa (1994). The areas in eastern Africa over which the tests were conducted included the Naivasha area and the area around the town of Thika in the Kakuzi Hills in Kenya. Two other areas (Korogwe and Kimara) in Tanzania were also included in the tests, as were those of Lusuka (Zambia) and Molepolole (Botswana). It was reported by Liwa (1994) and by Petrie and Liwa (1995) that SPOT Pan imagery can only supply the data for a preliminary or provisional edition at a 1:50,000 scale topographic map or for the rapid but incomplete revision of an existing map at that scale. They also stated that the present SPOT data is still substantially deficient in providing the information content needed to be included when producing a full or final edition of a new 1:50,000 scale map or for the comprehensive revision of an existing published map at that scale. These deficiencies are particularly apparent with regard to communication features and many of the smaller man-made cultural features that are present in the terrain of the test areas. To overcome these deficiencies, which amount to 30% of the total map content, an additional field completion is required. Of course, this will be both time consuming and an additional cost.

It will be seen that this experience has largely been repeated by the author in terms of the SPOT image data of the Misratah area. Thus many of the important topographic details that are usually shown on topographic maps at 1:250,000 and 1:50,000 scales could not be detected nor identified on the SPOT (Pan) images of the Misratah area. As has been discussed, this is due to the lack of resolution and contrast in the images. However these features still have to be shown on the image map if this new product is to be acceptable to the users. Besides which, during the interpretation of the satellite images, the author experienced several other difficulties recognising different features. For example, sometimes two completely different features display the same tone in the satellite images, e.g. rocky outcrops and small vegetated or cultivated areas, which causes further difficulties in interpretation. It was also difficult sometimes to differentiate between elevated land and a wadi. Obviously, successful interpretation would be impossible to accomplish without additional collateral information.

The additional important information that must be provided to the image map by external sources generally falls into one or other of three categories:

i) Information that cannot be recorded on the imagery such as names, contours, boundaries, etc.;

ii) Information that is only partially visible in the imagery such as roads;

iii) Locational information and features such as small villages, cemeteries, quarries, wells, water towers or any other small cultural features that are not resolvable on the SPOT imagery.

11.5 Checking and Field Completion Procedures

Field completion procedures are needed in all kinds of topographic mapping, especially concerning cultural features that usually change much faster than the other features comprising the map content. However the nature of the ground cover (especially agricultural areas and some vegetation types) may change quite rapidly too. Unfortunately, due to several problems and difficulties, this field completion could not be carried out in this project work, but still it is important to plan for this, if a new national space image map series is to be implemented for Libya.

11.6 External Sources for Additional Information

As will have been apparent from all the discussion conducted above, for the author's research project, the additional information that could not be obtained directly from SPOT (Pan) imagery was derived both from the aerial photographs at 1:40,000 scale and from the existing conventional topographic line maps of the test area of Misratah at 1:50,000 scale. The most recent aerial photography available for the Misratah region was flown in 1989 at nominal scale of 1:40,000. These aerial photographs have been used both to compile additional information and to confirm the identity of some other features that could be seen on the SPOT imagery.

Besides providing data on the positions of some of those villages that were too small to be identified on the SPOT imagery, the existing topographic maps at 1:50,000 scale have been also used to provide specific information such as grids, contours, symbols and names, which obviously could not be provided either by the SPOT panchromatic imagery or the aerial photographs. In addition, the fact that the author is originally from the area and was familiar with it was of great help during the image map compilation stage.

11.6.1 The Methods Used to Acquire Additional Information

Three methods were mainly used to acquire the additional data from the other sources of information mentioned above. These methods can be outlined as follows:

1- Visual Interpretation: This was the method adopted to collect and confirm the identity of those features that had been detected on the satellite images but could not be identified. As discussed above, in order to carry out this identification, the interpretation of the relevant stereoscopic aerial photography of the areas has been carried out by the author. Indeed, the three-dimensional viewing using the mirror stereoscopes available in the Department, helped greatly in defining and recognising those undefined features of the images. For example, small villages, quarries, cemeteries, etc. have all been detected, identified and marked on an overlay using this method.

2-Conventional Analogue Approach: The basic topographic information needed from the existing maps for the space image maps was compiled using a conventional analogue approach. This procedure provided a number of the point, linear features, and names needed for the image maps. In particular, the procedure was used for the locations of point features such as wells, spot heights, etc. for the Misratah satellite image map at 1:250,000 scale. First the point features that were needed have been located on the existing maps. Then the planimetric co-ordinates (x, y) of these point features were obtained by scaling them precisely off the 1:50,000 scale topographic maps available for the test area. In fact, this method is tedious and time consuming but produced good results. Names were also collected from maps and placed in the correct location by relative positioning on the image.

3- Digitization of Features: Some of this basic information being taken from the existing maps was then digitized by means of vector digitizing with the specific purpose of picking up the alignment of linear features and the location of point features. This method was used particularly for the collection of linear features such as contours and roads from the existing topographic maps at 1:50,000 scale. For this purpose, the

MAPDATA software package and Calcomp 9100 digitizing table that are available in the Department have been used to acquire these features. The locations of some point features such as wells, spot heights, etc. have also been digitized from the existing maps of the test area. This method has only been used for collecting data for the satellite image map of Misratah at 1:50,000 scale. In this way, the digitized topographic data was made available for cartographic processing.

11.7 Conclusion

In the author's opinion, the major question after all these interpretation tests and the compilation that has been carried out by the author (and by others elsewhere) must be – can SPOT Pan imagery be used for topographic map production in Libya? The answer to this cannot be straightforward, since SPOT image data has limited ground resolution for detecting and identifying small man-made features (such as buildings, wells, ruins, tracks, etc.) that must be included in topographic maps at 1:50,000 scale. Looking back to the analysis that has been carried out and the results that have been presented in this chapter – but also taking into consideration what other people have concluded in the same context regarding the amount of detail and the extent of the map content that can be obtained from SPOT images – much more can be said about this important matter.

In fact, for any space imagery to be considered sufficient for full topographic map production, then it must be able to provide at least 90% of all the features that are required to be shown on the map at any scale. The results of the interpretation tests that have been reported in this chapter have shown that SPOT Pan images can provide only 70% of the features that need to be included in topographic mapping at 1:50,000 scale. Thus the results of these interpretation tests, supplemented by the results obtained from other similar tests and production experience in Africa, show that the present SPOT imagery is substantially deficient in providing the information content needed for the production of a new 1:50,000 scale map. The SPOT deficiencies obvious when it comes to both the communication features and many of smaller man-made cultural features present in the terrain. To derive the missing 30% of the total map content, an additional comprehensive field completion is necessary – which of course, will require substantial effort, time and cost to undertake and complete. Moreover, without this field checking on the ground, there is a risk that the final product will be substantially incomplete and may then be mistrusted or even abandoned by the users.

The results of all the tests could lead to the conclusion that it does not seem a very good idea to use SPOT Pan images for the production of space image maps of Libya when so much field completion is needed, particularly in developed areas. Whereas, in other areas (such as rural areas), it could still be suitable to use the SPOT imagery. This then brings up the matter of the possibilities of using other higher resolution space imagery such as that being acquired from the IRS-1C and 1D sensors, and also that from the forthcoming American high-resolution space imagery. With the IRS-1C and 1D imagery, although the ground resolution is much better (6m ground pixel size v. the ground pixel size of 10m for the SPOT), the radiometric resolution of 6-bits (64 grey levels) is inferior to that of SPOT which gives 8-bit images providing 256 grey levels. Obviously further interpretation tests with IRS-1C and 1D imagery of Libyan areas are needed to establish its suitability to act as the basis of a space image map series for Libya. The author has already taken steps to acquire IRS-1C imagery of the Misratah area from Space Imaging Europe with a view to carrying out the necessary tests.

From Table 11-2, the clear difference in information content between SPOT Pan images and the 1:40,000 scale aerial photographs can be seen. With the aerial photos, much better interpretation results have been obtained than from SPOT Pan images. In fact, 1m is a quite realistic and appropriate ground resolution value for topographic mapping at 1:50,000 scale. Moreover, past experiences have shown that 1:40,000 to 1:50,000 scale aerial photography is indeed optimised for the work of compilation and revision of 1:50,000 scale topographic mapping.

However, although the SPOT image data is still substantially deficient in the details required for a full production of a topographic map at 1:50,000 scale, when compared to aerial photographs, they do have the advantage of cost, speed and availability. Certainly the last point – that of availability – has been paramount in the context of the author's research project. Furthermore the deficiencies of the imagery have been overcome through the use of the data from the aerial photographs and existing maps. Thus using the SPOT imagery for the present research into the cartographic design aspects of space image maps will still be valid.

In the next Chapter, the planning of the graphic representation and symbol design aspects of the Misratah space image maps at 1:50,000 and 1:250,000 scales – will be discussed and evaluated.

CARTOGRAPHIC DESIGN ASPECTS OF MEDIUM- AND SMALL-SCALE SPACE IMAGE MAPS – WITH SPECIFIC REFERENCE TO LIBYA

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CHAPTER 12: THE RESULTS OF THE SYMBOL DESIGN EXPERIMENTS OF THE MISRATAH SPACE IMAGE MAPS AT 1:50,000 & 1:250,000 SCALES

12.1 Introduction

In Chapter 11 , the planning of the content and the actual acquisition of the information required for image maps at 1:50,000 and 1:250,000 scales has been discussed. In any mapping project, once the features that need to be shown on a map have been collected and properly placed in classes or categories, the next step is their graphic representation - a stage usually referred to as symbol design. This is a very important stage in the map design, in which the different point, line and area symbols that are used need to be clearly distinguished from each other. This is achieved by utilizing the graphic variables (of form, dimension and colour) of the point, line and area symbols used to represent the different map features.

In image mapping, the basic symbol design may follow similar principles to those used in conventional line maps. However, the white space that is available on conventional maps is absent; instead, the whole map area has to be printed with the space image as a background. In fact, problems may arise from this situation. In particular, the background image must have sufficient contrast within itself to allow the detail that it contains to be clearly discerned – while, at the same time, any superimposed symbols must display sufficient contrast to stand out clearly against this background. This means that the problem of symbol design in image mapping can be very difficult to solve. In a sense, the cartographer has to attempt to combine two quite different levels of information - the realistic or "natural" image of the terrain, with the abstract conventional symbols that must be superimposed on top of it. In such a situation, the cartographer may not have too much freedom in the map design, and he is faced with many complicated problems the moment he starts to combine these entirely different forms of representation.

The terrain conditions or characteristics, the scale of mapping, and the time and financial resources available for the mapping, also influence the design of symbols. The map purpose and the map content specification will also influence the design, both in the treatment of the space image through digital image processing techniques, and in the addition of symbolised detail.

In the author's opinion, in order to reach the optimum symbol design and to test the integration of the symbol with the background image, various design alternatives - with variations in the form, dimension and colour - for each symbol should first be produced. In other words, a systematic approach should be taken with regard to the design of the symbols. In this chapter, all the considerations regarding the graphic representation and the design of the symbols used in the Misratah space image maps at 1:50,000 and 1:250,000 scales will be treated and discussed in some detail.

12.2 Graphic Representation

The three classes of symbols – point, line, and area – "provide the basis of representation and, in turn, these symbols have to be given a specific form, dimension and colour in the map design" (Keates, 1989).

(i) The form of a symbol refers essentially to its shape or its external contour;

(ii) the dimension concerns the overall size and the detailed measurements of the symbol such as the line width or the size (height and width) of certain elements of the symbol;

(iii) while colour can be defined in terms of three variables (hue, lightness, and saturation).

All of these must be carefully specified. The graphic or visual variables (form, dimension and colour) of any symbol in a map must be adjusted according to the information available and the significance of each class of feature in order to make the required differentiation between the different elements or features within the class. A still more detailed analysis of symbol design was given by Bertin (1981). In the view of Bos (1984), "Bertin deserves credit for his input to symbol design of a more fundamental basis for symbols, the visual variables" (Bos, 1984). The seven visual variables defined by Bertin - which are position, form, orientation, colour, texture, value and size - are shown in Figure 12-1.

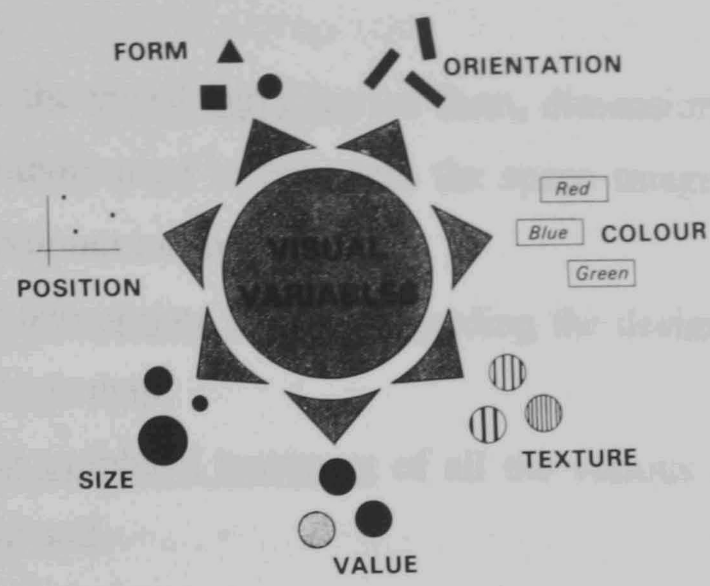


Figure 12-1: Bertin's System of Visual Variables (Bos, 1984)

Keates (1989), Dent (1990), and Robinson et al (1995) have described these visual variables in more detail.

12.3 The Actual Symbol Design Adopted in the Project

By now, the content of each of the two space image maps of the Misratah area (at 1:50,000 and 1:250,000 scales) respectively had been acquired, edited and properly placed into categories and classes. The author's task as a cartographer was then to convey this information to the map users through the use of suitable symbols. The utilization of symbols is essential in order to express the reality of the specified features or objects on the ground and to add value in an abstract way to the details that are visible on the image map. In which case, each different element of geographic information becomes a point, a line or an area that is characterised by a symbol having a certain form, dimension and colour. In any map project, since the design of each individual symbol is significant and plays a vital role in the overall design of the final map product, it must be handled with a great deal of care. A full knowledge and understanding of the cartographic design process is needed. Moreover, the designer must be familiar with the technical production methods available to produce the final map.

12.3.1 Systematic Approach

For the cartographic design of the prototypes of the proposed new space image map series, the author followed what he considers to be a systematic approach to the design of the symbols of the different individual point, line and area features contained in the maps. In particular, this approach has been adopted for the following reasons:

1) to guarantee that the different symbols of the image map are clearly distinguishable from one another;
2) to make sure that the visual variables (of form, dimension and colour) of the point, line and area symbols used to represent the space image map features have been utilized to the maximum extent possible;
3) to reach the most appropriate solution regarding the design of the different symbols required on the image map;
4) to ensure a proper graphical treatment of all the various aspects involved in space image map design; and
5) to achieve a high degree of unity or integration between the two levels of information – i.e. the natural space image and the additional cartographic symbolisation.

Furthermore, the adoption of this systematic approach has allowed the author to understand the problem of designing each map and then to tackle it with a good deal of confidence and creativity. In order to reach the optimum symbol design and to test the integration of the symbol with the background image, alternative versions of the graphic symbols were created through variations in their form, dimension and colour. Before starting the design experiments, it was very helpful that the author had consulted and analyzed a great number of existing image and topographic line maps at 1:50,000 scale to be familiar with their symbol design and specifications.

12.3.1.1 Use of Space Image Background

Initially, the author designed a number of different graphical forms for each individual symbol that could be superimposed on top of the space image. For these initial experiments in symbol design, representative small portions of the black and white space images were used as background. In this way, alternative designs - with variations in the form, dimension and colour - have been produced in this research project for each individual symbol. During these experiments, each category or group of features having certain characteristics in common (e.g. roads) were superimposed together on these small portions of the space image. The various alternatives in terms of their form, dimension and colour have then been tested visually against the background space image and evaluated. Modifications were then made until a good symbol design has been found. However, the evaluation of the symbol design at this stage has been carried out solely by the author and has depended on his cartographic education, skills and practical experience. The reasons behind this were:

- The design of symbols is a very technical matter and cannot be carried out by the users who may not have a sufficient cartographic knowledge and experience to be able to contribute to the design process.
- The time needed to run a great number of evaluation tests was not available.

In this project, the symbol design experiments have been carried out twice - once to select the most appropriate design for the symbols required to produce the space image map at 1:50,000 scale, and then a second time for the 1:250,000 scale map symbols. As noted above, those symbols having certain characteristics in common and having been placed in a particular group of features have been tested individually. This meant that the design of these symbols at this initial stage was not final and changes might take place later when all the symbols of each experimental space image map (at 1:50,000 or 1:250,000 scale) were integrated together to produce the whole map sheet.

12.3.2 The Experiments and Evaluation of the 1:50,000 Scale Image Map Symbols

The main considerations regarding symbol design and the actual experiments carried out with each class of feature are described below.

12.3.2.1 Roads

In the Libyan context, roads may be classified according to their significance in terms of their actual use; their width and the number of available lanes; and the surface material used. On this basis, they will comprise (i) highways; (ii) main paved (surfaced) roads; (iii) secondary paved roads; (iv) unpaved (i.e. unsurfaced) roads and (v) tracks. Highways are dual carriageway roads that are up to 20m wide, surfaced with asphalt and with their individual carriageways separated by physical divisions. Main paved roads are single carriageway roads that range from 8 to 12m in width and are surfaced with asphalt. Secondary paved roads are similar to the main paved roads in terms of the surface material and in having single carriageways. However, they differ in their width since secondary paved roads are those from 4 to 6m wide. On the other hand, unpaved roads are unsurfaced roads that have been created by a bulldozer or a grader and usually are located in rural areas. Whereas tracks are narrow linear features, that have usually been created through the repeated passage of vehicles over the ground – rather than being deliberately built for traffic. They lie mostly in areas outside the more populated and more developed areas where they can be considered the main lines of communication. With this background regarding the classification of the Libyan road system in mind, the author designed the road symbols using various alternatives - which vary in form, dimension and colour. Afterwards these alternative line symbols have been tested visually against the space image background in an attempt to reach the most appropriate design for each individual class of roads.

(i) Form

Generally speaking, the form of the line symbols used to show roads on maps has most to do with their real shape and with their classification. This means that, in practice, variations in the form of the lines should help map users to differentiate any one class of roads from the others. As can be seen in Figures 12-2a; -2b and -2c and Table 12-1, the line symbols have mainly been designed using single, double and triple lines with two main variations in line continuity – continuous lines and simple interrupted lines. The trials of each of these symbols have been carried out against the background image of an urban area, since this represents a more difficult situation than using a rather featureless open area.

In these experiments, the continuous lines stood out better against the background image than the interrupted lines. Since the use of a casing with road symbols appears to be common in mapping, all three types of surfaced road display such a characteristic. Furthermore, the use of single and multiple lines proved to be more useful for showing the real shape of the road. For example, highways have been made more distinguishable and more realistic by having the centreline incorporated as well as double road casings (triple continuous lines). Although main paved and secondary paved roads vary in size and importance, continuous double lines have been used to depict both types of road. Of course, further variations in their dimension and colour were then necessary in order to differentiate between these different classes. By contrast, single lines were more suitable for unsurfaced roads. In fact, the use of single continuous lines provided good contrast for unpaved roads, while single dashed lines have been selected to represent tracks since they stand out better than dotted lines. Figure 12-2d shows the most appropriate form of linear symbol that was selected for each individual class of roads.

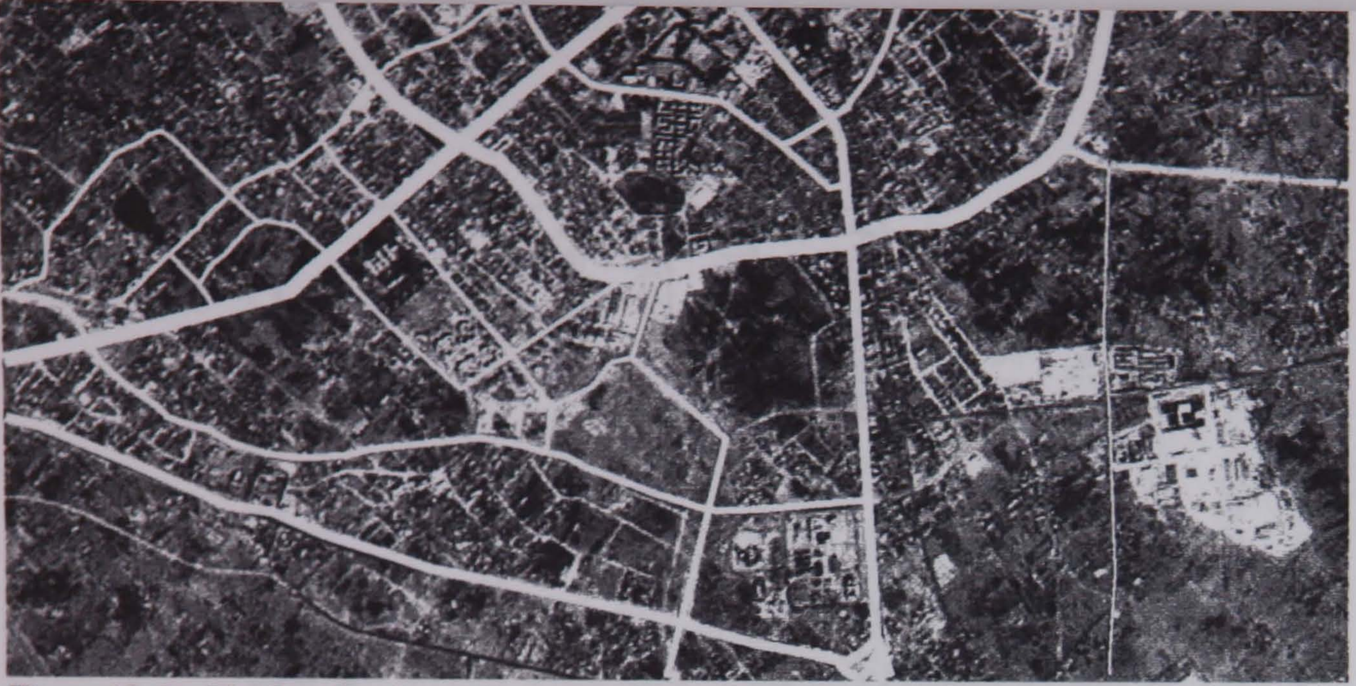


Figure 12–2a: The first line form alternative – only single lines have been used. (1:50,000 scale)

Figure 12–2b: The second line form alternative – single and double lines have been used. (1:50,000 scale)

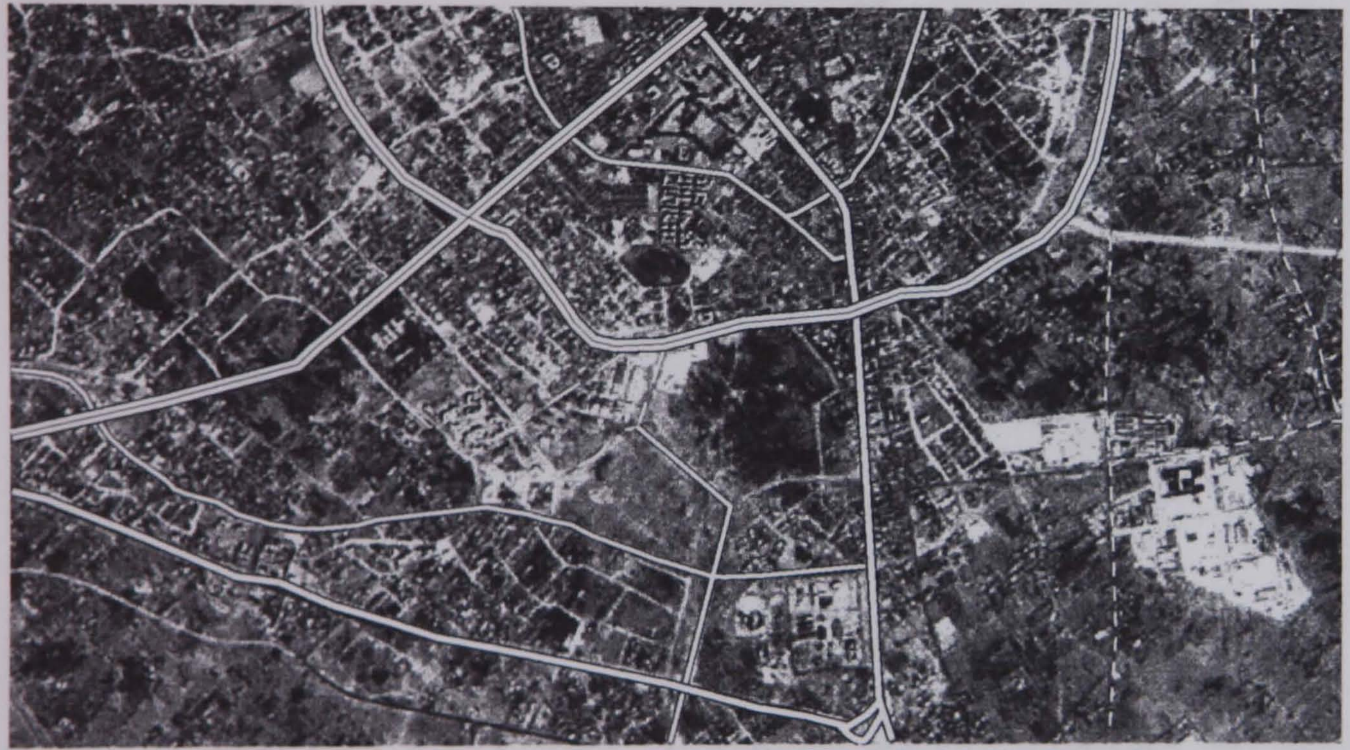


Figure 12–2c: The third line form alternative – single, double and triple lines have been used.(1:50,000 scale)

Figure 12–2d: The most appropriate line forms selected to represent the different classes of roads. (1:50,000 scale)

Road Class	Form 1 (Figure 12-2a)	Form 2 (Figure 12-2b)	Form 3 (Figure 12-2c)	Conclusion (Figure 12-2d)
- Highway	Single continuous line	Double continuous lines	Triple continuous lines	Triple continuous lines
- Main Paved Road	Single continuous line	Double continuous lines	–	Double continuous lines
- Secondary Paved Road	Single continuous line	Double continuous lines	–	Double continuous lines
- Unpaved Road	Single continuous line	Dashed line	Dashed line	Single continuous line
- Track	Single continuous line	Dotted line	Dashed line	Dashed line

Table 12-1: The Form Alternatives and Conclusion of each Individual Class of Roads.

(ii) Dimension

In the real world, roads vary both in width and in significance. Thus variations in line **dimensions** can put more emphasis on this particular differentiation between the various road classes. However, these lines should be designed taking into account factors such as their real size on the ground and the desired scale of the final map. Due to the relatively high ground resolution of the SPOT Pan imagery and the good contrast of the principal roads with their surroundings, roads with their different widths/dimensions have shown up clearly on the image map in many places. However there is still a need for artificial symbols to represent these linear features on the image map to emphasise their presence and extent to the various map users. Moreover, due to their lack of contrast with their surroundings, certain classes of roads were (sometimes) partially invisible in some parts of the space image; therefore, their cartographic representation through the use of line symbols was necessary to provide the missing road information.

Road Class	Dimension 1 (mm) (Figure 12-2e)	Dimension 2 (mm) (Figure 12-2f)	Dimension 3 (mm) (Figure 12-2g)	Conclusion (mm) (Figure 12-2h)
- Highway	0.20x0.30x0.10x0.30x0.20	0.20x0.40x0.10x0.40x0.20	0.20x0.50x0.10x0.50x0.20	0.20x0.35x0.10x0.35x0.20
- Main Paved Road	0.15x0.60x0.15	0.15x0.70x0.15	0.15x0.80x0.15	0.15x0.50x0.15
- Secondary Paved Road	0.10x0.40x0.10	0.10x0.50x0.10	0.10x0.60x0.10	0.10x0.30x0.10
- Unpaved Road	Line Width : 0.20	Line Width: 0.30	Line Width: 0.40	Line Width: 0.30
- Track	Line Width: 0.20 Dash Length: 1.00 Space Length: 0.50	Line Width: 0.20 Dash Length: 1.50 Space Length: 1.00	Line Width: 0.30 Dash Length: 2.00 Space Length: 1.50	Line Width: 0.25 Dash Length: 1.50 Space Length: 1.00

Table 12-2: The Dimension Alternatives and Conclusion of each Individual Class of Roads.

Figure 11–2e: The first alternative of line Dimensions those were used fot the different road classes.. (1:50,000 scale)

Figure 11–2f: The second alternative of line dimensions those were used for the different road (1:50,000 scale)

Figure 11–2g: The third alternative of line dimensions those were used for the different road classes. (1:50,000 scale)

Figure 11–2h: The most appropriate and selected line dimensions for the different road clas (1:50,000)

Figure 12–2i: The first alternative of line colours that have been used for the different road classes. (1:50,000 scale)

Figure 12–2j: The second alternative of line colours that have been used for the different road classes. (1:50,000 scale)

Figure 12–2k: The third alternative of line colours that have been used for the different road classes. (1:50,000 scale)

Figure 12–2l: The most appropriate line colours selected for the different road classes. (1:50,000)

Of course, another important factor to be considered is line width exaggeration. This is normal practice in mapping since the real value of the width of the road to be mapped - on a small-scale or on a medium-scale map - is often too small to be well represented on the map. For example, if a 12m wide road is to be represented on a 1:50,000 scale map, this is equivalent to a 0.24mm line width – which is rather too small to be easily discerned. Thus, as can be noted in Figures 12-2e; -2f; -2g and from Table 12-2, a certain degree of line exaggeration has been applied to all the line symbols used to depict roads. However, the image map is a different product than the conventional line map in the sense that the white space – that is available in a line map – is absent. Instead, the background is a space image that is characterised by the wealth of detail given by the tonal image. In this case, the cartographer does not have too much freedom in applying line exaggeration, since the line width/dimension exaggeration eliminates the image detail that belongs to adjacent features and may be useful in their representation. Therefore, excessive line exaggeration has been avoided in an attempt not to obscure more detail or to dominate the image and so disturb the visual balance of the final image map.

From Table 12-2, it can be seen that each individual class of roads has been designed using alternatives of line thickness and line separations. Obviously, from the discussion conducted in the previous section, continuous line road casings were only used for surfaced roads (highways, main paved and secondary paved roads). However, the casing lines used for main paved roads were thinner than those used for highways. For dashed lines, variations in line dimensions have also been created using different line widths, dash lengths and space lengths. Figure 12-2h sets out the most appropriate line dimensions that have been selected for roads. This Figure also shows that the exaggeration level has been kept to a minimum and that variations in line dimensions have been used to give more emphasis to the road classification.

(iii) Colour

If used correctly, colour is a powerful tool in any cartographic representation. Generally, roads need to be of a high visual level and exhibit good contrast against their background and so often solid (100%) colours are used rather than tints. It is always easier to read maps where each class of road is produced in a different colour. However the author sees no point in over-exaggeration in size and colour to achieve clarity and legibility, since the immediate problem of all image maps starts by having a highly detailed background image over the entire map area. Thus it would be more logical in terms of design to ensure that the space image should be printed in the lightest tone possible whilst retaining the smallest perceptible detail overall.

This would allow any symbols that need to be added to be of the minimum weight necessary to achieve an appropriate contrast with the background. This design practice has the advantage of giving the map clarity and legibility without adding to the crowded appearance of the space image. In turn, the danger of concealing minor, but important, image detail with over-exaggerated symbols will be reduced. However, the use of certain colours is necessary for road representation, since their visual contrast and clarity against the tonal image are matters of prime concern. Hence, as can be seen in Figures 12-2i; 12-2j; 12-2k and from Table 12-3, the colour treatment of the roads has involved the use of only four colours (red, yellow, black and white).

Road Class	Colour 1 (Figure 12-2i)	Colour 2 (Figure 12-2j)	Colour 3 (Figure 12-2k)	Conclusion (Figure 12-2l)
- Highway	Infill: 100% Red Casings: Black Central Line: Black	Infill: White Casings: 100% Red Central Line: 100% Red	Infill: 100% Yellow Casings: Black Central Line: Black	Infill: White Casings: 100% Red Central Line: 100% Red
- Main Paved Road	Infill: 50% Red Casings: Black	Infill: 50% Yellow Casings: Black	Infill: White Casings: Black	Infill: 30%Yellow Casings: Black
- Secondary Paved Road	Infill: White Casings: Black	Infill: 50% Yellow Casings: Black	Infill: 50% Red Casings: Black	Infill: White Casings: Black
- Unpaved Road	100% Red	White	Black	100% Red
- Track	100% Red	White	Black	White

Table 12-3: The Colour Alternatives and Conclusion of each Individual Class of Roads.

Since the space image covers the entire map area, this permits the use of drop out masks to produce a white space between the lines. From a cartographic design point of view, this can, and should be fully utilized to aid the clarity and legibility of the final product. In other words, with image maps, the designer has an extra colour to exploit, that of the paper itself. Hence features such as roads can be shown in white. For example, Figure 12-21 shows the effectiveness of using this technique in medium scale mapping, the secondary paved roads standing out clearly when white has been used as the infill colour for this class of roads. However, the use of white must not be carried to an extreme. In particular, if the background itself is very light, some degree of clarity and legibility could be lost through lack of contrast. In such a situation, the space image does appear to provide the most important features on the map, and the irrelevant information is all present without being obtrusive.

For surfaced roads, colour infills - including red, yellow, black and white - have all been used. Yellow, no matter whether it is partially or fully saturated, appears quite light yet gives a high contrast. Thus, when yellow was adopted for major roads, it provided a very strong appearance against the black and white background image and indeed it tended to dominate the entire image. Although the use of solid red provided a sufficient contrast for highways and integrated well with the space image, it failed to be prominent visually, particularly, when a white or yellow (tint) was used for thinner lines. Figure 12-21 shows that better results (in terms of contrast and visual order) have been obtained when colour infills of (a) white; (b) 30% yellow; and (c) white were used for the three classes of highways; main paved roads and secondary paved roads respectively. In order to distinguish highways from other surfaced roads, variations in colour have also been created for the casings. In fact, solid red was judged to be more suitable when used for the casings and central lines of the highways, while black has added more contrast, clarity and recognition to the main paved and secondary paved roads.

Unpaved roads and tracks are thinner than paved roads and are commonly represented using single lines. In conventional line mapping, another trend that is evident with these unsurfaced roads is that the colours used are less vibrant. Tints and lighter colours like yellow and white are very common. However, in image mapping, this is not always the case, since their clarity depends solely on the tone of the background image and on the terrain characteristics of the area to be mapped. Thus the tests carried out by the author have shown that solid red was the right choice for unpaved roads. White has worked well and maintained the visual harmony on the map when used for thinner interrupted lines to represent tracks.

12.3.2.2 Boundaries

Boundaries are an important element in any type of topographic map. As with roads, they exist in a hierarchy of importance and the weight and continuity of the line symbol should reflect that situation. However, unlike roads, usually they do not have a physical presence on the terrain and do not show up on the space image. In general, they can be divided into two sub-categories - international boundaries and internal national administrative boundaries. For Libya or for any other country, the international boundaries are considered a very important issue politically, since they represent the entity of the country. Hence, they are invariably depicted as maps using very prominent high contrast line symbols. On the other hand, since some of the administrative boundaries (such as those of the municipalities) in Libya are very critical and are regularly subjected to drastic changes, the author has only dealt with the international and provincial boundaries.

(i) Form

Variations in line form can make the distinctions between the different classes of boundary possible and can also prevent conflict with other linear features. Conventionally, international boundaries are usually shown using a multiple symbol, with a black line indicating the boundary position, while the accompanying colour riband is denoting its importance. In the experiments carried out by the author, both single (Figure 12-3a) and multiple (Figure 12-3b) line symbols have been tested for international boundaries. Although the complex line (a white dashed line and a continuous black riband) has provided a better appearance. the author felt that it would not be a good idea to select this line since many users may think it is a railway. As can be seen in Figure 12-5c and as specified in Table 12-4, the most appropriate symbol for international boundaries was to use a multiple line - comprising a dashed line with dots placed between the dashes and a continuous colour riband - in order to avoid any conflict with roads and railways. Since provincial boundaries are rather less important, they are commonly shown using single interrupted lines. From the examples given in Figures 12-3a and 12-3b, it can be seen that a simple interrupted line and a complex line (i.e. a line with additions) have been used to provide a better distinction between the classes and to create a hierarchy of importance. In the end, the single dashed line (Figure 12-3c) has been chosen for the representation of a provincial boundary.

Boundary Class	**Form 1** (see Figure 12-3a)	**Form 2** (see Figure 12-3b)	**Conclusion** (see Figure 12-3c)
- International	Single Continuous Line (Simple Line)	Multiple line symbol (Dashed Line with a Continuous Colour Riband)	Multiple line symbol (Dashed Line with Dot between Dashes and a Continuous Colour Riband)
- Provincial	Single Dashed Line (Simple Line)	Dashed Line with Dots between the Dashes (Complex Line)	Single Dashed Line (Simple Line)

Table 12-4: The Alternatives and the Selected Forms for Boundary Lines.

(ii) Dimension

Variations in line **dimensions** have also been used and tested for both levels of boundaries. Because of their importance, international boundaries have been represented using wider lines. For image mapping, this is not a desirable practice, since the width of the line should be kept to the minimum in order not to block out the more important details of the base image. However, as far as the 1:50,000 scale image map series is concerned, this is not a real problem since international boundaries will only be shown on a very limited number of map sheets. The alternative designs and the selected dimensions for boundary lines are shown in Figures 12-3d, 12-3e, 12-f and Table 12-5.

Figure 12–3a: The first alternative of line forms for boundaries – 1) a continuous single line, and 2) interrupted (dashed) single line. (1:50,000 scale)

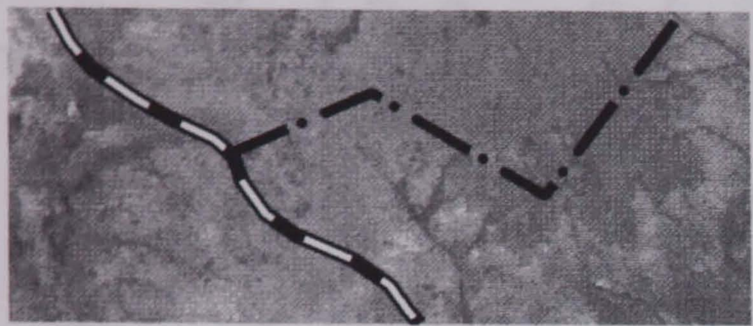


Figure 12–3b: The second alternative of line forms for boundaries – 1) dashed line with riband, and 2) dashed line with dots. (1:50,000 scale)

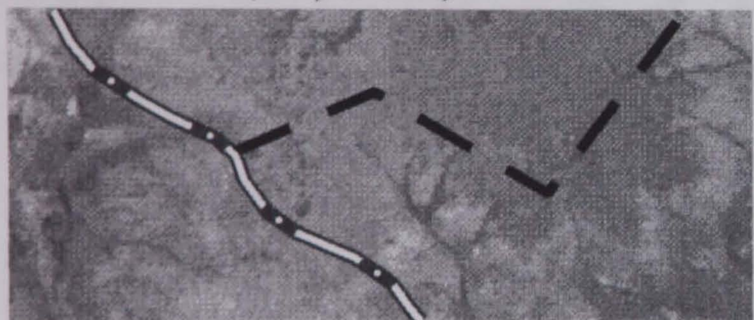


Figure 12–3c: The third alternative of line forms for boundaries – 1) dashed line with dots and riband, and 2) dashed line. (1:50,000 scale)

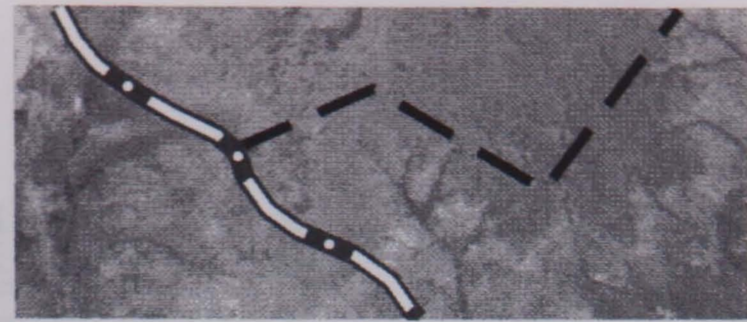


Figure 12–3d: The first alternative of line dimensions for boundaries. (1:50,000 scale)

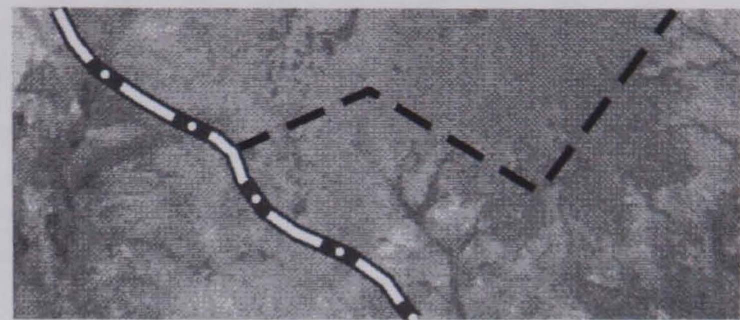


Figure 12–3e: The second alternative of line dimensions for boundaries. (1:50,000 scale)

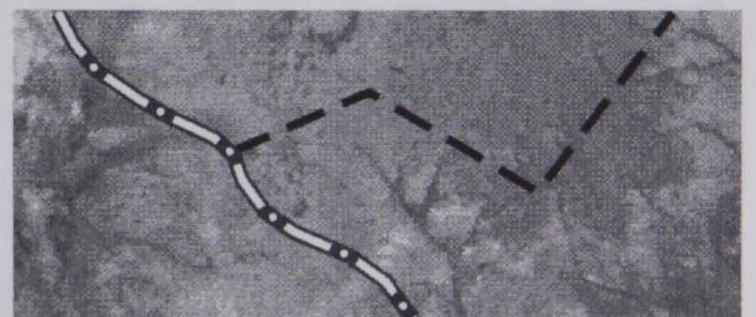


Figure 12–3f: The third alternative of line dimensions for boundaries. (1:50,000 scale)

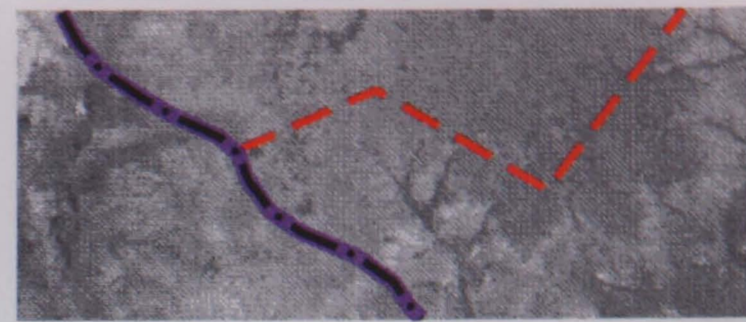


Figure 12–3g: The first alternative of line colours for boundaries. (1:50,000 scale)

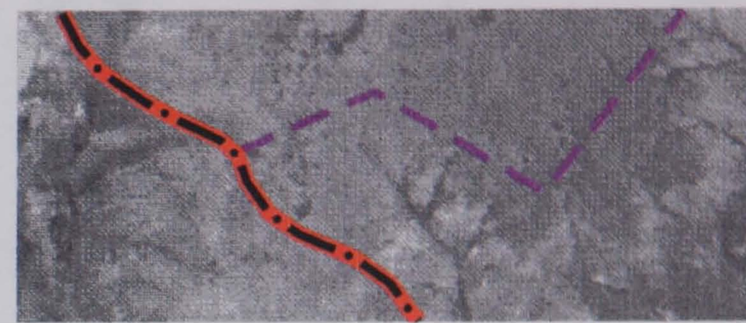


Figure 12–3h: The second alternative of line colours for boundaries. (1:50,000 scale)

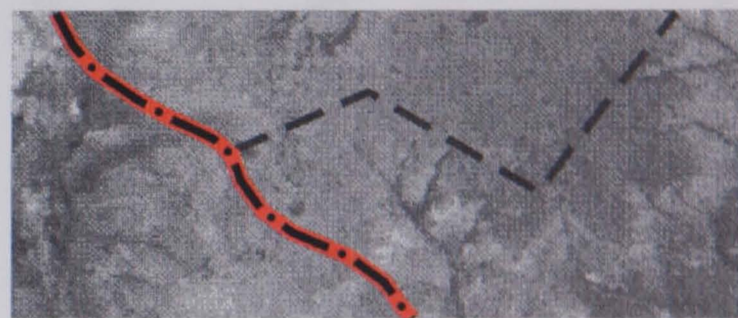


Figure 12–3i: The third alternative of line colours for boundaries. (1:50,000 scale)

Boundary Class	Dimension 1 (mm) (see Figure 12-3d)	Dimension 2 (mm) (see Figure 12-3e)	Conclusion (mm) (see Figure 12-3f)
- International	Line 1: Dash Width: 1.00 Dash length: 8.00 Space length: 5.00 Dot Diameter: 1.00 Line 2: Width: 2.00	Line 1: Dash Width: 0.90 Dash length: 6.00 Space length: 4.00 Dot Diameter: 0.90 Line 2: Width: 1.80	Line 1: Dash Width: 0.80 Dash length: 5.00 Space length: 3.00 Dot Diameter: 0.80 Line 2: Width: 1.60
- Provincial	Dash Width: 1.00 Dash Length: 6.00 Space length: 3.00	Dash Width: 0.80 Dash Length: 4.00 Dot Diameter: 2.00	Dash Width: 0.80 Dash Length: 4.00 Space length: 2.00

Table 12-5: The Alternatives and the Selected Dimensions for Boundary Lines.

(iii) Colour

Boundary lines, like the line symbols used for roads, need a high contrast with the background image and with each other in order to be properly recognised. **Colour** is always a useful and sometimes an essential tool in showing boundaries on maps. From the user's point of view, it was felt that it would be better to use the conventional colours (black; red and purple) for boundaries, since these colours have a good visual contrast and they are well known both within the mapping community and among the user community. As can be seen in Figures 12-3g; 12-3h and from Table 12-6, both solid colours and tints (of black; red and purple) have been tested visually against the space image - in an attempt to select the most appropriate colour or colours for international and provincial boundary lines. From this test, it could be seen that solid black has a high visual contrast and strong appearance; thus it was the only colour that has been used to show the position of the international boundaries on the final map. The importance of the international boundaries has been depicted using a tint of purple or 50% red ribands. Figure 12-3i shows that a black line and a 50% red riband have provided much better results in terms of contrast and visual balance. Whereas, when a single dashed line was employed using 100% red or a tint of purple (Figures 12-3g and -7h), both representations provided a low quality line with poor contrast against the image. Obviously, the use of black provided a more prominent and sharper representation than the other two colours: thus it was more appropriate to select it for the final map. However, tests have proved that a 50% of black (Figure 12-3i) was adequate for provincial boundaries in order to maintain a good visual balance.

Boundary Class	Colour 1 (see Figure 12-3g)	Colour 2 (see Figure 12-3h)	Conclusion (see Figure 12-3i)
- International	Interrupted Line 100% Black Riband 30% C + 70% M + 10% Y= Purple	Interrupted Line 100% Black Riband 50% M + 50% Y = 50% Red	Interrupted Line 100% Black Riband 50% M + 50%Y = 50% Red
- Provincial	100% M + 100% Y = 100% Red	20% C + 70% M + 10% Y = Purple	50% Black

Table 12-6: The Alternatives and the Selected Colours for Boundary Lines.

12.3.2.3 Water Features

Generally, there are no permanent surface water courses nor does any big area of surface water exist in Libya. Instead, there are some purely seasonal rivers, in the sense that they normally flow for only part of each year. Others may only discharge intermittently. The flow of all of these seasonal and intermittent rivers depends solely on the amount of the rainfall received in that particular season. However, the underground water resources and reserves are very important for the country. This means that springs and wells are of major importance as a source of water supply for both drinking and irrigation purposes. According to the map content specifications (for the 1:50,000 scale map of Misratah), the water features have been classified into sea; coastline; water bodies; wadis; springs; wells and water towers.

(i) Form

As can be understood from the above paragraph, the water features included at this medium-scale (1:50,000) cover all three basic types of features - which are point, line and area features. Since these water features differ in their nature, their form variations have been treated differently.

At least for the areas covered by the small windows of the image, the cartographic treatment of the sea is not too difficult, since it is easy to distinguish it and, in most cases, there is no image detail to be blocked out. Therefore, only a single form of area symbol has been used with no attempt to create alternatives (see Figures 12-4a, -4b, -4c and Table 12-7). The same can be said about the area symbol used for water bodies in a sense that only one form was used.

Since the coastline is of major importance, it has been shown using a heavy continuous line. For wadis (dry stream channels), the space background image has shown these features in a very good manner. Obviously, the use of the space background image has the great advantage of sometimes not requiring the construction of a symbol. However its success is always dependant on the clarity and the ground resolution of the image. After some experiments, it was felt that, in this particular case, the addition of any artificial symbol will simply result in the blocking out of the details and the disturbance of the natural image. However, although the space image can give detailed information about wadis to the map user, place-names are still essential to give a definitive location to the feature. As can be seen in Figures 12-4a; -4b and -4c, only the names of wadis have been added in an attempt to help the image map users to distinguish between them and recognise their location. Since the wadis are physical (natural) water features, a serif italic type face has been used both in capital and lower case forms to identify their names.

Considering next springs and wells, generally speaking, these point features are not easy to handle in image mapping, in the sense that they are very small in size and mostly cannot be seen on the image. Therefore they need to be shown as high contrast point symbols on this type of map. Using the proper form of point symbol can greatly ease its recognition and give its location. In fact, regular geometric point symbols are often those that are most easily distinguished and discriminated by the user's visual system. Therefore, for springs and wells, circles in different forms have been used extensively in the author's tests - see Figures 12-4a, 12-4b and 12-4c. During these tests, form variations have been created through the use of outline (empty) circles; solid circles and circles with inset symbols. The best results have been obtained when an outlined solid circle was used for springs, and when an outlined solid circle with additions (dot inside) was utilized to show wells (see Figure 12-4c).

Water Feature Class	**Form 1** (See Figure 12-4a)	**Form 2** (See Figure 12-4b)	**Conclusion** (See Figure 12-4c)
- Sea	Area Symbol (area tint)	–	Area Symbol (area tint)
- Coastline	Line Symbol (continuous line)	–	Line Symbol (continuous line)
- Water Body (e.g. Lake, Dam and Reservoir)	Outlined Area Symbol (area tint outlined with a continuous line)	–	Outlined Area Symbol (area tint outlined with a continuous line)
- Wadi	Text only Serif - Italic - Normal - Capital/Lower Case letters	Text only Serif - Italic - Bold - Capital/Lower Case letters	Text only Serif - Italic - Normal - Capital/Lower Case letters
- Spring	Point Symbol (solid circle)	Point Symbol (outlined solid circle)	Point Symbol (outlined solid circle)
- Well	Point Symbol (outlined solid circle with dot inside)	Point Symbol (outlined solid circle with smaller empty circle inside)	Point Symbol (outlined solid circle with dot inside)
- Water Tower	Point Symbol (solid square)	Point Symbol (outlined solid square)	Point Symbol (outlined solid square)

Table 12-7: The Alternatives and the Selected Forms for Water Feature Symbols.

Figure 12–4a: Form 1 for each class of water features.

Figure 12–4b: Form2 for each class of water features.

Figure 12–4c: The selected forms for each class of water features.

Figure 12–4d: Dimension 1 for each class of water features.

Figure 12–4e: Dimension 2 for each class of water features.

Figure 12–4f: The selected dimensions for each class of water features.

Figure 12–4g: Colour 1 for each class of water features.

Figure 12–4h: Colour 2 for each class of water features.

colourFigure 12–4i: The selected colours for each class of water features

(ii) Dimension

As far as using area symbols to show water features are concerned, the possibilities to use variations in dimension were very limited, and indeed often were not possible. Thus, for example, no dimension changes were possible for the area symbol used to show the sea. Whereas, since an outlined area symbol was selected for the representation of other water bodies, differences in dimension have been created through the use of different line widths for the definition of their continuous outline.

In these experiments for water features, two major types of line symbol were used – the first representing a coastline, and the second (which has been described above) acting as an outline to areas of inland water such as lakes, ponds, dams and reservoirs. Since the coastline is the line separating sea and land, it must be shown using sufficient width that allows it to be recognised on image maps. As can be seen in Figures 12-4d and 12-4e and from Table 12-8, two alternative line widths have been tested. The line was more obvious against the image when the 0.3mm value was assigned for the line thickness.

Water Feature Class	Dimension 1 (mm) (See Figure 12-4d)	Dimension 2 (mm) (See Figure 12-4e)	Conclusion (See Figure 12-4f)
- Sea	–	–	–
- Coastline	Line Width: 0.20	Line Width: 0.25	Line Width: 0.30
- Water Body	Outline Width: 0.10	Outline Width: 0.15	Outline Width: 0.20
- Wadi	Text Height: 3.50	Text Height: 4.00	Text Height: 3.70
- Spring	Outline: 0.30 Circle: 1.70 (Dia.)	Outline: 0.40 Circle: 2.10 (Dia.)	Outline: 0.30 Circle: 2.00 (Dia.)
- Well	Outline: 0.20 Circle: 1.80 (Dia.) Dot: 1.20 (Dia.)	Outline: 0.40 Circle: 2.10 (Dia) Dot: 1.50 (Dia.)	Outline: 0.30 Circle: 2.00 (Dia.) Dot: 1.40 (Dia.)
- Water Tower	Outline: 0.30 Square: 1.50 x 1.50	Outline: 0.30 Square: : 1.70 x 1.70	Outline: 0.60 Square: : 1.20 x 1.20

Table 12-8: The Alternatives and the Selected Dimensions for Water Feature Symbols.

At 1:50,000 scale, it was necessary to introduce point symbols to represent small point features such as wells, springs and water towers. At the same time, there was a danger that the small point symbols could not be detected against the background image. Consequently, according to conventional practice, they have to be exaggerated from their true size in order that they can be easily recognised. However, rather than exaggerate the size of the symbols, it is preferable to try other techniques, such as printing the symbol in a slightly larger outlined area or within a framed white area. As can be seen in Figures 12-4d and 12-4e, different dimensions of circles and squares have been tested to show springs, wells and water towers until the most appropriate sizes have been found (see Figure 12-4f).

For the wadi names, variations in size have been created through the use of different font heights. Thus a variation in the height of the letters has been used generally to describe the overall size and importance of the feature.

For the different alternatives and the final selection of the most appropriate dimensions that have been assigned to the various water feature symbols, refer to Figures 12-4d; 12-4e and 12-4f and Table 12-8.

(iii) Colour

Following cartographic convention, blue is the only colour that has been used for water symbols on maps; however, **colour** variations have been created through the use of solid or different tints of blue in order to distinguish between the various area-based water features. For example, areas of water are normally distinguished on a topographic map by being shown as an area of blue colour on multi-colour maps. There are cases when different blues may be used to distinguish fresh from salt water. In this particular research project, it was very obvious that the only effective graphic variable that could be used to represent different areas of water such as sea and inland water bodies was a variation in colour. Figures 12-4g and 12-4h indicate that different degrees of blue tint have been used. The blue that has been selected to show the sea (Figure 12-4i) had to be sufficiently light to allow names to appear clearly over it. On the other hand, care had been taken when dealing with the small areas of in land water to use a deeper blue, since invariably they are quite small and require a stronger contrast than large areas.

Water Feature Class	**Colour 1** (See Figure 12-4g)	**Colour 2** (See Figure 12-4h)	**Conclusion** (See Figure 12-4i)
- Sea	50% Cyan	100% Cyan	40% Cyan
- Coastline	100% Cyan + 100% Magenta	100% Cyan + 60% Magenta	100% Cyan + 100% Magenta
- Water Body	Area: 30% Cyan Outline: 100% Cyan	Area: 60% Cyan Outline: 100% Cyan + 100% Magenta	Area: 60% Cyan Outline: 100% Cyan + 100% Magenta
- Wadi	Text: 100% Cyan	Text: 40% Cyan	Text: 100% Cyan
- Spring	Outline: 100% Black Circle: 100% Cyan	Outline: 100% Black Circle: White	Outline: 100% Black Circle: 100% Cyan
- Well	Outline: 100% Black Circle: White Dot: 100% Cyan + 100% Magenta	Outline: 100% Cyan + 100% Magenta Circle: White Dot: 100% Cyan	Outline: 100% Black Circle: White Dot: 100% Cyan
- Water Tower	Outline: White Square: 100% Cyan	Outline: 100% Cyan Square: White	Outline: White Square: 100% Cyan

Table 12-9: The Alternatives and the Selected Colours Used for Water Feature Symbols.

Since thin line symbols – such as those used for the coastline and the outlines of water bodies – need to be depicted with more emphasis in order to display the boundaries between land and water, the use of a dark blue was the most appropriate representation and has been selected for this purpose. Of course, the use of this colour provides a better appearance and a stronger contrast in lighter areas. The appropriate text has been tested using 40% and 100% cyan, but the latter appears to give a better contrast against the space image. Although 100% cyan has provided better results in darker areas, it may not contrast well in lighter regions.

The proper selection of the colour has also played an essential role in increasing the contrast of the small geometric point symbols used for springs, wells and water towers. As can be seen in Figures 12-4g; 12-4h and 12-4i, the use of a solid circle of 100% cyan outlined with black for springs allowed the symbol to appear clearly against the space image. Indeed, the use of black outlines and white frames have helped these small point symbols to stand out against the background space image. The use of a white circle outlined with black and with the addition of a 100% cyan dot – which has been placed inside the circle – resulted in a clear differentiation between wells and springs and made the former more distinguishable. For more information, see Figures 12-4g; 12-4h and 12-4i.

12.3.2.4 Cultural Features

Within the general framework of symbolisation, it is often necessary to further define particular features, e.g. buildings, etc., or to simply emphasise the presence of a feature that might not be immediately apparent from the space image – e.g. isolated buildings, or features that cannot be defined due to shadow or have been obscured by vegetation. Thus some methods or solutions of enhancing indefinable or poorly defined detail, or of supplying more complete information, must be found. To a large extent, this will concern only the cultural (man-made) detail, since, in general terms, the space image is capable of supplying a much better representation of most natural or physical features than can any conventional symbolised map. Thus, to a great extent, the need for further cartographic treatment is required more for the cultural landscape than the physical landscape.

The features falling within this category comprise settlements (which include towns, small towns, main villages, villages, hamlets and isolated buildings), cemeteries, mosques, shrines, schools, quarries, ruins, bridges and airports. Each of these has its own functional, cultural or economic significance that must be reflected in its appearance on image maps at 1:50,000 scale. Area and point symbols have mostly been used to show these cultural features. Indeed, line symbols have only been used to define the real physical extent of the runways of airports.

Whereas area symbols have been adopted to represent towns; small towns and main villages, and point symbols have been used to show mosques, schools, shrines, etc.

(i) Form

Regarding **form** variations, since these cultural features differ greatly in their nature, appearance and in the type of symbols (point, line or area) that may be used to represent them, they have been treated somewhat differently in order to select the most appropriate symbol design for each of these cultural classes.

Cultural Features	Form 1 (See Figure 12-5a)	Form 2 (See Figure 12-5b)	Conclusion (See Figure 12-5c)
- Town	Area symbol	Area symbol with the name of the town associated.	Area symbol with the name of the town associated.
- Village	Geometric point symbol (solid circle)	Geometric symbol with addition (solid circle inside solid square)	Geometric point symbol (outlined solid circle)
- Isolated Building	Geometric point symbol (solid square)	Geometric point symbol (solid rectangle)	Geometric point symbol (outlined solid rectangle)
- Mosque	Geometric point symbol With extension	Geometric point symbol With extension (Framed point symbol)	Geometric point symbol With extension (Framed point symbol)
- Shrine	Geometric point symbol With extension	Geometric point symbol With extension (Framed point symbol)	Geometric point symbol With extension (Framed point symbol)
- School	Geometric point symbol With extension	Geometric point symbol With extension (Framed point symbol)	Geometric point symbol With extension (Framed point symbol)
- Cemetery	Geometric point symbol With extension	Geometric point symbol With extension (Framed point symbol)	Geometric point symbol With extension (Framed point symbol)
- Quarry	Iconic point symbol	Iconic point symbol (Framed point symbol)	Iconic point symbol (Framed point symbol)
- Ruins	Geometric point symbol With addition	Geometric point symbol With addition (Framed point symbol)	Geometric point symbol With addition (Framed point symbol)
- Bridge	Iconic point symbol (imitating the outer profile)	Geometric point symbol	Iconic point symbol (imitating the outer profile)
- Airport	Single continuous line	Double continuous line	Double continuous line

Table 12-10: The Alternatives and the Selected Forms for Cultural Feature Symbols

At 1:50,000 scale, settlements may occupy a considerable area of land and should be depicted accordingly. Those such as towns; small towns and main villages are larger in size with a higher density of buildings and population. Therefore these types of settlement have been represented using area symbols (employing transparent areas of colour); names have also been added to help identify their location. In the case of these larger settlements, as can be seen in Figures 12-5a; 12-5b and 12-5c and Table 12-10, the form variations that have been experimented with were very limited, since no artificial patterns have been used. This reflects the author's view that these areas are best represented by the patterns and textures that are present in the space image itself. In this respect, a space image map can, to a large extent, be a different and potentially superior product to that of the conventional line map. Any use of artificial patterns will interrupt the natural background image and hide its more important details – to the detriment of the final product. By contrast, these Figures also show that there were more possibilities of using the form variations possible with artificial symbols when representing the smaller settlements such as villages and isolated buildings through the use of various geometric point symbols (i.e. circles. rectangles and squares). Various alternative forms of these geometric point symbols – including both solid and outlined solid shapes – have been tested. The results of these tests showed that outlined solid circles and outlined solid rectangles have provided better forms for the representation of villages and isolated buildings, respectively.

As mentioned above, among the cultural features are certain point features – e.g. mosques, schools, shrines, cemeteries, quarries, ruins, bridges, etc. – which have been represented using either geometric or iconic point symbols. Generally speaking, geometric point symbols are those most easily distinguished and discriminated by the human eye. Whereas, iconic forms imitate in a simple manner the profile of the real feature. However, there are situations where they can also represent some other physical property, or a concept associated with the nature of the feature (Keates, 1989). Indeed, since point symbols are small in size, therefore they are always not easy to handle as far as the cartographic design is concerned. Particularly, this is the case in space image mapping where the white space that is available in conventional line maps is absent. Instead there is a tonal background image that may reduce the contrast of any superimposed symbol if a special cartographic treatment has not been undertaken to reduce this effect. As can be seen in Figure 12-5a, geometric point symbols with extensions have been used to represent mosques, shrines and schools, while iconic point symbols have been adopted to depict bridges and quarries. These point symbols could hardly be recognised against the background image and so the alternative that has been explored has been to enclose each of these point symbols in a circle or square (see Figure12-5b). Framing the symbol in this way has made it clear and assisted in the speed of searching for and locating the symbol. For ruins, although both simple geometric point symbols and geometric point symbols with additions have been tested, the latter symbols have yielded better results.

For representation of the airport, only a continuous line has been used to pick out the runway. This cartographic solution provided a more realistic impression of the feature and was a good way to aid its identification. The line widths of the linear symbols used to represent airports range between 1.2 and 1.5mm.

As a result of these experiments of symbol form, the most successful symbol designs for the various cultural features to be shown on the 1:50,000 scale image map are shown in Figure 12-5c.

(ii) Dimension

Normally, changes in **dimension** can be applied very easily to point and line symbols. However, this is certainly not the case when dealing with area symbols, which are restricted to changes in the dimension of those lines outlining the areas being depicted by this type of symbol. Of course, some changes in the size or dimension of the names associated with these area symbols can be implemented but not in the size and shape of the areas being covered by the area symbols themselves. Thus the larger and more significant settlement features such as towns, small towns and main villages have been shown using different name sizes according to the size and significance of the particular settlement (see Figures 12-5d and 12-5e and Table 12-11).

Cultural Features	Dimension 1 (mm) (See Figure 12-5d)	Dimension 2 (mm) (See Figure 12-5e)	Conclusion (mm) (See Figure 12-5f)
- Town	Text: 4.00	Text: 6.00	Text: 5.00
- Village	Diameter: 2.50	Diameter: 3.00	Diameter: 2.70
- Isolated Building	2.00 x 1.50	1.50 x 1.00	1.50 x 1.00
- Mosque	2.50 x 2.50	3.00 x 3.00	2.80 x 2.80
- Shrine	2.50 x 2.50	3.00 x 3.00	2.80 x 2.80
- School	2.50 x 2.50	3.00 x 3.00	2.80 x 2.80
- Cemetery	2.50 x 2.50	3.00 x 3.00	2.80 x 2.80
- Quarry	2.50 x 2.50	3.00 x 3.00	2.80 x 2.80
- Ruins	2.50 x 2.50	2.00 x 2.00	2.20 x 2.20
- Bridge	2.50 x 4.00	3.00 x 4.50	3.00 x 4.50
- Airport	0.15 x 1.20 x 0.15	0.15 x 0.90 x 0.15	0.15 x 1.20 x 0.15

Table 12-11: The Alternatives and the Selected Dimensions for Cultural Feature Symbols.

As has been described in Section 12.3.2.3, point symbols on image maps invariably require a considerable degree of exaggeration in order to be within the perceptual guidelines. With this in mind, Figures 12-5d; -5e and Table 12-11 show that a certain exaggeration level has been applied when designing alternative point symbols for mosques, shrines, schools, cemeteries, quarries, etc. Nevertheless, the over-exaggeration of size is a matter that has to be avoided, since it may produce poor design results and unbalance the overall map.

In fact, the definition of all dimensions of the symbols used to show the various cultural features on the image maps at 1:50,000 scale were handled with a great deal of care. This was to ensure that all symbols should be within the visual perception of the map user and to obtain the desired contrast between each other and against the image. The most appropriate symbols in terms of dimension are shown in Figure 12-5f.

(iii) Colour

As mentioned previously, area features on image maps are always not easy to represent, since there is invariably a strong danger of them obscuring or breaking up the natural image and concealing significant details of the background image if artificial patterns or solid polygons are used. Indeed, in the author's opinion, the use of the natural image displays these area features more effectively and in more realistic manner than any artificial symbols can do. This was certainly the case when dealing with features such as the towns, small towns and main villages that were present in the test area. Thus it was felt that the use of transparent colours would be more appropriate to pick out specific areal features, since this would still show the real structure of the streets and building blocks and this would aid the interpretation of these features, besides retaining their information level. Figures 12-5g; -5h and Table 12-12 indicate that, after a good deal of prior thought and various preliminary trials with other colours, transparent light pink and transparent light red with 40% of opacity have been used to show the town area. The name of the town was also tested using both black and white colours, but white provided much better results when viewed against the transparent colour. As the particular settlement feature (e.g. small town or main village) becomes smaller in area, the transparent colour needs to become darker in order to ensure good contrast. With the really small villages, the need to retain tiny structures is diminished, so they were represented symbolically using solid magenta, solid red and orange circles outlined with black.

Figure 12–5a: Form 1 for the various classes of cultural features. (1:50,000 scale)

Figure 12–5b: Form 2 for the various classes of cultural features. (1:50,000 scale)

Figure 12–5c: The selected forms for the various classes of cultural features. (1:50,000 scale)

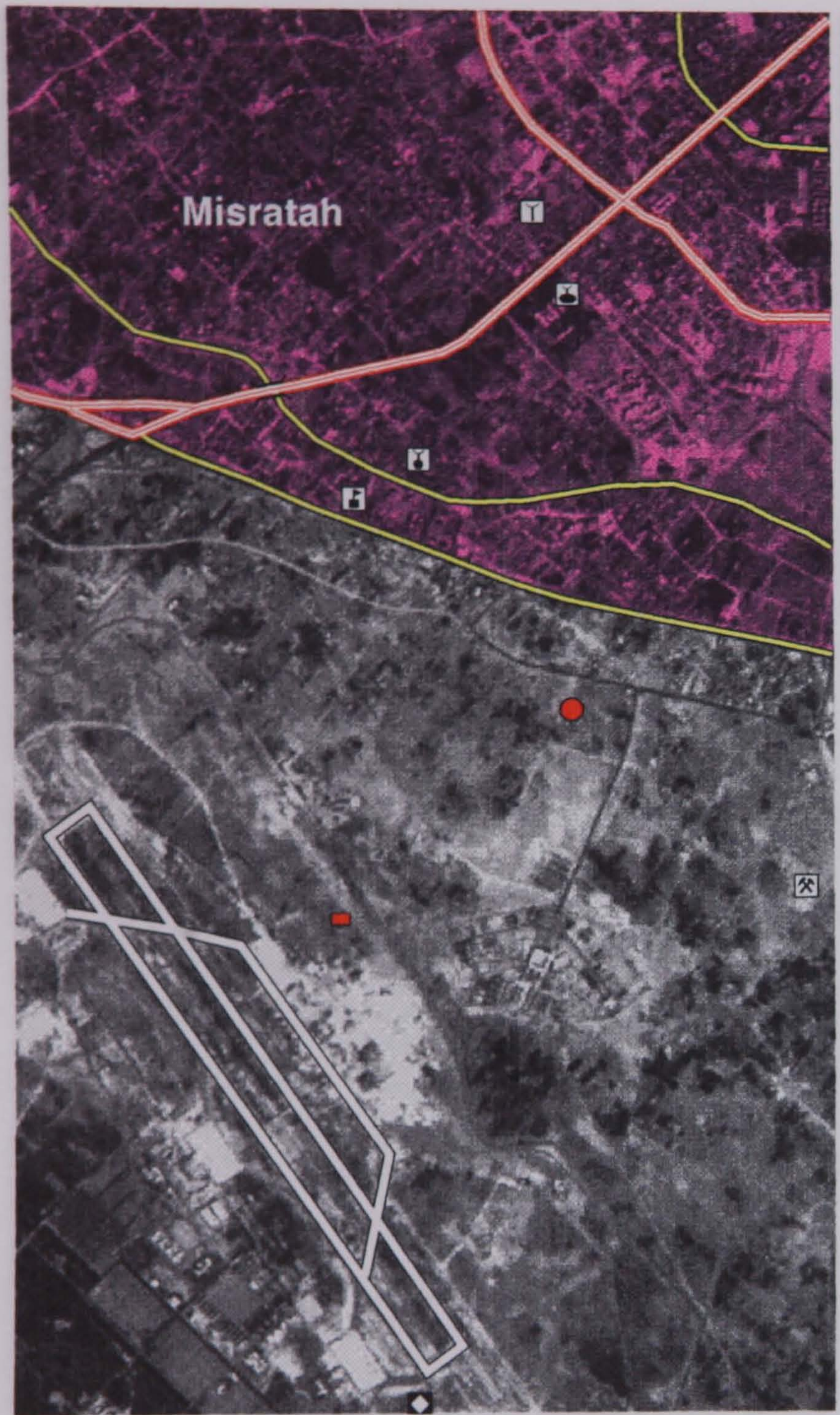


Figure 12–5d: Dimension 1 for the various classes of cultural features. (1:50,000 scale)

Figure 12–5e: Dimension 2 for the various classes of cultural features. (1:50,000 scale)

Figure 12–5f: The selected dimensions for the various classes of cultural features. (1:50,000 scale)

Figure 12–5g: Colour 1 for the various classes of cultural features. (1:50,000 scale)

Figure 12–5h: Colour 2 for the various classes of cultural features. (1:50,000 scale)

Figure 12–5i: The selected colours for the various classes of cultural features. (1:50,000 scale)

Cultural Features	Colour 1 (See Figure 12-5g)	Colour 2 (See Figure 12-5h)	Conclusion (See Figure 12-5i)
- Town	Transparent: 80%M + 40%Y Text: Black	Transparent: 80%M + 80Y Text: White	Transparent: 80%M + 50%Y Text: White
- Village	Outline: Black Solid Circle: 100%M	Outline: Black Solid Circle:100%M + 100%Y	Outline: Black Solid Circle:70%M + 100%Y
- Isolated Building	Outline: Black Solid Rectangle: 100%M	Outline: Black Solid Rectangle: 100%M + 100%Y	Outline: Black Solid Rectangle: 100%M
- Mosque	Outline: Black Background: 100%Y Symbol: Black	Outline: Black Background: 100%C + 100%Y Symbol: Black	Outline: Black Background: White Symbol: Black
- Shrine	Outline: Black Background: 100%Y Symbol: Black	Outline: Black Background: 100%C + 100%Y Symbol: Black	Outline: Black Background: White Symbol: Black
- School	Outline: Black Background: 100%Y Symbol: Black	Outline: Black Background: 100%C + 100%Y Symbol: Black	Outline: Black Background: White Symbol: Black
- Cemetery	Outline: Black Background: 100%Y Symbol: Black	Outline: Black Background: 100%C + 100%Y Symbol: Black	Outline: Black Background: White Symbol: Black
- Quarry	Outline: Black Background: 100%Y Symbol: Black	Outline: Black Background: 100%C + 100%Y Symbol: Black	Outline: Black Background: White Symbol: Black
- Ruins	Outline: Black Background: White Rhomb: Black	Outline: White Background: Black Rhomb: White	Outline: Black Background: White Rhomb: Black
- Bridge	White	Black	Black
- Airport	Outline: Black Infill: 50%M + 50%Y	Outline: Black Infill: 100%M + 100%Y	Outline: Black Infill: 50%M + 50%Y

Table 12-12: The Alternatives and the Selected Colours for Cultural Feature Symbols.

M = Magenta Y = Yellow C = Cyan

Once again, from the user's point of view, individual point features such as mosques, schools, shrines, ruins, etc. – which mostly occur within built-up areas – are very important items to be shown on image maps. However, at 1:50,000 scale, they are too small in dimension to be shown as an area symbol. So inevitably they must be included as a point symbol which will, of course, obliterate the image of the feature itself. Furthermore, this is always not a straightforward task, since the contrast of the point symbol against the surrounding image can be reduced if it is not treated properly to retain contrast against its background. This would happen if, for example, the point symbols for mosques, schools, shrines, cemeteries and quarries were designed in solid black. In which case, they would exhibit insufficient contrast against the black and white space image. The solution that was adopted was to use outlined solid frames (see Figures 12-5g and 12-5h). These act like a background for each of these point symbols in order to reach sufficient contrast against the background of the urban area. Alternative symbols in solid yellow, solid green and white colours were used and tested visually against the image. However, black symbols and white frames outlined with black have provided much better results than the others – see Figure 12-5i.

The colour treatment of the runway of the airport, described above as a linear feature, was much easier, since 50% red and solid red have provided a good contrast against the image.

However, since the solid red was much too strong in appearance, it was decided not to select this colour in order to maintain equal visual order and, in turn, the balance of the final image map.

In summary, alternative forms of symbols for the built-up areas; other settlements; quarries; ruins; religious buildings and airports have all been designed and tested visually against the background space image. Consequently, as can be seen in Figure 12-5i, the most appropriate point, line and area symbols have been selected for the representation of these cultural features.

12.3.2.5 Land Cover & Vegetation

Generally speaking, there is very little agreement among countries world-wide as to the information and level of detail concerning cultivation and vegetation that should be included on topographic maps. Those produced in some countries are very detailed while others have no areal symbolisation at all. In fact, types of cultivation and natural vegetation vary all over the world, and they can even vary greatly from one area to another within the same country. Libya has a mainly arid and semi-arid landscape and the areas of the natural vegetation and cultivation are concentrated in relatively small areas in the north west and north east parts of the country. Apart from these, there are only a few other areas with vegetation – e.g. those surrounding the oases located in the middle part of Libya. Land cover and vegetation in Libya can be classified into six main classes – which include cultivated land, forest, orchard, palm trees, olive trees and fallow land. All of these features have been produced or altered through the action of man.

(i) Form

As far as variations in **form** are concerned, a number of alternatives have been created in order to select the most appropriate symbol for each of these area features. Again, with each of these area types, the main objective was to maintain the natural appearance of the background image and not to introduce any artificial pattern or solid polygon that will disturb the natural image and hide its important details. As can be seen in Figure 12-6a and Table 12-13, first of all, transparent areal symbols with the identifying abbreviated letters (e.g. **Cul** for cultivated land) located in the centre of each specific area have been designed and superimposed on top of the space image. Secondly, as an alternative, a wide transparent outline has been used to represent cultivated areas, forests, orchard and fallow lands, while, for the palm tree and olive tree areas, only text was used to inform users about these types of vegetation areas, see Figure 12-6b. Further differentiation between these areal features would be made through the adoption of different colours and tints. Figure 12-6c and Table 12-13 show the alternative forms selected to represent land cover and vegetation.

Land Cover & Vegetation	**Form 1** (See Figure 12-6a)	**Form 2** (See Figure 12-6b)	**Conclusion** (See Figure 12-6c)
- Cultivated Areas	Areal Symbols With Text (abbreviation)	Thick Outline Only	Areal Symbols Only
- Orchards	Areal Symbols With Text (abbreviation)	Thick Outline Only	Areal Symbols Only
- Forests	Areal Symbols With Text (abbreviation)	Thick Outline Only	Areal Symbols Only
- Palm Tree Areas	Areal Symbols With Text (abbreviation)	Text Only	Text Only
- Olive Tree Areas	Areal Symbols With Text (abbreviation)	Text Only	Text Only
- Fallow Lands	Areal Symbols With Text (abbreviation)	Thick Outline Only	Areal Symbols Only

Table 12-13: The Alternative Forms Selected for Land Cover and Vegetation symbols

(ii) Dimension

The potential to make changes are very limited when dealing with those area symbols being used to represent land cover and vegetation. As can be seen from Figures 12-6d and 12-6e and Table 12-14, they only involved the use of different text sizes as alternatives to represent palm and olive tree areas.

Land Cover & Vegetation	**Dimension 1 (mm)** (See Figure 12-6d)	**Conclusion (mm)** (See Figure 12-6e)
- Cultivated Areas	-	-
- Orchards	-	-
- Forests	-	-
- Palm Tree Areas	Text height = 1.8	Text height = 2.5
- Olive Tree Areas	Text height = 1.8	Text height = 2.5
- Fallow Lands	-	-

Table 12-14: The Alternative Dimensions Selected for Land Cover and Vegetation Symbols

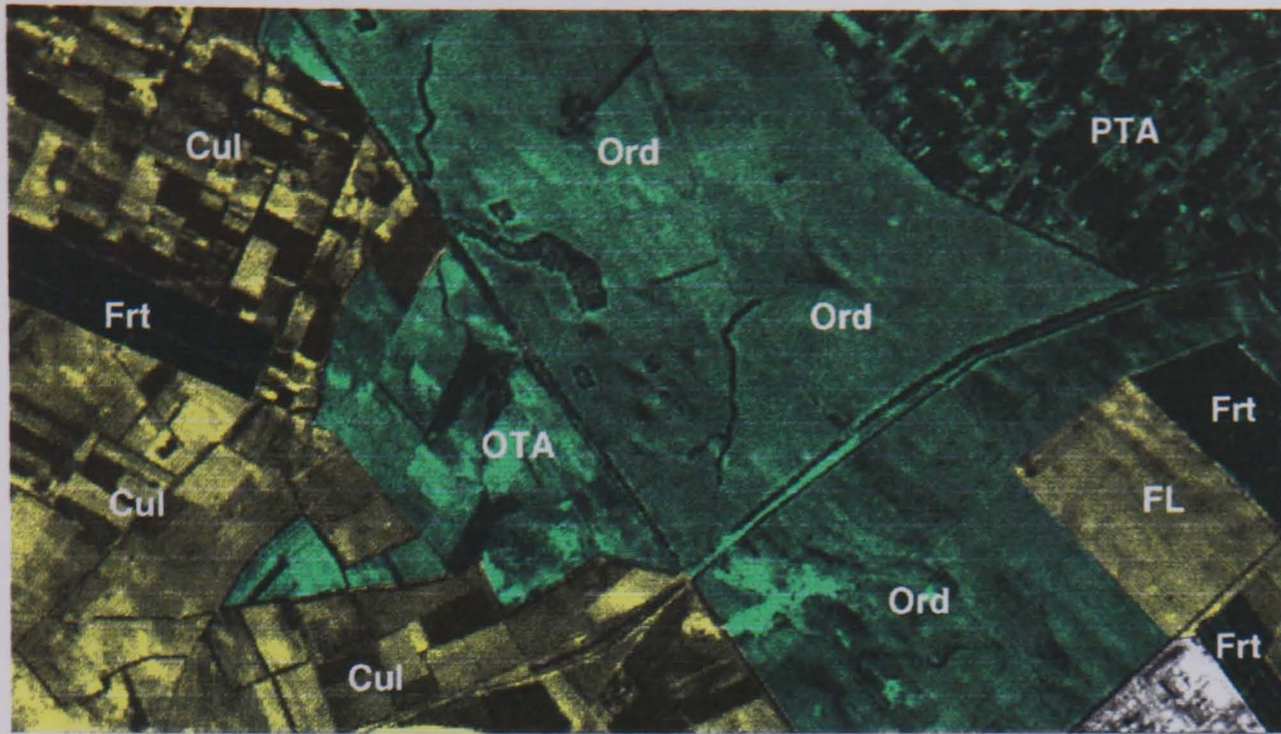


Figure 12–6a: Form 1 for each class of land cover and vegetation. (1:50,000 scale)

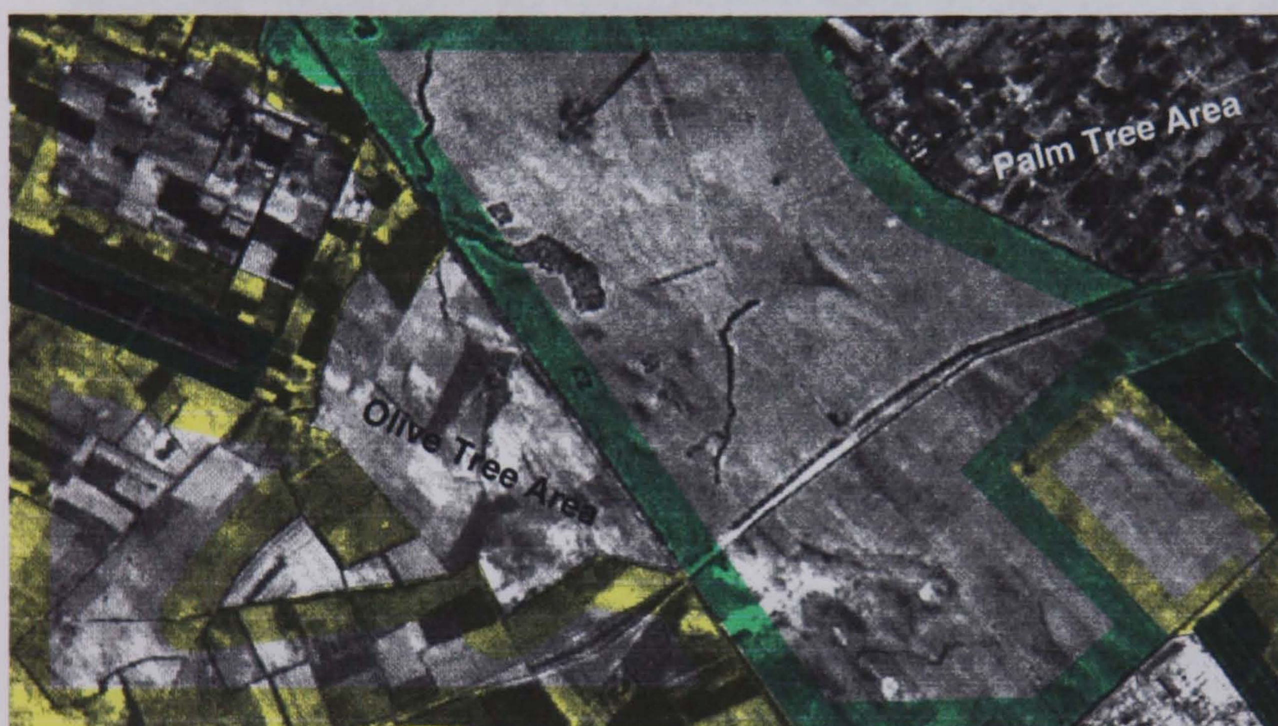


Figure 12–6b: Form 2 for each class of land cover and vegetation. (1:50,000 scale)

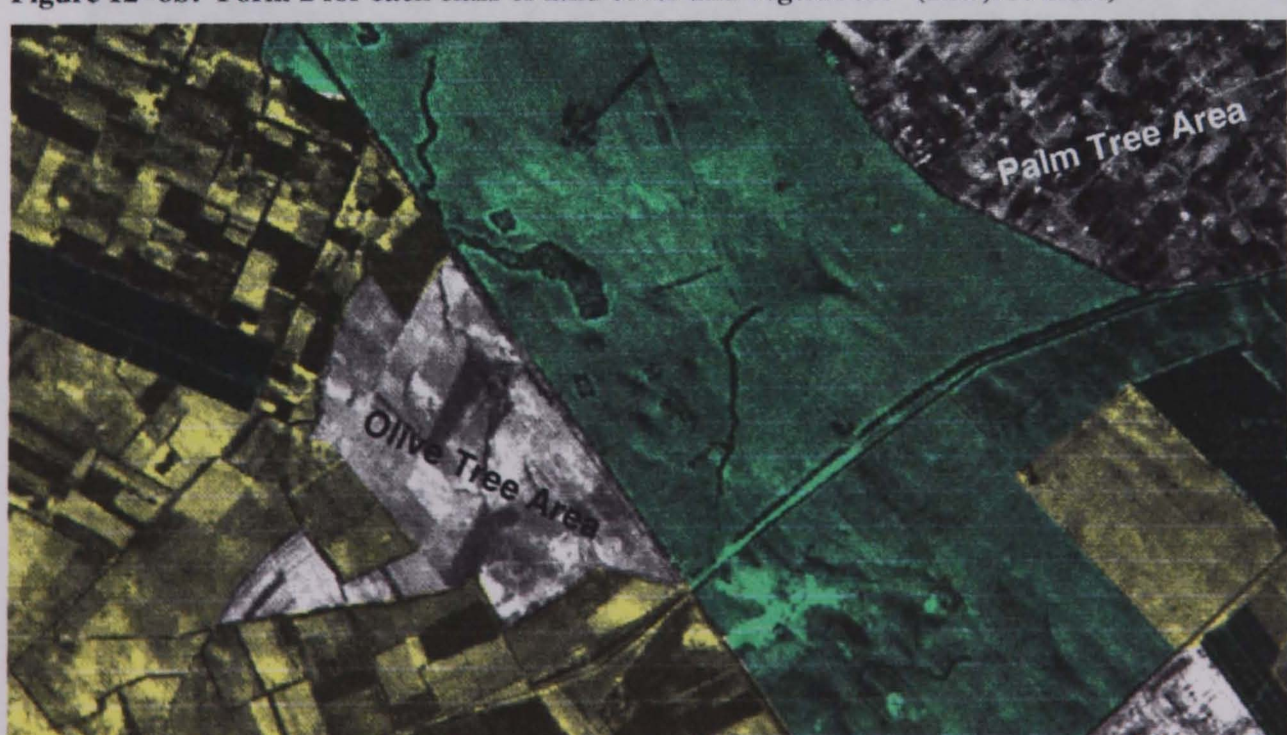


Figure 12–6c: The selected Forms for the different land cover and vegetation classes. (1:50,000 scale)

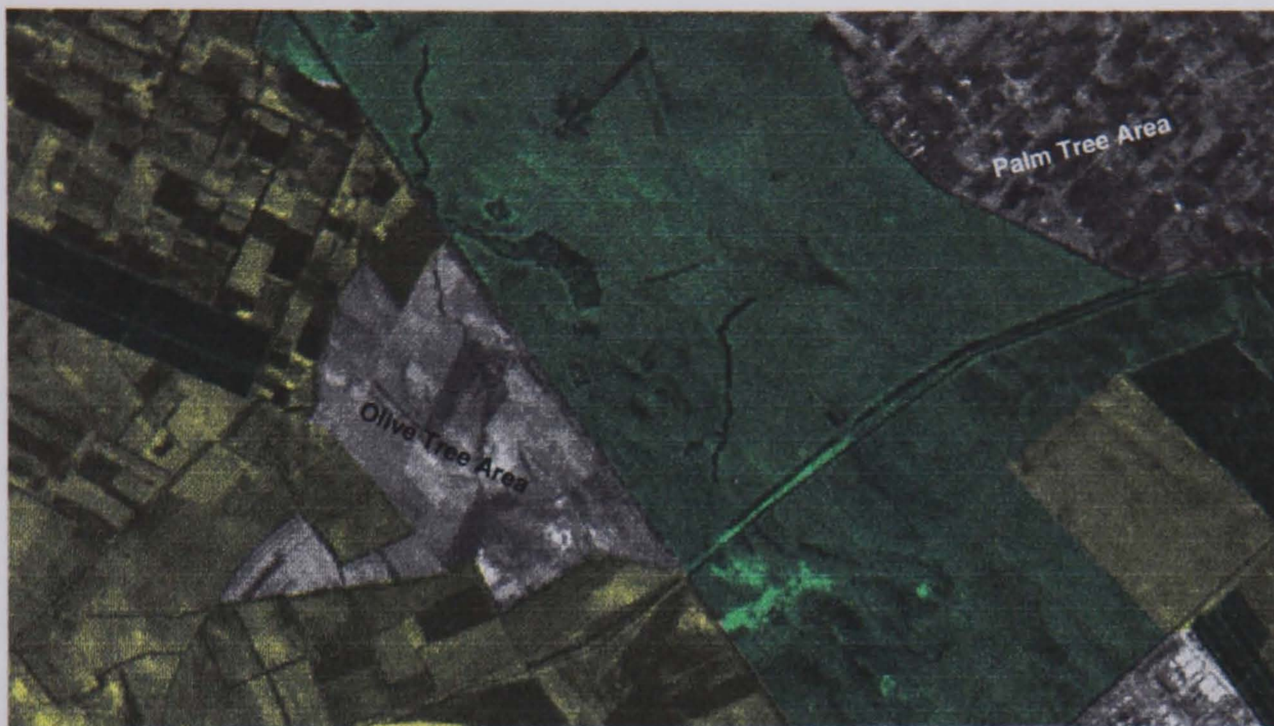


Figure 12–6d: Dimension 1 for each class of land cover and vegetation. (1:50,000 scale)

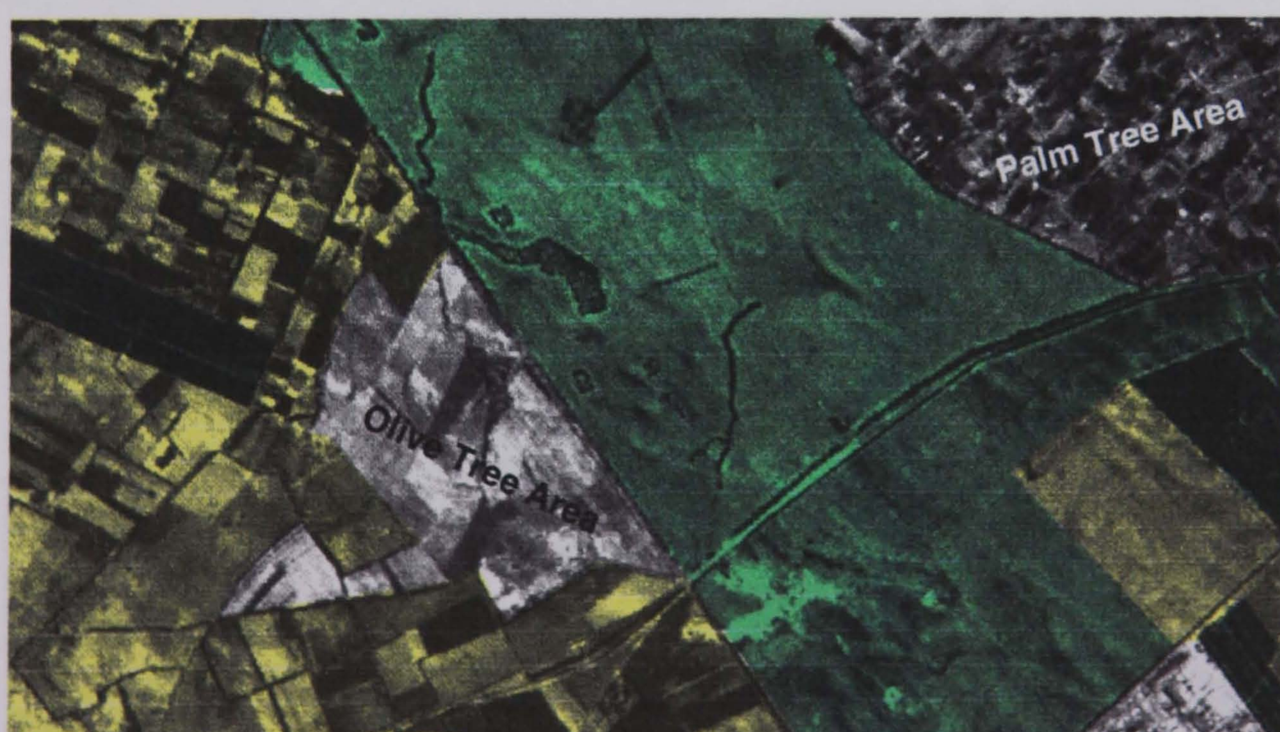


Figure 12–6e: The selected Dimensions for the different land cover and vegetation classes. (1:50,000 scale)

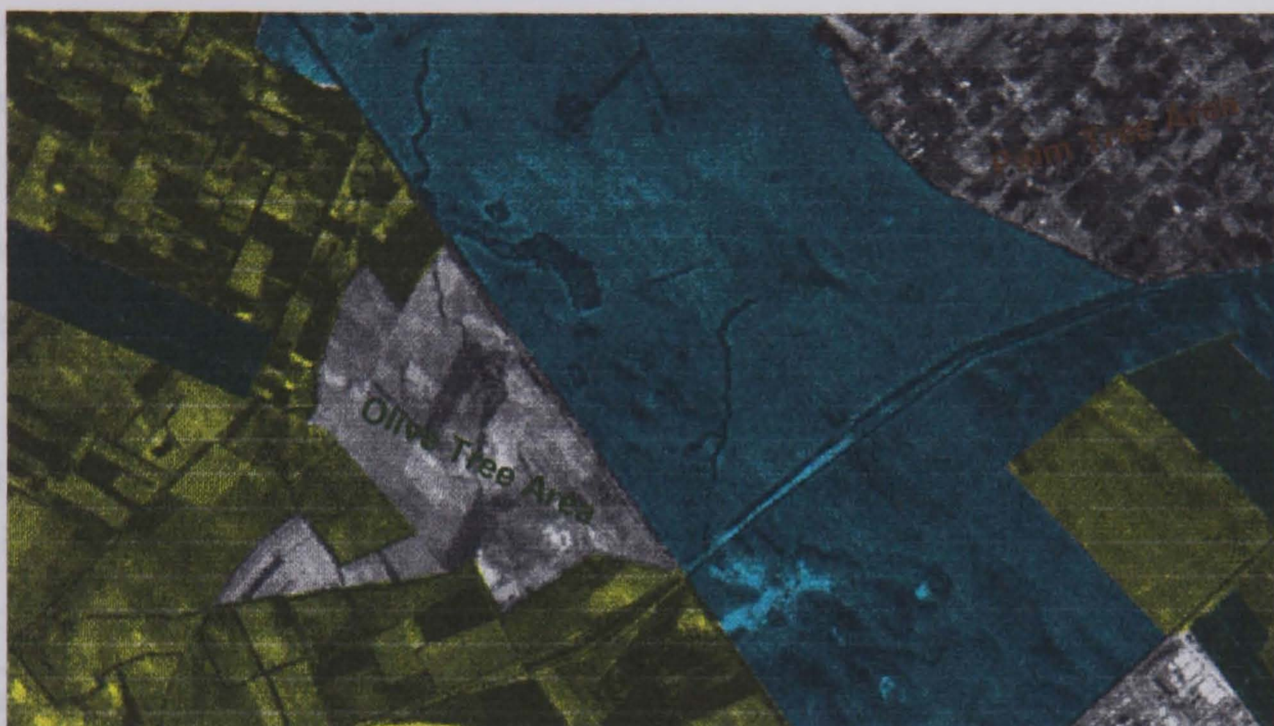


Figure 12–6f: Colour 1 for each class of land cover and vegetation. (1:50,000 scale)

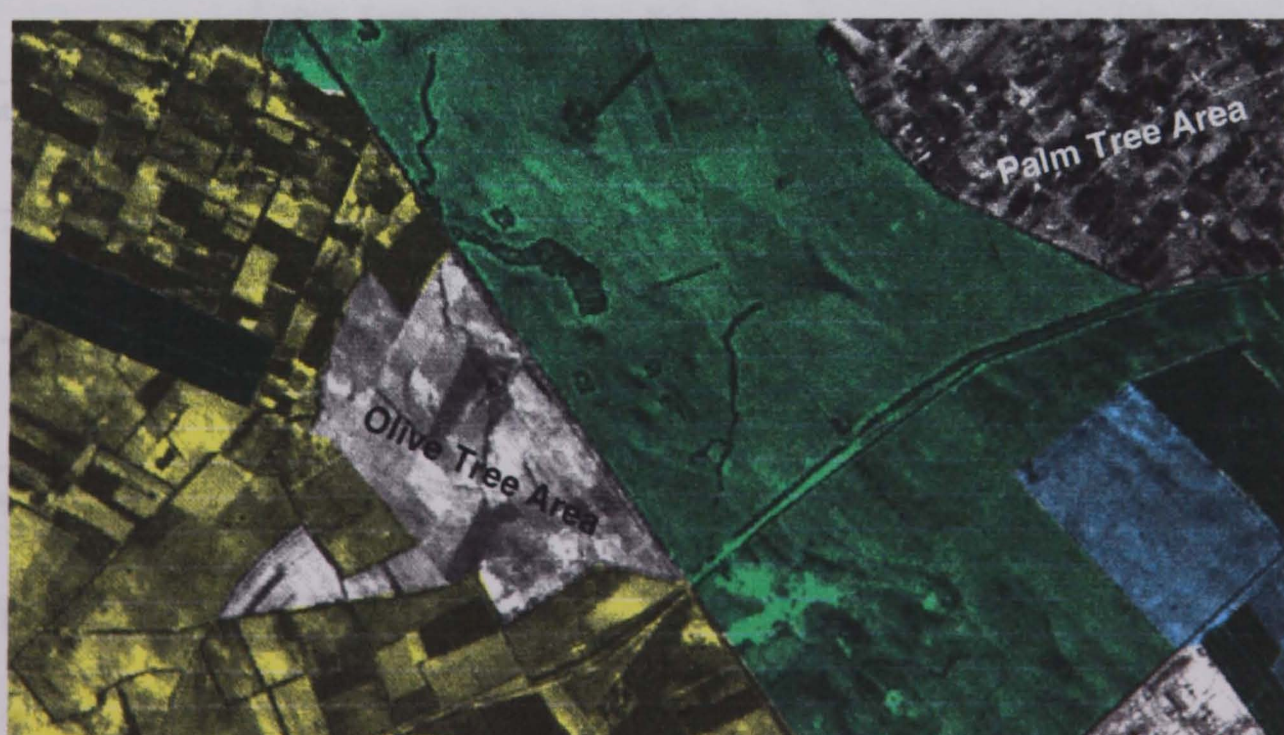


Figure 12–6g: The selected colours for the different land cover and vegetation classes. (1:50,000 scale)

(iii) Colour

Colour is by far the most important and most effective graphic variable in showing land cover and vegetation using areal symbols. From the user's point of view, the standard colour convention used with line maps should be followed since yellow and green are the colours most used to represent cultivated areas and forest respectively and thus are well known and well understood by most map users. In the author's opinion, when treating vegetation on image maps, the cartographer should always bear in mind that the natural physical appearance and characteristics of land cover, land use and vegetation features should be maintained whenever possible. For example, it is always helpful and provides far more information about the area to the users of image map users if they can see the small fields with different cultivation patterns within the cultivated lands. As can be seen in Figures 12-6f and 12-6g and Table 12-15, cultivated lands have been represented using two different degrees of transparent yellow specified with different opacity. For orchards, the regular pattern of the planted trees can be seen and maintained through the use of a transparent light green or bluish green. Whereas, transparent dark green and transparent light yellow or bluish green have been used for the representation of forest and fallow lands respectively. Black and white texts have been used to pick out the areas of palm and olive trees. Figure 12-6g and Table 12-15 show the most appropriate colours selected to display the different classes of land cover and vegetation.

Land Cover & Vegetation	**Colour 1** (See Figure 12-6f)	**Conclusion** (See Figure 12-6g)
- Cultivated Areas	Transparent Colour (Opacity = 50%) 20% Magenta + 100 % Yellow	Transparent Colour (Opacity = 35%) 100 % Yellow
- Orchards	Transparent Colour (Opacity = 50%) 100% Cyan + 20 % Magenta + 60% Yellow	Transparent Colour (Opacity = 35%) 100% Cyan + 100 % Yellow
- Forests	Transparent Colour (Opacity = 50%) 80% Cyan + 50 % Magenta + 80% Yellow	Transparent Colour (Opacity = 35%) 100% Cyan + 70% Magenta + 100 % Yellow
- Palm Tree Areas	Brown Text 30% Cyan + 70% Magenta + 100% Yellow	White Text
- Olive Tree Areas	Green Text 50% Cyan + 40% Magenta + 100% Yellow	Black Text
- Fallow Lands	Transparent Colour (Opacity = 50%) 50% Cyan + 50 % Magenta + 100% Yellow	Transparent Colour (Opacity = 35%) 100% Cyan + 20% Magenta + 60 % Yellow

Table 12-15: The Alternatives and the Selected Colours for Land Cover and Vegetation Symbols

12.3.2.6 Other Area Features

The other main types of physical feature that are present in the test area comprise sabkhahs (salt marshes); hummocks and ridges: and sand hummocks with low growth. These mainly occupy the south-eastern part of Misratah region. The representation of such physical areas on image maps is quite significant in terms of human activities in the area and it is important for map users to know their nature, location. extent and distribution. To a certain extent. a similar approach in terms of cartographic treatment and design to that applied to land cover and vegetation has been adopted to retain the natural and real appearance of these features as far as possible in an attempt to aid interpretation. The other important issue was the distinction between the different classes of these physical features and also between them and the land cover and vegetation classes.

(i) Form

As far as **form** variations are concerned, there were not too many differences as compared with those applied to land cover and vegetation features. Figures 12-7a and 12-7b and Table 12-16. show that the only major differences were the use of interrupted outlines and letters (abbreviations) to emphasise the distinction between them and the land cover and vegetation categories.

Other Area Features	Form 1 (See Figure 12-7a)	Conclusion (See Figure 12-7b)
- Sabkhahs	Outlined Areal Symbols	Outlined Areal Symbols With Text (abbreviations)
- Hummock & Ridges	Outline Only	Outline with Text (abbreviations)
- Sand Hummocks with Low Growth	Outlined Areal Symbols	Outlined Areal Symbols With Text (abbreviations)

Table 12-16: The Alternative Forms Selected for the Other Area Feature Symbols

(ii) Dimension

Dimension changes were only applied to the width of the outlines and the size of the text. Interrupted lines with different dimensions – dash widths, dash lengths and spaces between dashes – were used and tested visually. Alternatives of letter sizes were also used. see Figures 12-7c and 12-7d and Table 12-17.

Other Area Features	Dimension 1 (mm) (See Figure 12-7c)	Conclusion (mm) (See Figure 12-7d)
- Sabkhahs	**Outline**: width = 0.15 Dash Length = 1.00 Space = 0.60 **Text Height**: 2.20	**Outline**: width = 0.20 Dash Length = 1.20 Space = 0.80 **Text Height**: 2.50
- Hummock & Ridges	**Outline**: width = 0.15 Dash Length = 1.00 Space = 0.60 **Text Height**: 2.20	**Outline**: width = 0.20 Dash Length = 1.20 Space = 0.80 **Text Height**: 2.50
- Sand Hummocks with Low Growth	**Text Height**: 2.20	**Text Height**: 2.50

Table 12-17: The Alternative Dimensions Selected for the Other Area Feature Symbols

(iii) Colour

The use of transparent **colour** (in solid or tint forms) allows, to a considerable extent, the map users to see the natural appearance of the area feature underneath. This helps these users to interpret and distinguish the specific type of feature involved. Indeed, this is really helpful since, for example, urban areas have their own surface characteristics (i.e. street structures and building blocks) by which these areas can be distinguished. The same can be said about cultivated lands, which can be recognised by the pattern and shape of the small cultivated fields. However, the identification of such features on the space image is invariably resolution dependent – though this is not a serious issue when SPOT Pan image data with a 10m ground pixel size is being used.

From a cartographic point of view, the use of solid colours to represent large area features on image maps is a thoroughly undesirable design practice, since they introduce the real danger of disturbing and unbalancing the final image map. As can be seen in Figures 12-7e and 12-7f and Table 12-18, different shades (tints) of brown and dark blue have been used for sand hummocks with low growth and for sabkhahs respectively. No colour has been used for the hummocks and ridges; instead only a 20% black (grey) outline and white text were used to distinguish these areas. In fact, grey and white were also used to delineate the outlines and for the names or text used to distinguish the other classes (sabkhahs and sand hummocks with low growth). The most appropriate area symbols for these area feature classes are shown in Figure 12-7f.

Figure 12–7a: Form 1 for each class of the other area features. (1:50,000 scale)

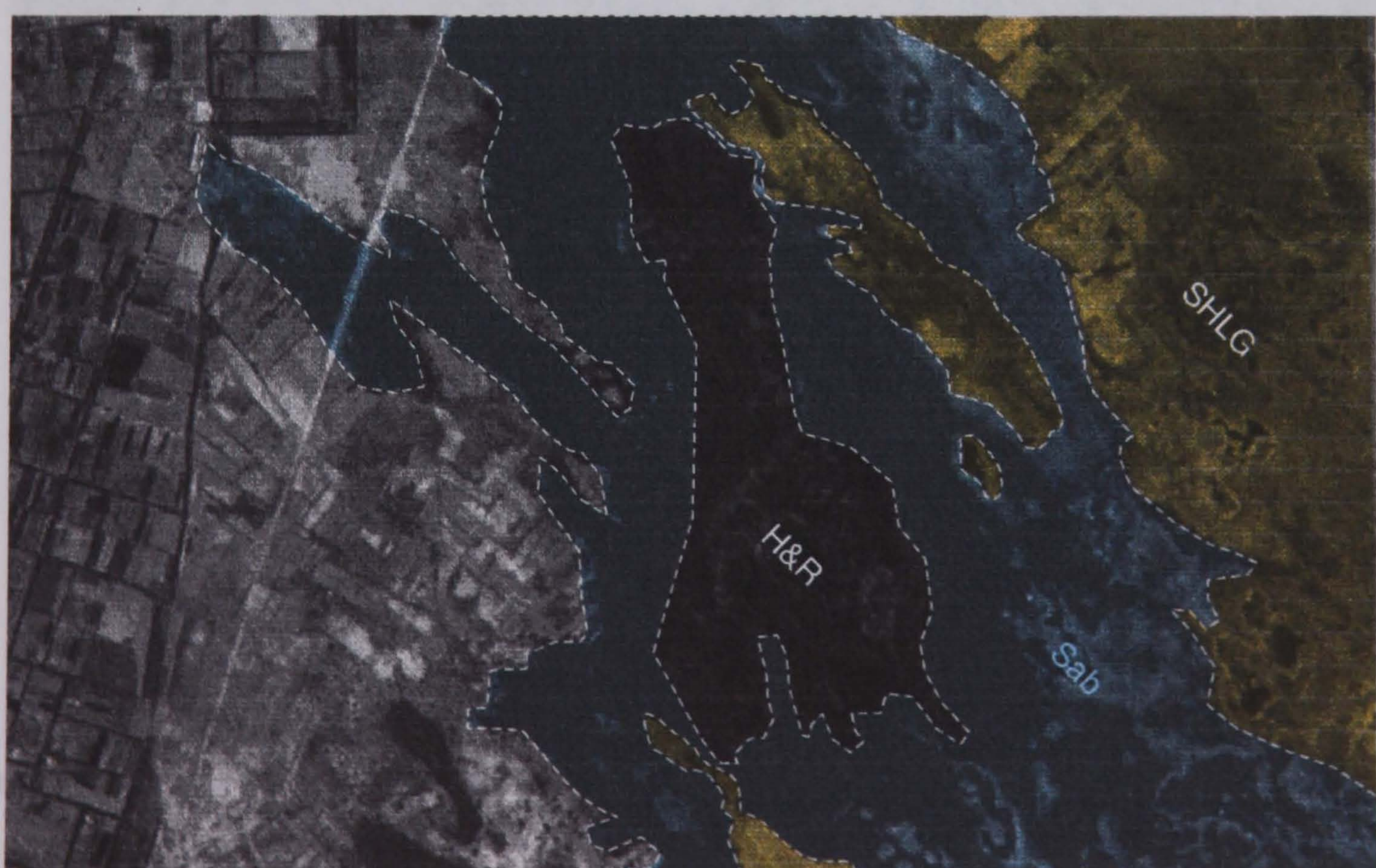


Figure 12–7b: The forms selected for the three classes of the other area features. (1:50,000 scale)

Figure 12–7c: Dimension 1 for each class of the other area features. (1:50,000 scale)

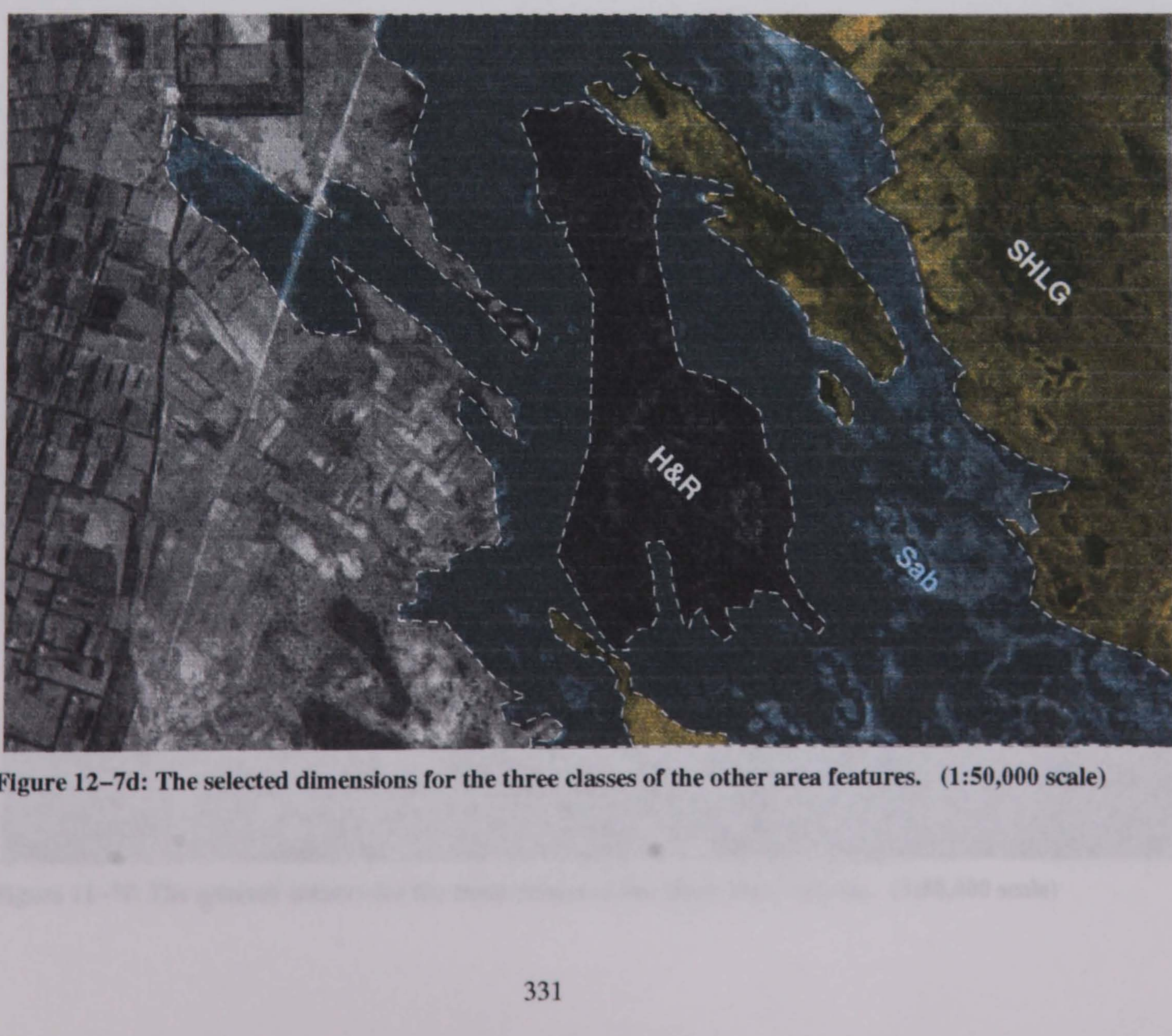


Figure 12–7d: The selected dimensions for the three classes of the other area features. (1:50,000 scale)

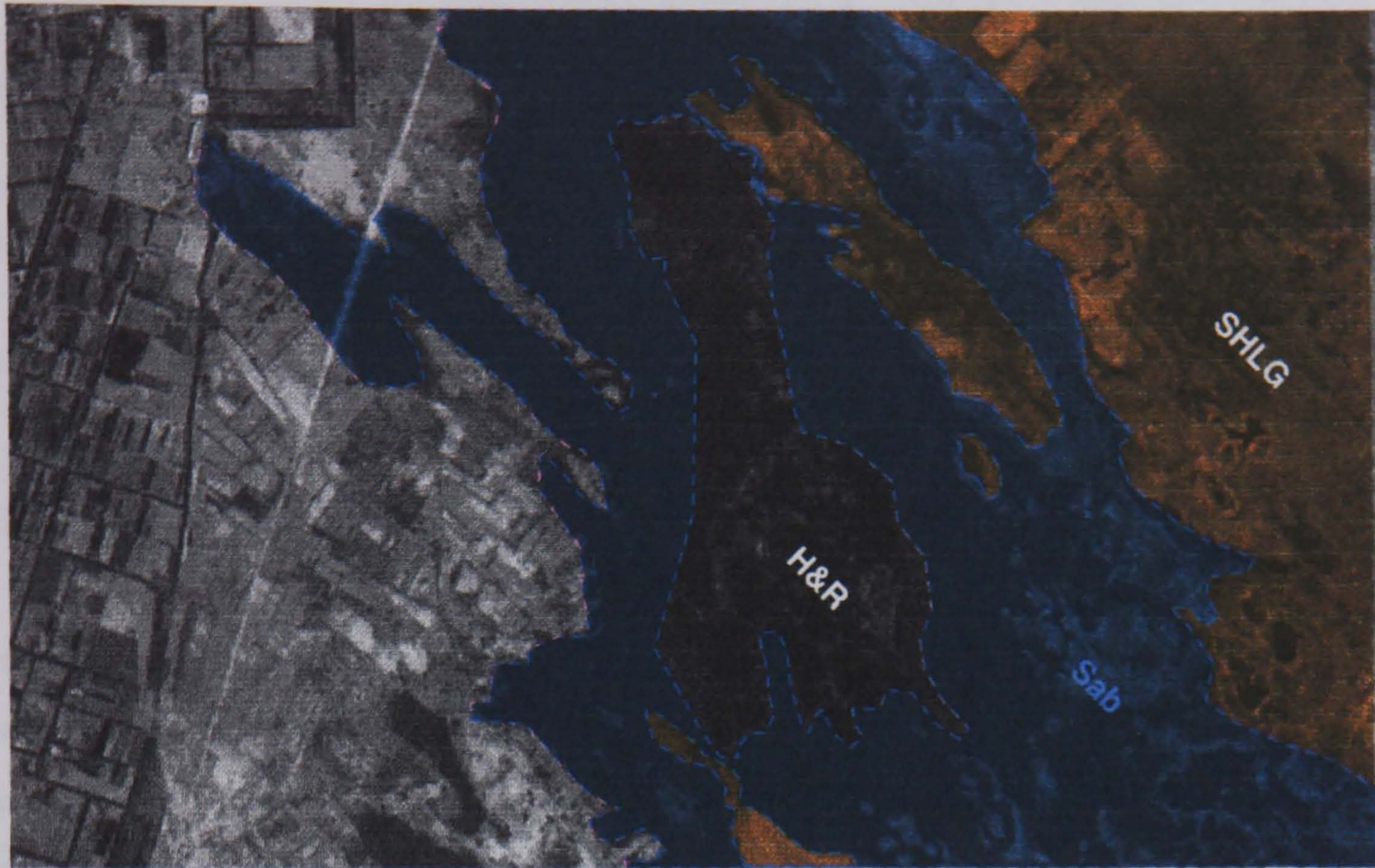


Figure 11–7e: Colour 1 for each class of other area features. (1:50,000 scale)

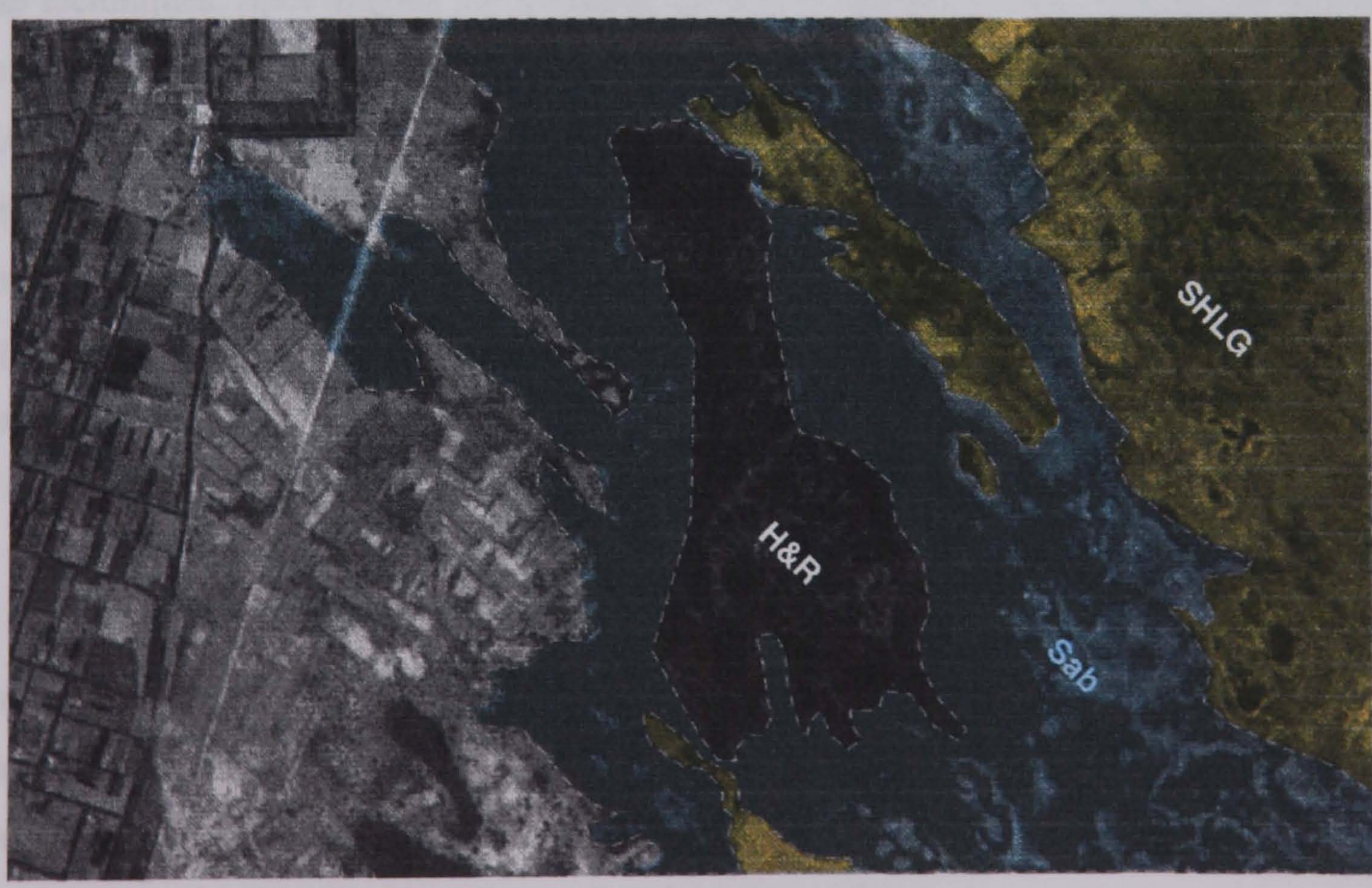


Figure 11–7f: The selected colours for the three classes of the other area features. (1:50,000 scale)

Other Area Features	Colour 1 (See Figure 12-7e)	Conclusion (See Figure 12-7f)
- Sabkhahs	Areal Transparent Colour (50% Opacity) 100% Cyan + 70% Magenta +500% Yellow Outline Colour: 100% Cyan + 30% Magenta Text Colour: White	Areal Transparent Colour (40% Opacity) 80% Cyan + 60% Magenta +40% Yellow Outline Colour: 20% Black Text Colour: White
- Hummock & Ridges	Outline colour: 10% Cyan + 40% Magenta +100% Yellow Text Colour: White	Outline colour: 20% Cyan + 60% Magenta +100% Yellow Text Colour: White
- Sand Hummocks with Low Growth	Areal Transparent Colour (50% Opacity) 50% Cyan + 80% Magenta +100% Yellow Text Colour: White	Areal Transparent Colour (40% Opacity) 80% Cyan + 70% Magenta +100% Yellow Text Colour: White

Table 12-18: The Alternative Colours Selected for the Other Area Feature Symbols

12.3.2.7 Relief

A combination of contours and spot heights is commonly used to depict relief on most topographic maps, and can be considered to be the best method of relief representation for space image maps also. They do however need careful treatment if they are not to dominate or disrupt the appearance of the map, and must be carefully designed to blend in with the terrain features that are shown by the space image. The space image can be utilised to show small but important relief features, such as gullies, minor breaks of slope, or small depressions or elevations which often cannot be shown quite as well using conventional topographic line map techniques. Spot heights are normally used in conjunction with contours to provide key elevations, and in comparatively flat areas such as much of the Misratah area, they can provide adequate relief information when viewed in conjunction with the space image. In the majority of cases, however, contours are necessary, and, if they are picked out and represented well in relation to the background space image, it is possible that a much better impression of relief can be obtained on the space image map than on a contoured line map. Certainly, the absolute height information given by the contours will often be supplemented by the background image to bring out minor relief features.

(i) Form

For contours and spot heights, there were no **form** changes to be made since only one form is available, given the fact that these methods of relief representation are always shown on maps through the use of single continuous lines (for contours) and the individual dots associated with the elevation numbers accompanying the spot heights.

(ii) Dimension

Figures 12-8a and 12-8b and Table 12-19, show that **dimension** variations were possible for both contours and spot heights. This means that various alternative line widths (between 0.1 and 0.3mm) were used in order to obtain the most appropriate value for the contour lines. For the spot heights, dots of different diameters associated with elevation numbers of different sizes were also used. The most appropriate and selected dimensions for relief symbols are shown in Figure 12-8c.

Relief	**Dimension 1 (mm)** (See Figure 12-7a)	**Dimension 2 (mm)** (See Figure 12-7b)	**Conclusion (mm)** (See Figure 12-7c)
- Contour Lines	**Index Contours:** Line Width: 0.15 **Other Contours:** Line Width: 0.15	**Index Contours:** Line Width: 0.25 **Other Contours:** Line Width: 0.15	**Index Contours:** Line Width: 0.30 **Other Contours:** Line Width: 0.20
- Spot Heights	**Spot Height:** Diameter: 0.50 **Text Height:** 1.50	**Spot Height:** Diameter: 0.50 **Text Height:** 2.20	**Spot Height:** Diameter: 0.80 **Text Height:** 1.80

Table 12-19: The Alternative Dimensions Selected for Relief Symbols

(iii) As mentioned above, contours are not easy to handle and need special cartographic treatment as far as image mapping is concerned. Although **colour** can be considered as the most effective graphic variable for contours, in particular when designing image maps, it may not give successful results if not treated properly. This is particularly the case, if (as is usually the case) the background is a black and white image with tonal variations. In this case, black contours will vanish in dark areas and white lines will not be seen in very light regions having a high surface reflection. Figure 12-8d shows how the use of heavy black lines for contours gives a poor result, since they appear to "float" above the landscape and bear little or no relation to it. The use of brown for contour lines (Figure 12-8e) may give better results in terms of ensuring that they blend in with the terrain and give a better contrast, especially if the background image is in a light yellow or sandy colour. As can be seen in Figure 12-8f, the use of white is another possibility, but the line width should then be kept as fine as possible. This figure also shows that the use of white has also provided better results for the representation of spot heights. Figure 12-8f and Table 12-20 show the finally selected parameters in terms of the symbol design used to depict relief on image maps.

Relief	Colour 1 (See Figure 12-7d)	Colour 2 (See Figure 12-7e)	Conclusion (See Figure 12-7f)
- Contour Lines	Black	Brown	White
- Spot Heights	Black	Brown	White

Table 12-20: The Alternative Colours Selected for Relief Symbols

In summary, it will be seen from all these experiments and discussions relating to the cartographic symbols designed for use with the space image map (at 1:50,000 scale) of the Misratah area, that there is no single or absolute solution that can be applied to each type of map symbol (point, line or area). This resulted from the fact that, in reality, the various features vary in form, extent or size and in the colour or tone of their natural appearance. In some situations, a good result in terms of contrast and integration with the background image may not be provided when the same symbol design is used all over the map. This is because the terrain characteristics differ from one area to another within the same map sheet. Although the cartographer must always be aware of ensuring a sufficient contrast and distinction between the various symbols, he must bear in mind that other factors – such as scale, terrain characteristics, technical limitations, etc. – may not allow him to do so. Obviously, it is always a matter of cartographic judgement as to how the cartographer should deal with each individual design problem in image mapping. This is, of course, will rely totally on his cartographic education and practical experience and on the time and money available for the task.

Besides the well known conventional methods – i.e. contour lines, spot heights, hill shading, hypsometric colours, etc. – of depicting relief, very recent investigations have shown that new 3-D visualisation techniques developed by Dr. Therry Toutin (1995) of the Canadian Remote Sensing Centre using the effect known as chromo-stereoscopy could also be used in the production of space-based image maps for use in office and field. In particular, this technique could be of a great value in showing the characteristics of the physical terrain in Libya and could be used as a complementary product to space image maps to depict relief and the various landforms of the terrain – see Appendices VII, VIII and IX.

Figure 12–9a: Dimension 1 for each represented class of relief. (1:50,000 scale)

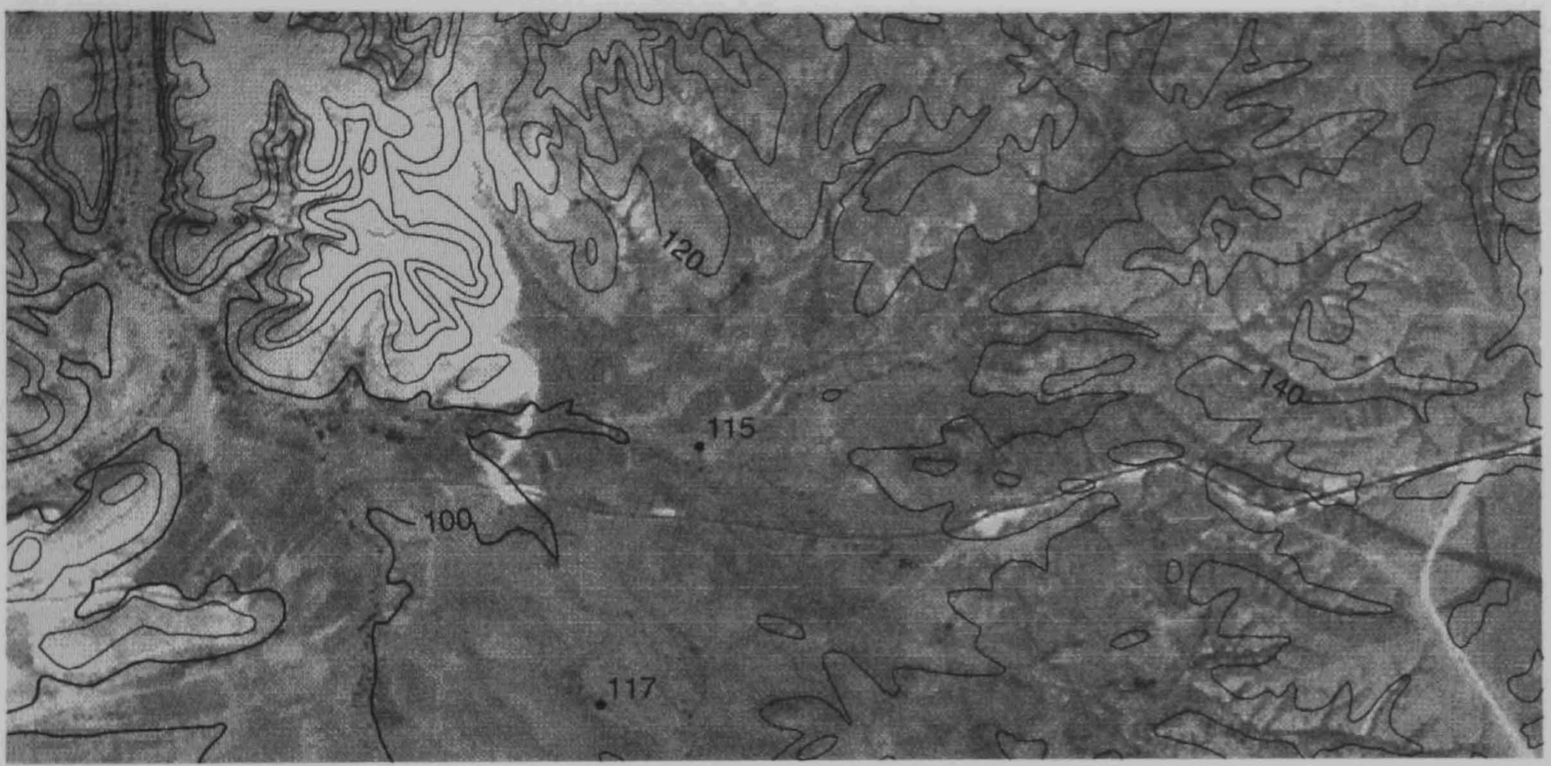


Figure 12–9b: Dimension 2 for each represented class of relief. (1:50,000 scale)

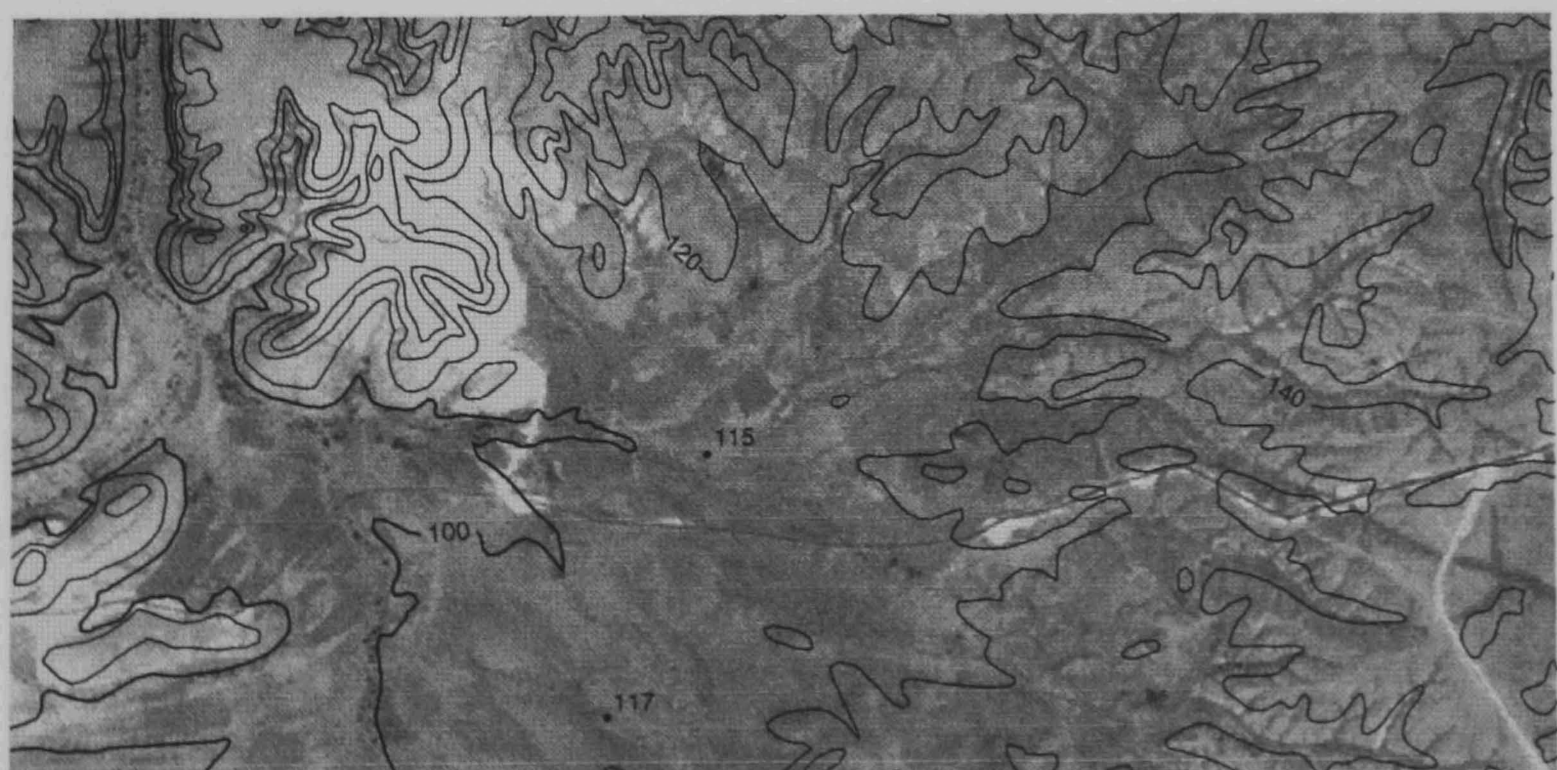


Figure 12–8c: The selected dimensions for tthe two classes of relief. (1:50,000 scale)

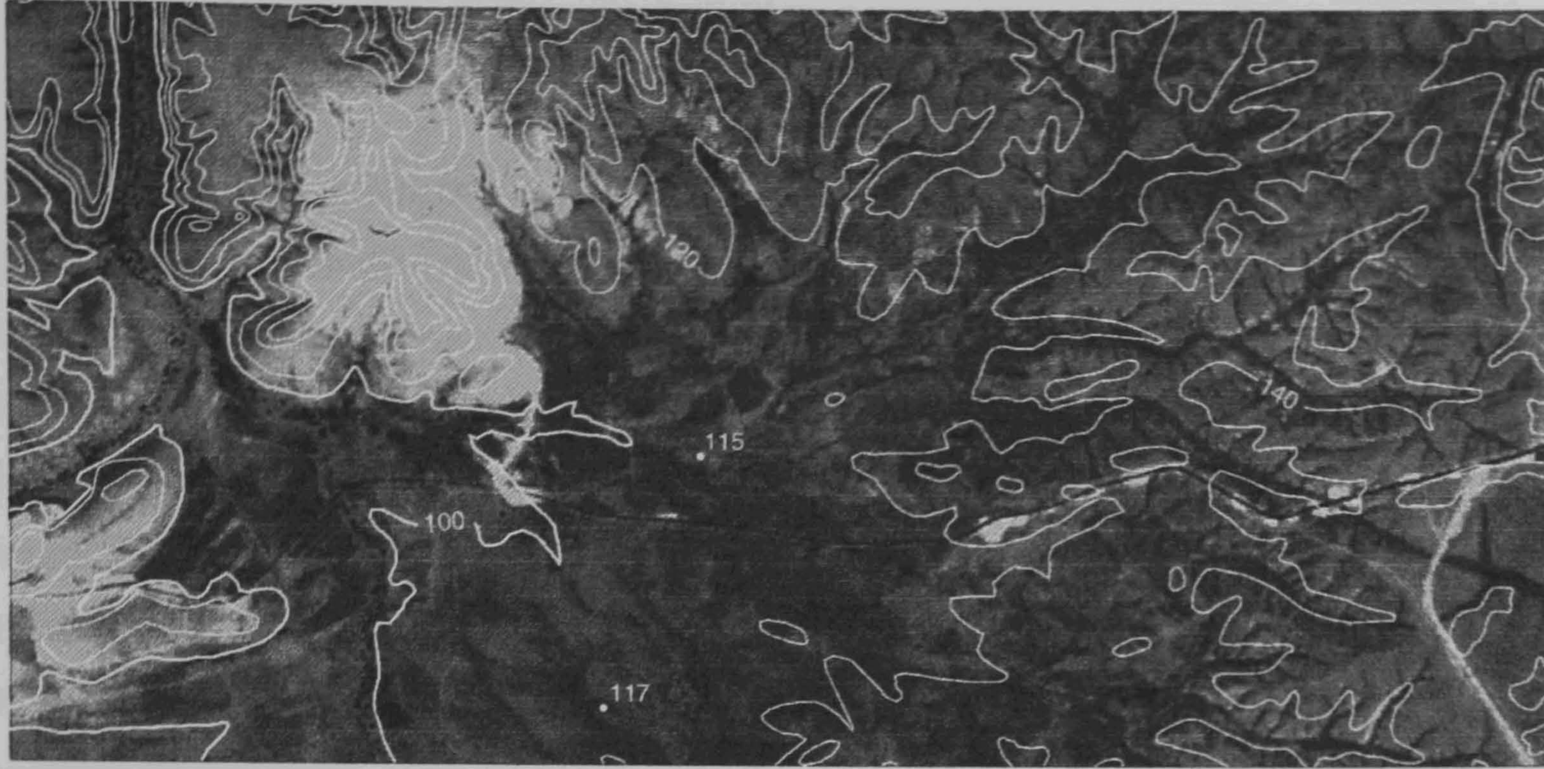


Figure 12–8d: Colour 1 for each represented class of relief. (1:50,000 scale)

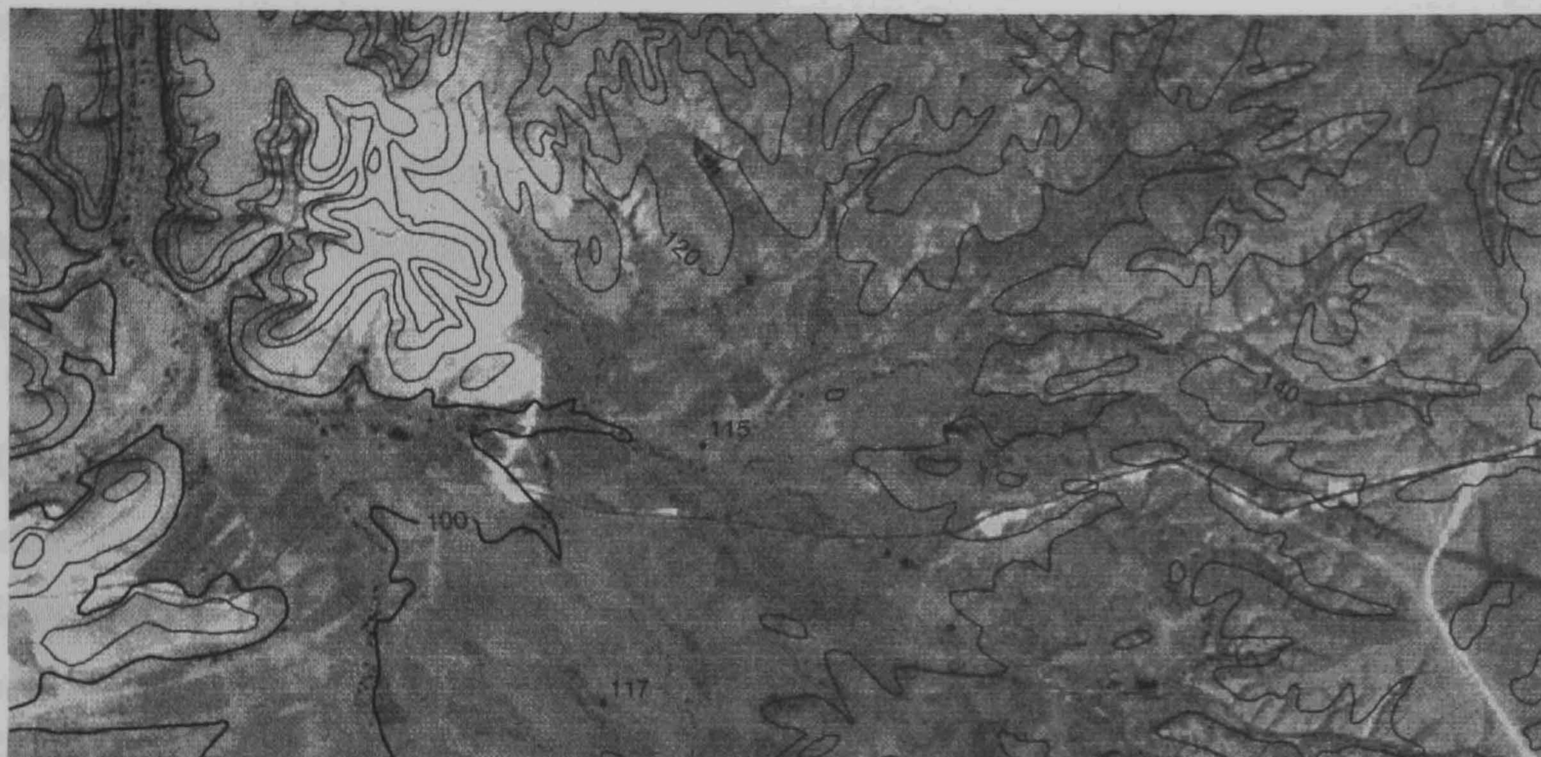


Figure 12–8e: Colour 2 for each represented class of relief. (1:50,000 scale)

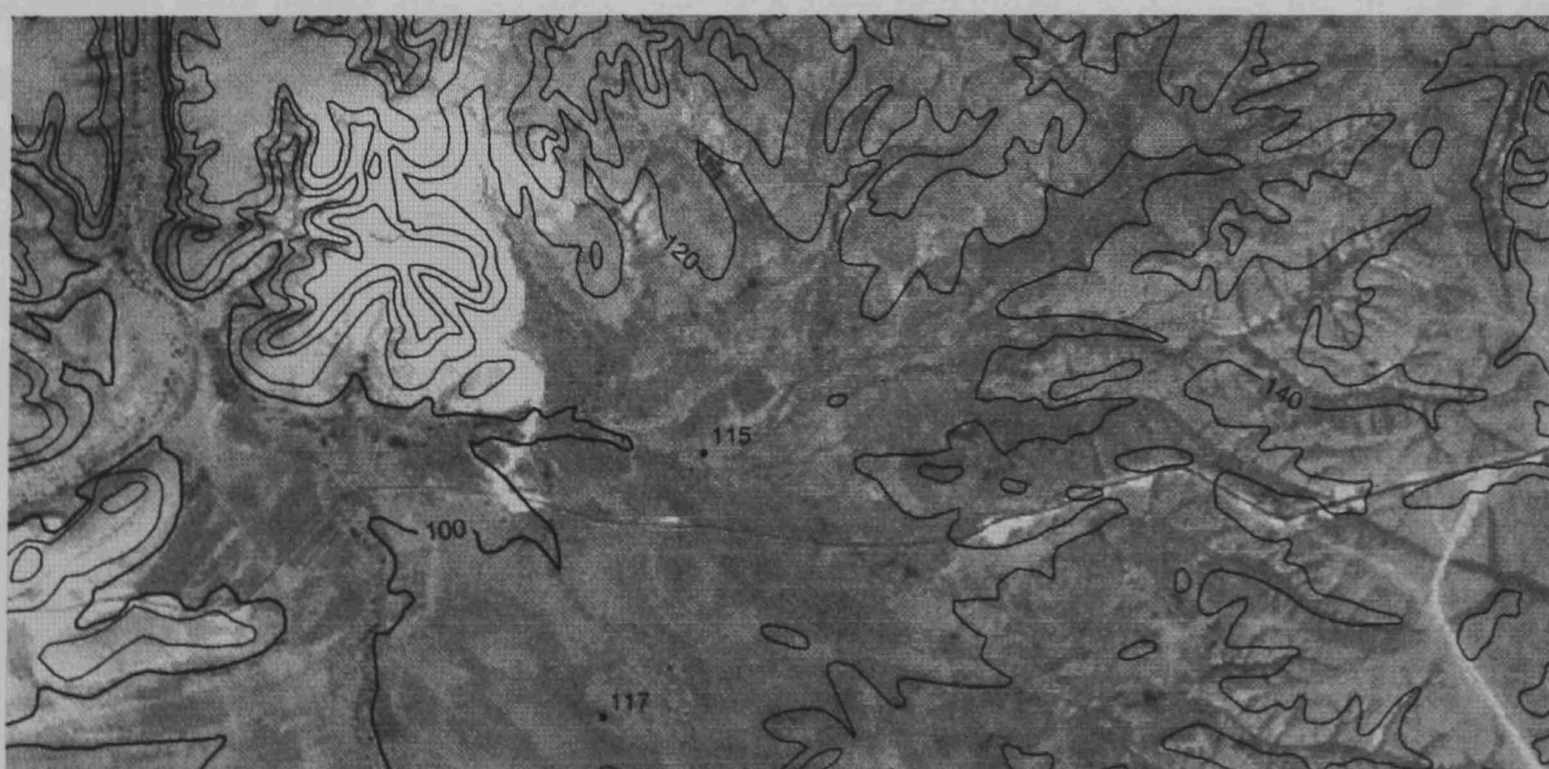


Figure 12–8f: The selected colours for the two classes of relief. (1:50,000 scale)

12.4 The Experiments and Evaluation for the 1:250,000 Scale Image Map Symbols

As the scale of the image map gets smaller, the need to use more symbols to supplement the space image becomes apparent. In fact, the scale and, therefore, the ground resolution of the imagery control the amount of detail that can be displayed on the space image in the first place. Normally, it is true that the smaller the scale of the map, the greater will be the degree of generalisation. This means that the results of generalisation are most evident at the smaller scales. In this context, only those features should be shown that are of importance for the 1:250,000 scale image map of Misratah area in Libya. Certain features (such as water towers, schools, church, mosques, etc.) that are of minor importance at the smaller scale may be omitted. At this point, it is obvious that, as the scale is reduced – by 5 times in this particular case – so is the total space (reduced by 25 times) that is available for the map symbols. However these cannot be reduced in proportion, since this would certainly produce tiny symbols that would be unclear or illegible. Clarity and legibility depend on symbol size, form and colour. In turn, these affect the contrast of these symbols against the tonal background of the space image.

To a considerable extent, the design experiments for the symbols to be used in the 1:250,000 scale image map have followed similar procedures and tests to those undertaken for the design of the 1:50,000 scale image map symbols. Once again, the author consulted a considerable number of existing image and topographic line maps at 1:250,000 scale in order to be more familiar with their symbol design and specifications. The design experiments for 1:250,000 scale image map symbols have also been undertaken systematically in a deliberate attempt to ensure a successful design for each individual symbol used in the map. This means that various alternatives in terms of form, dimension and colour have been created for each individual symbol in order to reach the most appropriate design for it. The author's main target was to achieve both clarity and visual contrast between the symbols, and between them and the background image. In this respect, similar accounts will not be discussed or repeated in this section. Instead only certain specific matters in terms of cartographic design and treatment will be explained in some detail.

Figure 12-9: The most appropriate symbols in terms of form, dimension and colour for cultural features representation. (1:250,000 scale)

12.4.1 Differences in Point Symbol Experiments

To start with, due to the scale limitations, only a certain number of the point features that were included in the 1:50,000 scale image map have been included and shown on the 1:250,000 scale map. Thus only certain important point features have been added to the space image. In this respect, although wells are very small in size, they have been included since they are the only water sources in some parts of the study area and vital to the inhabitants of these areas. Scale reduction has also resulted in the main villages being shown through the use of geometric point symbols (outlined solid circles) rather than area symbols. While airports have been represented using iconic point symbols inside circles instead of the real representation of the runway using line symbols. Other point features such as shrines, cemeteries, ruins, etc. have been displayed using framed point symbols. Since all the point symbols became smaller in size, even with a certain degree of exaggeration, strong colours (such as red, black, yellow and light blue) with sufficient contrast have been used to enable these point symbols to be clear and legible. Of course, yellow, as a bright colour of good contrast, has been used as a hold out mask (background) for black point symbols. The most appropriate point symbols in terms of their form; dimension and colour are shown in Figure 12-9.

12.4.2 Differences in Line Symbol Experiments

(i) General-purpose small-scale topographic maps often place a great deal of emphasis on **roads** and their classification. This is done on the basis that road information is especially valuable to the general user at such scales. Indeed they are often used as road maps. Thus road symbols are likely to be exaggerated further on 1:250,000 scale maps. Therefore, graphic requirements are affected both by judgements of their importance and the particular function and style of the map. This is exactly the case with the Misratah area. Furthermore, although tracks are small in width, they should still be shown on 1:250,000 scale maps since they are perhaps the only means of communication in many areas. Hence the need to emphasise these small but important details in the space image will obviously increase as the map scale decreases.

Roads are very important and must be shown on the space image maps at 1:250,000 scale. Of course, this is not easy to achieve, since the line symbols will become thinner and yet they must have sufficient contrast to be clear and legible against the space image. This is a real problem especially when different areas and different landscape patterns will present their own particular problems. Consequently, the reduction in scale certainly does make it more difficult to represent roads on this type of map. In such a situation, since the line symbols that will be used to show roads will become thinner, a reasonable level of line exaggeration has to be implemented and a careful balance of colour and control of contrast must be achieved. Apart from indicating the presence of the road features in the landscape, there must be an evaluation of the significance of these features. For example, major roads must be made more obvious than tracks through variations in form, dimension and colour.

Road Class	Dimension 1 (mm) (Figure 12-10a)	Dimension 2 (mm) (Figure 12-10b)	Conclusion (mm) (Figure 12-10c)
- Highway	0.10x0.30x0.10x0.30x0.10	0.15x0.30x0.10x0.30x0.15	0.15x0.35x0.10x0.35x0.15
- Main Paved Road	0.10x0.50x0.10	0.15x0.50x0.15	0.15x0.60x0.15
- Secondary Paved Road	0.10x0.30x0.10	0.10x0.40x0.10	0.10x0.40x0.10
- Unpaved Road	Line Width: 0.20 Dash Length: 2.50 Space Length: 1.50	Line Width: 0.30 Dash Length: 3.00 Space Length: 2.00	Line Width: 0.40 Dash Length: 2.00 Space Length: 0.80
- Track	Line Width: 0.20 Dash Length: 1.20 Space Length: 0.80	Line Width: 0.25 Dash Length: 1.50 Space Length: 1.00	Line Width: 0.25 Dash Length: 1.40 Space Length: 0.80

Table 12-21: The Dimension Alternatives and Conclusion for each Individual Class of Roads. (1:250,000 scale).

Figure 12–10a: The first alternative of line dimensions that have been used for the different classes of roads. (1:250,000 scale)

Figure 12–10b: The second alternative of line dimensions that have been used for the different classes of roads. (1:250,000 scale)

Figure 12–10c: The most appropriate line dimensions selected for the different road classes. (1:250,000 scale)

Figure 12–10d: The first alternative of line colours that have been used for the different classes of roads. (1:250,000 scale)

Figure 12–10e: The second alternative of line colours that have been used for the different classes of roads. (1:250,000 scale)

Figure 12–10f: The most appropriate line colours selected for the different road classes. (1:250,000 scale)

Figures 12-10a and 12-10b and Table 12-21 indicate that five classes have been used to represent roads on the image map of Misratah at 1:250,000 scale. Different line widths and different dimension specifications have been used to help the user to distinguish one type of line symbol from another. Various levels of exaggeration have been applied to make each line symbol clear in order to be perceived visually – see Figures 12-10a and 12-10b. At the same time, over-exaggeration of these features has been avoided in an attempt to maintain the visual balance of the final image map product. In fact, to achieve clarity and legibility by increasing the size (and visual impact) of symbols is simply not the right solution, since this will only result in a crowded appearance in the overall image map. The final appearance will then be too heavy and lack clarity against the background image with the superimposed cartographic details competing with one another instead of complementing one another. As can be seen in Figure 12-10c and Table 12-21, the selected lines were those that proved to be most appropriate (in terms of line **dimensions**) for the five classes of roads.

To a certain extent, the **colour** treatments used for the various road classes at 1:250,000 scale were different to those used with the 1:50,000 scale map. As a result of the scale reduction, the line symbols needed to become thinner, which then needed stronger colours in order to be clearly legible and to achieve sufficient contrast against the black and white space image. However the cartographer should always bear in mind that the use of very strong colours can contrast strongly against the background image and would produce poor results in terms of design. Figure 12-10e shows an example of this type of unsuccessful design solution. In this particular example, an unpaved road was represented using a dashed line in solid black. This line symbol contrasted sharply against the natural image and could be perceived as floating above, rather than blending in with the space image. In fact, in the author's opinion, it appears completely divorced from this image. Better results have been obtained when a 60% yellow or white line symbol was used to show this class of road – see Figures 12-10d and 12-10f. On the other hand, the colours used to display the different classes of roads (Figure 12-10d) did have sufficient contrast with the background. Unfortunately, they were not represented in a good visual order since white, yellow, red, white and black have been used to show highways, main paved, secondary paved, unpaved roads and tracks respectively. Figure 12-10f shows that better results were achieved when lighter colours were used for the lower–order road classes. The selected and most appropriate line symbols in terms of colour treatment are shown in Figure 12-10f and summarised in Table 12-22.

Road Class	Colour 1 (Figure 12-10d)	Colour 2 (Figure 12-10e)	Conclusion (Figure 12-10f)
- Highway	Infill: White Casings: Black Central Line: Black	Infill: 100% Red Casings: Black Central Line: Black	Infill: 100% Red Casings: Black Central Line: Black
- Main Paved Road	Infill: 60% Yellow Casings: Black	Infill: White Casings: Black	Infill: 70%Yellow Casings: Black
- Secondary Paved Road	Infill: 100% Red Casings: Black	Infill: 70% Yellow Casings: Black	Infill: White Casings: Black
- Unpaved Road	White	Black	White
- Track	Black	White	White

Table 12-22: The Colour Alternatives and Conclusion of each Individual Class of Road. (1:250,000 scale).

(ii) The representation of those features which are not visible on the terrain, such as <u>contour lines</u>, must be executed with extreme caution. These are imaginary lines, in the sense that they do not exist in nature, although from the cartographic viewpoint they are an essential part of the terrain representation. Ideally the lines representing contours should blend into, rather than contrast sharply with the space image. As mentioned previously in Chapter 11, although contours were included in the content specifications of the image map of Misratah at 1:250,000 scale, there were no digitized contours available for the whole study area that could be superimposed on top of the image. Nor was a separate contour plate available that could be readily examined and digitized. For the 1:250,000 scale experiments, digitized contour lines with contour intervals of 20m were only available for relatively small area within the study area of Misratah; these contours having been derived from topographic maps at 1:50,000 scale. Selective omission has been applied to these contour lines (Figure 12-11) in order to obtain better design results and refrain from concealing important information shown on the natural space image. Once again, it was found that the use of the white colour was more appropriate, since this colour appeared to integrate better with the background image than any alternative that was tested.

12.4.3 Differences in Area Symbol Experiments

Cartographic treatment is necessary to bring some order into the undifferentiated space image. For example, built-up areas must be clearly differentiated from open areas. Differences in land cover and vegetation must be picked out in order to help the user. In other words, aid must be given to image map user to enable the quick recognition of the most important features, which might otherwise be difficult to discriminate from the wealth of other information contained in the space image. However, the representation of those features requiring emphasis will naturally rely on the scale and the terrain characteristics of the area covered by the image map. The use of natural colour, or some colour associated with certain classes of natural objects, such as green for vegetation, blue for water areas, etc. will have the advantages of retaining the natural appearance of terrain representation and, through colour association, giving the map user more aid for the image map interpretation. This can be done, for example, by printing the background image in black and white, and overprinting transparent area colours to designate the various area symbols.

(i) For built-up areas, the scale reduction to 1:250,000 has resulted in the omission of certain small area features. Thus, for example, towns were only shown through the use of area symbols at 1:50,000 scale. However, since the size of this type of feature became much smaller on the 1:250,000 scale image map, the transparent red colour that was used on the 1:50,000 scale map has been darkened in order to achieve sufficient contrast against the background image, see Figure 12-9. However, at the same time, very strong colours had to be avoided in order to maintain agreement with natural image.

(ii) The same or similar remarks can be made in the case of land cover and vegetation, since, as the scale became much smaller, only three land cover and vegetation classes were included – which were cultivated lands, orchards and forests. To emphasise the presence of cultivated land and vegetation from those open areas with no vegetation and to ensure their differentiation from other area features, a transparent green colour with yellow outlines has been used for all three classes. However, as can be seen in Figure 12-12, to help users differentiating between cultivated land, orchard and forests, abbreviated text has been used to identify each individual class.

12.5 Conclusion

The design and cartographic treatment of symbols in image mapping is a complex task, and very much depends on the nature of any particular area being mapped. The need for symbols increases in the inhabited areas, and hence the problem of achieving clarity and some degree of integration with the background image is at its greatest in such areas.

From the design aspect, the needs of a map series, as opposed to those of an individual map, are still more complex. For example, a conventional map series, such as the SDL 1:50,000 coverage of Libya uses the same conventional symbols and design over the whole area being mapped within the country. Considering the variety in the Libyan landscape, the same approach probably cannot be applied with image maps. So to achieve a similar national image map coverage, the cartographer will almost certainly be forced to modify the design of individual maps to suit the variety of landscape characteristics visible in the imagery.

In the next Chapter, the combination and integration of the different elements and the overall design and specifications of the experimental space image map at 1:50,000 scale will be presented and discussed in some detail.

Figure 12-11: Shows the treatment of contours on image maps. (1:250,000 scale)

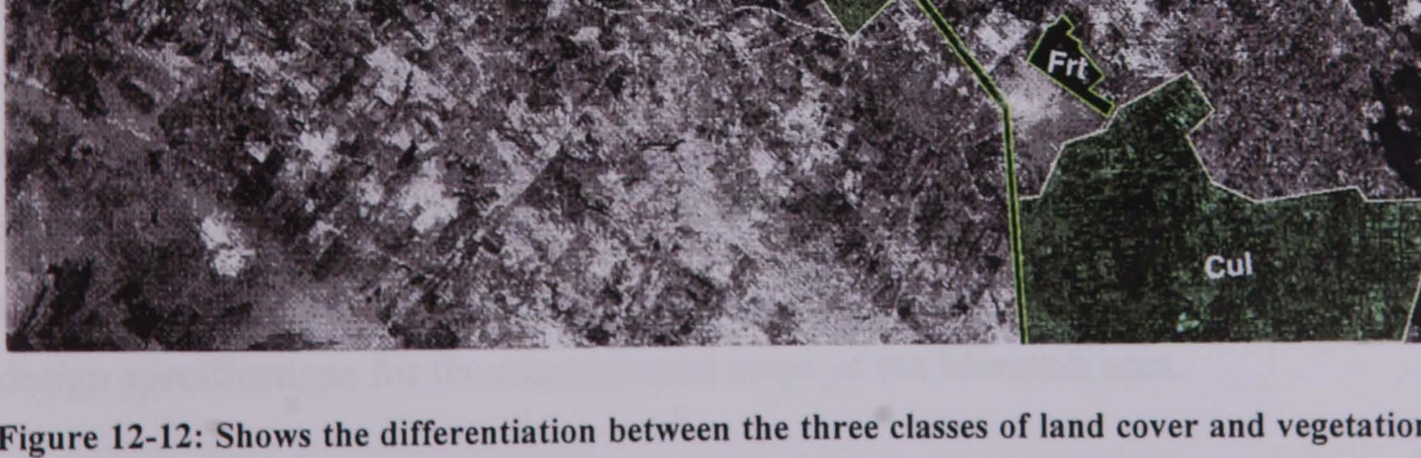


Figure 12-12: Shows the differentiation between the three classes of land cover and vegetation. (1:250,000 scale)

CHAPTER 13: THE COMBINATION AND INTEGRATION OF THE DIFFERENT ELEMENTS OF THE EXPERIMENTAL SPACE IMAGE MAP AT 1:50,000 SCALE.

13.1 Introduction

The process of designing and testing the individual symbols of the image maps has been described in detail in Chapter 12. Through this process, each different item of geographic information included in the map content specification for 1:50,000 scale has been represented in the form of a point, line or an area symbol. The selection of the most appropriate symbol design was based on testing (visually) various alternatives of form, dimensions and colour against an appropriate small window of a black and white space image. For each individual symbol, this meant that its clarity and legibility, and its contrast and integration with the background space image could be achieved. However, at this stage, the selection of symbols was not final, since each class or category had been tested separately rather than collectively. An additional stage was needed, which involved putting all the different elements of the map together in order to check the visual balance of the map design, so creating an appropriate visual order and being able to differentiate between features.

In this Chapter (13), the author will deal with the overall design incorporating all the individual elements of the experimental space image map of Misratah at 1:50,000 scale. Thus all the point, line and area symbols were superimposed together over the background space image to test their design quality in terms of their form, dimension and colour. All the other map elements such as the grids, text, marginal information, etc. were also included at this stage. An interactive design process took place, in which alternative versions of space image maps were produced for each scale in an attempt to reach an optimal solution in the design of these image map products. In fact, this meant that extensive experimental work has been carried out by the author to test and evaluate all the individual elements of the image map. As a result, a final design solution was then selected for each of the experimental space image map at 1:50,000 scale. In turn, this overall design process led to the establishment of the final design specifications for the experimental maps of the Misratah area.

13.2 The Combination of the Different Elements and Overall Design of the Experimental Space Image Map at 1:50,000 Scale

At this stage, all the different elements of the experimental space image map at 1:50,000 scale were brought together to examine their design quality as a whole in order to reach a successful design and a good balanced final appearance. As described in Chapter 12, each group of symbols representing the same category (e.g. roads) had been designed and tested separately against small windows of the space image rather than collectively alongside the other symbols of the experimental map. The nature of an image map can be characterised by having two different levels of information, which are the background image and the additional cartographic elements that are superimposed on top of it. Therefore, for the 1:50,000 scale image map, the overall design experiments started with the production of a subset image from the whole space image mosaic of the Misratah area that had been processed earlier, as described in Chapter 10. This subset image covers an area of 15' x 15' around the town of Misratah, comprising parts of two topographic line maps (sheets Nos. 2289-I and 2389-IV) that have been produced by the SDL. The most important reason for selecting this particular area is that it contains most of the topographic (both physical and cultural) features that need to be shown on a 1:50,000 scale image map series of Libya. This has allowed the designer to test a very representative map.

13.2.1 The Selection of the Background Colour

The selection of the appropriate colour for the background image is an important issue in image map design, since this could affect the clarity and contrast of the image detail to a large extent and could also influence the clarity, legibility and contrast of any additional symbols, text, grid, etc. From previous experiences (e.g. as described in Chapter 6), a monochromatic image always gives good results in terms of ground resolution and it is usually more compatible with the additional cartographic elements. Whereas using many colours may well affect the contrast of the symbols and names and make the design more complicated and more difficult. Furthermore, for a country like Libya, in particular, where most of the terrain surface is a little altered physical landscape with relatively few man-made features, the use of a monochromatic background image is well suited to the representation of such terrain. Potentially the use of a light yellow or sandy colour would be more appropriate for imitating the real appearance of the desert area. Unfortunately, the technical limitations of the cartographic software (ACE), which was used extensively in this mapping project, did not allow the author to obtain good results as far as introducing an overall background colour to the image map was concerned. In particular, ACE does not have the facility to change the colour of the raster image from the grey scale to, for example, RGB colour system, which can allow the introduction of a sandy or light yellow image that will be used as a background. By contrast, as can be seen in Figure 13-1a, better results have been obtained when **Adobe PhotoShop** image processing software package was used to generate the background colour.

Figure 13-1a: A window showing a small part of the background image (in light brown), which was processed using Adobe PhotoShop software package.

Figure 13-1b: The same small window showing a small part of the background image (in black & white).

Although **PhotoShop** has provided a good quality sandy colour for the background image of a very small part of the test area, it cannot handle the large images that, of course, cover larger areas on the ground. It seems that PhotoShop is not capable of processing files as large as 125Mb. Moreover, the author has found that even if the **PhotoShop** software package could process large images, the space image looses its geo-referencing whenever it is exported from **ACE** to the **Adobe PhotoShop** system. With all these technical limitations in mind, it has been decided to use a black and white colour for the main background image representation, see Figure 13-1b. In fact, this has not been a serious deficiency and, as noted above, it has positive advantages in terms of the ground resolution of the features that are present in the test area.

13.2.2 Space Image Map Symbolisation

Since the information supplied by the space image is largely tonal in nature, conventional symbols had to be added to give the additional detail necessary to produce a good quality image map. In other words, the space image, after a suitable image processing treatment, has supplied a very accurate descriptive representation of the terrain surface. However further cartographic treatment and the addition of specially constructed symbols, names, grids and marginal information were necessary. Any superimposed cartographic elements should have sufficient contrast against the space image to be clear and legible. At the same time, in order to avoid a heavy appearance in the final image map, the space background image needed to be printed in the lightest tone possible (see Figure 13-1b) whilst retaining the maximum amount of perceptible detail overall. This allowed the addition of symbols to the image map with fewer problems in achieving contrast with the background. The issues involved adding symbols to the map will be discussed in the next section.

However the author would like to highlight a very important point before giving any explanations about the symbolisation of features. As described in Chapter 12, the symbolisation of each category of features was tested visually in isolation from other categories or class of features. Thus, for example, road lines were superimposed on top of small windows of black and white space image and tested visually. But this was not the end of the matter and, after putting together all the elements of the image map, there are still possibilities for changes to take place until a good quality design is found. Therefore, when the author gives the specifications (in terms of form, dimension and colour) of the new symbol or name, he is not simply repeating what has already been written in Chapter 12.

13.2.2.1. Symbolisation of Linear Features

(i) **Roads:** The appearance of roads in space image maps might be confused with other linear features such as railways or canals – except that these are seldom present within Libya. Furthermore, the images of roads may not be continuous or obvious throughout their lengths due to shadows or overhanging trees. Without further help, it would be very difficult even for experienced users with sufficient local knowledge of the area to locate all of the roads and to place them in the appropriate road class. Thus information on the various classes that those roads should occupying had to be gained from other sources and suitable symbols had to be used to define and enhance these important features and to complete their missing parts.

The three line symbols used for the surfaced roads (Figure 13-2a) are clear, and they contrast and integrate well with the background space image. However, it was felt that, if 100% red infill with black for the casings and centre line was used for highways, it might better emphasise this major class of roads, since red is always considered as a stronger colour. Moreover, when a 50% yellow infill was used for the main paved roads, it showed too strong an appearance and seemed to disturb the visual order and affect the balance of the final map. Furthermore, as can be seen in Figure 13-2b, the use of a 100% red infill with black for the casings and the centre line resulted in a dull appearance being imparted to the highway line symbols. As a result, these symbols appear thinner than they should be, even though no size changes took place. By contrast, a 20% yellow infill provided better results for main paved roads – see Figure 13-2b. In the case of secondary paved roads, although continuous double lines were also used, a differentiation was made through the use of thinner line symbols and different colours (e.g. white infill and black casings). The use of a white infill and black casings seemed the most appropriate for the depiction of secondary paved roads. In the author's opinion, this combination of colours has shown a better performance than other colour alternatives in terms of their contrast and unity against the space image background.

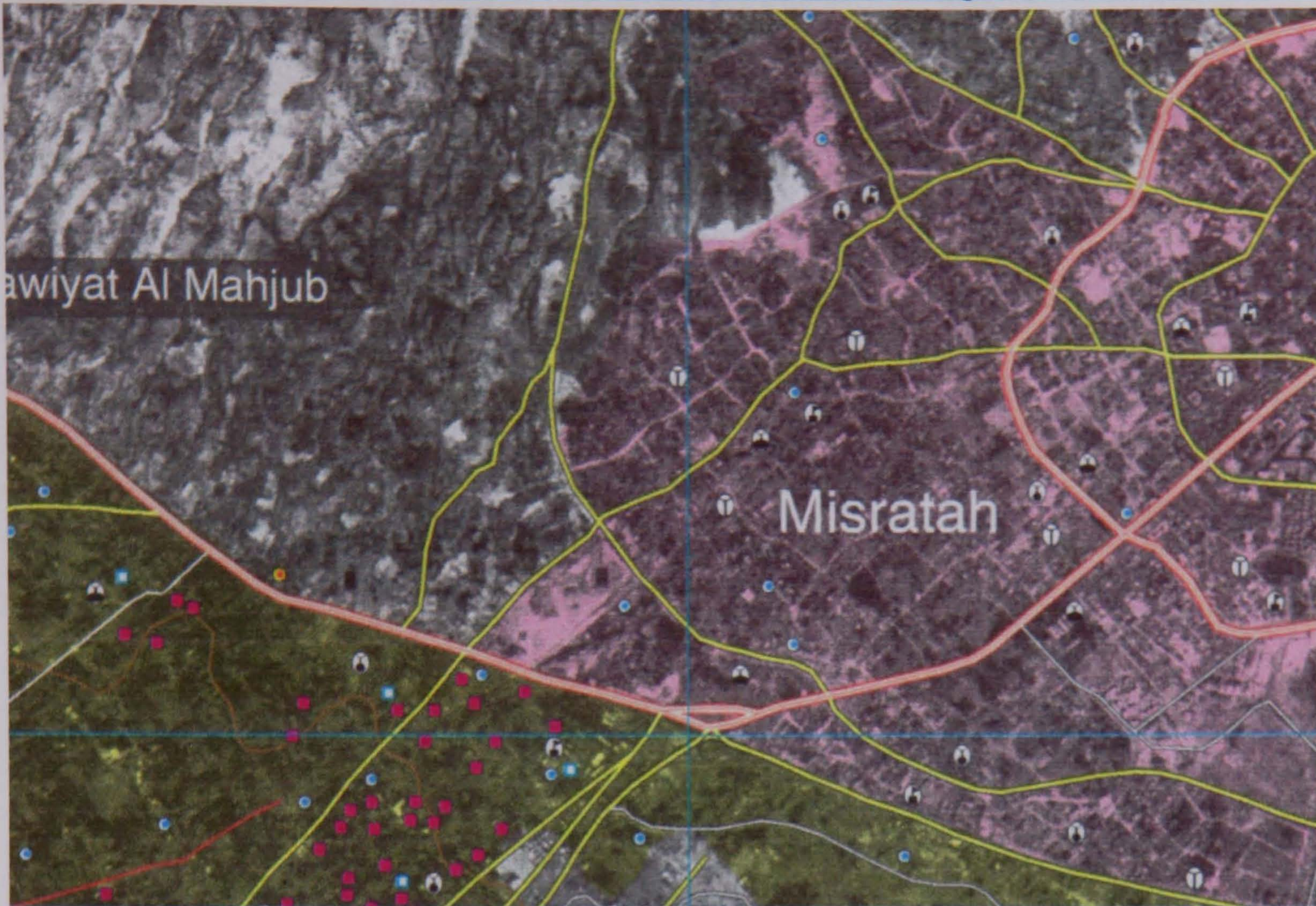


Figure 13-2a: A small window shows the representation of the different classes of roads on the experimental 1:50,000 scale image map. The line symbols used for highways (with red casings and white infills), the secondary paved roads (with black casings and white infills) and tracks (in white) have achieved sufficient visual contrast, clarity and integrated well with the background image. However, the colours used for main paved roads (black casings and 50% yellow infills) and unpaved roads (100% red) appeared somewhat too strong and this may disturb the balance and final appearance of the map.

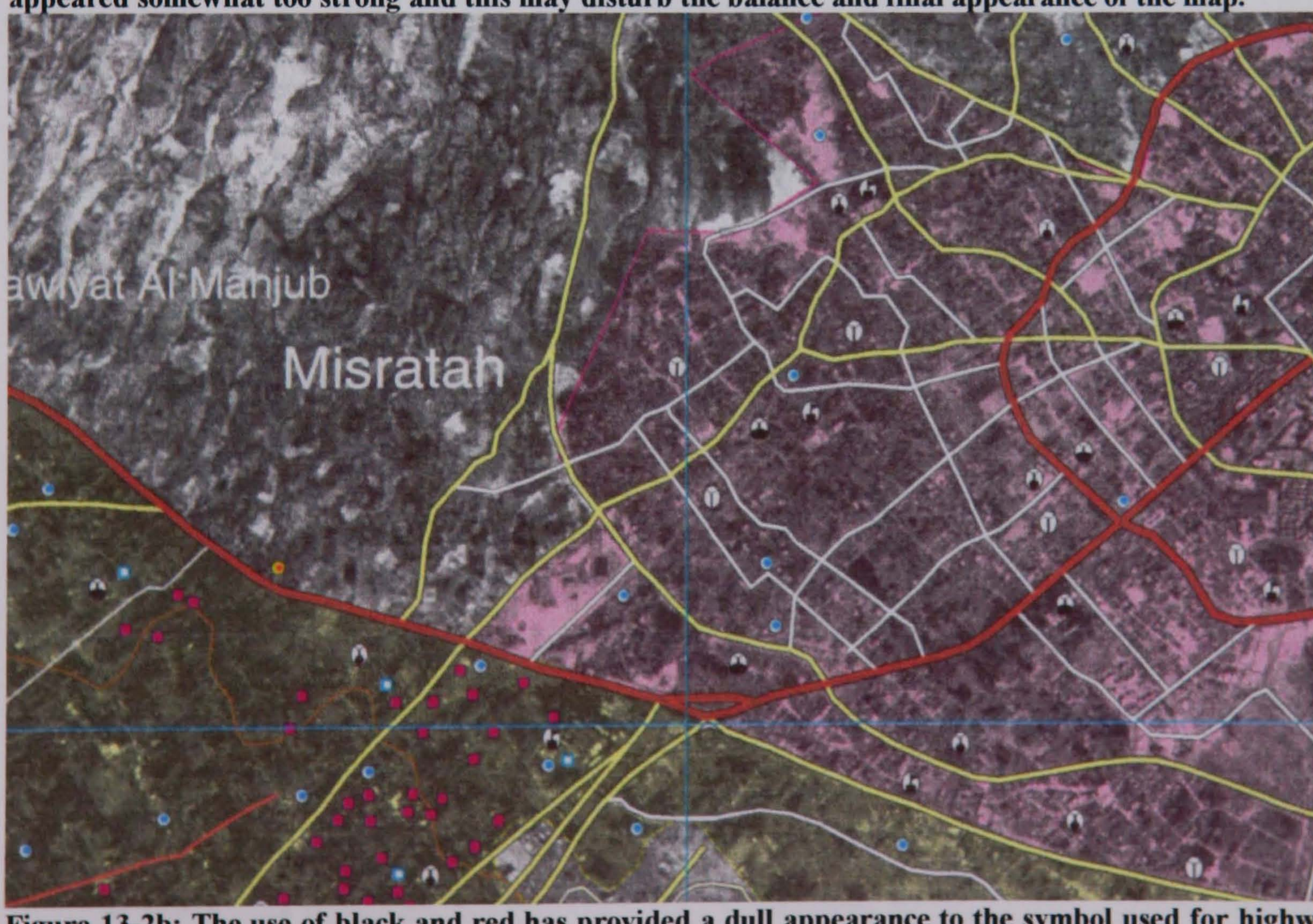


Figure 13-2b: The use of black and red has provided a dull appearance to the symbol used for highways, in turn, this disturbed the hierarchy of roads on the map. Better results were obtained when a lighter yellow and red were used for main paved roads and unpaved roads, respectively.

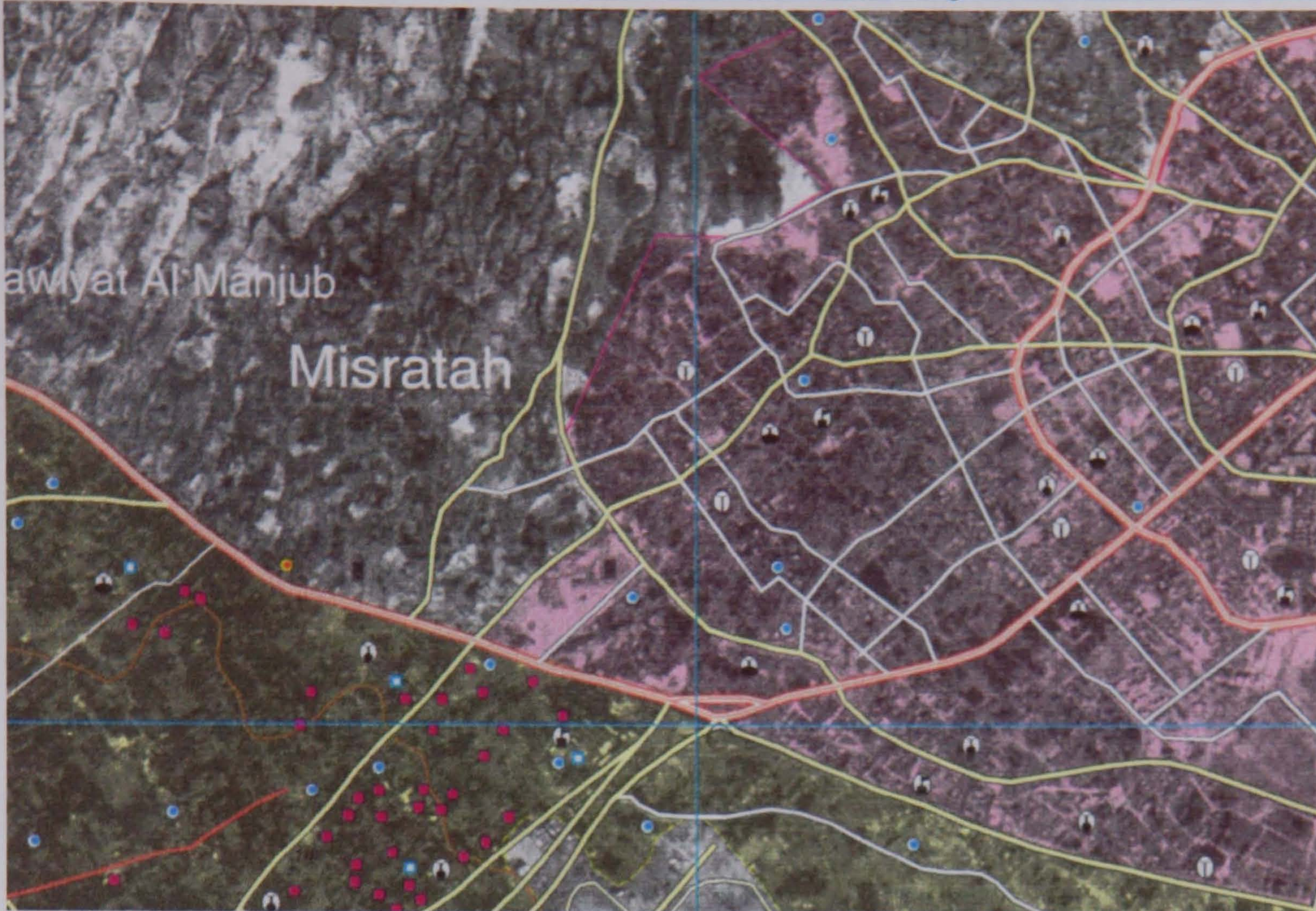


Figure 13-2c: These are the most appropriate and selected line symbols to show the different road classes on the final experimental map of Misratah at 1:50,000 scale.

Unsurfaced Roads: Although unsurfaced roads are important features within parts of the Misratah area. They did not show up 100% on the SPOT Pan imagery. So the missing sections were completed from existing (1:50,000 scale) line maps by vector digitizing methods. Thus a line symbol had to be used in order to make these features visible on the map. The colour used for the symbol was 100% red (Figure 13-2a), and to indicate the difference in importance between the surfaced and unsurfaced roads, a continuous single line was used to represent the unsurfaced roads. The colour finally used for the unsurfaced road symbol was a 50% red which has provided a better visual balance, see Figure 13-2c.

Tracks: Not all the tracks present within the test area could be detected on the SPOT Pan imagery. Again, since they are an important class of roads in the more remote areas, they had to be shown on the map. Once again, these missing parts were digitized from 1:50,000 scale topographic line maps of the same area. A continuous single white line was used to represent these tracks: this was made narrower than that used for unsurfaced roads. From Figure 13-2a, it can be seen that no changes have been made to this line since it was quite suitable for showing tracks.

As can be seen in Figure 13-2c, after the application of the small modifications discussed above, the finally selected line symbols that were used to represent all the different classes of roads appeared to be appropriate in terms of contrast, visual order, balance and unity with the background image. Indeed, in the author's opinion, they have shown the hierarchy of roads in a good manner and have resulted in a good quality design, which later will help the map users to understand very easily the road network shown on the final space image map of Misratah.

(a) (b)

Figure 13-3: (a) White lines used to emphasise the runway of the airport have achieved a good contrast and clarity against the image. (b) Grey lines did not achieve a sufficient contrast and were not suitable for the purpose.

Figure 13-3c: Although pink lines have achieved sufficient contrast, but appeared more artificial against the natural background image.

(ii) <u>Airport</u>: The runway of Misratah airport can be easily recognised on the SPOT Pan imagery. However some degree of cartographic treatment – through the enhancement of the real appearance of the runway using line symbols – was necessary to achieve a better design quality. In turn, this would ease the interpretation of this type of feature in the final map product. Unfortunately, the 50% black (grey) did not provide satisfactory results either in terms of contrast or in terms of its integration with the space image background. This grey line symbol appeared to be floating above instead of blending with the background. Furthermore the 50% red (pink) appeared more artificial and this may disturb the natural appearance of the image. On the other hand, the use of the white line appeared to be the most appropriate, since it blended into the background image appearing more natural and realistic.

(a) (b)

Figure 13-4: (a) black contours provide heavy appearance and float against the background image. (b) white contours have better appearance and blend with the background, but they disappear in light areas.

(iii) Contours:

The decision was made to use light brown, at least in this current project, as a compromise solution for contour lines. Although light brown (Figure 13-4c) can be inconsistent in terms of achieving sufficient visual contrast, particularly against light yellow areas, it certainly gave better results than any of the other colours that were tested so it was selected to depict the contour lines included on the final space image map. In this respect, the space image itself can be fully utilised to show small but important relief features such as gullies, minor break of slope, or small depressions or elevations which cannot adequately be shown by conventional contour lines – which is a definite plus as far as the users are concerned.

13.2.2.2 Point Symbols

A considerable number of important, cultural (man-made) topographic details do not appear on the SPOT Pan image due either to a lack of ground resolution or to a lack of contrast with the surroundings. These features still have to be represented on the space image map in some manner if this product is to be complete. The individual feature may be so small that, even if it could be detected, a point symbol would still be needed to bring such a feature to the visual perception level and notice of the map user. Typical examples of such features are very small villages (hamlets); important isolated buildings; wells; water towers; schools; mosques; cemeteries; quarries; etc. In such cases, the use of point symbols is inevitable. As mentioned earlier in Chapter 11, the design of the symbols has mainly followed conventional usage. In many situations, the use of frames and dropout masks was useful to exclude the SPOT Pan image from the area around the symbol, drawing attention to its presence, besides improving its clarity and recognition.

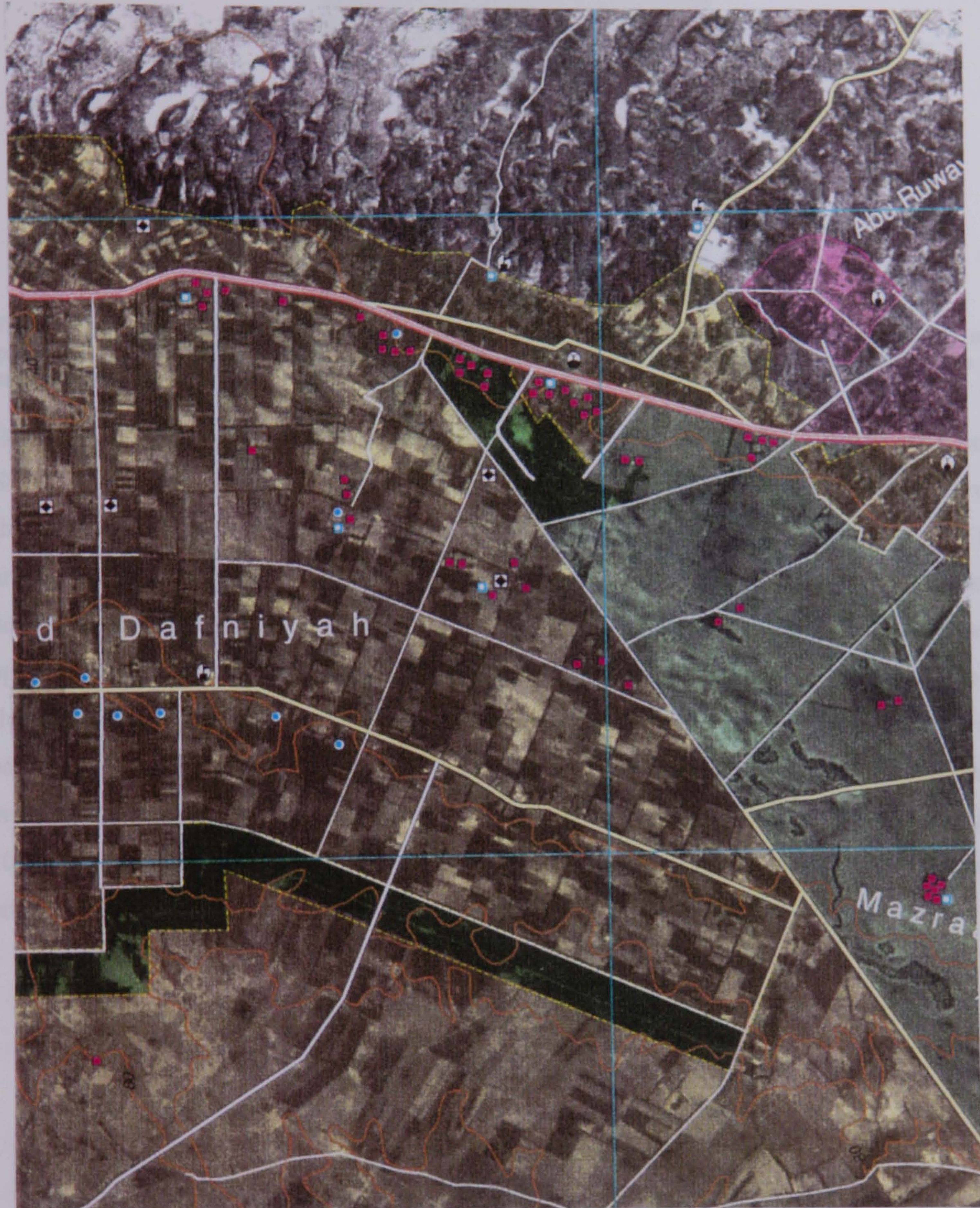


Figure 13-4c: Light brown is the compromise solution used for contours, and they appear quite natural against the space image.

Village: This is a very important type of feature that needs to be represented clearly on the map. Therefore, a distinctive geometric point symbol (a circle) was used. Figure 13-5 shows that a solid orange circle with a black outline has been tested against the image background and proved to have a sufficient contrast when place against the space image. In the author's opinion, this symbol was appropriate in terms of its form, dimensions and colour to display villages on the experimental space image map at 1:50,000 scale.

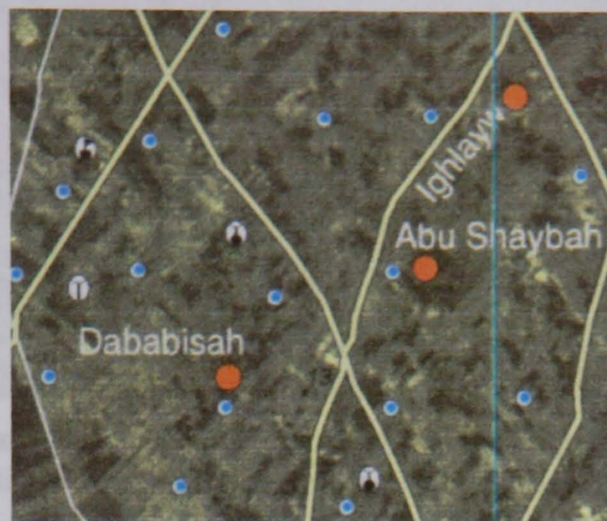


Figure 13-5: A small window shows the success of the representation of villages through the use of geometric point symbols (outlined solid circles). The outline was in black, while the solid circle was in an orange colour.

Isolated Building: At 1:50,000 scale, isolated buildings could not be distinguished on the SPOT Pan imagery. Hence, it was necessary to introduce special point symbols to represent this important type of man-made feature – one which is often especially important in rural areas. The point symbol used is a simple magenta square that needed to be exaggerated according to conventional practice from the true size of the building in order that it would appear clearly on the experimental space image map. From Figure 13-6a, it can be seen that the size of the initial symbol was somewhat over-exaggerated and might affect the visual balance and appearance of parts of the map. Hence, the proper solution to such a design problem was to decrease the size of the point symbol and to increase its colour percentage to 100% of magenta. This has provided a symbol of a good design quality in terms of its contrast, visual balance and unity with the background space image. (see Figure 13-6b).

Figure 13-6a: This small window illustrates how over exaggeration of the point symbols (magenta-coloured squares) used to show isolated building may affect the balance and appearance of the map.

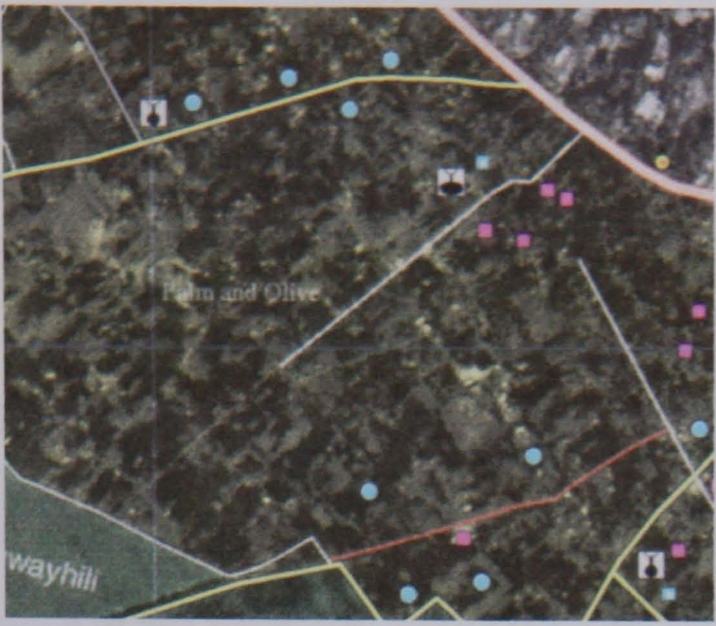


Figure 13-6b: The reduction in size and the increase in the percentage of red have provided much better results in terms of the design of the point symbols used for isolated buildings.

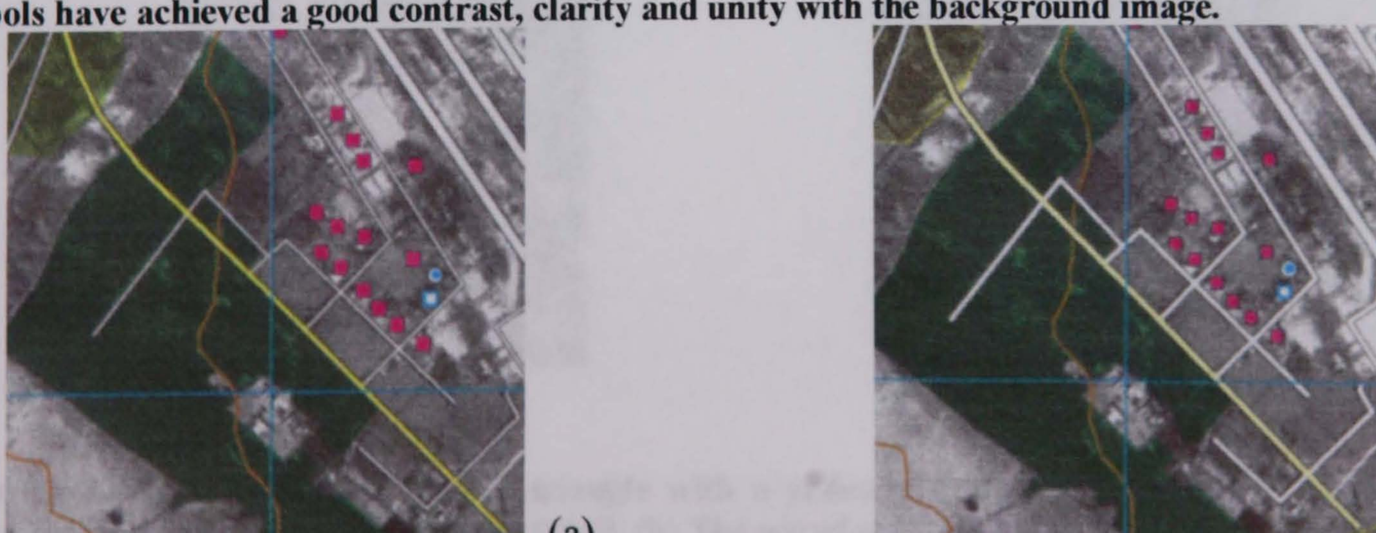
Wells and Water Towers: In Libya, wells and water towers are often the only water resources available for human, animals and irrigation purposes. Hence, these minor, but very important features, must be shown on the country's medium- and small-scale topographic maps. This has been achieved through the use of geometric point symbols (circles and squares), that have been exaggerated from their true size to one which provides a visual level that suits the map users. It is also important to recognise that an increase in size to achieve contrast against the tonal image, is not a suitable design practice, since it may confuse the visual order and in turn unbalance the appearance of the image map.

For wells, as can be seen in Figure 13-7a, a geometric point symbol, consisting of an outlined solid circle with a small dot inside, has been used. In terms of colour, the outline was in black, the solid circle was in white and the dot was in 50% cyan. However, it was felt that these dimensions were over-exaggerated. Furthermore, in reality, the well is smaller in size than any individual building, yet it had been made larger on this map. The solution was to reduce the size of the circle (see Figure 13-7b), and to increase the cyan to 100%, in order to achieve sufficient contrast against the space image.

Water towers are also important water features in the Misratah area, hence they should appear on the experimental map at 1:50,000 scale. Due to the insufficient ground resolution of the SPOT Pan imagery both to show such small features and to be able to recognise them, it was necessary to represent them through the addition of cartographic symbols. To accomplish this, outlined solid squares were used and superimposed against the space image to show this particular type of water source. The outlines were in 100% cyan, whereas white was used for the solid squares. From Figure 13-8a, it was considered that the size of the geometric point symbol used was larger than it should be and that this might affect the visual balance of the map. Hence, although the size of the symbol was slightly reduced, this did not affect its visual contrast against the background due to the use of a good combination of colour, that is 100% cyan and white (see Figure 13-8b).

Figure 13-7a: The over exaggeration of the point symbols (outlined solid circles with dot inside), used to display wells, has made the well symbol appear larger than an isolated building – which in reality is not true.

Figure 13-7b: The reduction in size and the correct selection of colour (white and cyan) used for the well symbols have achieved a good contrast, clarity and unity with the background image.



(a) (b)

Figure 13-8: (a) The use of a large (square) geometric point symbol for the water tower has disturbed the balance and dominates the map totally. (b) A better design solution was obtained when the size of the square used for the water tower was reduced.

Ruins: Because these ruins are mostly quite small in size and they were built using local materials that have no contrast with the surroundings, they did not show up on the SPOT Pan imagery. As can be seen in Figure 13-9, the consequence of using a suitable colour combination of black and white to show this small symbol against the space image, has provided the required results in terms of clarity, contrast and unity with the background.

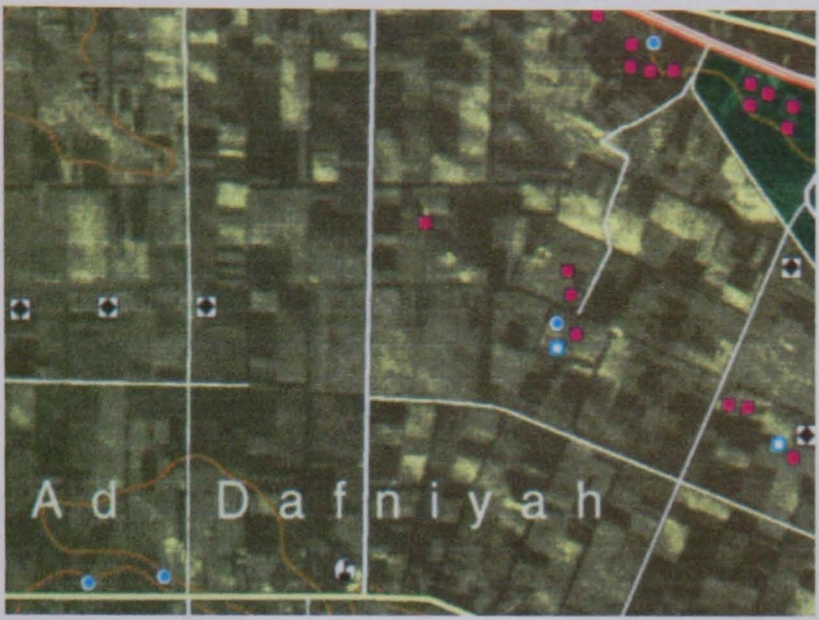
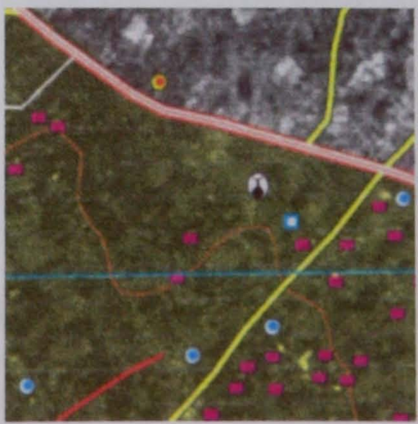


Figure 13-9: The black and white square used for ruins was appropriate and contrasted well against the space image and with the other elements of the map.

Monuments: From the cultural point of view, these important small point features, which again are not visible on the space image due to lack of ground resolution, need to be shown on the space image map of Misratah. This has been achieved in a quite simple manner using a solid black triangle with a small yellow solid circle inside (Figure 13-10a). However this symbol was rather too large in size and appeared to suffer from a lack of unity with the background space image. Therefore an alternative geometric point symbol comprising an outlined solid circle with a small dot inside was designed and appeared to give better results in terms of form, dimension and colour, providing good integration with the background, see Figure 13-10b.

(a)



(b)

Figure 13-10: (a) The use of a black triangle with a yellow circle inside was not successful to show monuments, since it has obscured more detail. (b) The use of outlined yellow circle with red dot inside has achieved good visual contrast and obscured less image detail.

Other Man-made Point Features: The other man-made features that needed to be included in the map comprise mosques, schools, shrines, cemeteries, churches and quarries. Once again, it is always not an easy task to obtain clarity, contrast and unity with the background space image as far as the design of these point symbols is concerned. Indeed, the selection of squared frames (Figure 13-11a) was not successful since these did not appear to integrate well with the space image and seemed to disturb somewhat the real appearance of the natural image. The alternative, as shown in Figure 13-11b, was to test smaller frames that are oval in shape. Both the outlines and the actual symbols were in black, while the oval shaped background was in white colour. It appeared that the design of symbols using these oval frames was indeed more successful in terms of achieving sufficient contrast yet unifying instead of divorcing them from the background space image.

(a)

(b)

Figure 13-11: (a) The white frames (squares) used as background for some point symbols (to show mosques, schools, etc.) has increase the contrast of these symbols, but they appeared more artificial and obscured more detail due to their larger size. (b) The oval shape of the frames was more successful and provided a much better representation for these man-made point features.

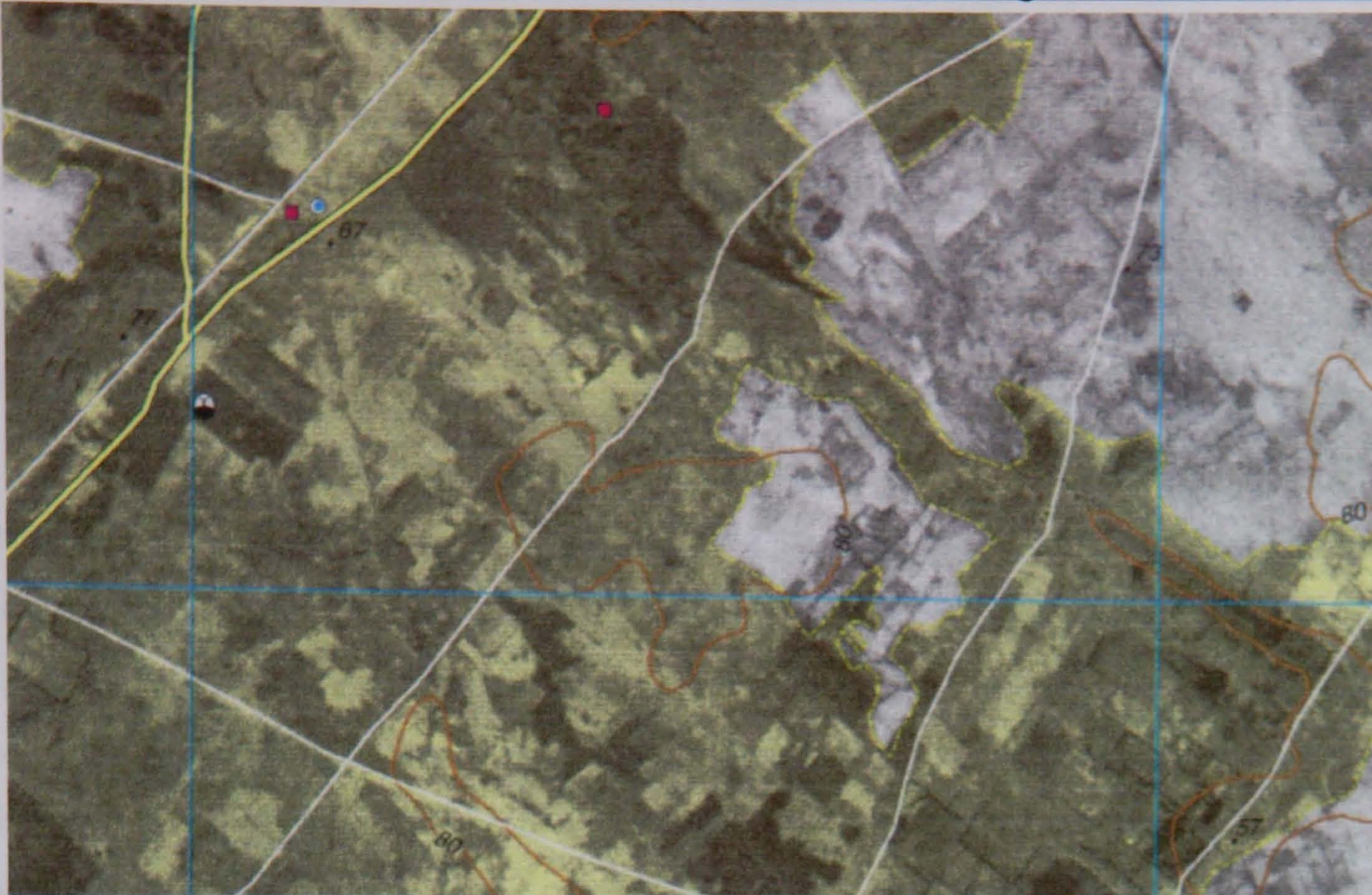
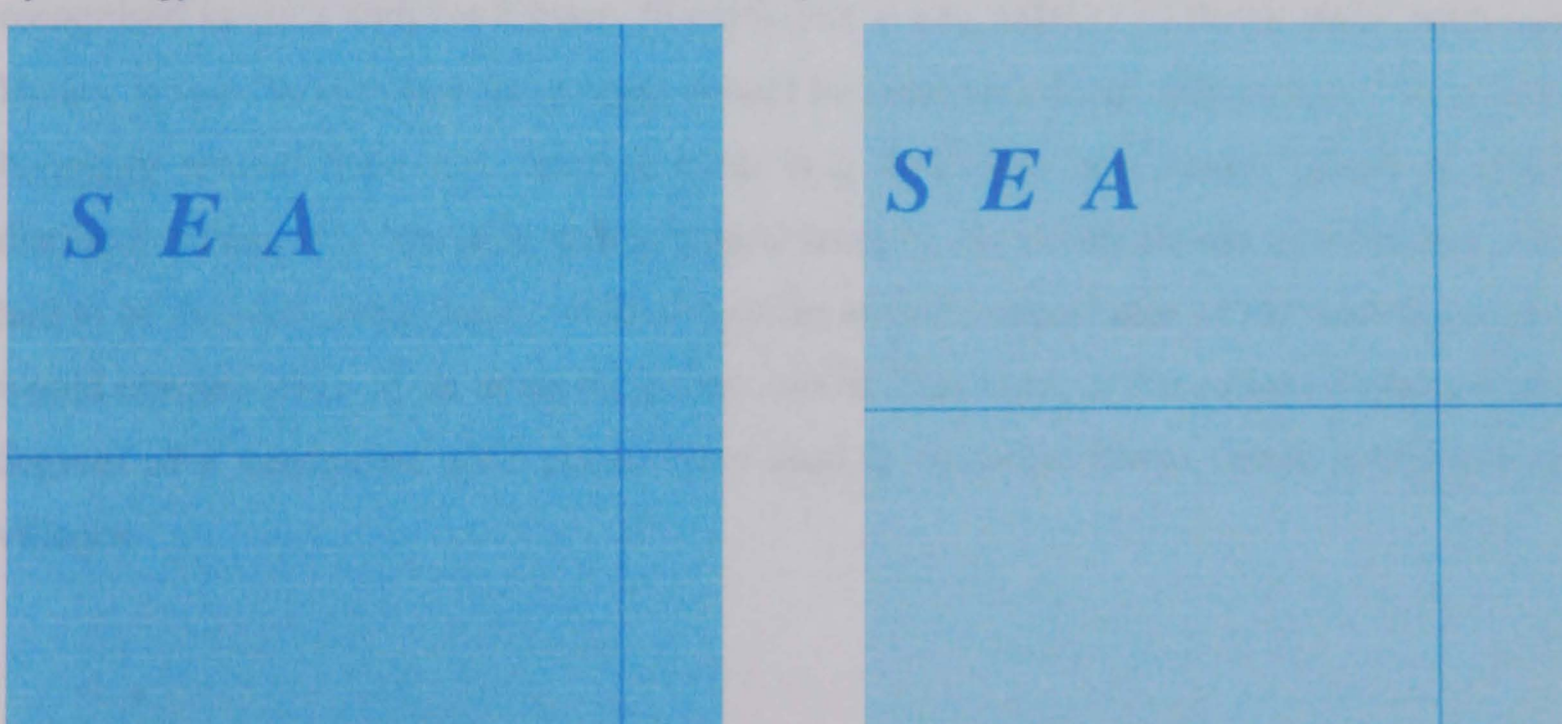


Figure 13-12: Spot heights were clearer and achieved sufficient visual contrast against the background when a black colour was used.

13.2.2.3 Area Symbols

These posed their own specific challenge in that the detail given by the underlying space image needed to be retained to help the recognition of the area feature while the added symbology or colour had to add value and help to differentiate one area from another.



(a) (b)

Figure 13-13: (a) The use of 30% of cyan for the sea was somewhat strong and seemed to dominate the map and affect the appearance of the grid and names. (b) A better representation for the sea area has been obtained when a lighter colour (20% cyan) was used, when the other elements such as the name and the grid appeared clearer.

(i) **Water Areas:** Apart from the sea area, no permanent surface water area exists in the area covered by the space image map of Misratah at 1:50,000 scale. As has been noted earlier in this chapter, the area depends entirely on its underground water resources, access to which is given by a large number of wells which are distributed all over the Misratah area.

Sea: The Mediterranean Sea bounds the northern part of Misratah area; in fact, part of this Sea covers about quarter of the area falling within the map. Since the area covered by sea has appeared black on the space image, from which no useful information can be extracted, the author felt that the normal convention should be followed through the use of a low percentage of the cyan colour. This would of course imitate the real appearance of the sea and, in turn, this eases the interpretation of this area of water for the user. In this project, both 30% (Figure 13-13a) and 20% (Figure 13-13b) of cyan have been tested, but the latter percentage has provided a much better appearance. Thus this lighter colour (tint) of cyan was selected to represent the sea on the final image map, since it was more compatible (as a background) when additional elements such as names and grids were added to the map. This allowed them to appear with sufficient visual contrast.

(ii) Built-up Areas: Although the built-up areas (i.e. towns, small towns and main villages) did appear on the space imagery, their images were not distinctive enough to allow them to be recognised as such with confidence. In particular, it was difficult to define their exact extent. Hence, it was decided that these areas should be emphasised and differentiated by placing a boundary around them and showing them in a distinctive area colour (pink) in order to distinguish them from the surrounding natural features. However, the use of solid area colours had to be avoided, since these would disturb the realistic appearance of the natural image and would obscure some of its more important details. Therefore, in the current project, different degrees of a transparent pink colour were used to represent towns, small towns and main villages.

Figure 13-14a: The use of transparent pink for built up areas was quite useful since it retained the real appearance of the space image, but it was very difficult to define the boundary with other areal features. The built up area cannot 100% be recognised, since the structure of main streets was not cartographically enhanced.

Figure 13-14b: Through the addition of a boundary line and the enhancement of main streets in the built up area, more information have been given to aid location and provide a better appreciation of the overall urban structure.

Town: Although the town of Misratah was large enough to appear on the SPOT Pan imagery, its exact boundary with the surroundings was only defined after consulting the aerial photography (at 1:40,000 scale) and the existing topographic maps (at 1:50,000 scale) of the same area. As can be seen in Figure 13-14a, although a light transparent pink was used successfully to show the large area of the main town on the space image map of Misratah at 1:50,000 scale, this by itself only aided the interpretation to a limited extent since the structure of the streets was not enhanced. However, the addition of numerous continuous road lines (using white infill and black casings) has enhanced the street structure and has resulted in a much easier recognition and a better interpretation of the built-up area. It was also obvious (see Figure 13-14a) that, because of the use of light transparent pink, it was then very difficult to recognise the boundary between this town and the unclassified areas. However, the application of a continuous outline in a 100% magenta colour proved to be very useful in discriminating the exact extent of the town from the surrounding area features (see Figure13-14b).

Small Towns and Main Villages: Besides the large town of Misratah, there is another small town named Zawiyat Al Mahjub and two quite large villages, Zurayg and Abu Ruwayyah. As the size of the built-up area becomes smaller, its recognition on the space imagery becomes more difficult; therefore, some degree of cartographic enhancement is necessary. So, although these smaller built-up areas were given a similar colour treatment (in transparent pink) to that used for the larger town, since the area was much smaller, the transparent colour has been made slightly darker in order to achieve sufficient visual contrast against the tonal image. In addition, continuous outlines in 100% magenta have been used to define the boundaries between these small areas and other surrounding area features. Further differentiation between the small town and the main villages has been made through the use of different letter sizes in the associated names.

Land Use/Land Cover: Those areas of land whose use has been altered by man – such as cultivated lands, orchards and forests – generally appear on the SPOT Pan image in a dark tone against the very light tone of the surrounding non-vegetated areas with their high reflectance. The interpretation of such areas when they are cultivated and contain a certain pattern of fields can be quite easy and straightforward. So, in general, are the planted orchards or forest. On the other hand, when the areas comprise natural vegetation, they have an indefinite shape and intermingle with other features such as settlements. In which case, the correct delineation of a boundary becomes rather difficult. In such cases, reference has had to be made to external sources of information such as aerial photography or existing maps, to obtain the correct delineation. However, additional cartographic work is still necessary in order to emphasise and clearly differentiate these areas of land use and vegetation from each other and from other area features. To aid the interpretation of the map by the user through colour association while, at the same time, trying to retain the natural appearance of the cultivated areas, orchards and forests, these areas and their bounding lines have been printed on the image map in yellow, light green and dark green, respectively. The author has always tried to avoid the use of solid polygons of colour or patterns, since they would appear very artificial in the context of an image map and could well hide more important image information which, in turn, would only complicate the interpretation task.

Cultivated Areas: Cultivated areas cover about 40% of the map sheet. These include both the large Mashru Ad Dafniya project besides many other small areas that are cultivated by private individuals. As has been noted above, the small field patterns of the cultivated lands were visible and easy to distinguish on the space imagery. Hence, to differentiate these cultivated lands from other land use and vegetation areas, a transparent colour in medium green was specified and tested visually against the background, see Figure 13-15a.

Figure 13-15a: Although the use of transparent green in different percentages to show land use/vegetation (cultivated areas, orchard and forests) has provided good results in terms of contrast and unity with the background image, unfortunately, the green was distributed all over the sheet and hence dominated the overall appearance of the map.

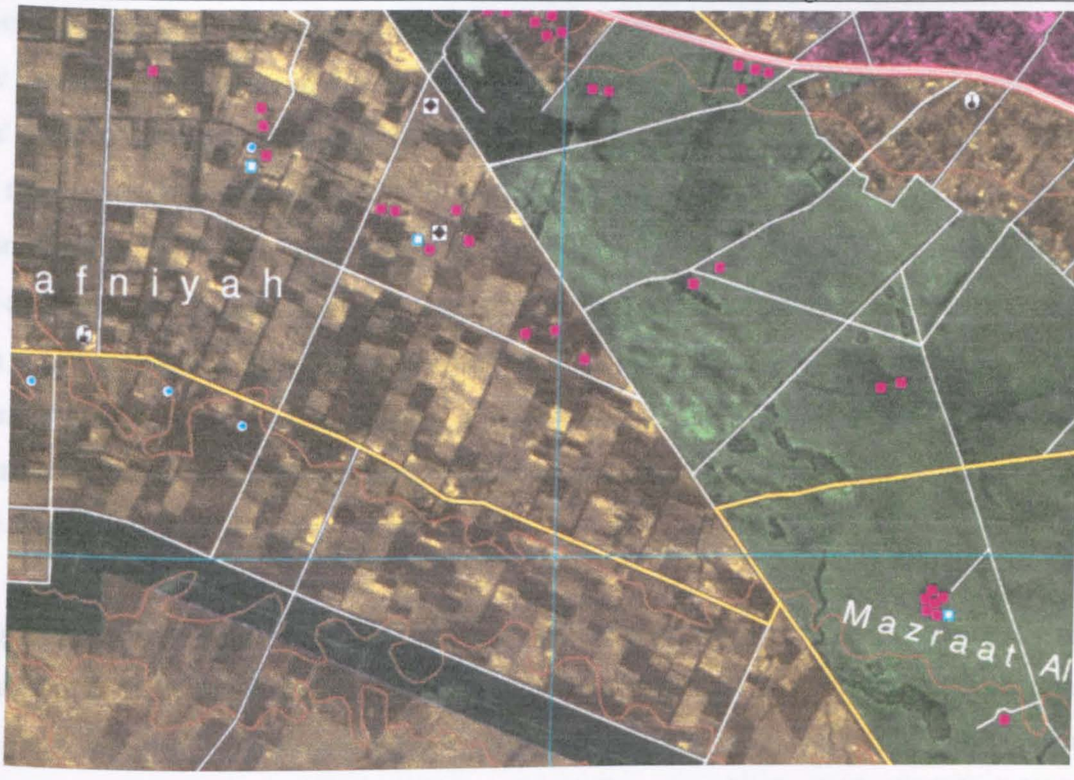


Figure 13-15b: The use of yellow for the cultivated area has made it much easier to differentiate between the land use/vegetation classes. However, both yellow and green (for orchard representation) were considered stronger than they should be and needed to be reduced for better design and appearance.

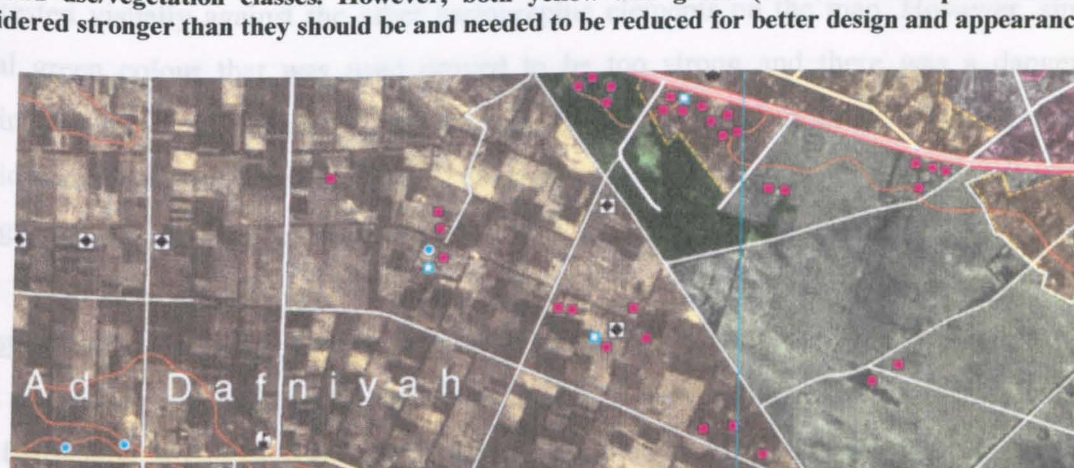


Figure 13-15c: The reduction of yellow and green percentages for cultivated areas and orchards made the land cover classes much clearer and created a better contrast against the space image. The use of dark green was quite appropriate for forests.

Although the use of a medium green colour has provided sufficient visual contrast against the image background, unfortunately this was not the correct colour selection for cultivated lands.

It dominated the map appearance, since green has also been used (in different percentages) to show orchards and forests in the Misratah area. Obviously it would be much better, from the users' point of view, if another colour – yellow – was used to show cultivated areas on the final map. As can be seen in Figure 13-15b, the use of a strong yellow was not good in terms of contrast and balance for larger areas, since this tended to dominate the map and disturb its final appearance. Unfortunately, the use of certain degrees of light yellow do not show up when superimposed on top of the space image. Thus quite extensive experimental work had to be undertaken, to select the lightest yellow possible for cultivated areas. Eventually a reasonable level of a light (transparent) yellow was found and chosen to represent this land cover class, see Figure 13-15c.

Orchards: It was difficult to identify the orchard areas on the space image, since the size of the individual trees lies below the ground resolution of the SPOT Pan image. The extent of these areas was only located with the help of aerial photographs and existing maps. As can be seen in Figures 13-15a and -15b, a darker transparent green colour was used against the image and tested visually against the other cartographic elements on the map. However, since the initial green colour that was used proved to be too strong and there was a danger of it dominating the final appearance of the map, it was reduced to quite a light green. This provided much better results in terms of contrast and ensured its integration and unity with the background image, see Figure 13-15c.

Forest: Another very important type of land use in this area is the forest. Man has planted most of the forest formed in the Misratah area. Obviously, from their uniform texture and their belt shape, it can be seen that they had been planted to protect the agricultural land of this area from wind and sandstorms. Due to the very dark appearance (black) of forests on the space image, the degree of the added colour was not so important since it will always appear dark. Therefore, only one degree of green was used – see Figures 13-15a, 15b and -15c.

Unclassified Information: In addition to these land use/land cover classes, scattered areas of bushes occurred which were not easy to detect or to define. Hence no attempt was made to delineate them on the map. Instead the natural monochrome (black and white) space image was left to speak for itself. This background colour would cover the whole sheet except those areas in blue (the sea), pink (the built-up areas) and yellow or green (for land use/vegetation).

13.2.2.4 Symbolisation of Other Important Elements

Other details that must be added according to the map specification, include important items such as boundaries and grids. Obviously conventional symbols may be used satisfactorily, and the final emphasis of treatment will depend on the overall map specification. This means that the map purpose will largely determine the emphasis given to such features. Where the map is intended for general use, as was the case with the Misratah map, the use of lines with just sufficient contrast to achieve clarity and legibility against the image background is again a general principle. However the use of colours other than black and the use of the white paper to produce line symbols may again need to be considered.

Boundaries: These include both international and provincial boundaries. Generally these important linear features should be shown by conventional line symbols with just sufficient contrast to achieve clarity against the background. No local administrative boundary lines were actually included on the space image map of Misratah at 1:50,000 scale – since they are not finally defined and drastic changes seem to take place annually due to administrative conflicts. Indeed, given the fact that he has been away for some years from his country, the author prefers not to deal with boundary matters that may lead to further problems on his return home.

Grids: For the experimental image map of Misratah at 1:50,000 scale, both grids and a graticule were included, with the grid being shown in full across the image map while the graticule took the form of marginal ticks only. In image mapping, a close mesh of grid lines needs to be avoided, since it would cause too much intrusion and a possible diversion from the rest of the map information. Therefore it was decided to include the lines to form a 5,000 x 5,000 metre (100 x 100 mm) grid. In terms of their representation on image maps, the overall weight of these grid lines needed to be reduced as far as possible through the use of fine lines in the most appropriate colour. For this project, Figure 13-16a indicates that initially the grid was incorporated using fine lines (0.10 mm) of a dark blue (100% cyan and 100% magenta) colour. However this was not a successful colour selection, since the grid lines could hardly be seen against darker areas of the tonal image. Furthermore, the use of both cyan and magenta, particularly for line symbols, is somewhat risky since the two colours may not be well registered during the production stage, and this of course will harm the appearance of the final map. In view of these factors, the thickness of the grid lines was increased to 0.20 mm and only 100% cyan was used to show the grid all over the map. As can be seen in Figure

13-16b this achieved better clarity and sufficient visual contrast for the map user to be able to use them.

Figure 13-16a: The use of dark blue (100% magenta and 100% cyan) grid lines meant that these could hardly be seen against the tonal image.

Figure 13-16b: The grid lines achieved sufficient visual contrast and appearance against the black and white image when 100% cyan only was used.

13.2.3 Text and Lettering

The inclusion of appropriate names and text is an integral part of the overall map design. Furthermore because of the important functional role of the lettering and its impact on the final appearance of the map, the choice of the actual font to be used must be carefully considered. Wrongly specified or poorly designed lettering can confuse the map user instead of helping him, and if poorly positioned, it can interfere with the other detail present on the map. Hence, it cannot be treated in isolation, nor treated lightly when designing a map.

The brief discussion that has been given in Chapter 8 – about the dual language systems on Libyan topographic line maps – was to give a general idea about the advantages and the problems that the use of dual systems can cause.

In the Libyan context, the intention is, in the near future, to replace the existing topographic line maps (at 1:50,000 scale) with image maps at the same scale based on the use of space imagery. If not for the whole series, at the very least, it is likely to be implemented in those areas where most of the terrain is a non-vegetated physical landscape with few or no cultural (man-made) features. Therefore, the use of similar lettering systems to those adopted in Libyan topographic line maps should be considered.

13.2.3.1 The Actual Text and Lettering of the Misratah Experimental Map at 1:50,000 Scale

Before the actual generation of the text and lettering started, the author had hoped to incorporate dual language systems (Arabic and English) on his image map. However due to the technical limitations of the cartographic software (ACE) and the non-availability of the financial resources needed for this part of the project, it was not possible to use Arabic script on the experimental space image map of Misratah. In fact, what was needed to enable the ACE software package to support Arabic lettering, was the availability of (i) a number of Arabic PostScript fonts, (ii) an Arabic version of Windows 95; and (iii) an Arabic keyboard for input purposes. All together this cost more than £1,000. Unfortunately, the Department did not have the money to spend on this particular purpose, especially when no one else was likely to use it again. Therefore, it has been decided that the author should carry on with the mapping project using the available Roman script (English), and later during his work with the SDL he should undertake further experimental work to deal with the matter of incorporating dual language systems on the space image maps of Libya.

Obviously, the names that are included on a map operate in conjunction with the other symbols and are indeed a basic means of place identification. "When the type style of the name being sought is known to the viewer, the search time is reduced and conversely, unfamiliarity with the type style increases the search time" (Wood, 1972). The names used in this project have been varied in hue, size, style and boldness to represent the relative importance of the different named elements as well as ensuring their correct visual level in the map.

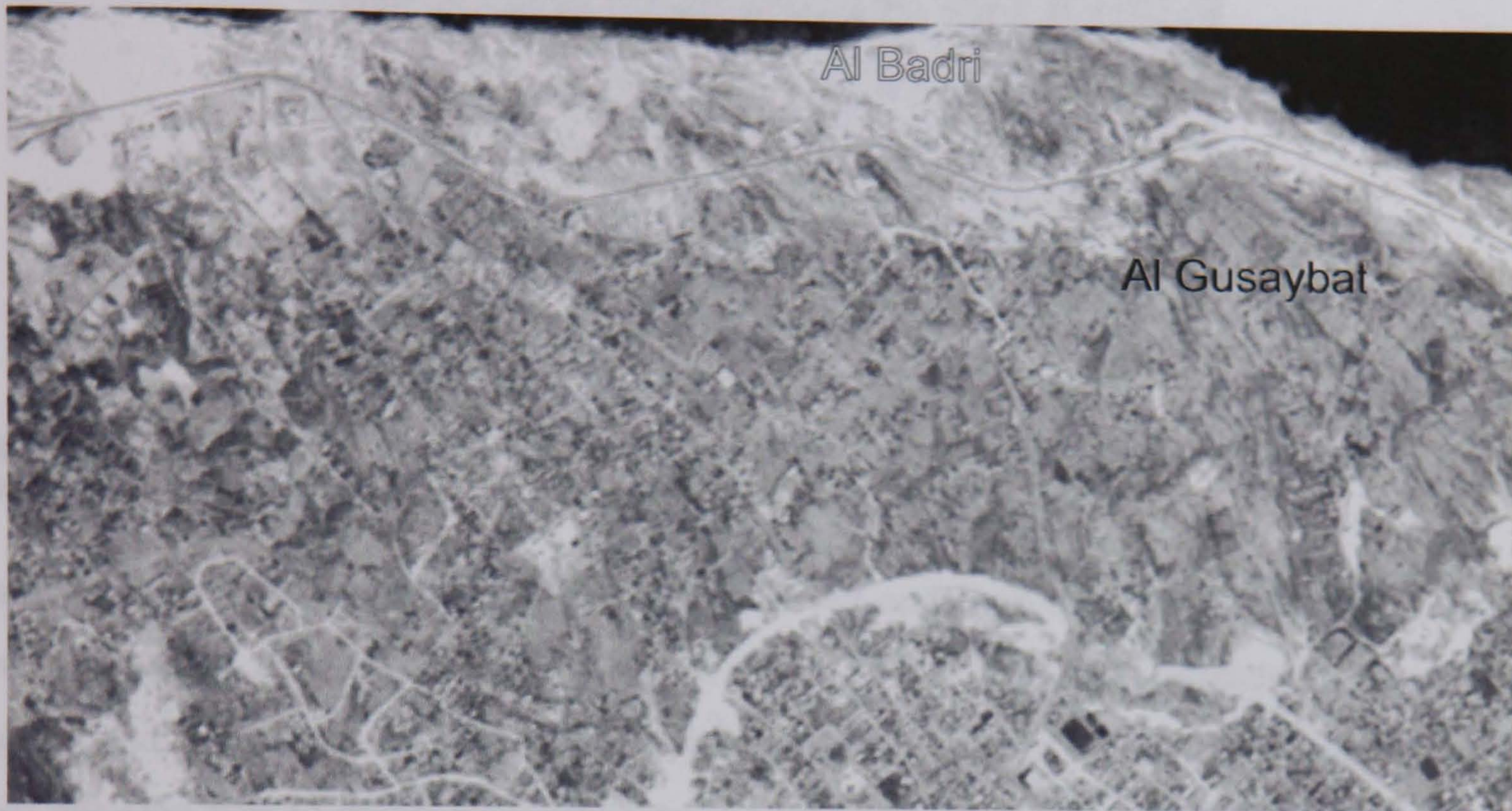


Figure 13-17a: This window shows how effective the use of halo around each character when names are included on an image map.

In image mapping, name placement is considered to be a serious design problem, especially when dealing with a black and white image background. In this case, if black names are used, they can hardly be seen in the darker areas of the tonal image, while white names disappear in the lighter areas of the same image. In the author's opinion, the most appropriate solution to the problem is to use white or black halos around each individual letter. For example, if the letters are in white, then the halos should be in black; and white halos should be used around black letters. Indeed, this practice can provide a good result. Unfortunately, due to the technical limitations of ACE software package, this solution could not be adopted in this project. However, the author has used Corel Draw software to implement the effect of using halos around letters in order to achieve sufficient visual contrast against the background image. Figure 13-17a indicates that, when this technique has been used in both the dark and light areas of the space image, the names were legible and clear and could be read easily.

This figure also reveals that white letters and black halos integrated sufficiently with the background image. Since it was not possible to adopt this successful technique of including names on space images, the alternative was to put the names in black boxes (halos) as an attempt to increase the contrast against the background. However, as can be seen in Figure 13-

17b, this alternative was not suitable, since the underlying box obscures more details and appears more artificial while, at the same time, it disturbs the natural image.

Figure 13-17b: The use of a black box (halo) behind the name was not a good solution, since it hides too much of the background image.

Names were produced in other colours such as red and brown to test their appearance and contrast against the tonal image. However they did not stand out sufficiently against the background; in fact, they were hardly to be seen or recognised against the dark image. The final decision was to select a compromise solution and use white names, since they contrast and integrate well with the space image and reasonably legible and clear and can be read relatively easily over most of the map area – see Figure 13-17c.

A ***serif*** type face was used for those names identifying physical features, while the ***sans serif*** form was adopted for those names that identify man-made features. In most cases, a hierarchy of typeface sizes has been used which aids the classification of the features being shown on the map. This hierarchy has been applied to emphasise the relative importance and size of a particular class of cultural feature – e.g. towns, small towns, main villages and villages. To differentiate between the corresponding names, the type set is varied in terms of the upper and lower case forms that have been used; the use of roman and italic forms; the point size, and bold and normal. To indicate the physical feature of the sea, a serif type set in an italic form has been used for the Mediterranean Sea name. This was in 100% cyan to ensure a distinction between the water and land names.

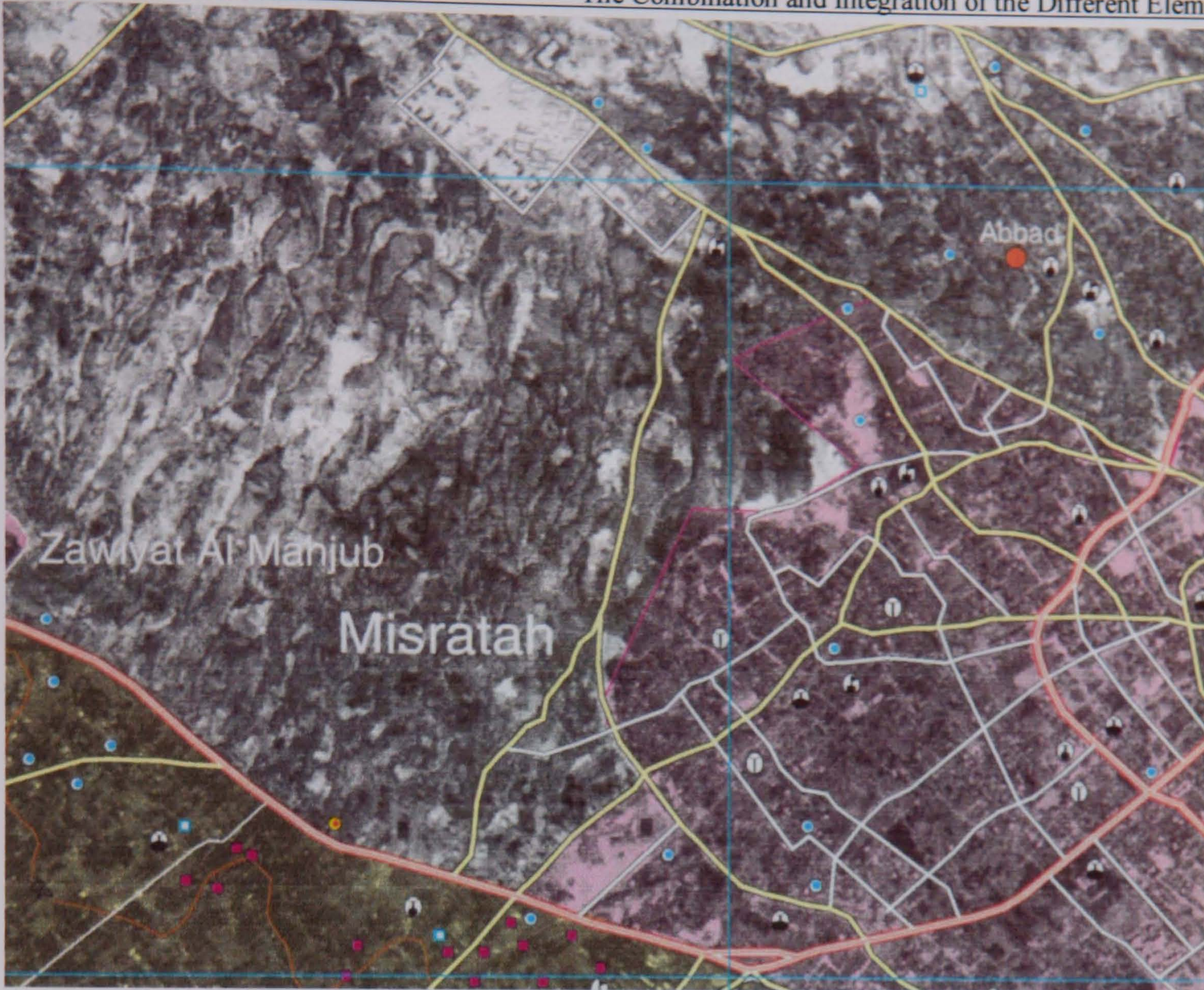


Figure 13-17c: White names have provided better results in terms of contrast and legibility.

13.2.4 Map Arrangement and Marginal Layout

The map arrangement and layout is another important task for the cartographer, since these can affect both the final appearance and the use of the map product. The parameters to be considered include the sheet size or format, the border and co-ordinate reference systems, scale, legend and marginal information.

Sheet Size: The sheet size of the experimental map at 1:50,000 scale has been chosen to lie within the limits of the printing formats more commonly used in Libya and considering the users' point of view that the size should be manageable both in the office and in the field. Therefore, it has been decided to adopt the same rectangular format or sheet size (700 x 500 mm) that has been used in the existing 1:50,000 topographic map series of the Surveying Department of Libya. The reason for the adoption of the same sheet size was because these existing maps had been well received by the actual map users who did not face any difficulties when using them in the office and in the field.

Border and Co-ordinate Reference Systems: It is normal practice for a topographic map to contain a border (Figure 13-18), lying outside the neatline, together with marginal information related to sheet and series. Along with the border, two reference co-ordinate systems (both that based on the Universal Transverse Mercator projection and that based on geographical co-ordinates) have been included. The necessary numbers relating to the values of these two reference co-ordinate systems values were placed adjacent to the neatline in 100% cyan and black, respectively.

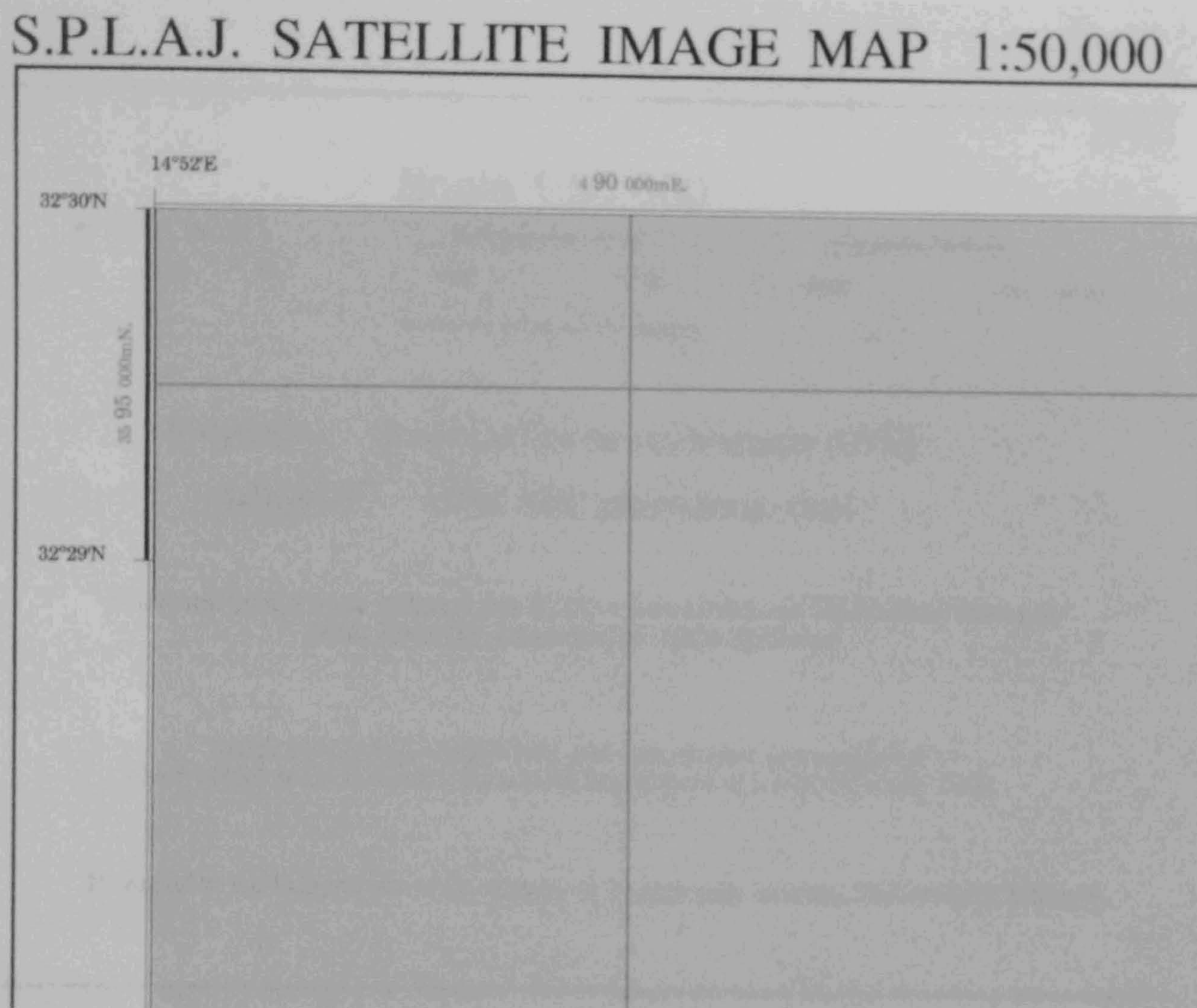


Figure 13-18: This window shows the arrangement of the borderline and the co-ordinate reference systems on the experimental map at 1:50,000 scale.

Legend and Marginal Information: The arrangement of the legend and marginal information has also had careful design treatment. This has included the information concerning symbols; the inclusion of graphical scales; the index to the adjoining sheets; the data sources, etc. (see Figure 13-20).

Both the numerical expression and the corresponding graphical scales were provided on the experimental map, see Figure 13-19a. In fact, the numerical expression of the scale was given prominence as part of the identification of the experimental sheet. However, from the users' point of view, the graphical scale is likely to be more useful in providing some measure or estimate of distances.

Whatever the information contained in the map, there must be a legend to describe the symbols and to provide essential information about the map and the additional data sources used. According to Wood (1968), the "... symbols are not standardised as they are in a written language and a legend is always required for each map to allow complete interpretation." This is particularly the case with an image map series in which the symbols will inevitably be substantially different to those of a conventional line map. In fact, the design of the legend took quite a time, experimenting with different layouts before a satisfactory solution was achieved.

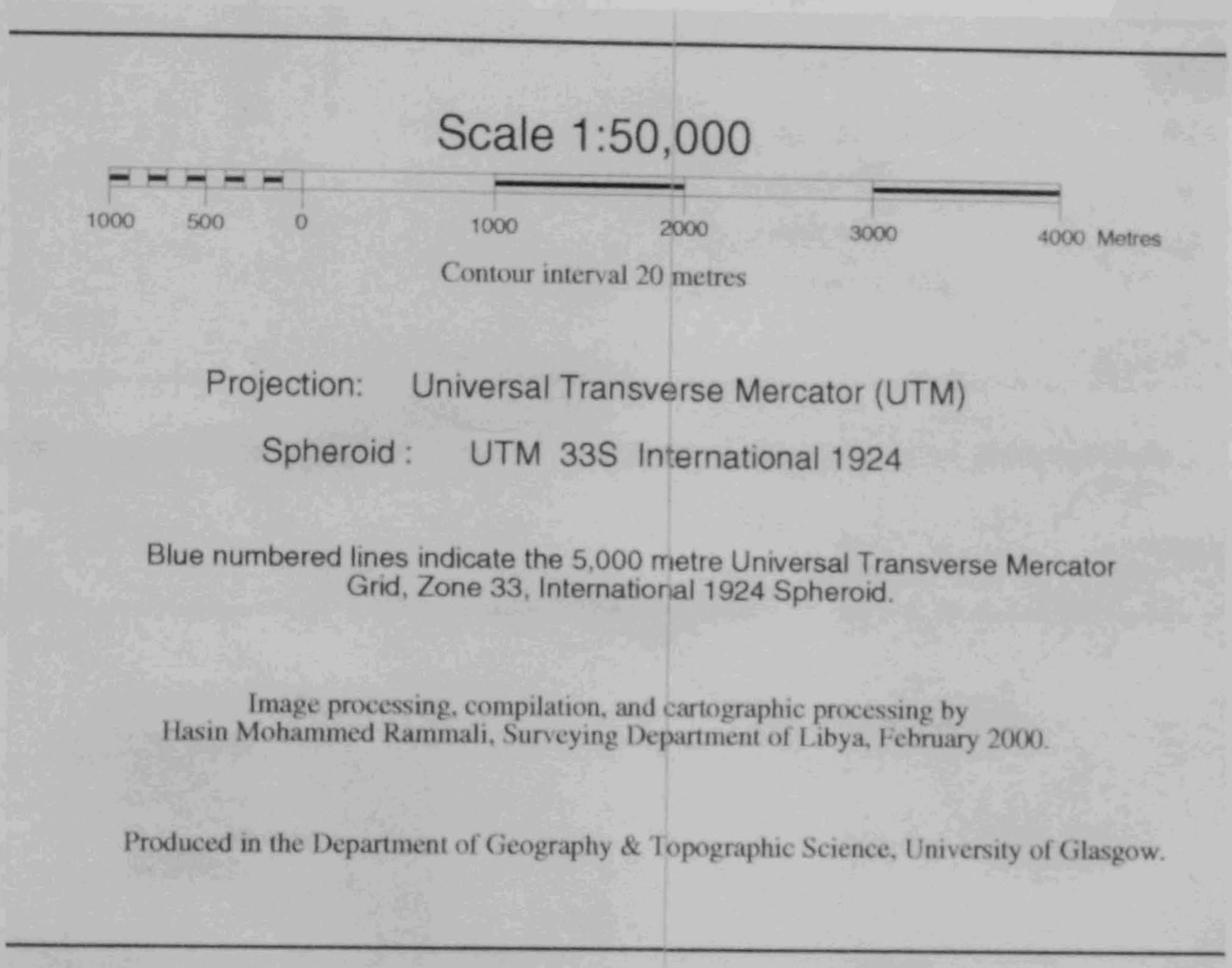


Figure 13-19a: The arrangement of the graphic scale, projection detail and other marginal information.

The title of the map was made large in size, bold and in upper case in order to emphasise its importance. It was centred at the top of the map body. The legend was placed at the bottom section of the sheet containing the explanations of the symbols (Figure 13-19b), scale, index to adjoining sheet (Figure 13-19c), etc.

Generally, the arrangement and layout of the final map appears – in the author's opinion –to be well balanced and quite clear. Furthermore, the type size and type style used for marginal information appear to be appropriate for the purpose.

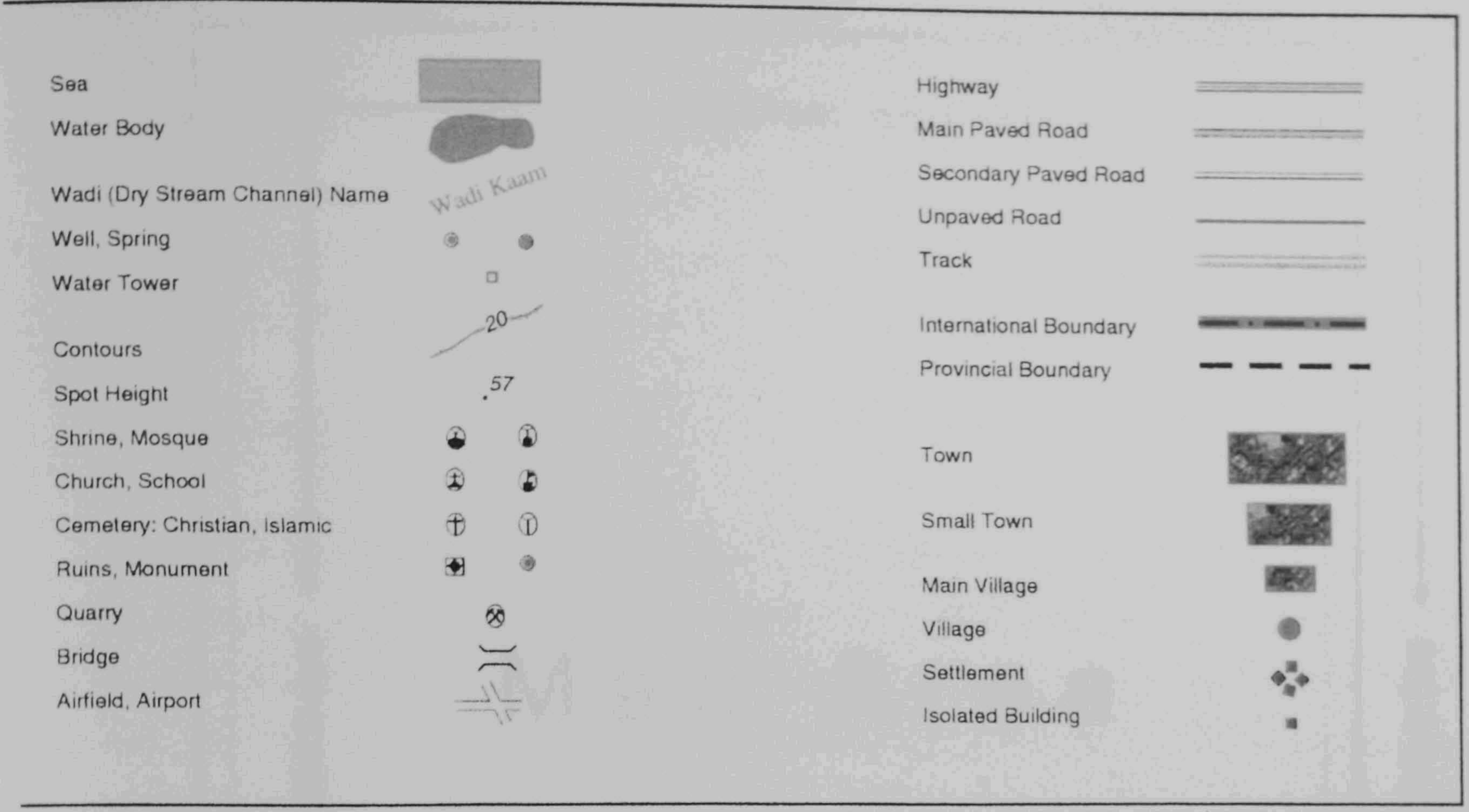


Figure 13-19b: A small window displaying the arrangement of the explanation of the symbols.

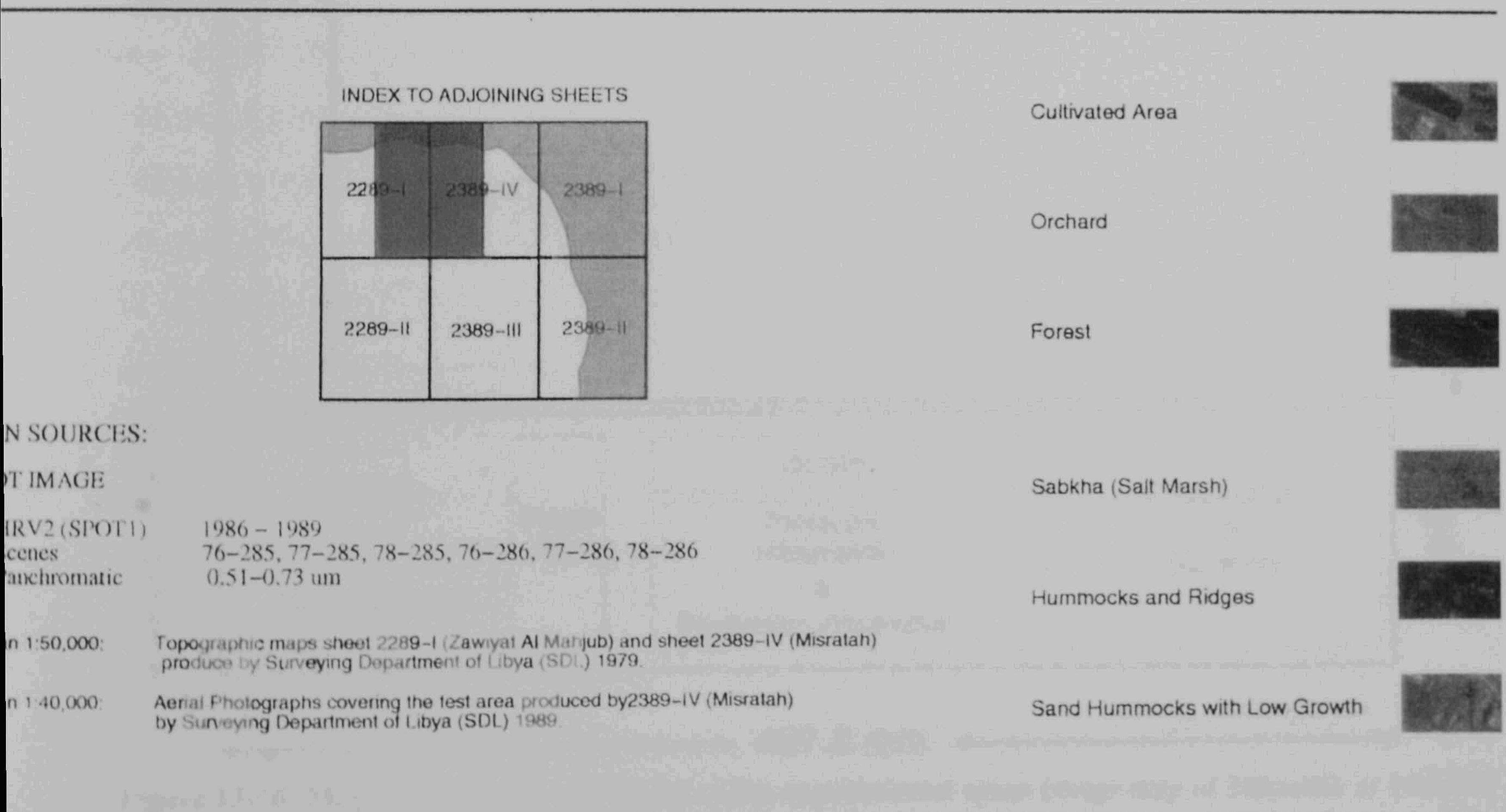


Figure 13-19c: This window showing the arrangement of the index to the adjoining sheets in the series, the data source details and the image keys.

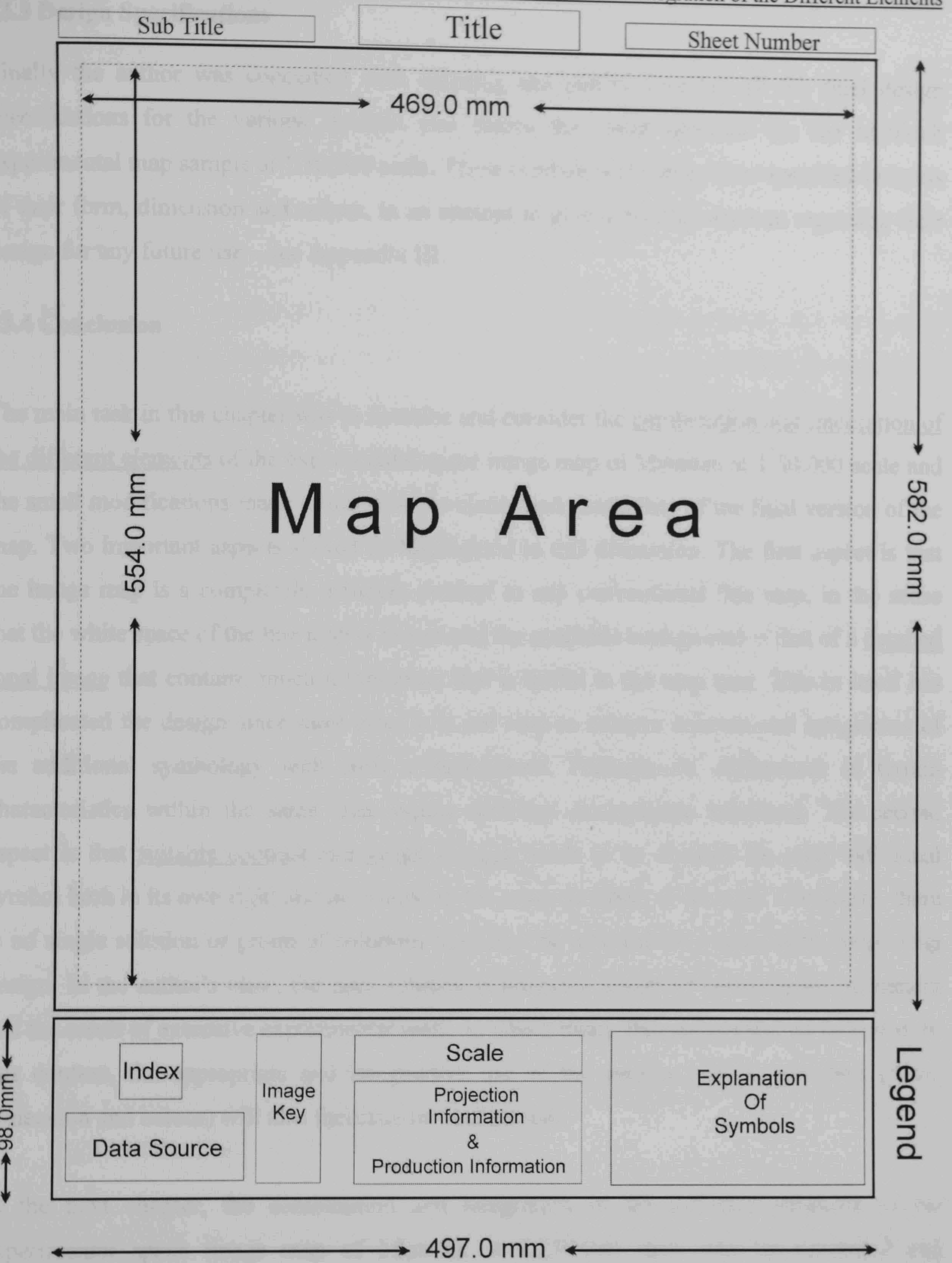


Figure 13-20: Map arrangement and layout of the experimental space image map of Misratah at 1:50,000 scale.

13.3 Design Specifications

Finally the author was concerned with defining and putting together all the final design specifications for the various symbols and names that were specified for the Misratah experimental map sample at 1:50,000 scale. These symbols and names were specified in terms of their form, dimension and colour, in an attempt to give a detailed account regarding their design for any future use – see Appendix III.

13.4 Conclusion

The main task in this chapter was to describe and consider the combination and integration of the different elements of the experimental space image map of Misratah at 1:50,000 scale and the small modifications made to improve the clarity and readability of the final version of the map. Two important aspects should be highlighted in this discussion. The first aspect is that the image map is a completely different product to any conventional line map, in the sense that the white space of the line map is absent and the available background is that of a detailed tonal image that contains much information that is useful to the map user. This in itself has complicated the design since most often it is not easy to achieve contrast and integration of the additional symbology with such a background. Furthermore, differences in terrain characteristics within the same area require different cartographic treatment. The second aspect is that suitable contrast and visual balance needs to be ensured for each individual symbol both in its own right and in relation to the other elements of the map. Obviously, there is no single solution or group of solutions that must be adopted for a successful image map design. In the author's view, the final solution is always a matter of cartographic judgement and the result of extensive experimental work, in which many alternatives should be tested. In this context, the appropriate and imaginative use of the various graphic variables (form, dimension and colour) will also facilitate the design task.

In the next chapter, the combination and integration of the different elements of the experimental space image map of Misratah at 1:250,000 scale will be presented and discussed.

CHAPTER 14: THE COMBINATION AND INTEGRATION OF THE DIFFERENT ELEMENTS OF THE EXPERIMENTAL SPACE IMAGE MAP AT 1:250,000 SCALE.

14.1 Introduction

In Chapter 13, the combination and integration of the different elements and the overall design involved in the creation of the experimental space image map of Misratah at 1:50,000 scale have been carefully treated and fully discussed. As explained earlier in Chapter 13, there are three significant factors that can influence the design of any space image map. These are (a) the scale; (b) the purpose or the function of the map; and (c) the terrain conditions or characteristics of the area to be covered by the image map. In the case of the 1:250,000 scale map, the latter two factors (function and terrain) are only slightly altered. However the scale has been drastically changed – by a factor of five (1:50,000 to 1:250,000). Since the scale of the map is so much smaller, the need for generalisation increased and, in turn, this has affected both the map content and its cartographic representation. At the larger scale (1:50,000 scale), the map covers a smaller area which allows the inclusion of more point, line and area features in the map product. At the smaller scale (1:250,000 scale), these are greatly reduced. In general, the design of 1:250,000 scale map has followed, to a certain extent, similar experimental procedures and solutions to those adopted in the case of the 1:50,000 scale map. However, the intention is not to repeat the discussion of similar procedures and solutions. Instead only the significant differences experienced during the design and production of the 1:250,000 scale map will be treated in this chapter.

14.2 The Combination and Integration of the Different Elements of the Experimental Space Image Map at 1:250,000 Scale

Since the 1:250,000 scale allows a larger area of the terrain to be covered, this allows the map user to obtain a much broader view of the terrain, but it also means that fewer cartographic details can be included due to scale limitations. This means that many of the smaller features – the man-made features in particular – that were shown on the 1:50,000 scale map cannot be included in this smaller scale map. Moreover the increased area covered by the map consists largely of natural semi-arid terrain with few man-made features. However, the inclusion of certain small but important features such as tracks, wells, shrines, ruins, etc. that will not appear on the space image still need to be included at 1:250,000 scale. From a map design point of view, the inclusion of fewer details on a larger mapped area may give the designer of the map more freedom and space, which allows him to design a good quality and uncrowded final product. However, this scale change will also produce a problem or problems of different nature, since there will be a need for the greater exaggeration of a feature or a symbol from its true size. Consequently, the type or method of representation on the smaller scale image map will be different and possibly more complicated. For example, main villages were represented on the 1:50,000 scale map through the use of an area symbol (containing a medium degree of transparent pink) However, the area occupied by this class of settlement is very small on the 1:250,000 scale image map and will need to be shown using some type of geometric point symbol. Furthermore, all these various considerations will have some effect on the time, effort and cost needing to be expended on the production of the map.

14.2.1 The Background Space Image

The background space image was produced by enhancing and joining (i.e. mosaicing) together six SPOT Pan images to form the overall image mosaic of the whole study area. As has been described in Chapter 10, the available image processing software packages (PCI EASI/PACE & Adobe PhotoShop) were used extensively for the required geometric corrections, radiometric enhancements and mosaicing procedures. A sub-set from the whole image mosaic was produced (in digital form) to be used as a base for the main mapped area of the experimental image map at 1:250,000 scale. This sub-set has a rectangular shape with its width greater than its height. The dimensions of the image map area are about 440 x 560 mm.

14.2.2 Differences in Symbolisation

Once the mosaicing operation had been completed, all the different elements of the map have been put together to test their performance collectively instead of in isolation as has been done in the earlier design stages. Particularly for the point and line symbols, the reduction in scale made it more difficult to achieve sufficient visual contrast against the tonal image. Even with a certain degree of exaggeration from their true size, these symbols were still very small in size and required the use of solid colours with good contrast in order to be clear and recognisable on the image map. In the author's opinion, there was no point in simply reducing the symbols from those used at 1:50,000 scale, since the reduction in scale requires a completely different representation to be adopted when incorporating certain symbols in the smaller scale map. Therefore, new symbols have been designed to meet the 1:250,000 scale specifications and these have then been used on the experimental map of Misratah at this scale.

(i) Roads: As mentioned above, the 1:250,000 scale image map covers a larger area of the terrain containing many different types of roads. In reality, minor roads and tracks are very thin in terms of their actual size and width on the space image. Consequently they might not be shown on maps produced at the same or similar scales in highly developed countries. However, in most parts of the Misratah area, these minor roads and tracks are very important to the local community and often are the only lines of communication within the area. Therefore, all five classes of roads – highways; main paved roads; secondary paved roads; unpaved roads and tracks – have been included in the experimental map.

The representation of these roads has been based on the classification of these roads according to different criteria – the real width, number of lanes, type of surface, etc. The author has included in his design considerations the effects of the exaggeration of the symbol dimensions. As already discussed in the context of the 1:50,000 scale map, the basic graphic variables of form, dimension and colour were again used to establish an appropriate hierarchy for the different roads, increasing the clarity of the image map. The use of red, yellow and white as road infill colours provided an appropriate gradation and differentiation and emphasised the road classification. Moreover, the use of single (continuous or interrupted), double, treble lines at different widths has also facilitated the discrimination of the different classes by the user. Figure 14-1 shows how the selected line symbols for roads have achieved sufficient visual contrast and clarity and a good integration with the tonal image without dominating the map.

(ii) Water Features: As described previously in Chapter 12, no major surface water courses exist in the Misratah area. The wadis contain water for only a very limited period during a good raining year but they still form an important part of the natural drainage system. They vary from those with a quite definite extent to those whose extent can be quite ill-defined. In view of their seasonal character, they could not be represented in the same manner as other permanent bodies of water and hence could not be placed at the same visual level as rivers and water bodies. Eventually, after much thought and some trials, it was decided to leave the SPOT Pan image as it stood for the representation of these wadis – since they were plainly visible without any need for enhancement – but to identify them as water features by overprinting their names in blue along their courses, see Figure 14-2.

Figure 14-1: The representation of the roads on the Misratah space image map at 1:250,000 scale. Lighter colours have been used to represent the road line symbols, through the selection of the most appropriate colours, in order to increase their visual contrast and clarity against the black and white image. This means, that dull colours have been avoided since they decrease the contrast and disturb the visual order and map balance.

However, this approach of leaving the space imagery without any cartographic enhancement or alteration to represent the wadis has led to a few problems. Sometimes these features appear in similar tones to those of certain small areas of steep or elevated ground and thus they are very close to each other in terms of appearance on the final printed image map. In these situations, it is hoped that the use of the blue names has helped to resolve this potential misunderstanding.

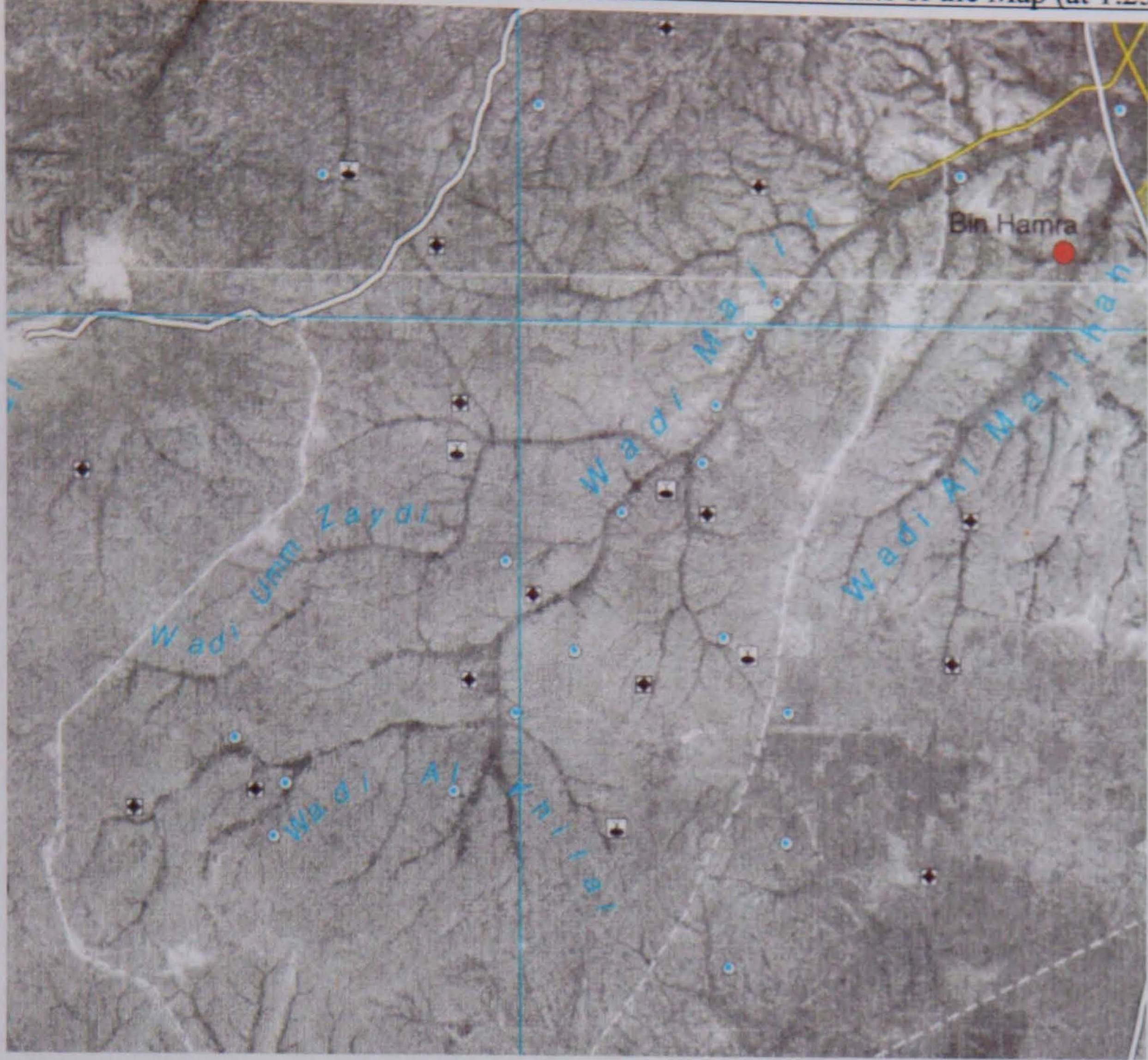


Figure 14-2: A small window illustrates the representation of wadis on the experimental space image map of Misratah at 1:250,000 scale. The natural representation of the wadis on the space imagery was more effective than any conventional representation. However the use of blue names to help their identification was very useful in terms of interpretation.

(iii) Cultural Features:

With regard to the representation of the cultural features that needed to be included on the 1:250,000 scale map, a number of differences have been experienced while designing and producing this map. Due to the scale reduction, <u>towns</u> are the only settlement areas that have been represented through the use of area symbols. Smaller settlements (e.g. main villages) became so much smaller in size on the 1:250,000 scale map that the use of point symbols was unavoidable. To achieve a sufficient visual contrast against the background image, the solution was to increase, to an extent, the percentage of the transparent magenta that was used (Figure 14-3a) since smaller areas require stronger colours in order to be sufficiently well recognised on the space image. Scale restrictions have also affected the representation of the <u>main villages</u>, which are no longer represented by area symbols, as was the case on the 1:50,000 scale map. Instead, an outlined solid circle in a red colour was used to show the main villages on the final 1:250,000 scale map of Misratah. To emphasise their importance and higher order, the size of the circle used was made larger than those circles used to show villages. As can be seen in Figure 14-3a, they were clear and achieved good contrast and unity with the background.

Figure 14-3a: A small window illustrates the representation of towns on the 1:250,000 scale map produced in the current project. As the size of this area feature gets smaller due to scale changes, the percentage of transparent magenta was increased to obtain sufficient visual contrast and clarity.

With regard to the airport, Figure 14-3a also illustrates the fact that the large changes in scale did not allow the retention of the real appearance of the airport runway. Thus a quite different method of representation was adopted for the airport. This was an iconic point symbol of an aircraft in a red colour, which was placed inside an outlined solid circle (in white colour) as a background. In other words, this design solution was implemented in an attempt to increase the visual contrast of the point symbol. In turn, this will speed up the time needed for its recognition on the part of the map user.

Variations in representation were also necessary when dealing with other cultural features such as shrines, cemeteries and quarries. The oval shape that was used for such point symbols (either as a frame or a background) during the design of the 1:50,000 scale map, proved not to be suitable for use at the 1:250,000 scale – since the reduction in their size made the symbols unclear and they could not be identified easily. Instead white squares were used as frames for these black point symbols, by which means, their clarity and contrast increased greatly, as shown in Figure 14-3b.

Figure 14-3b: This small window shows the representation of other cultural features such as shrines, cemeteries and quarries. White frames having a square shape were used instead of the oval frames used in the 1:50,000 scale map.

(iv) Other Area Features: Sabkhas or salt marshes were the other type of area feature that have been included at this smaller scale. They cover most of the area located to the south-east of Misratah town. Although a transparent area colour (blue) was used to help show the sabkhas, unfortunately, the dark appearance of these features on the space image did not allow any useful detail to be extracted. In an attempt to aid the identification of their location and extent, the appropriate names were overprinted in white – see Figure 14-4.

Figure 14-4: A small window illustrating the extent of the sabkhas (salt marshes) in the Misratah area. The overprinting of white names was very useful in terms of identification and interpretation.

(v) Relief Representation: Although <u>contours</u> are usually the most appropriate means of relief depiction on topographic maps of all types and scales, unfortunately, contour lines were not available in digital form for the whole of the area of the experimental map at 1:250,000 scale. Of course, it would have been possible to derive the contours from 1:50,000 scale topographic maps, but this would have required a very large effort and a great deal of time to digitize these lines. Therefore, it was decided not to include contours, at least for the time being, on this map and to only include the spot heights (Figure 14-5).

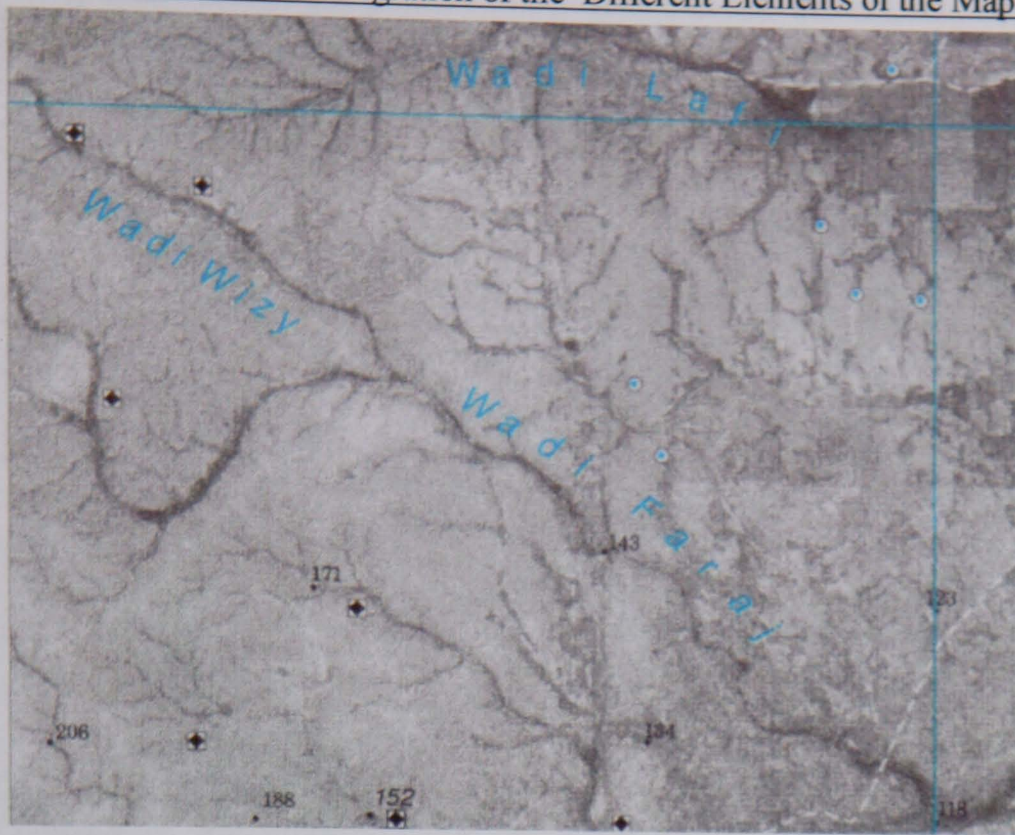


Figure 14-5: A small window indicates that spot heights were the only means of representing relief used on the experimental map (1:250,000 scale).

14.2.3 Differences in Text and Lettering

The text and lettering used with the 1:250,000 scale was somewhat different to that used on 1:50,000 scale map. In particular, more colours (e.g. black, white, cyan and magenta) were used to name and describe the physical and cultural features that were present on the map. It was decided to use mainly two quite different (i.e. serif and sans serif) type faces in order to emphasize the distinction between the physical and the cultural (man-made) features. Unfortunately, this did not work out well, particularly in the case of the names of the wadis which provided poor results in terms of legibility and contrast against the tonal image (see Figure 14-6a). When the serif type face was used for those names utilized to locate and describe wadis, the serif type face used was thinner in width. The result was an unsuccessful solution in terms of legibility and contrast. It was found that the only way to increase the legibility and contrast of these names was through the use of a sans serif type (Helvetica) in a blue colour. Eventually, for consistency purposes, all water features were named using either a blue or white sans serif type face in its italic form. As a result of this decision, a better result in terms of legibility and contrast has been obtained – see Figure 14-6b.

Figure 14-6a: This small window illustrates the poor results in terms of legibility and clarity that have been obtained when a serif type face was used for the wadi names.

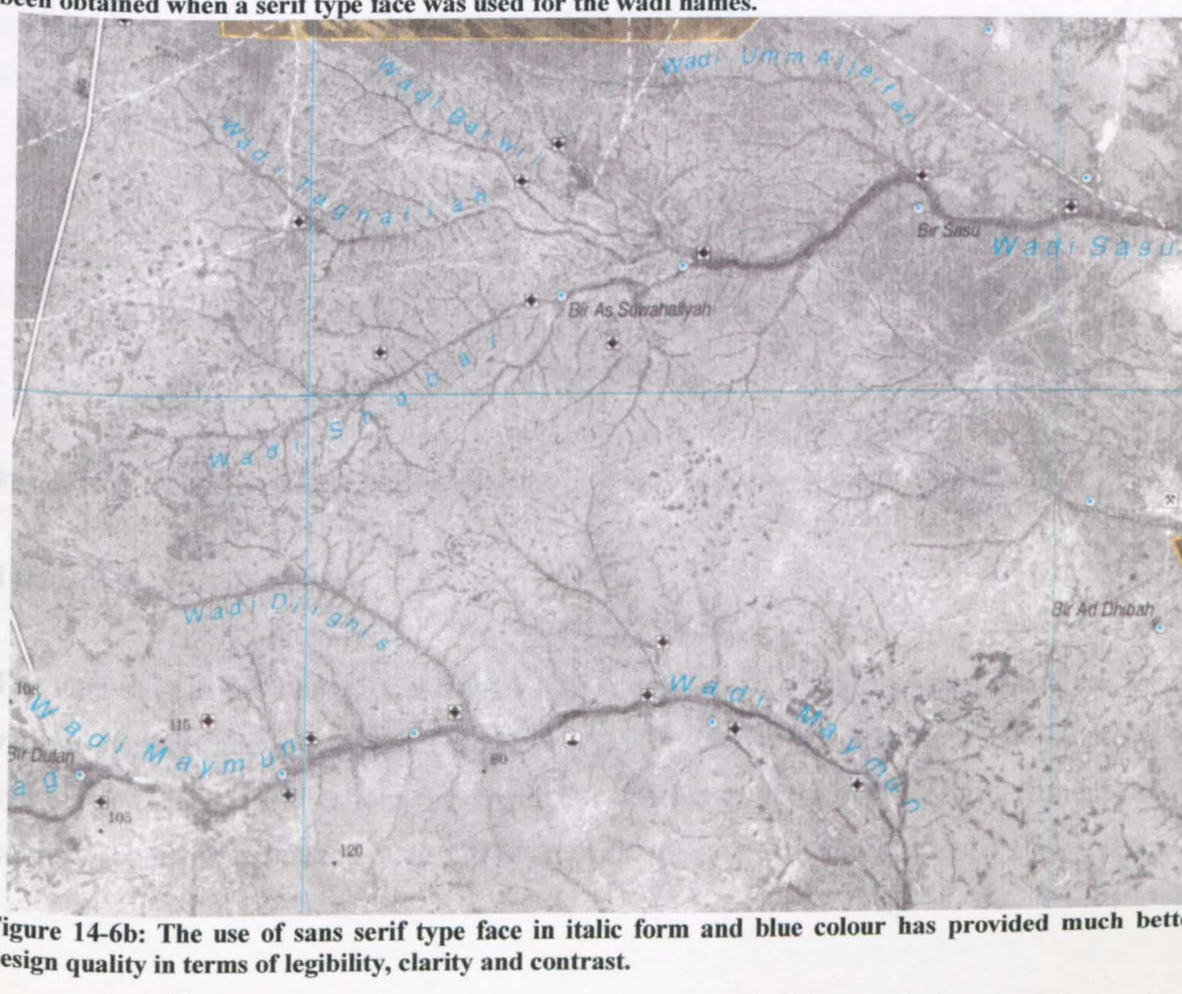


Figure 14-6b: The use of sans serif type face in italic form and blue colour has provided much better design quality in terms of legibility, clarity and contrast.

14.2.4 Map Arrangement and Marginal Layout

No major difficulties have been experienced when designing the map arrangement including the marginal layout and legend. The only differences concerned the sheet size (480.5 x 600.5 mm) and the shape of the format, which is rectangular in form with the wider side in the horizontal (west-east) direction – see Figure 14-7.

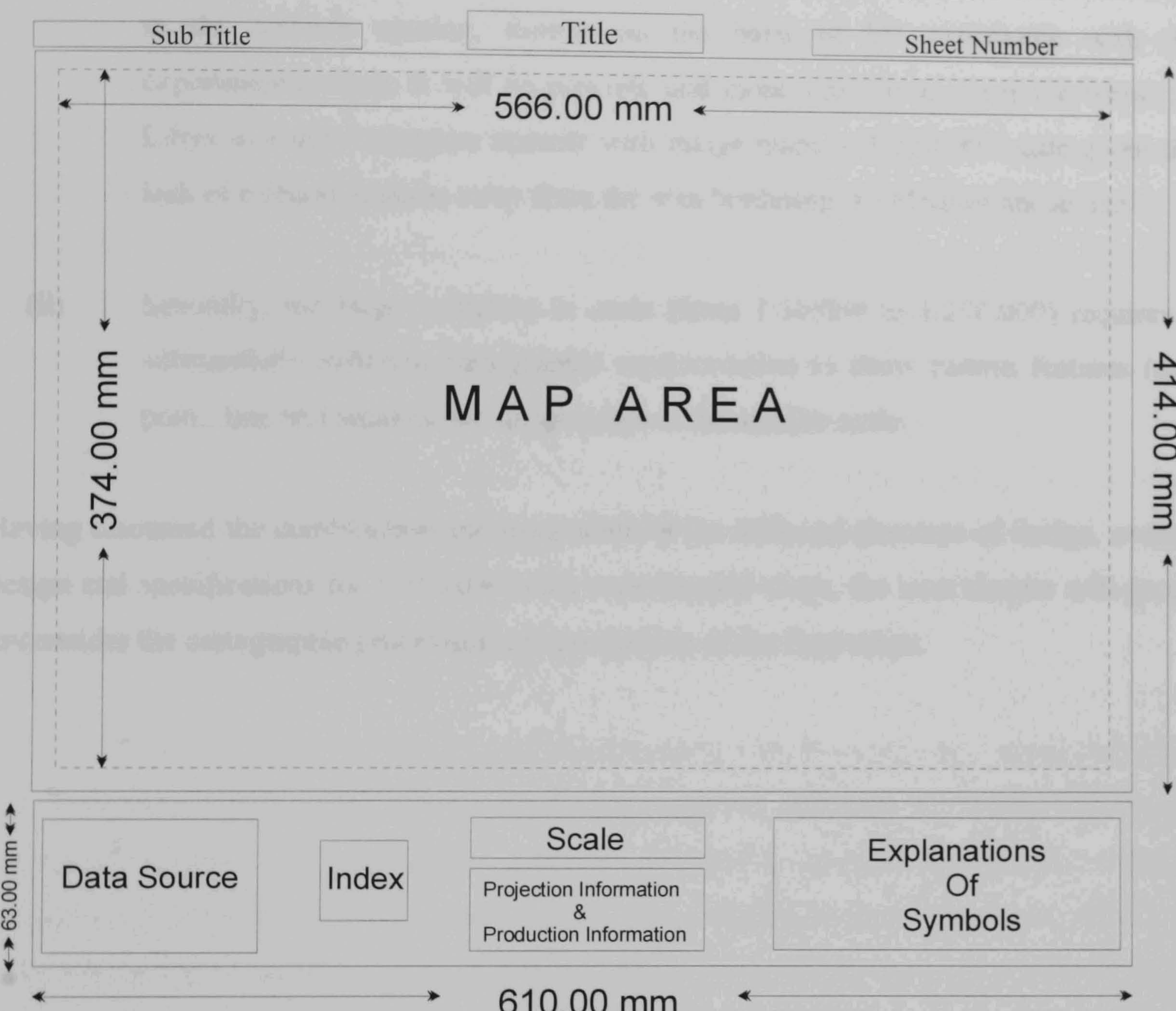


Figure 14-7: Map arrangement and marginal layout of the experimental map 1:250,000 scale.

14.3 Design Specifications

The next step in the image map design was to put together the final specifications for the various symbols and lettering that were specified for the 1:250,000 scale image map. All the symbol and name specifications that have been defined in terms of their form, dimension and colour for both experimental maps of Misratah are given in Appendix IV.

14.5 Conclusion

The main two points that have been highlighted in this chapter are:

(i) First, the reduction in scale from 1:50,000 to 1:250,000 scale – by a factor of five – allows a much larger area of the terrain to be covered in a single sheet. In turn, this allows the map user to obtain a much broader view of this terrain. Therefore, in the author's opinion, formed on the basis of his experience with the experimental sheet, it will be possible and more suitable to cover the whole of Libya in a quite adequate manner with image maps at 1:250,000 scale given the lack of cultural features away from the area bordering the Mediterranean Sea.

(ii) Secondly, the large reduction in scale (from 1:50,000 to 1:250,000) requires a substantially different cartographic representation to show certain features (e.g. point, line and area) on the image maps at the smaller scale.

Having discussed the combination and integration of the different elements of design, overall design and specifications for 1:250,000 scale experimental maps, the next chapter will go on to consider the cartographic processing and production of the final maps.

CHAPTER 15: CARTOGRAPHIC DATA PROCESSING & PRODUCTION OF EXPERIMENTAL SPACE IMAGE MAPS

15.1 Introduction

The combination of the different elements and the overall design and specification of the experimental space image maps at 1:250,000 and 1:250,000 scales were described in Chapters 13 & 14. This chapter now describes the actual cartographic data processing and production of the experimental space image maps at these scales that was carried out by the present author using the facilities available in the Department. The processes carried out include the initial image processing, data capture, cartographic data processing, reproduction activities and the final printing of the experimental maps. Finally the stages, processes, software and the material used in the image map production are shown by a production flow diagram. This demonstrates the number of different components that are necessary to produce the actual map and their relationship to one another. This is a critical factor, since obviously it will relate to the overall time required and the final cost of producing the map.

15.2 Image Processing Activities

The first step in any space image map production starts with the image processing activities and procedures. The six SPOT Pan images that were used in this mapping project had already been geometrically corrected and radiometrically enhanced in the early stages of this research project – see Sections 10.3, 10.4 and 10.5 in Chapter 10. Next, these enhanced SPOT Pan images were joined together – to form the image mosaic that covers the whole of the Misratah test area – using the mosaicing procedures and techniques that were described in Section 10.6. This image mosaic of the whole study area was then ready for the application of further processing procedures. However the area covered by the whole space image mosaic was a little larger than the area that needed to be covered by the experimental map at 1:250,000 scale. Thus it was necessary to select the image area that matched the desired map area. Furthermore, a smaller part of the overall image mosaic, which covers only the area around Misratah town, was also selected to act as the background image for the experimental map of Misratah at 1:50,000 scale. The selection was carried out using the **Subset** tool available in the **Image Works** module of the **PCI EASI/PACE** software package. At this stage, two files (i.e. Des250.pix and Des50.pix) had been created in digital form and were available for further cartographic data processing. Each of these digital files contained an image mosaic that would act as the base image to either the 1:250,000 or the 1:50.000 scale experimental image map when imported later to the ACE software package for the cartographic processing.

15.3 Topographic Data Capture

Some topographic features that did not form part of the space image (e.g. such as contours) and some objects (in particular, small man-made features) that could not be wholly or partially detected and identified on the space image had to be added to the data set. From the users' point of view, these topographic data are very important and need to be shown on the experimental maps at 1:50,000 and 1:250,000 scales. Consequently, these features were derived from the existing topographic line maps at 1:50,000 scale by manual vector digitizing. Each of the selected 1:50,000 scale topographic maps was placed on a **CalComp 9100** large-format tablet digitizer and digitized utilizing the **MAPDATA** software package.

The order of this additional data capture was carefully considered prior to the digitizing operation. This has eliminated possible problems with data structure at a later stage and reduced the time required for editing. Separate sets of data files were created for contours, unpaved roads and tracks, villages, isolated buildings, wells, etc. with each map feature being given a separate feature code to allow for data manipulation at a later stage. No major problems occurred during the data capture stage and all the digitized files were saved separately in the readable **ASCII** format for further processing.

In digital mapping, it is important to consider the immediate and possible future of all the different forms of digital data created during the data capture process. At this stage, **MAPDATA** had produced the required topographic features in separate files and in a readable ASCII format. Normally this would allow this data to be re-formatted and output in a format suitable for import to other digital mapping and graphic software packages. Unfortunately, this was not the case with this project, since the **ACE** software package does not support the **MAPDATA** format. The solution was to convert these digital data files to **ARC/INFO** ungenerated **(.UGN)** format using a small **FORTRAN** program that was available in-house. These digital data files with the **.UGN** extension were then imported to **ACE** and used as separate vector layers during the design and production stages.

15.4 The Colour and Choice of Printing Inks

The available choice of colours and the permissible number of printing plates and inks have an obvious relation to the design, production and ultimate appearance of any map. Because of rising costs, there is increasing interest in the use of the four-colour process using cyan (C), magenta (M), yellow (Y) and black (K) for the printing of multi-colour maps. Through the use of these colours, it is (theoretically) possible to create any desired colour, in which case, this will avoid the need for producing maps using six to nine separate printing colours – as has often been done in the past. Printing by offset-lithography is expensive and the use of numerous specific colours, each requiring a separate printing plate and an additional print run, will substantially increase the overall cost of a map. Thus this matter needed to be considered at an early stage of the planning process. In the printing trade, labour and equipment costs substantially outweigh the costs of printing materials and consumables. It is generally accepted therefore that, the greater the number printing plates and inks used, the higher the cost of the printing process; while, at the same time, the larger the print run, the cheaper the cost per printed sheet.

However, these issues are not as straightforward as it may seem since many other technical considerations are involved. These include the quality and register of the fine lines that are produced through colour combination; the fact that the colours produced by combinations may appear less pure or less clean than separate ink colours; the extreme care required for machine preparation to ensure proper register and ink flow prior to the printing machine being run; and the more frequent checks of these operations necessary during the actual printing operation. All of these matters have to be taken carefully into account and weighed against one another to decide whether it is justifiable to shift from traditional colour-separated methods for the production of multi-colour maps to the use of four-colour process – especially in the context of a map based on the use of space imagery. In this project, it was decided to use the four-colour process, partly as an experiment to examine its feasibility for application to image maps. In addition, the use of the four-colour process that would keep the projected final printing costs to a minimum would also allow the map to be output as a proof in colour on widely-available four-colour raster printers. Indeed, potentially the four-colour process offers the widest possible range of colours through tint and half-tone combinations and will portray more precisely flesh tones in images, since cyan and magenta are more spectrally pure than red and blue. However, it is well-known that many of the less expensive raster colour printers/plotters that are used in editing and checking operations have distinct limitations in this particular respect.

15.5 Cartographic Data Processing

This stage was concerned with the actual creation and representation of the various point, line, area features and text that were involved in the design of the experimental space image maps. A specialist cartographic software package – namely ACE (Advanced Cartographic Environment) from PCI – was available in-house and this was used extensively for the cartographic data processing of the experimental space image maps. Initially Versions 2.0 and 3.0 of ACE were used, and indeed the majority of the author's experimental symbol design activities were carried out using these versions. During the later stages of the project, Version 3.1 of ACE was made available. Version 2.0 of ACE was mounted on a Fujitsu-ICL PC equipped with a 133 MHz Pentium I processor and running the Microsoft Windows 3.11 operating system, while Versions 3.0 and 3.1 were mounted on a Tiny PC equipped with a 233 MHz Pentium II processor and running the Microsoft Windows 95 operating system. This ACE package incorporated extensive cartographic handling capabilities and was utilised for data structuring and editing; symbol design and specification; sheet layout; and the addition and placement of names. The main advantages of this software package are its capability of handling both raster and vector data, and its close integration with the EASI/PACE package that had been used for the image processing stages of the project. Thus it was very suitable for designing and producing the experimental space image maps of Misratah – though, in fact, the ACE package is still in the process of being added to and developed further for cartographic production purposes.

For the cartographic data processing carried out in this project, those procedures that have been applied at 1:50,000 scale are largely those that have been applied at 1:250,000 scale. Hence these cartographic processing procedures will be discussed together.

15.5.1 Map Project

In ACE, the collection of map data is called a map project or simply a map. The first level of the graphical map manager represents a map. In this project, the map contains everything that will be printed on a sheet of paper – vector and raster map data; the scale bar; the title; and the grid and marginal information. The map project has two primary types of working file, which have a common base name but different extensions. These files are the map project itself (**.mah**) and the PCIDSK file (**.pix**). The map project file (**.mah**) is the main working file used in ACE. It is an **ASCII** file that lists all the information relating to the current map project (i.e. filenames, parameter values, etc.). The **.pix file** stores the actual vector and image data (raster) in segments. The map project (**.mah**) file describes the *contents* of the **.pix** file; while the **.pix** file is the one that can actually be viewed on the monitor screen. In other words, the **.pix** file contains the data needed to build up the map. As a matter of fact, the **.pix** file is always associated with the map project file and is generated when creating a new map.

Another important file type is **.rst**. Files with this extension contain the RepCode Setup Table, which is the file containing the graphical representation for each feature included in the map. With this go the actual symbol files (.sym). These two file types will be discussed later in more detail in Sections 15.5.1.3 and 15.5.1.4 respectively.

The relationship between a map project file and the other file types that it uses is illustrated below:

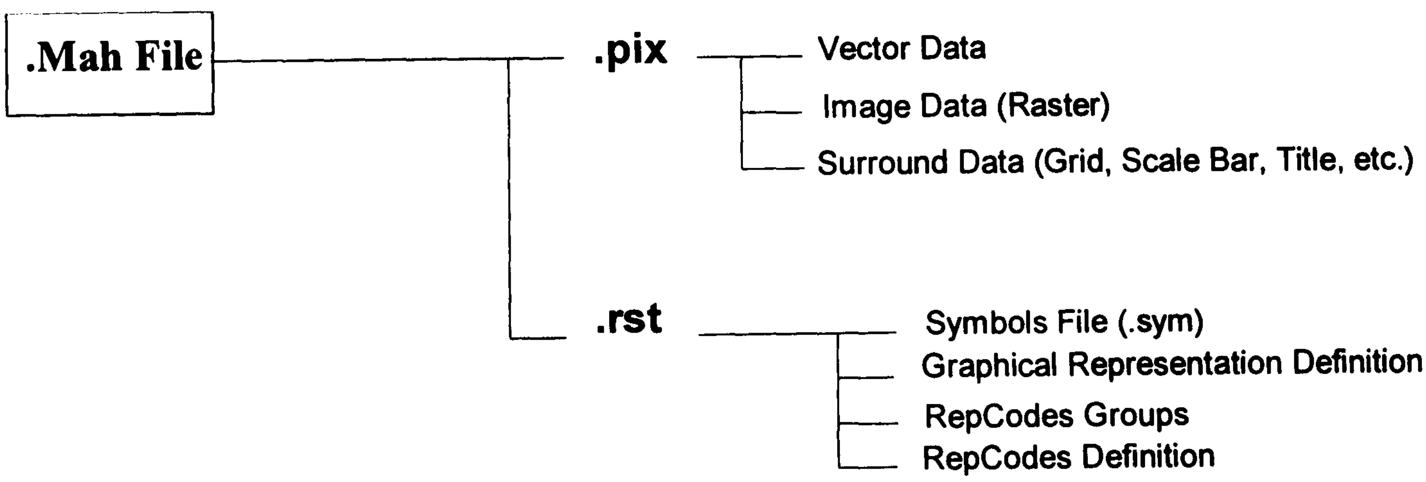
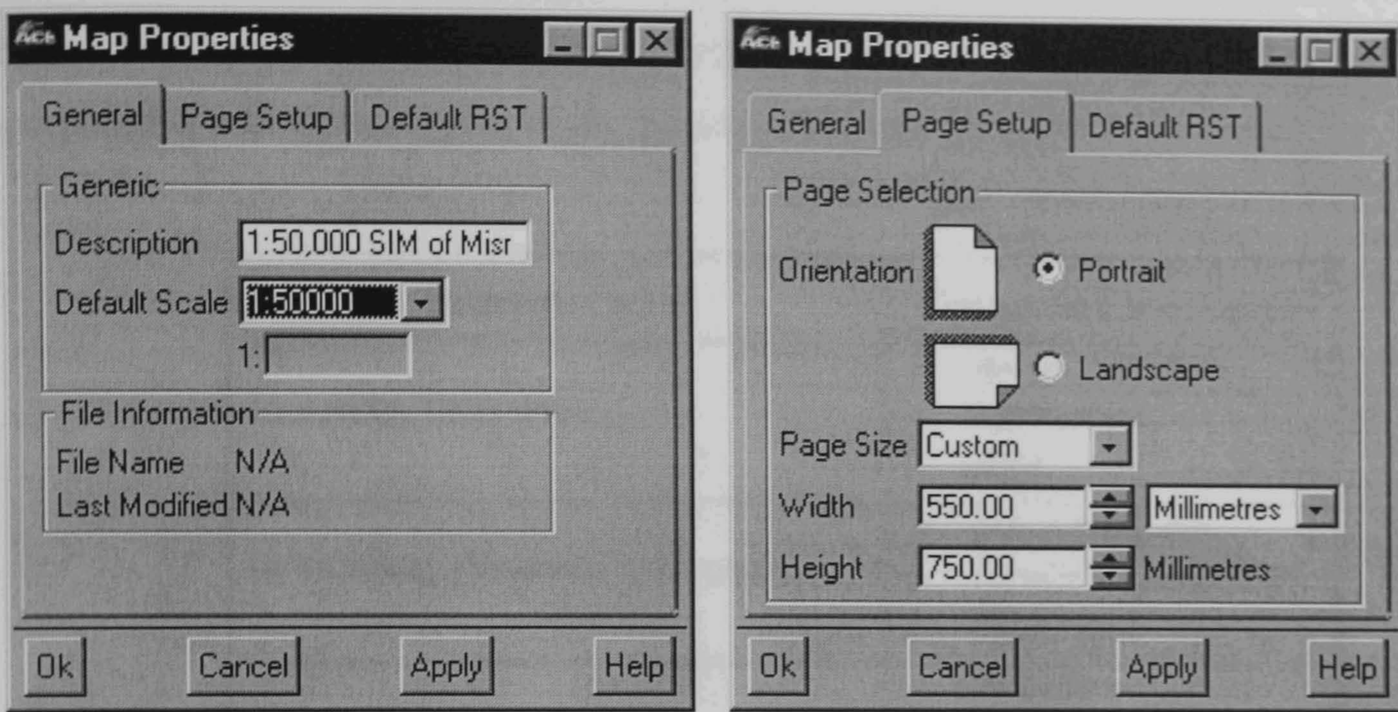


Figure 15-1: The relationship of the .mah file and other files

The **.mah** file defines the following parameters:

- Scale
- Paper Range
- Geographical Range
- Area Descriptions
- Projection Information
- Attributes Definition

The mapping operations started with the creation of the Map Header **.mah** (see Section 9.3.3.31 in Chapter 9), within which the desired scale and the paper size of the map were specified, see Figure 15-2. Afterwards the subsequent areas and layers would have this specific scale.



(a) (b)

Figure 15-2: (a) Map Properties: General window showing the scale specification (b) Map Properties: Page Setup showing the paper range.

15.5.1.1 Graphical Map Manager

The Graphical Map Manager is located on the left side of the ACE 3.0 window. It displays, in a single view, all the information that is contained in a map in such a way that the cartographer can easily access all its components through the actions carried out using the PC's mouse, without having to browse through ***menus*** and ***sub-menus***. As can be seen in Figure 15-3, the Graphical Map Manager represents the map information in the form of a tree. The main *level* of this tree represents the map project and its name (e.g. 1:50,000 SIM of Misratah) is displayed. The level is then sub-divided into sub-levels called *branches*, which contain the proper information according to what is included in the map (called *elements*). Table 15-1 shows the various map elements that a Graphical Map Manager may contain.

ACE is operated through user-friendly graphical user interfaces (GUIs) and makes extensive use of multiple windows, pull-down and floating menus, dialogue boxes, icons, and drawing tools operated under mouse or keyboard control (Figure15-3). The acronym "**WYSIWYG**" – What You See Is What You Get – is often used to describe such a graphical interface, since the cartographer is able to see, in preview mode, the design and specification of features as they are drawn on the screen. WYSIWYG options let the cartographer define how map features should be displayed on the screen of the PC. When the options are ***on***, features are displayed on screen exactly as they would be printed on a sheet of paper. When the options are ***off***, in certain circumstances, they can allow the cartographer to more easily interpret the information contained on the map by letting him see information that otherwise would not be visible. So the screen can be viewed either in on- or in off-modes and the layout can incorporate a user-defined grid, ruler, drawing area, etc.

Branch Level	Elements Included
In a ***map,*** there are:	⇨ ***Areas*** ⇨ ***Surround*** ⇨ ***RST***
In an ***area,*** these can be found:	⇨ ***Vector Layers*** ⇨ ***Image Layers*** ⇨ ***Surround***
In a ***surround,*** these can be found:	⇨ ***Neatline*** ⇨ ***Grid*** ⇨ ***Logo*** ⇨ ***Legend*** ⇨ ***North Arrow*** ⇨ ***Scale Bar*** ⇨ ***Title*** ⇨ ***Border***
In an ***RST,*** these can be found:	⇨ ***Symbol files***

Table 15-1: The Elements that a Graphical Map Manager May Contain.

From all of the above, it can be understood that the main important elements are ***areas*** and ***layers***, ***RST*** and ***symbol files***, and the ***surround***. Each of these will be discussed in some detail in the following sections.

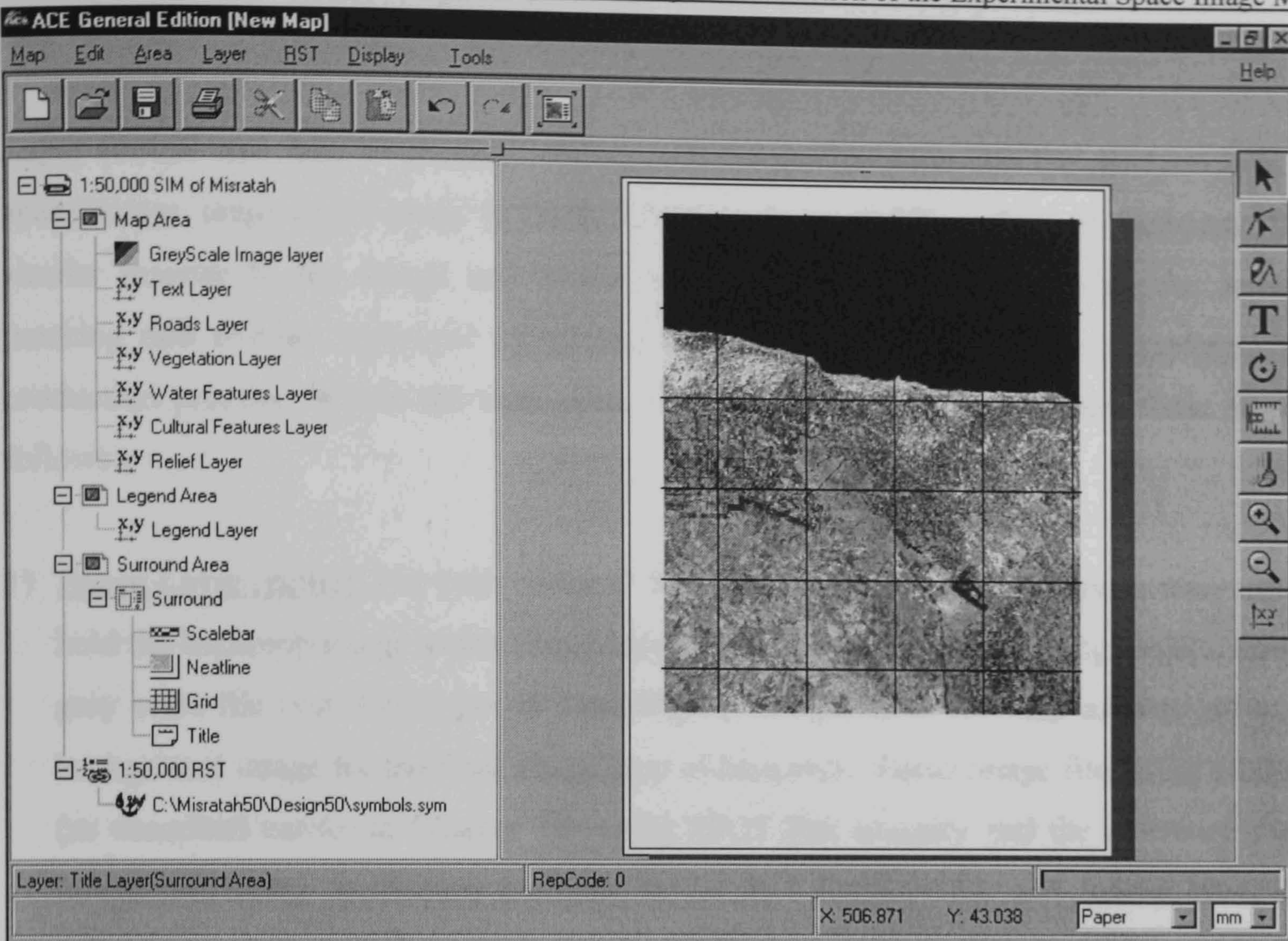


Figure 15-3: The Graphical Map Manager of the Space Image Map (SIM) of Misratah (1:50,000 scale).

15.5.1.2 Areas & Layers

ACE utilizes a hierarchical structure of ***map***, ***area***, ***layer*** and ***feature*** to provide the professional user with considerable flexibility in design, layout and composition. A ***map*** can be composed of an unlimited number of ***areas*** that are scalable, re-sizeable and movable. ***Areas*** can contain an unlimited number of ***layers***, containing either *vector* and/or *raster* data with no constraints as to which type overlays the other.

Areas: When adding (raster or vector) data to a map, ACE uses the concept of an Area (Figure 8-3) to represent the various parts that a full map may contain. In the current mapping project, there were three such areas on the map sheet, each one representing different types of information – these were the map area, the legend area and the surround areas. Furthermore, an area can contain one or more layers and may comprise either vector or raster (image) data. ***Layers***: One of the most useful and powerful features of ACE software package is the ability to create multiple layers (containing both raster and vector data) to allow the separation of map features as they are created or imported from the digital data base. The number of layers that can be created is limited only by the memory of the computer.

15.5.1.2.1 The Actual Layer Control

Layer control was used extensively during both the design stage and the production of the space image maps of Misratah (at both 1:50,000 & 1:250,000 scales). It functioned in a similar manner to the image and colour separation procedures employing the scribing, masking and overlay technique on plastic materials in the corresponding analogue map production process. Within the map **area**, two types of layers were added; these were as follows:-

1) Image Layer (raster): For both scales (1:50,000 & 1:250,000), image layers were used to hold the backdrop image to the vector maps. Specifically for this mapping project, an 8-bit grey scale file (e.g. Des50.pix or Des250.pix) was added to the map **area** to act as the background image for the final image map of Misratah. These image files were produced (as described earlier in Chapter 10) using SPOT Pan Imagery and the advanced digital image processing techniques available in the PCI EASI/PACE and Adobe PhotoShop software packages. In fact, ACE also has some image processing capabilities and these were used by the author to carry out further image enhancements – e.g. the **Darken** and **Brighten** options were used to enhance the images.

2) Vector Layers: Each layer of information was defined and utilized to represent only one type of geographic feature – e.g. roads, water features, vegetation, cultural features, relief, etc. An important aspect of the layer control is the ability to modify the design and specification of all features contained within a selected layer with a single command and to move and copy objects from one layer to another. As it appears in the layer manager, each layer is fully editable and can be individually locked or unlocked, made visible or invisible in on- or off-mode and can be set to be printed or non-printed. It is possible to rearrange the order of individual layers and the viewing order of features within layers, since ACE has the facilities of specifying different priority and parts order. Actually, the part order is a number that should be given to each individual line or point symbol within a symbol formed using multiple parts to ensure the order of its appearance. In this respect, the ACE software package has a much better system of layer arrangement and control than any other software packages (e.g. CorelDraw, Adobe Illustrator, etc.) used by the author. This means that, in ACE, there is no need to place, for example, a text layer on top of vegetation layer interactively on the screen. Instead this can be done by giving the text layer a higher priority number to be on top of all other layers. If care was not taken when

working with the order of layers, some map features would not print since they may be held out unintentionally by the features placed on the layers above.

15.5.1.3 The RepCode Setup Table (RST) Creation

ACE technology is based on the use of the **.rst** file. The graphic display of each feature that is included in the map is controlled by this **.rst** file, which is linked to a feature by a ***RepCode***. To change the graphic display of a feature, the ***RepCode*** parameters in the **RST** must be edited. As a result, all modifications are automatically applied to all features with that particular ***RepCode***. ACE controls the superimposition of features by using a display priority parameter in each ***RepCode***, ***Layer*** and ***Area***. For the actual creation of the **.rst** file for the Misratah map at 1:50,000 scale, the different categories of features – such as boundaries, roads, water features, cultural features, vegetation, and so on – were given a ***RepCode group number*** to differentiate each one from another. In ACE, the **RST** works on a tree-based structure, with branches running from the main body into separate groups and then further separated into individual ***RepCodes***. In actual practice, for each group created, an individual identifier (***RepCodes***) was required for identification purposes.

Figure 15-4a indicates that many groups (categories) were included in ***Map50.rst*** file. The right tree list of this figure shows the name and the specific group number that was given to each individual category of feature included in the map. For example, roads as a main group were given a group number (100000) and then classified into five different classes. Each class of roads was defined with a description name and a ***RepCode*** – e.g. the highway class in the right tree list (Figure 15-4a) was given a ***RepCode*** of 100005. This procedure was applied to each individual group and, in turn, to each class or sub-group included in the map. Once a ***RepCode*** had been given to each object or feature on the map, other attributes were specified. These included the specific the graphical representation that was needed, which, in this case, comprised different line style; solid-polygon; transparent polygon; simple-point; point symbol and vector-text. As can be seen in Figure 15-4b, other options such as symbol form, width and colour were also available and were used extensively during this cartographic design project. Figure 15-4b also shows that the **RST** uses two important concepts to portray features on a map, which are the ***Parts*** and ***Priority***. These two concepts are closely intertwined. The ***Part no.*** field is used to show which part of a ***RepCode*** is currently selected (a feature can be composed of many parts). The ***Priority*** field is used to define which part/feature goes on top of another. At the end, when each group had been created and all features had been given

RepCodes, the whole **.rst** file was then saved as **Map50.rst**. Of course, this **.rst** file can be edited; this meant that features could be modified or removed and new groups could be added as the design process evolved.

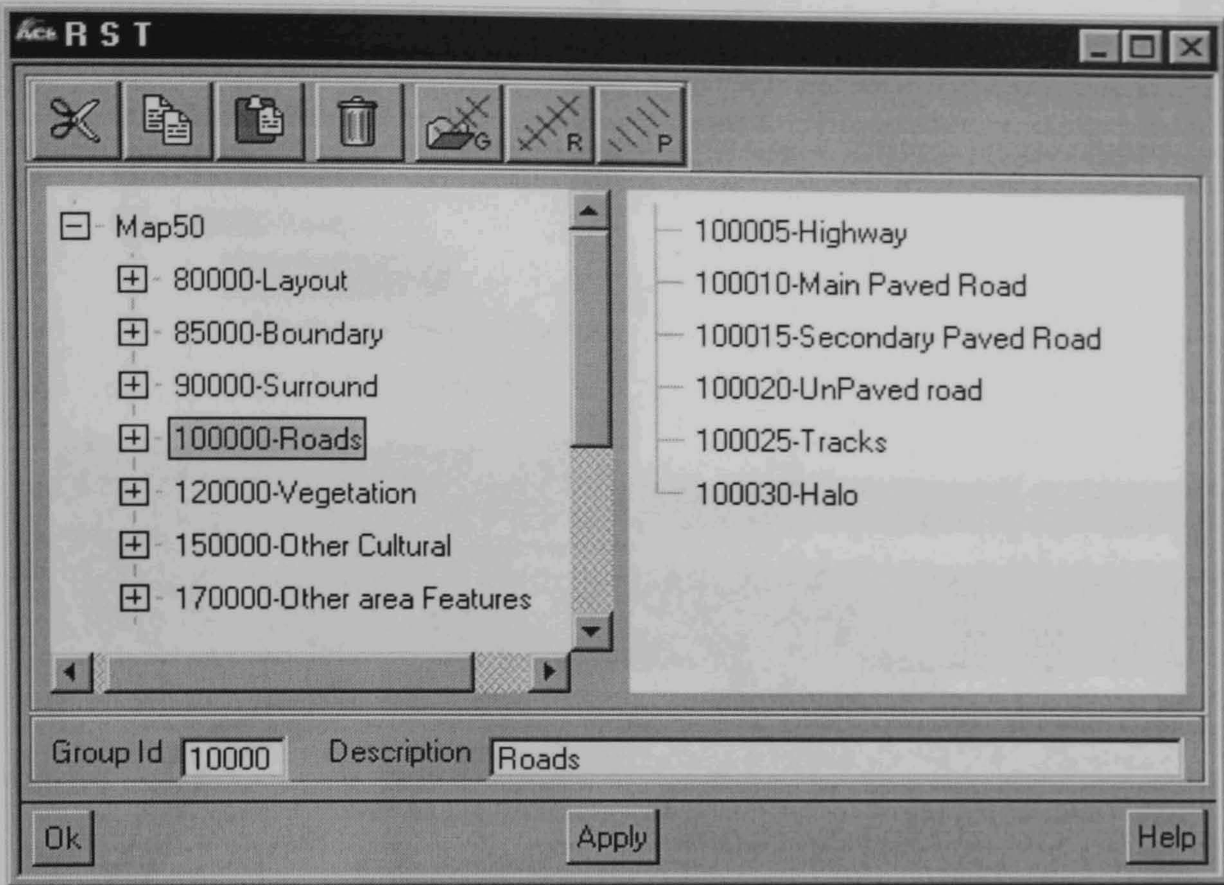


Figure 15-4a: The left tree list showing the Group IDs of the different features, while the right tree list shows the RepCodes of the different road classes.

15.5.1.4 Symbol File (.sym) Creation

The symbol file contains the point symbols that the cartographer needs to insert in his map for the representation of cultural features. Some simple geometric point symbols such as circles, squares, and rectangles were already available in the ACE library. Thus the present author was able to use them in designing his own symbols. Although many other point symbol files were also available in ACE, they were not suitable for use in the space image map design process.

This meant that a considerable number of point symbols had to be drawn from scratch using the ***Symbol Editor tools*** available in ACE, see for example Figure 15-5. For each individual point symbol that has been created, a **RepCode** was given to each for further identification purposes. Once all the symbols were created, then the symbols file was saved as **FSIM50.sym**. This symbols file (**FSIM50.sym**) was then linked to the **Map50.rst** file to allow the author to specify the required point symbols for the final map.

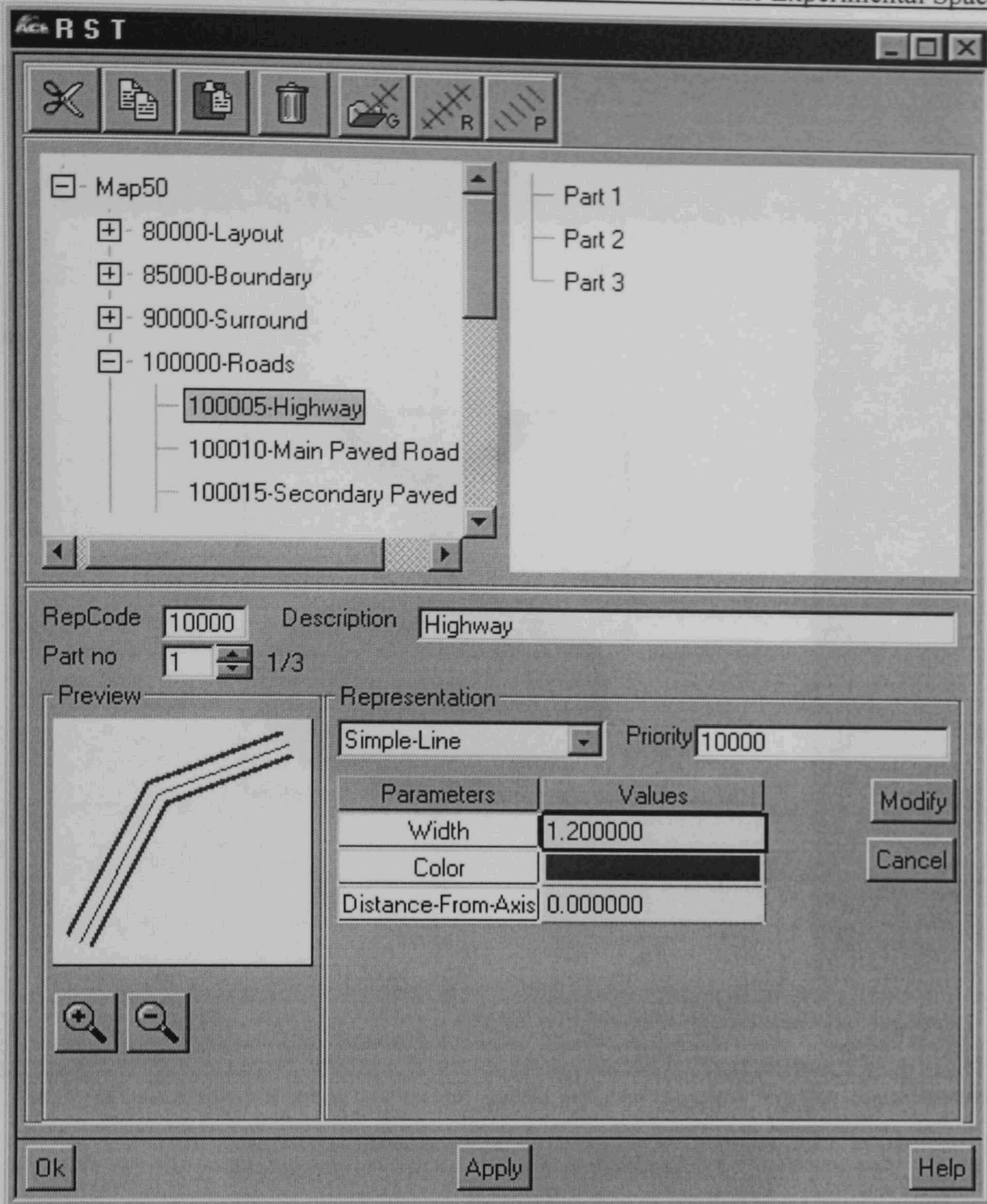


Figure 15-4b: When a RepCode is selected, the right tree list displays the parts of the selected RepCode. Information (such as line form, width, colour, priority, etc.) pertaining to the selected RepCode is also displayed in the bottom half of the RST editor.

15.5.1.5 Linking Vector Layers to the RST

With the RST table created and linked to the symbols (**.sym**) file and all the layers created or imported into ACE, it was then necessary to link each of these layers to the **Map50.rst** file in order to generate the specific graphical (point, line and area) representation required in the corresponding layer. This was achieved through highlighting each layer and then clicking on ***Layer: Link RST:*** using the PC's mouse. A tabbed interface then appeared (Figure 15-6), offering various setup options. By using the mouse to click on the **Representation** tab, then the appropriate RST (Map50.rst) was linked to each vector layer in the map.

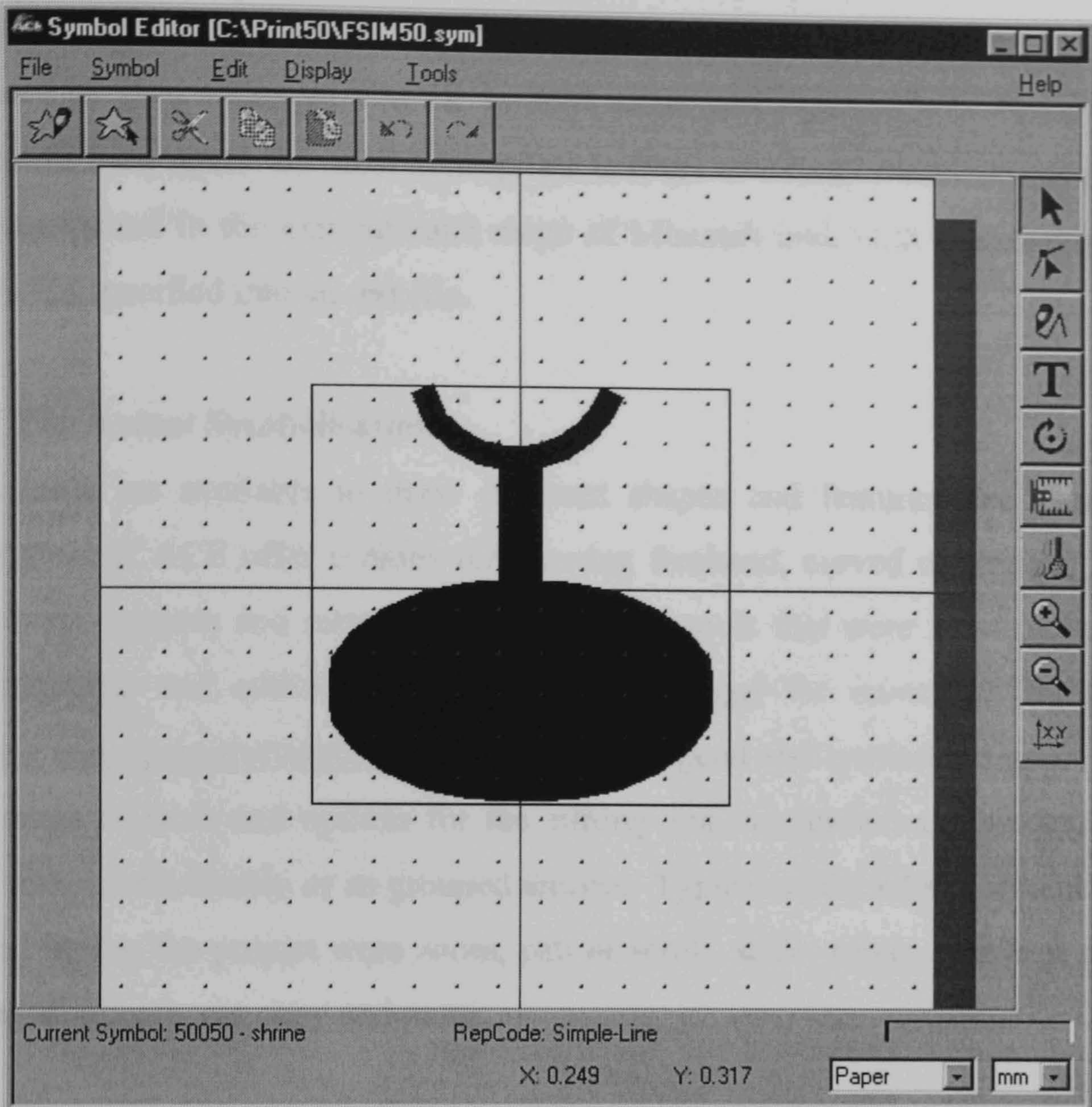


Figure 15-5: The Symbols Editor used to create the point symbols needed for the experimental maps

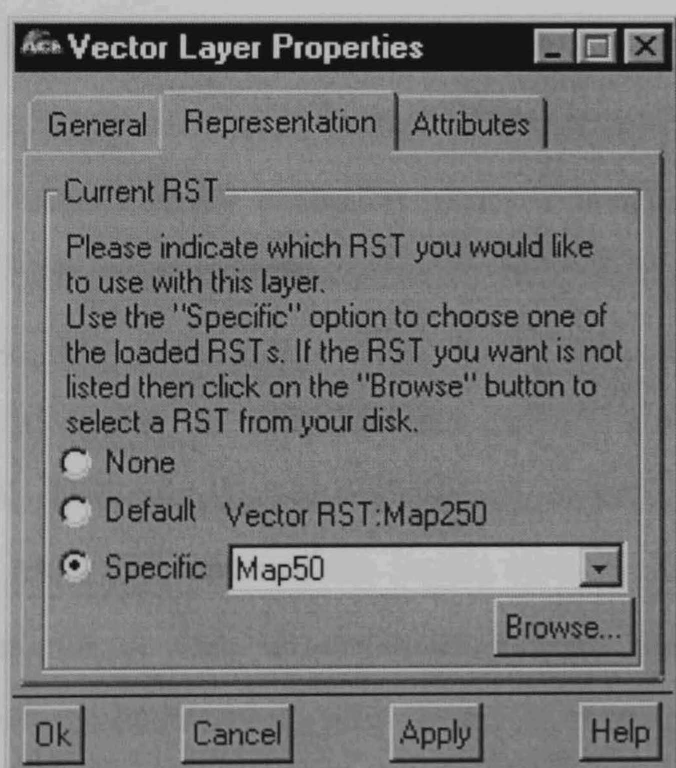


Figure 15-6: Shows Vector Layer Properties from which each vector layer in the map project was linked to Map50.rst file.

15.5.1.6 Colour Model

There are different colour models (Grey Level, RGB, CMYK and HLS) available in the ACE package. In this mapping project, the CMYK colour model was used to represent the different features contained in the map. A similar approach (through the setup of the **.rst** file) was utilized to set the colours that were to be used for the final map. A sample page was produced and printed to give a sample CMYK in 20% steps (see Figure 15-7). From this sheet, the author could then select the most appropriate colours or colour combinations for the various features contained in the experimental maps of Misratah and, with some adjustments, these colours were specified into an **.rst** file.

15.5.1.7 The Actual Symbolisation

Various tools are available to draw different shapes and features, see Figure 15-8. The drawing tools of ACE offer options for drawing freehand, curved or straight line segments, circles, ovals, squares and rectangles. The drawing tools that were most frequently used for digital mapping and editing work were the line tool for on-screen digitizing and the circle/oval and square/rectangle tools used for the legend and symbol design. ACE also offers a wide range of tools and options for the editing and manipulation of nodes, segments and objects, either individually or as grouped entities. Typical of the editing commands that were employed during the project were zoom, pan or scroll, scale, rotate, attach or detach, change RepCode, duplicate, cut copy and paste.

The specification of the form, dimension and colour of the point, line and area symbols used to represent the various map features, was accomplished in ACE through the creation and editing of the **.rst** file, which, in turn, was linked to the symbol (**.sym**) file. As described above, any map feature or object entity could be given a **RepCode** and a fill specification from the extensive range of pre-set or custom options available in ACE.

Point Symbol Generation and Additions: The first step after setting the technical specifications of the symbols was to generate the actual point symbols (both in their geometric and iconic forms). This step started with the creation of solid geometric shapes (e.g. circles, squares, rectangles, etc.) and some of the iconic symbols that were required according to the design specifications. Of course, the **Symbol Editor** was used extensively for this purpose, within which, each point symbol was given a specific ***RepCode*** in order to be identified later during the selection (in the **.rst** file) and the drawing stages. As a result of using frames and outlines, most of the point symbols, when specified in the **.rst** file, were produced in three or more ***parts*** and each ***part*** was given a different ***Priority*** number to allow the parts of the symbol to be placed on top of each other. Before creating and/or positioning any point symbol on the map with the tool available, the ***layer*** of the desired symbol was activated and the ***RepCode*** of this symbol was defined. Indeed, ACE proved to be the right package needed to generate and position the various point symbols on the experimental space image maps of Misratah.

Figure 15-7: ACE process colour chart as printed by the Epson Stylus 1520 colour inkjet printer.

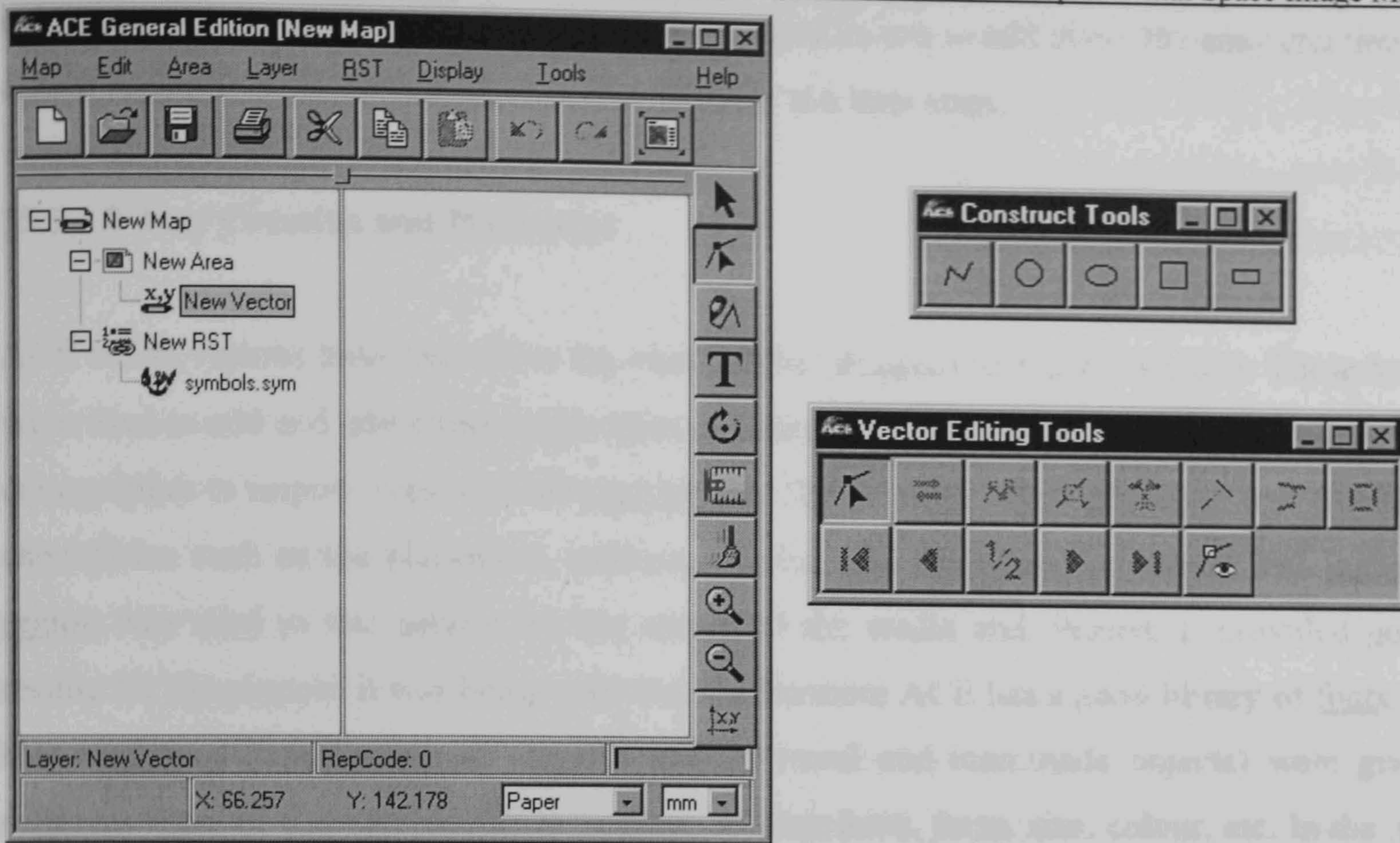


Figure 15-8: ACE drawing and editing tools

Line Symbol Generation: During this stage, all the different forms of lines (e.g. simple continuous lines, dashed and dotted lines) that were available in ACE have been employed extensively to show the different types of linear features contained in the map. The different classes of roads, the contour lines, grid, etc. are typical examples of those linear features that have been involved in this work. Those linear symbols that required some special care and attention in their design and specification, were the double and treble line symbols used for road classes such as highway, main paved road and secondary paved road. Once again, the ***Parts*** and ***Priority*** commands were used during the design of these double and treble lines to show the major roads. Each colour was given a ***Priority*** number to allow them to be superimposed one on top of the other in the final form of the map. The representations of highway, main paved road and secondary paved roads were typical examples of linear features produced in this way.

Area Symbol Generation: Area features were found to be the most difficult features to represent in image mapping and they had to be handled with especial care. As has been discussed in Chapter 6, most of the previous work that has been done by others have utilized area features using solid polygons or/and pattern fills, which are artificial additions that disturb the natural background image. For this current project, the author has employed transparent polygons in different colours and opacity to represent the different area features, e.g. built up areas, cultivated area, orchard, forest and sabkha. With ACE, the cartographer can apply the specific colour that he wants for each of the individual features. The **CMYK** colour model was used in this mapping project, since its use would allow the easy creation of colour separations for four-colour process printing at a later stage.

15.5.1.8 Text Creation and Placement

ACE offers various tools that allow the cartographic designer to work with text. These tools were used to add and edit either single lines or entire paragraphs of text. ACE also allows the cartographer to import, type and edit text blocks. The package offers advanced text handling capabilities such as the placement, rotation, curving and smoothing of names. The curving option was used in this project for the names of the wadis and, indeed, it provided good results for the purpose it was being used for. Furthermore ACE has a good library of fonts. In this respect, different types of features (e.g. physical and man-made objects) were given different types of text representation in terms of their fonts, form, size, colour, etc. In the **.rst** file, each name for an individual feature has been given a **RepCode** and its style, size and colour were specified and saved. The names were handled with care, since their legibility and actual placement against the highly detailed image background is a serious problem in all forms of image mapping. When compared to other software packages (such as Corel Draw and Adobe Illustrator), ACE does not as yet have the full capability for designing names. For example, ACE did not have the facility of giving a white or black halo for each individual letter of a specific name.

Generation of Other Features: Other features of any map such as grids, scale bar, title, etc. are also important and were created using the ***Surround*** tools available within the ACE package. This ***Surround*** tool was highly customisable and well able to satisfy the needs and specifications of the experimental image maps. ACE generates the specific ***Surround*** element by using information already present on the map. Currently there are eight ***Surround*** elements available. These are neatline, grid, border, legend, title and sub-title, scale bar, logo and north arrow. In this mapping project, not all of these ***Surround*** elements were used to produce the map and provide the descriptive information located around it.

In summary, the compilation of the topographic data from the SPOT Pan images has been carried out using on-screen digitising techniques and the resulting data was then combined with the point and line features digitised from the existing topographic maps at 1:50,000 scale, and integrated to produce the final data set. With regard to the software used, ACE provides an advanced cartographic environment that has only recently become available for digital mapping design and production by cartographers and cartographic organisations. In fact, the present author has gained very substantial experience in the use of ACE package for map design and production and has formed a very favourable impression of its capabilities. As a result, ACE proved to be very useful and was used heavily in the design and production stages of the experimental space image maps of Misratah.

As described by Keates (1989), the process of generalisation in map compilation and production involves procedures as "simplification, exaggeration, combination and selective omission". These procedures took place during manual compilation and digitising, or by interactive editing at the data capture and final map design stages. In this project, it was decided that no generalisation would take place at the data capture stage. However, through the careful organising and grouping of features within the same category – through the use of individual ***group numbers*** and ***RepCodes*** – at the data capture stage, it was possible to easily generalise such features as minor villages or wells by "selective omission". Other generalisation procedures such as simplification and exaggeration have been applied by digital methods during the design and production stages. Of course, the reduction in scale from 1:50,000 to 1:250,000 scale required more generalisation to be applied later.

15.5.2 Output and Display

By this stage, each symbolised file (e.g. Map50.mah and Map250.mah) had been created using ACE. Producing maps would not be useful and correct without the ability to output the results both as an on-screen display and in hardcopy form. This is necessary to ensure both the correctness and completeness of the map and its widespread distribution to various users later.

15.5.2.1 On-Screen Display

Display of the map on the monitor screen may be useful for certain purposes. It does, of course, allow the cartographer to view the design and appearance of the map, which in turn can be modified and edited to ensure a good quality in the final design of the map. The colours on the monitor screen used for the current project are of course those generated by the light projected from the three electron guns of its cathode ray tube (CRT) using the additive primary colours of red, green and blue. By contrast, the colours shown on hardcopy output depend entirely on the light reflected from the subtractive secondary colours of the cyan, magenta, yellow and black inks. The 17-inch colour monitor that was used throughout this project together with the zooming tool available in ACE made it relatively easy for the author to design and edit his experimental maps. However, while it is generally accepted that it is possible to check the content or the design of a map on a display monitor up to a certain level, in practice, it always desirable to produce a hardcopy plot or print of the map for the purpose of further checking and proofing. The main shortcoming of proofing on screen is the inconvenience of having to continually scroll and zoom the map due to the size and resolution limitations of the display monitor that can be used with PCs. Moreover, the displayed map is not permanent, since it disappears the moment the monitor screen is turned off.

15.5.2.2 Small Format (Hardcopy) Colour Inkjet Printing

Printing is an important process to any cartographer practicing digital mapping, since it enables him to produce a hardcopy of his map for checking or publication purposes. During the design and production stages of the experimental maps of this project, printing direct to paper using small format colour inkjet printers was an available and much used option. The printing process was achieved initially on an A4-sized Hewlett-Packard Deskjet 850C inkjet raster printer and latterly on A3-sized Hewlett-Packard Deskjet 1120 and Epson Stylus 1520 inkjet printers. A large number of printed copies of parts of the maps were produced in colour during the experimental design stages. This was to check the symbol design; the integration of the symbols and the background image; the name placement; the map arrangement and that of the marginal information; etc. Despite the limitations in format and the colour appearance of the output produced by these printing devices, they provided a relatively inexpensive and quite acceptable option for printing the numerous plots that were required during both the early and the later stages of the experimental image map design and production. Fortunately, the ACE software package supports all three inkjet printers mentioned above, and allowed the present author to setup the specific printer. When printing a map, ACE first transferred the map directly to a file ready for printing. Then the transferred file was sent to the particular printer concerned using a specific DOS command.

On completion of the data capture process and the creation of the digital data files, the next stage of the output process that was undertaken was to attempt to proof in colour the final map sheets produced by ACE. The output quality and colour fidelity achieved using the Epson Stylus 1520 printer was reasonably good. The Epson 1520 inkjet print utility software offers a wide range of standard options relating to printing resolutions, paper types and sizes and it also provides advanced options for colour control. When the experimental 1:50,000 and

1:250,000 scales maps were printed, each required four full-sized A3-sized printed colour sheets from the Epson 1520 colour printer to be produced to form the whole image map sheet (Appendix V). This was possible since the ACE package offered an option within the printing dialogue box that enabled the author to print the single large map sheet in the form of multiple pages. These were then trimmed and pasted together to form the final map sheet.

15.5.2.3 PostScript File Output

Once the design and production stages had been completed, the final data files were saved as Map50.mah and Map250.mah files for further format conversion. After considerable thought and discussion, it was decided that the output for the final space image maps of Misratah at 1:50,000 and 1:250,000 scales would be in the form of Adobe PostScript (.ps) level 2.0 files. PostScript is a widely-used page description language that is supported by the ACE package, and can be used to send instructions to the printing device as to how each page should be printed. It is a well-established data format that lends itself to the transfer of data, not only between computer software applications, but also between these applications and peripheral printing devices. The sizes of the files (57Mb and 235Mb) were not seen as a problem to the conversion process. Outside mapping agencies typically accept single PostScript files much larger than these files with no difficulty. Thus, both digital map files were converted to PostScript format that was then ready for digital proofing and final printing. However, although it is a widely used and accepted form of information exchange, some problems were encountered when using ACE and its PostScript drivers. Numerous attempts to use these files with large-format IRIS and Hewlett-Packard plotters at a number of different bureaux all failed.

15.6 Colour Printing Options – Large Format Printer/Plotters

Nowadays, there are a considerable number of high-quality colour printing devices available on the market. At the present time, inkjet colour printers are a popular form of raster output device. However these printers differ greatly from one another in terms of resolution, format size, output quality and colour fidelity. In general terms, the higher the resolution, the larger the format and the better the output quality, the more expensive the printer.

As described above in Section **15.5.2.2** of this chapter, low resolution inkjet printers were used to produce A4 and A3-sized plots of the experimental maps. These cost from £150 to

£400 each. Again, as noted above, the output quality and colour fidelity achieved using the Epson Stylus 1520 printer was the best among the available (in-house) low resolution inkjet printers, so this printer was used to produce the check plots of the experimental space image maps of Misratah.

The other possibility of producing the experimental image maps in-house was to use another type of inkjet plotter – a large format (A0) Encad Novajet. Within ACE, the process of using this device started with the conversion of the .mah files of the final experimental maps into the form of HP RTL files which are supported by the Novajet plotter. Then these files were sent to the plotter for printing using a DOS command. Although the colours did not match the output on-screen, the plots were mainly produced for the purpose of checking all the map elements; the completeness and correctness of the contents; the registration of the map features relative to each other; and finally as means of examining the success of the map arrangements and layout; etc. Some errors were found at this stage and they were corrected before the final printing of the maps. However it must be said that the quality of the final plots with the Novajet was no better, indeed somewhat less good, than that achieved with the Epson Stylus 1520.

The other possibility was to use a medium resolution colour printing device such as the large format (up to 36-in wide) Hewlett-Packard DesignJet 2500CP using high-quality paper supplied in rolls. This is a better quality (600 dpi) raster printer, though of course, its price – ranging from £7,000 to £14,500 – is much higher than that of the low resolution printers that have been described in the previous paragraphs. Actually, this raster printer is very suitable for good quality plots and an example owned by Survey & Development Services of Bo'ness has been used for this purpose using files written in TIFF format.

There is a wide selection of still higher resolution printing devices suitable for colour printing and map production. Currently at the top of the range are the IRIS inkjet printers from Scitex. These printing devices are however very expensive (ranging from £35,000 to £50,000). However, in spite of the large investment that is needed, they are much used by large graphic arts companies and mapping organisations, since they can produce an output of a very high resolution (2,540 dpi) and excellent colour quality. Unfortunately, although several companies in the Glasgow area were asked to provide higher quality plots using their IRIS printers, all attempts to do so failed completely using both Postscript and TIFF files. This information has been fed back to PCI, the company that has developed the ACE package.

15.7 Colour Separation and Film Writing

Colour separation is the process of converting an image into its CMYK components usually with a view to final printing using offset-litho methods. Each pixel in the image is analyzed for its colour and reduced to the four primary colours – cyan, magenta, yellow and black. This separation is a complex process that can be done in one of several different ways, depending on the actual printing process that will be used to print the final map and the type of paper that it will be printed on. If the image maps are to be printed using offset-lithography, the final files will be required to be input to a high resolution raster **Imagesetter** at 1,240 to 2,540 dpi to produce wrong-reading film positives or negatives as required for use as colour separations for plate-making. A film-writer such as the **Barco BG 3800** or the **Scitex Dolev** that are widely available within the graphic arts and printing industries is frequently employed for such purposes. These can produce stable film negatives and positives at very high resolutions (up to 4,000 dpi). The positive film separations may then be used to produce a high quality photomechanical colour proof such as that produced by the Cromalin process to give a further final check of image quality and colour fidelity prior to plate-making.

15.8 Photo-Mechanical Proofing (Cromalin System)

In this process, a special light-sensitive layer is laminated on to a plastic sheet, the final image formation depending upon the adhesion of powdered pigments. This process, in its most widely available form, uses positive images. This type of proof is used primarily to proof the colour separations on film for the standard colour reproduction (process) inks of cyan, magenta, yellow and black.

15.9 Platemaking and Final Printing Options

The final map should be printed in paper form by conventional offset-litho methods. In the author's opinion, printing on paper, particularly in Libya, can be considered to be by far the most suitable form of publication for the final image maps, even if the data can also be supplied in digital form. In Libya, computer technology has still not adopted widely in many of the government and private organisations that may be identified as the potential users of such digital image map products. In any case, the publication of the maps in paper form will allow the maps to be accessible to a wider range of users than otherwise and will be far more convenient for use in the field.

Two options exist for producing printed paper copies of image map sheets (i) conventional printing by offset-lithography or (ii) digital printing direct to paper.

(i) Offset-Lithography: Once the appropriate plates have been produced. the final stage is to use these plates for printing by offset-lithography. Printing using this method would produce a good-quality final map product at an economical cost and provide a large number of copies. The technology and experienced operators are available in Libya.

(ii) Digital Printing Direct to Paper: Often referred to as print-on-demand, which can be considered a suitable option for very short-run colour printing. Many of the colour printing devices that are now becoming available on the market in highly developed countries can provide digital printing direct to paper at high resolution and in a reasonably large format. But none of this technology is currently available in Libya and it may be some considerable time before it reaches the country. Thus, at present, the technique cannot be considered seriously for use in the production of the new space image map series. Offset-litho is definitely a better option.

Once the four colour film separations have been made, the four right-reading positive aluminium plates can be produced by conventional methods. However, it is now also possible to output the digital data by direct exposure to a printing plate without recourse to film separations, e.g. using **Barco LithoSetter** (Petrie, 1997b). This technology has not, as yet, been adopted widely in highly developed and technologically advanced countries, let alone Libya.

15.10 Production Flow Diagram

The map production flow diagram included as Figure 15-9 is a graphical representation of all the stages, processes and materials needed to produce a map from the initial compilation to the finished product. Such a flow diagram is useful in establishing the initial production plan and it may also be used to assess various alternative production possibilities in relation to available material, software packages, instrumentation and labour resources. Once the production scheme has been finalised, the diagram can then be used to plan the sequence of events and to derive the necessary details regarding the required materials, software and labour to provide the basis for the estimation of the time and cost involved in the production of the space image maps.

The notation used in the flow diagram is that developed by the ITC in Netherlands and published by the International Cartographic Association (ICA). and is explained in Figure 15-10.

15.11 Conclusion

There are many options in the cartographic design process and production processes that can be and were explored using the ACE software package. Based on the fairly extensive investigations carried out by the author, it can be said that it is quite suitable for the design and production of space image maps of Libya. The matter of producing Arabic text is a matter that still need to be explored further, but, in general, the package offers many possibilities for establishing cartographic production flow line.

This chapter has also outlined the extensive cartographic processing required to produce space image maps. A further discussion covered several output devices and the proofing options associated with them. In this context, plots from several devices were produced successfully using ACE. It is hoped that the processes, materials and software packages used and described within this chapter provide a reasonable insight as to how the final image maps can be produced and how they will appear when printed through the final offset-lithographic process.

In spite of the various problems encountered, the experimental space image maps originating from this project were produced successfully. Furthermore, they do indicate the feasibility of being able to utilize similar techniques to design and produce a national series of space image maps of Libya at 1:50,000 and 1:250,000 scales.

In the next chapter, the evaluation and analysis of the experimental space image maps based on the results of user tests will be described in some detail.

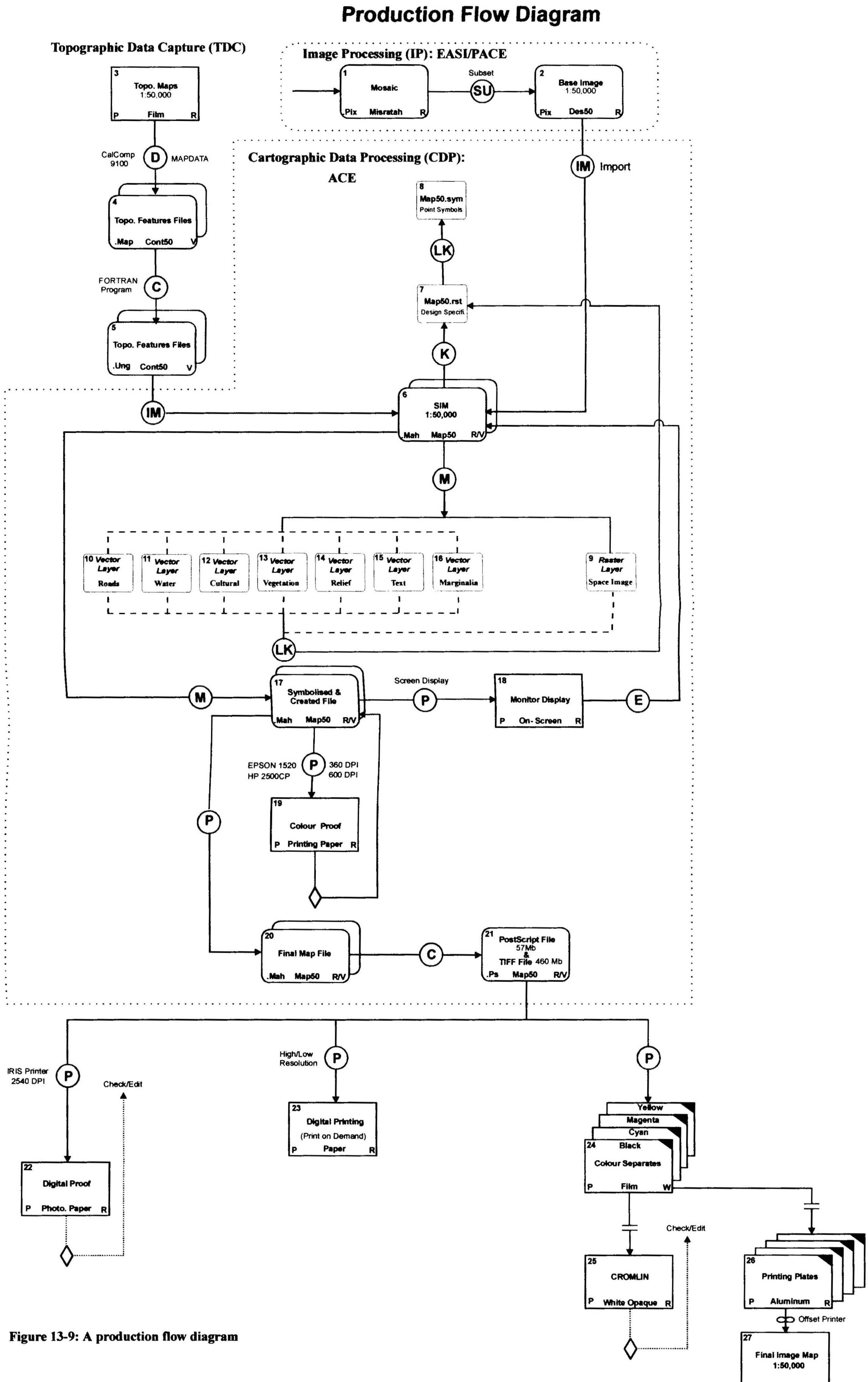


Figure 13-9: A production flow diagram

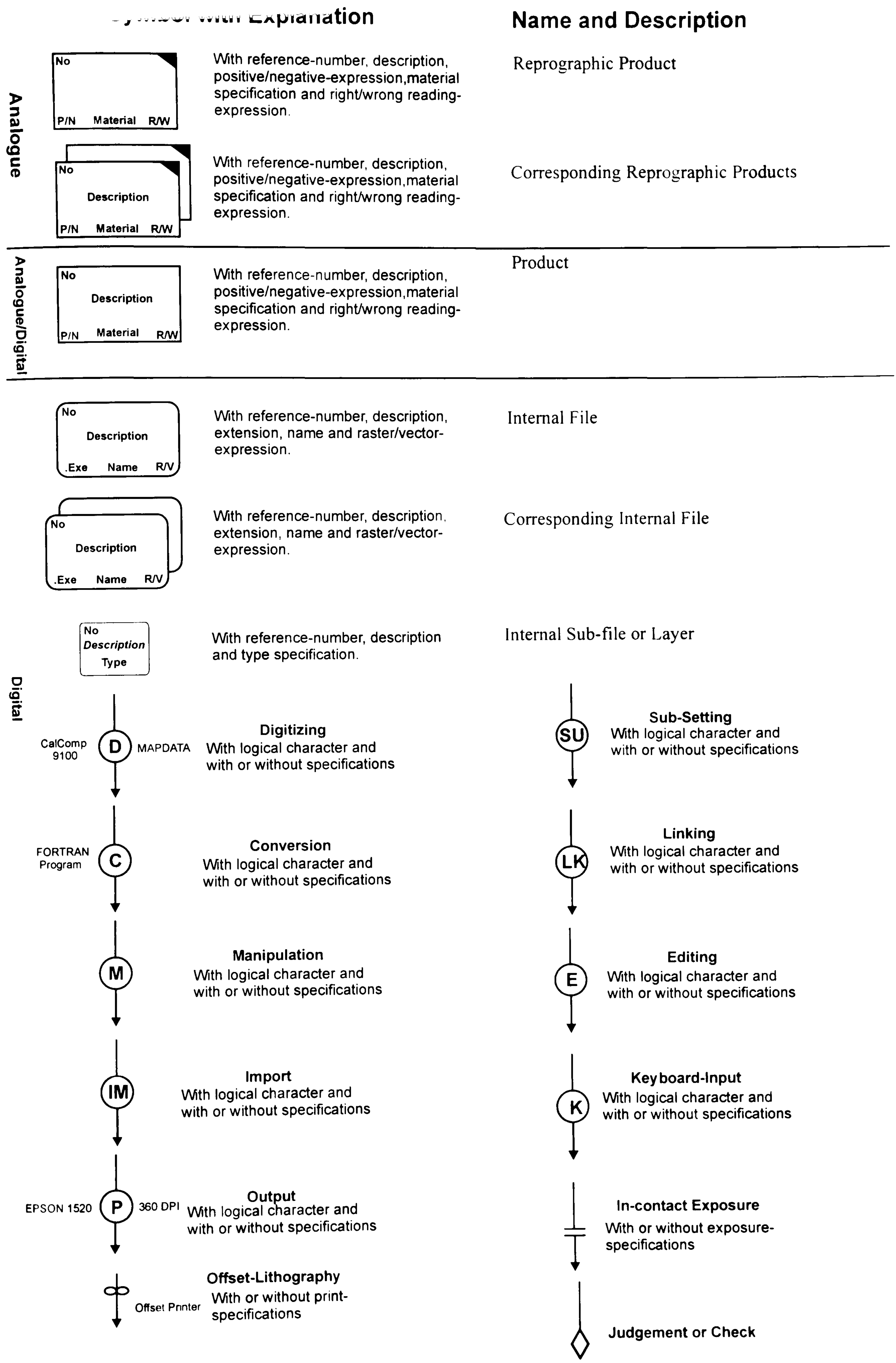


Figure 15-10: The Notation Used to Explain the Flow Diagram.

CHAPTER 16: USER TEST & ANALYSIS OF THE EXPERIMENTAL 1:50,000 SCALE SPACE IMAGE MAP

16.1 Introduction

Maps are always produced to satisfy a specific purpose or a function; therefore, they must be well designed to transfer effectively – through graphic representation – the required locational and other geo-spatial information in order to be easily understood by the users. To a large extent, the success of any map design can be related to the cartographic education, skills and practical experience of the map designer. However, as stated by Wood (1968), ".... It should be realised that the failure of many maps cannot be always totally attributed to the designer. The fault may lie in the method of communicating his specifications, or perhaps in his incomplete knowledge of the printing process." Of course, the lack of success may also be due to the deficiencies in the knowledge and skills of the map user. Increasingly cartographers show a strong desire to question and examine the different design aspects of the maps they are making. The results of their studies and tests will no doubt influence design and production of any new maps produced in the future. In the Libyan context, it seems that, in the past, little attention was paid to the design and the visual presentation of the maps themselves and whether they communicated information effectively to the various map users. This point will be addressed specifically in this chapter.

Particularly in arid and semi-arid areas – most of which are a purely physical landscape with relatively very few or no cultural (man-made) features or objects – space image maps can be expected to be more suitable than conventional line maps in terms of depicting the terrain surface in a realistic manner. As discussed previously, the nature of the space image map is quite different to that of the conventional line map in the sense that there are two different levels of information. Thus the detailed natural space image acts as a background on which the additional cartographic elements are superimposed. These two elements are combined together to produce a more realistic representation both for general purposes and for specialist various users. On this basis, as described previously (in Chapters 12, 13, 14 and 15), the author has designed and produced his two experimental space image maps at 1:50,000 & 1:250,000 scales for the Misratah area in north Libya.

One of the main objectives of this research work was to evaluate the design aspects of the experimental maps. Thus it was necessary (as a part of the overall design strategy) to design and execute a test among a group of map users (geo-science graduate students) who were asked to examine and evaluate the design quality of the space image map samples that have been produced by the current research project.

In order to evaluate the design aspects of the map samples produced in this project, a map evaluation form (see Appendix VI) was designed, produced and distributed to 30 post-graduate students having a geo-science background. Among these were geologists, hydrologists, geographers, surveyors, agriculturists and planners, all of whom are students living in Glasgow. In this particular case, twenty-seven of the students are Libyans who are very familiar with Libyan terrain characteristics; the other three came from Egypt, Sudan and Jordan, most of which are characterised by similar terrain conditions. These thirty participants have different levels of experience both in conventional line map and in image map reading and use. In fact, seventeen of these participants are very experienced in reading and using maps, while the others have gained a considerable experience with maps during their previous work.

The evaluation form was broken down mainly into two sections: (i) the space image map evaluation and (ii) a comparison between the experimental image maps and the existing topographic line maps of the test area. In turn, each of these sections was also broken down into a number of sub-sections. More details regarding the design and the content of the form will be discussed next in this chapter.

16.2 The Design and Content of the Evaluation Form

Once the two experimental map samples had been produced, a method had to be found where the different design aspects of these space image maps could be tested efficiently and effectively. It was decided that each of the two experimental maps (at 1:50,000 and 1:250,000 scales respectively) would be examined using the same criteria. At the same time, it was necessary to bear in mind that, due to the reduction in scale from 1:50,000 to 1:250,000 scale, certain small cultural (man-made) features or objects – that had been included and shown on the 1:50,000 scale image map – would not be shown on the 1:250,000 scale map. A summary of the content of the evaluation form and the questions included will be discussed next. Deliberately, most of the questions have been made very simple and were purely factual, straightforward and direct. A simple five-point evaluation scale – i.e. excellent (E), very good (V), good (G), satisfactory (S) and poor (P) – was provided for the purpose. However the participants were always given the opportunity of making written comments whenever possible, to justify, expand or modify their answers.

16.2.1 The Experimental Space Image Map Evaluation (Section I)

The first section of the evaluation form concentrated on examining the different design aspects of the experimental space image map samples. This section was broken down into eight sub-sections covering (1) map content; (2) background image; (3) symbolisation; (4) typography; (5) general elements of design; (6) layout and map arrangements; (7) overall appearance; and (8) an overall rating of the experimental map.

(1) Map Content: Four questions have been asked in this sub-section, which are:

(i) *The level of information included and shown by the natural space image.*

(ii) *The level of detail added through cartographic elements.*

(iii) *The number of categories that had been included emphasizing important topographic features.*

(iv) *The level of classification made to distinguish between features within the same category.*

When answering any of these four questions, the participant was asked to tick one of the evaluation scale classes (E, V, G, S and P) and make a general comment whenever he wished to explain further his opinion as a map user.

(2) Background Image: In this sub-section, the participants were asked to evaluate (using the E, V, G, S or P ratings) the background space image quality in terms of it:

(i) *Showing physical features.*

(ii) *Depicting cultural (man-made) features.*

(iii) *Representing all features (both physical and cultural).*

Within each question, the participant was asked to place an emphasis on the clarity and the contrast of the features contained in the space image. General remarks or comments were also solicited when answering the three questions in this sub-section.

(3) Symbolisation: This sub-section contains the evaluation of the additional cartographic symbols and names. It was divided into eight categories concerned with road detail, boundary information, water features, cultural features, land cover and vegetation, other area features, relief information and typography. In turn, each of these categories was broken down into sub-categories or classes of features – e.g. the road detail category comprises the five classes of highway, main paved road, secondary paved road, unpaved road and track. With each of these categories of symbols or names, an emphasis was placed on the clarity & legibility, the contrast (of the symbol both against the background image and in relation to other symbols) and of the unity or integration of the various symbols or names with the space image. For this particular sub-section, the participants were expected to evaluate separately the clarity & legibility, contrast and unity of each class of symbols using the evaluation scale (E, V, G, S, or P) provided. They were also asked to write their general comments whenever possible to justify their answers. In order to ensure more reliable results from the evaluation, it was felt that oral instructions should be given to all of the participants before they answered any of the questions contained in this sub-section. They were informed that their rating must be based on how successful is the representation of each individual (point, line or area) symbol or name in terms of its form, dimension and colour.

(4) Typography: This was divided into two parts:

(i) Basic characteristics of typography (style, form, size and colour) and;
(ii) Text and names representation

(5) In General: The participants were asked to evaluate the general elements that have been included in this sub-section, which were:

(i) Point symbols, selection and representation.
(ii) Line symbols, selection and representation.
(iii) Area symbols, selection and representation.
(iv) Grid representation.
(v) Co-ordinate numbers representation.
(vi) Background colour treatment.

In order to evaluate each one of the general elements mentioned above, all the participants were asked to tick only one class of the evaluation scale (E, V, G, S or P). They were also expected to write down their general comments if they were willing to do so.

(6) Layout & Arrangements: This involves items such as the title, graphic scale, legend (symbols explanation) and marginal information that concern the overall map layout. The evaluation was to be based on the clarity and visual balance of each individual item of the layout. Once again, all the participants were asked to rate their answers by ticking one of the evaluation scale classes (E, V, G, S or P) and they were also given the proper space to write their general comments.

(7) Overall Appearance: Both experimental map samples were also to be evaluated in terms of their readability, balance (contrast), effectiveness of the representation method, use of colour and the practicality of the format size. A space was also provided with each individual item used to evaluate the overall appearance of the map. This was to allow general comments to be made whenever possible.

(8) Overall Rating of the Image Map: In this sub-section, the participants were asked to rate the overall performance of the experimental space image map.

16.2.2 Comparison between the Experimental Space Image Maps and the Existing Topographic Line Maps of the Same Area (Section II).

The users were also asked to compare the space image map samples with the existing conventional topographic line maps of the same area. Of course, this comparison had the objective of providing a great deal of help to the present author in helping him to decide whether the image map products can be recommended as a total or partial replacement for the topographic line map series in Libya. The questions included in this section were designed to make a comparison between the two different map products in terms of their content, representation, overall design and performance and use/suitability to show the Libyan terrain. The questions were concerned with the following matters:

- *(i) The level of details contained in the map product.*
- *(ii) The number of categories and classes of features included in each type of map.*
- *(iii) The representation of point features on the map.*
- *(iv) The representation of line features on the map.*
- *(v) The representation of area features in each type of map.*
- *(vi) The relief depiction used on each map product.*
- *(vii) The selected texts and names and their placement as they appear in each type of map.*
- *(viii) The various forms adopted to show the different symbols on the map.*
- *(ix) The various widths/dimensions selected to represent different symbols on the map.*
- *(x) The various colours used to depict the different symbols on the map.*
- *(xi) Map layout, arrangements and legend.*
- *(xii) The overall rating for each product of maps.*
- *(xiii) The suitability and effectiveness of the map to show this particular terrain.*

Once again, oral instructions were given to all of the participants prior to them answering the questions in Section II. These were found to be very useful. The rating scale (E, V, G, S and P) used was the same as before and the participants were again given the chance to provide their general comments to justify or supplement their answers.

16.3 Material & Method

Once the experimental space image maps at 1:50,000 & 1:250,000 scales had been produced and the evaluation form for the user test had been designed, the author contacted all the participants to confirm the test date. Fortunately, all of these 30 student participants live in Glasgow and the majority of them come to the Arabic School – where the author's daughters study – regularly on the Saturday and Sunday of every week during the academic year. Eventually, the dates (11th & 12th and 18th & 19th March 2000) were set for the user tests of the experimental maps at 1:50,000 and 1:250,000 scales, respectively.

The thirty participants were divided into two main groups – each of which comprised fifteen post-graduate students. Since only three copies of each experimental map were available for the user test, the evaluation process for either the 1:50,000 or 1:250,000 scale map was conducted in ten individual sessions. These comprised five sessions per day over two days, so that, in each single session, the author was dealing with three participants only. In other words, the evaluation tests for both experimental map samples (at 1:50,000 & 1:250,000 scales) were conducted over a total of twenty sessions. Oral instructions were given by the author to all of the participants to give sufficient explanations regarding image mapping in general and the space image map products in particular. In order to understand the questions included in the evaluation form, full explanations were also provided in an attempt to ensure that all the participants understood all the various objectives and implications of the test. Indeed, this procedure did help the participants to understand the individual questions and so provide better answers and a more valuable and reliable feedback.

During the administration of the user test, each of the test participants was given the following materials:

(i) Two copies of the three page evaluation form to be used for evaluating the experimental space image map samples at the 1:50,000 scale:

(ii) The experimental space image map of Misratah at 1:50,000 scale that has been produced during the present project.

(iii) The existing topographic line maps at 1:50,000 scale covering the Misratah area.

For the evaluation of each of the experimental map samples (at 1:50,000 or 1:250,000 scale), although no time limit was imposed, in general, each participant took no more than sixty minutes to complete the test.

16.4 Results & Analysis

Before analysing any results, the author wishes to emphasize that this test was not aimed at providing general information about the use of maps in Libya. Thus issues such as the type of maps used; what the maps are used for; and what opinions people have about them; etc., were not the subject of this test. The test was aimed specifically at an examination of the design of the experimental space image maps of Misratah that have been produced by the author during this research project and to establish to what extent their design was successful in terms of both content and representation. However, in this test, there was also the expressed intention to compare the performance of the image map samples that had been produced with that of the existing topographic line maps that cover the same area. Thus this comparison put more emphasis on the use and suitability of each of these map products for showing the characteristics of Libyan terrain. Of course, this could have a great impact and could support any recommendation regarding which map type is more appropriate to represent such terrain.

All the results of the user test with their associated questions have been summarised and organised in tabular form. The results have also been represented graphically – through the use of bar diagrams – for comparison purposes. This systematic and organised manner of representing the results of the evaluation form appears to have been quite effective and helpful and, in turn, has enabled the author to extract more useful information and to carry out a more detailed analysis of the results than would otherwise be the case.

16.4.1 The Evaluation of the Experimental Map Sample at 1:50,000 Scale

As described above, the evaluation test regarding the design of the space image map of Misratah at 1:50,000 scale was conducted first. Although all the questions on the evaluation form were fairly self-explanatory and easily understood, as noted above, they were also explained orally before the test in an attempt to avoid any ambiguity that might occur.

16.4.1.1 Section I: Evaluation of the 1:50,000 Scale Space Image Map

In this section, the author will deal exclusively with the evaluation of the various design aspects of the space image map of Misratah at 1:50,000 scale that had been produced as a result of this research project. As described earlier in this chapter, this section was divided into eight sub-sections, which, in turn, were broken down into various categories and classes of features. The results and the analysis of the answers to the questions contained in each sub-section will be given in the following section:

1) **Map Content**: It has been stated previously that the contents of a particular topographic map will reflect the nature of the terrain that it represents and that this accounts for much of the diversity in appearance of topographic map series at the same scale. The answers to the four questions that have been included regarding the map content sub-section have been tabulated in Table 16-1. First (in Question 1), the participants were asked to evaluate the *level of information included and shown by the natural space image*. It was evident to all of these participants that the incorporation of the tonal image was providing an enormous amount of information regarding the terrain that has been covered by this image map. This impression was supported by the results given in Table 16-1 & Figure 16-1. Obviously, most of the participants in their answers rated the natural image highly – as being excellent (given by 3 participants), very good (by 10 participants), good (by 13 participants) and satisfactory (by 4 participants) – in terms of the level of detail being given by the image. None of them thought it was poor. A number of written comments were also made with regard to the level of information being given by the natural space image. The inclusion of the SPOT Pan image was appreciated for displaying the characteristics of the terrain surface in a natural and useful manner. Several respondents said that the image was providing a really good general overview of the area being covered. In fact, they said it would be possible even for non-experienced locals (such as farmers) with adequate local knowledge to pick up information about the area being covered by the image. However, only three participants mentioned in their comments that the undifferentiated image needs skills, training, experience and local knowledge in order to be fully interpreted.

In Question 2 (Table 16-1), the respondents were asked to examine the *level of detail added through cartographic elements*. These cartographic elements have been added on top of the background space image to emphasise the existence of certain features; to differentiate between features; and to represent those features that are partially or totally invisible on the SPOT Pan image. In general terms, all the participants were fairly satisfied with the level of cartographic information added to the background image. The results given in Table 16-1 and Figure 16-1 indicate that the evaluation ratings, regarding the level of cartographic elements added, were excellent (by 1 participant); very good (by 5 participants); good (by 17 participants) and satisfactory (by 7 participants). Several participants noted in their general comments that the addition of cartographic elements on the background image made the interpretation easier and brought meaning and definition to many features. Others indicated that the image without additional cartographic enhancements would be difficult to read and, in turn, would not be useful for many map users.

In the third question (Question 3), the participants were expected to evaluate the *number of categories that have been included to emphasize important topographic features*. For the general-purpose space image map at 1:50,000 scale, the great majority of the participants felt that the number of categories that had been defined and included was very suitable both in terms of the scale and purpose of the map. This impression was confirmed by the results given in Table 16-1 & Figure 16-1, which indicate that the majority of the participants felt that this number was excellent (stated by 5 participants); very good (by 8 participants) or good (by 14 participants). Only three participants felt it was only satisfactory while no single participant has considered or rated the number of categories added as poor. Although none of the participants had written any comments when they answered this question, they did mention orally that they feel that the education, background and experience of the present author had helped him to define which categories of features needed to be included to satisfy the various users.

Regarding the *level of classification made to distinguish or differentiate between features within the same category* (Question 4); most of the participants were pleased with the classification level that has been established to make those features that lie within a single category distinguishable and easy to discriminate from the others. As can be seen in Table 16-1 & Figure 16-1, the evaluation ratings, when all the participants answered this question, were excellent (by 4 respondents); very good (by 10 respondents); good (by 11 respondents) and satisfactory (by 5 respondents). One general comment made by several respondents was that the classification level was good enough to allow them to distinguish the different classes of roads, land cover and vegetation, settlements, etc.

In summary, as can be seen in Table 16-1 & Figure 16-1, the great majority of participants in the test were pleased with the outcome of the experimental space image map of Misratah at 1:50,000 scale with regard its content. This confirmed that the background space image itself contained plenty of useful information that would be unlikely to be represented otherwise. Furthermore, the additional cartographic material appears to have been well chosen and well organised in terms of the number of categories that were included; and in terms of the level of classification made within each category to help distinguish between the different classes of features. However, they have also reported orally that it is impossible to design a map that will suit the requirements (in terms of information content) of each individual map user. They were also surprisingly well aware of the fact that the space image map is an entirely different product to the conventional line map. In turn, they seemed to appreciate the fact that the addition of too much detail can obscure more important image information and result in a crowded appearance to the final map.

Question No.	Map Content Questions	E	V	G	S	P
Question 1	Level of information shown on the natural space image.	3	10	13	4	0
Question 2	Level of detail added through cartographic elements.	1	5	17	7	0
Question 3	Number of categories included emphasising important features.	5	8	14	3	0
Question 4	The level of classification made to distinguish between features within the same categories.	4	10	11	5	0

E= Excellent V= Very Good G= Good S= Satisfactory P= Poor

Table 16-1: The Results of the Answers to the Four Questions Included in Sub-section Number 1.

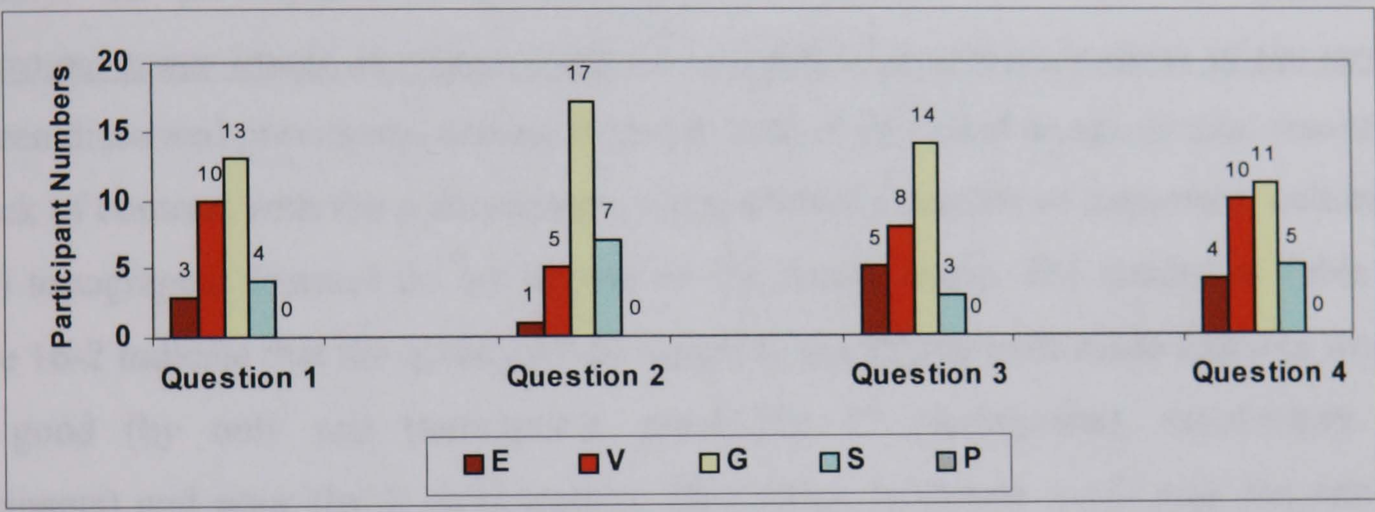


Figure 16-1: The results of the answers to the four questions included in sub-section number 1 shown as a graphic representation.

2) Background Image: This sub-section is concerned with the quality of the space image in displaying physical features and cultural (man-made) features and attempts to assess its overall performance in representing all the features contained in this image. Since they all came from a geo-science background, most of the participants had already acquired a considerable amount of information regarding space imagery in general and a surprising number of them have used space images during certain stages of their previous practical work in Libya. They were also quite familiar with the basic concepts concerning those factors – such as the ground resolution of the imagery and the contrast of terrain features with their surroundings – that control the detection and interpretation of features on the space image. Indeed, the author regarded himself as being very fortunate in having such a knowledgeable and interested group of participants with which to carry out the test.

In this sub-section, the author also asked (in Question 1) all the participants to examine the *quality of the background space image in showing the physical features of the terrain*. As reported by all the respondents, the physical features were well shown and relatively easily recognised. This opinion was well supported by the results given in Table 16-2 & Figure 16-2, which reveal that the quality of the space image in displaying physical features was rated as being very good (by 13 respondents), good (by 16 respondents) and satisfactory (by only 1 respondent). The main and most pertinent comment that was received from several participants was this type of image is particularly suitable for arid and semi-arid areas, where most of the terrain surface is an unvegetated and bare physical landscape. They also commented orally that the image ground resolution was sufficient to extract the required information that can be used for their geo-science activities.

Secondly, the participants in Question 2 were requested to assess the *quality of the background space image in representing the cultural (man-made) features of the terrain*. As has been discussed previously, arising from the lack of sufficient image ground resolution and the lack of contrast with the surroundings, a considerable number of important, cultural (man-made) topographic features do not appear on the space image. The results in Table 16-2 & Figure 16-2 indicate that the quality of the image in displaying man-made features was graded very good (by only one participant), good (by 12 participants), satisfactory (by 17 participants) and poor (by 2 participants). This rather moderate result was not unexpected. Indeed the majority of participants have mentioned in their general comments that the small cultural (man-made) features or objects were much less easily recognised due to insufficient ground resolution of the image or/and the lack of contrast of this type of feature with its surroundings. They felt that, even if certain small cultural features can be detected, these features still need to be represented on the space image map in some other manner (e.g. through additional symbolization) if this type of map is to be complete and acceptable to users.

Question 3 was the last in this sub-section, in which the respondents were expected to evaluate the *quality of the background space image in depicting all the features* that exist on the terrain surface. Generally speaking, most of the respondents were satisfied and they believe that between 65% and 70% of all details that need to be shown on 1:50,000 scale map can, in practice, be extracted directly from this (SPOT Pan) space image. As can be seen in Table 16-2 & Figure 16-2, thirteen of these participants rated the quality of the background image in displaying all features as being good, while the other seventeen valued this image as being merely satisfactory. This result is in line with the rather similar results obtained for the representation of the cultural (man-made) features (see Table 16-2).

Regardless of the fact that the physical features of the area were much more easily recognised and identified on the space image background than the cultural (man-made) features, all the participants still felt that the use of the image as a background gives a far better and more realistic impression overall about the surface of the terrain than any conventional line representation (see Figure 16-2). As a matter of fact, two of the participants are originally from Misratah and have a very good local knowledge of the area covered by the image map. These two students emphasised that this type of image can be understood and will be useful even for non-specialist local users who know the area well.

Question No.	Background Image Questions	CLARITY & CONTRAST				
		E	V	G	S	P
Question 1	The quality of showing physical features	0	13	16	1	0
Question 2	The quality of representing cultural (man-made) features	0	1	12	15	2
Question 3	The quality of depicting all features in general	0	0	13	17	0

E= Excellent V= Very Good G= Good S= Satisfactory P= Poor

Table 16-2: The Results of the Answers to the Three Questions Included in Sub-section Number 2.

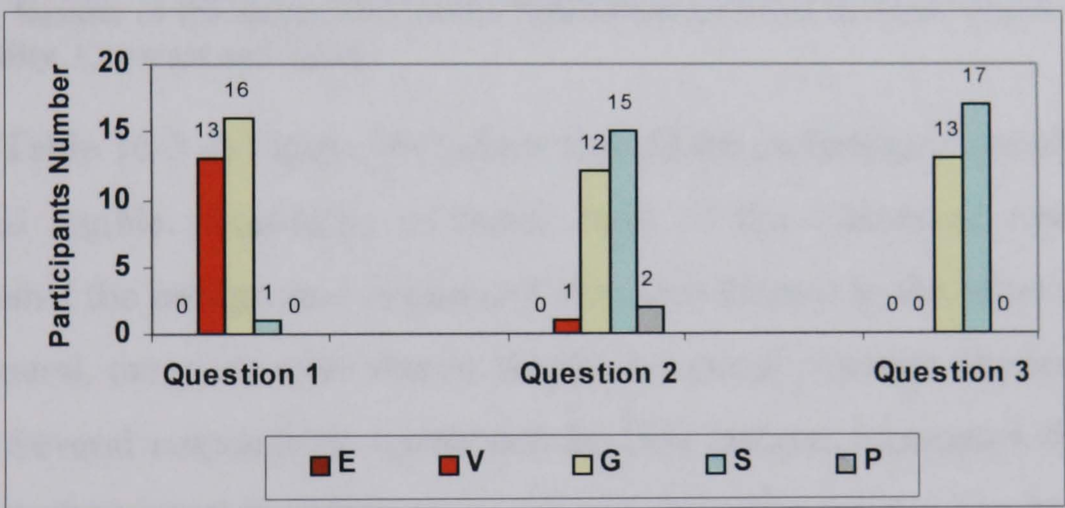


Figure 16-2: The results of the answers to the three questions included in sub-section number 2 shown as a graphic representation.

3) <u>Symbolisation</u>: In this sub-section, all the different types of symbolised feature – such as road detail, boundary information, water features, cultural features, etc. – were also broken down into various classes. Since each class of topographic feature has been related graphically to a particular point, line or area symbol, the participants were asked to measure how successful was the design of each individual symbol included in this map. The design evaluation was based primarily on the clarity & legibility and the contrast of the symbol against the background image. It was also assessed in relation to the other map elements; and to the unity or integration of each individual symbol with the space image. The evaluation and analysis of the sample map that he has produced allow the author to see what type of symbolisation is effective in representing those features that are important to Libyan users.

(i) **Road Detail**: This is one of the most significant categories included on the Misratah space image map at 1:50,000 scale. It was divided into five different classes of highway; main paved road; secondary paved road; unpaved road and track. On the map being tested, the graphic variables of form, dimension and colour had been used to distinguish the different road classes. Obviously the road network was very important to all of these users and this was reflected by their answers and their oral comments and explanations. In general, all of the participants were happy with regard to the road symbolisation used on the map. Their first impressions of the sample map were very favourable in that they deemed all the roads to be clear and legible, and they felt that, in general, they all have achieved a good contrast against the background image and with respect to the other elements included on the map. They also felt that the road network had been classified in an effective manner.

Road Representation Qs.	CLARITY & LEGIBILITY					CONTRAST					UNITY				
	E	V	G	S	P	E	V	G	S	P	E	V	G	S	P
Highway	7	13	10	0	0	4	7	14	5	0	1	5	18	6	0
Main Paved Road	5	11	14	0	0	3	8	12	7	0	0	3	19	8	0
Secondary Paved Road	2	7	19	2	0	1	5	16	8	0	0	1	16	13	0
Unpaved Road	0	8	17	5	0	0	3	15	11	1	0	0	14	13	3
Track	0	5	13	12	0	0	1	9	17	3	0	0	13	12	5

Table 16-3: The Results of the Evaluation of the Symbolisation Used to Show Roads – in Terms of their Clarity & Legibility, Contrast and Unity.

The results in Table 16-3 & Figure 16-3 show that all the participants stated that all the roads were clear and legible. According to them, most of the classes of roads can be easily recognised against the background image and also with respect to the other items included on the map. In general, the roads were shown clearly in a simple manner and leave no doubt as to their identity. Several respondents mentioned in their general comments that the success in achieving good clarity and legibility for roads on this map sample can be attributed to the correct selection of line forms, the appropriate specification of line widths/dimensions and the good use of colour when designing the different road classes. However, as can be seen in Figure 16-3, the results also reveal that the symbols used for the surfaced roads (i.e. highway, main paved roads and secondary paved roads) were deemed to be much more successful in terms of their clarity and legibility than those used for the unsurfaced roads (which are the unpaved roads and tracks). Obviously the symbols for the latter classes need to be improved, especially that used for the tracks, which only achieved a satisfactory rating.

Table 16-3 & Figure 16-4 indicate that the respondents were highly satisfied with the contrast of the line symbols used for road representation against their background. In their opinion, the road symbolisation was simple yet very effective, contrasting well against the background space image and with respect to the other objects contained in the map. Unsurprisingly, as can

(i) **Road Detail**: This is one of the most significant categories included on the Misratah sp image map at 1:50,000 scale. It was divided into five different classes of highway; m paved road; secondary paved road; unpaved road and track. On the map being tested, graphic variables of form, dimension and colour had been used to distinguish the differe road classes. Obviously the road network was very important to all of these users and this w reflected by their answers and their oral comments and explanations. In general, all of participants were happy with regard to the road symbolisation used on the map. Their f impressions of the sample map were very favourable in that they deemed all the roads to clear and legible, and they felt that, in general, they all have achieved a good contrast agai the background image and with respect to the other elements included on the map. They a felt that the road network had been classified in an effective manner.

Road Representation Qs.	CLARITY & LEGIBILITY					CONTRAST					UNITY			
	E	V	G	S	P	E	V	G	S	P	E	V	G	S
Highway	7	13	10	0	0	4	7	14	5	0	1	5	18	6
Main Paved Road	5	11	14	0	0	3	8	12	7	0	0	3	19	8
Secondary Paved Road	2	7	19	2	0	1	5	16	8	0	0	1	16	13
Unpaved Road	0	8	17	5	0	0	3	15	11	1	0	0	14	13
Track	0	5	13	12	0	0	1	9	17	3	0	0	13	12

Table 16-3: The Results of the Evaluation of the Symbolisation Used to Show Roads – in Terms of t Clarity & Legibility, Contrast and Unity.

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Regarding the unity or integration of the line symbols used to represent roads against the background image, the results given in Table 16-3 & Figure 16-5 reveal that most of the respondents rated the unity as only being good or satisfactory. In their general comments, five participants referred to the achievement of a good unity of the line symbols used to show roads with the space image and to the good selection of colours used. These colours did not over contrast or divorce the line symbols used from the background image; instead they blended in as though they were part of this image.

(ii) Boundary Information: This includes both international boundaries and provincial boundaries, which were represented through the use of conventional line symbols with sufficient contrast to achieve clarity against the background. Thick black interrupted lines with a 50% red ribands were specified for international boundaries, while thinner dashed lines in black were specified to show provincial boundaries. Unfortunately, none of these boundary line symbols were present in the space image map of Misratah at 1:50,000 scale and they were only shown in the legend of the map. Thus, none of the participants could rate boundary symbolisation. Instead, they reported orally that the line symbols used to represent both boundary classes appeared to be clear enough and the colours used should achieve sufficient contrast when superimposed against the space image.

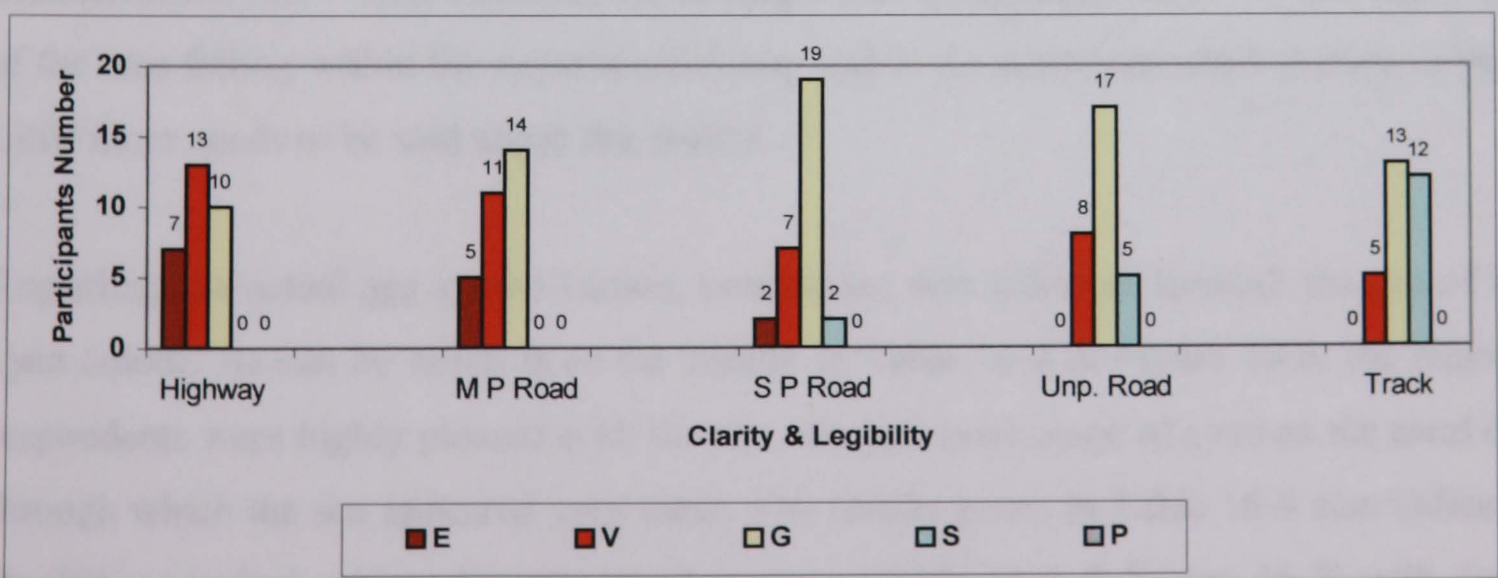

Figure 16-3: The results of the evaluation (in terms of clarity & legibility) of the symbolisation used to show roads given as a graphic representation.

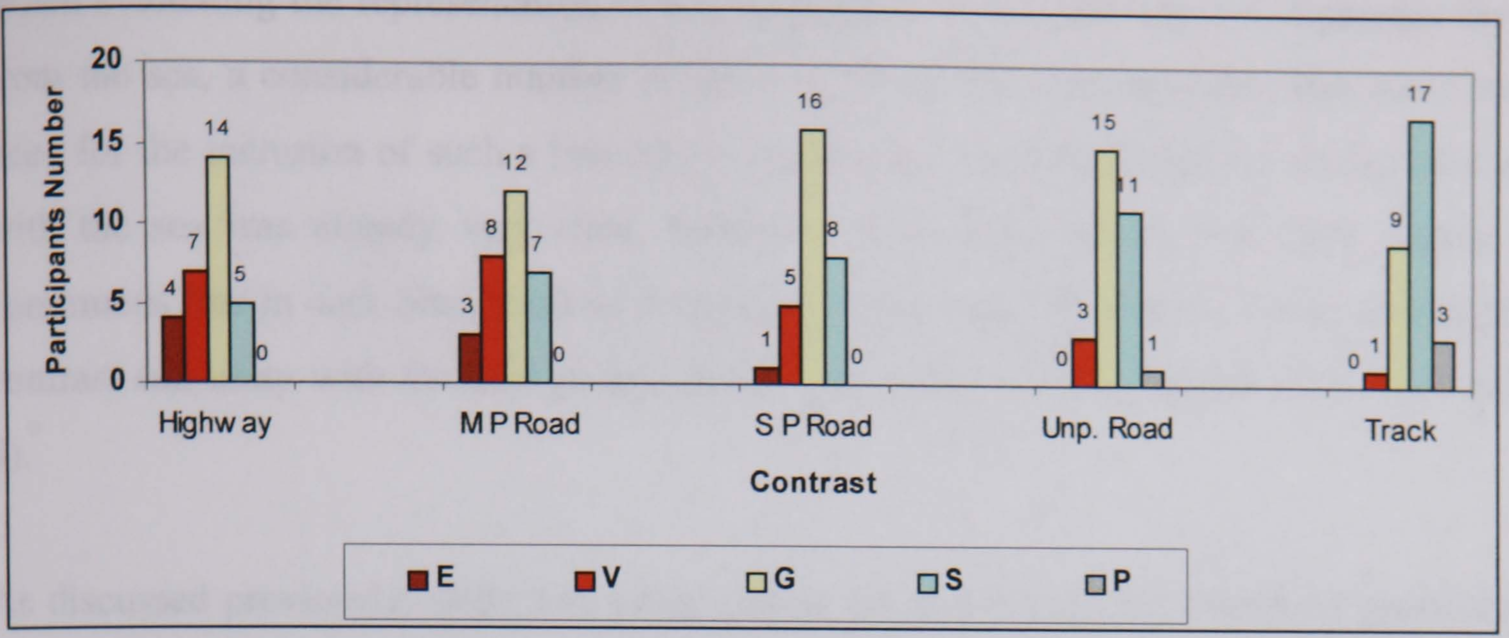

Figure 16-4: The results of the evaluation (in terms of contrast) of the symbolisation used to show roads given as a graphic representation.

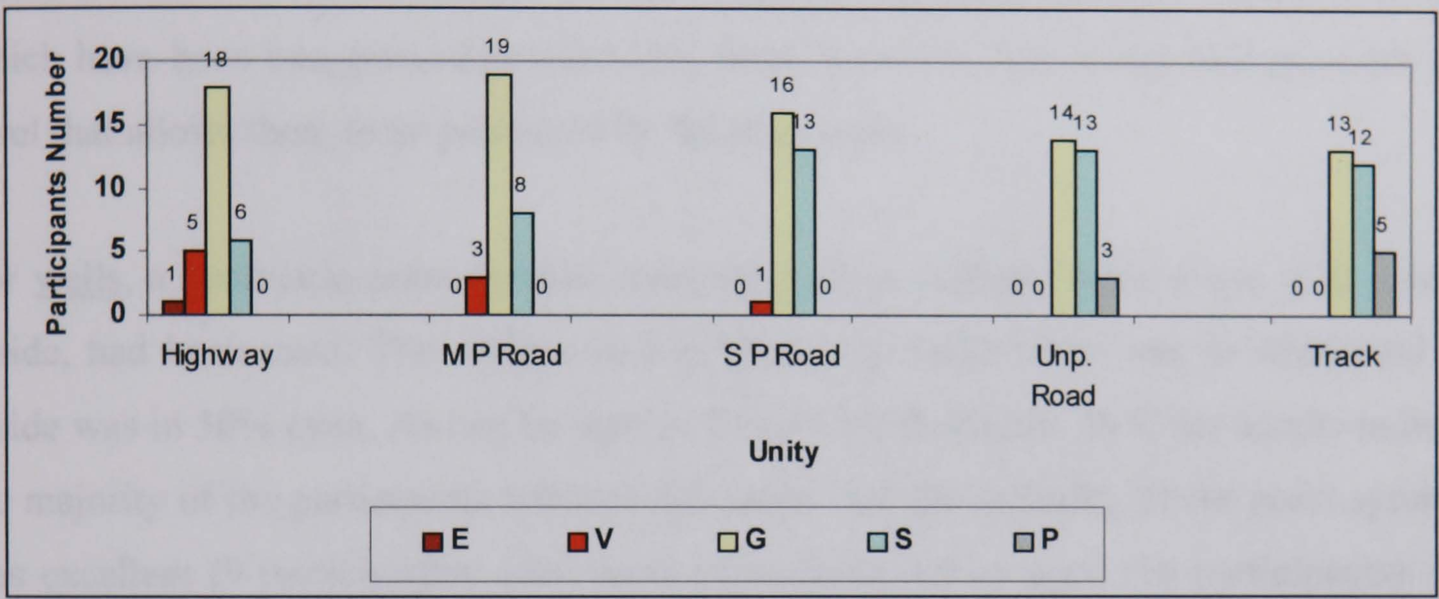

Figure 16-5: The results of the evaluation (in terms of unity) for the symbolisation used to show roads given as a graphic representation.

(iii) Water Features: Unsurprisingly, all participants noted that, apart from the sea, no permanent surface water is present in the area covered by the space image map of Misratah at 1:50,000 scale. In fact, it was only too obvious to all the participants that part of the Mediterranean Sea – which bounds the northern part of Misratah area – covers about quarter of the area falling within the experimental map and is the dominant water feature in the area. Little more needs to be said about this matter.

Regarding the actual sea symbolisation, convention was followed through the use of a 20% cyan colour. As can be noted from the results in Table 16-4 & Figure 16-6, the majority of respondents were highly pleased with the use of a low percentage of cyan as the areal colour, through which the sea appeared very clear. The results given in Table 16-4 also indicate that the 20% cyan had achieved a very good contrast (Table 16-4 & Figure 16-7) with the other elements of the map. Indeed, all the participants reported that the area symbol used for the sea integrated well with the rest of the background space image (see Table 16-4 & Figure 16-8).

When evaluating the representation of the coastline, which is the line that separates the land from the sea, a considerable number of the participants felt (in particular) that there was no need for the inclusion of such a line on an image map, since the boundary of the land image with the sea was already very clear. However, since the coastline had been shown by a continuous line in dark blue, most of participants were satisfied with its clarity and legibility, contrast and unity with the background image (see Table 16-4 & Figures 16-6, 16-7 and 16-8).

As discussed previously, wells and water towers are minor but very important point features that do need to be included in the map. Their symbolisation on the map sample (at 1:50,000 scale) has been achieved through the use of geometric point symbols (circles and squares), which have been exaggerated considerably from their true size to one that provides a visual level that allows them to be perceived by the map users.

For wells, a geometric point symbol, consisting of an outlined solid circle with a small dot inside, had been used. The outline was in black, the solid circle was in white and the dot inside was in 50% cyan. As can be seen in Table 16-4 & Figure 16-6, the results indicate that the majority of the participants felt that the clarity and the legibility of the point symbol used was excellent (9 participants), very good (4 participants) or good (16 participants). Only in one single case was the clarity and legibility thought to be only satisfactory. Most of the respondents have also formed the impression that the symbol used achieved a good contrast against the background image and the other items included in the map.

Water Features	CLARITY & LEGIBILITY					CONTRAST					UNITY				
Representation Qs.	E	V	G	S	P	E	V	G	S	P	E	V	G	S	P
Sea	8	11	10	1	0	5	13	12	0	0	2	7	11	10	0
Coastline	3	6	14	7	0	0	3	18	9	0	0	1	13	12	4
Well	9	4	16	1	0	4	13	11	2	0	3	7	11	9	0
Water Tower	4	1	11	14	0	1	6	17	5	1	0	2	22	4	2

Table 16-4: The Results of the Evaluation of the Symbolisation Used to Show Water Features – in Terms of their Clarity & Legibility, Contrast and Unity.

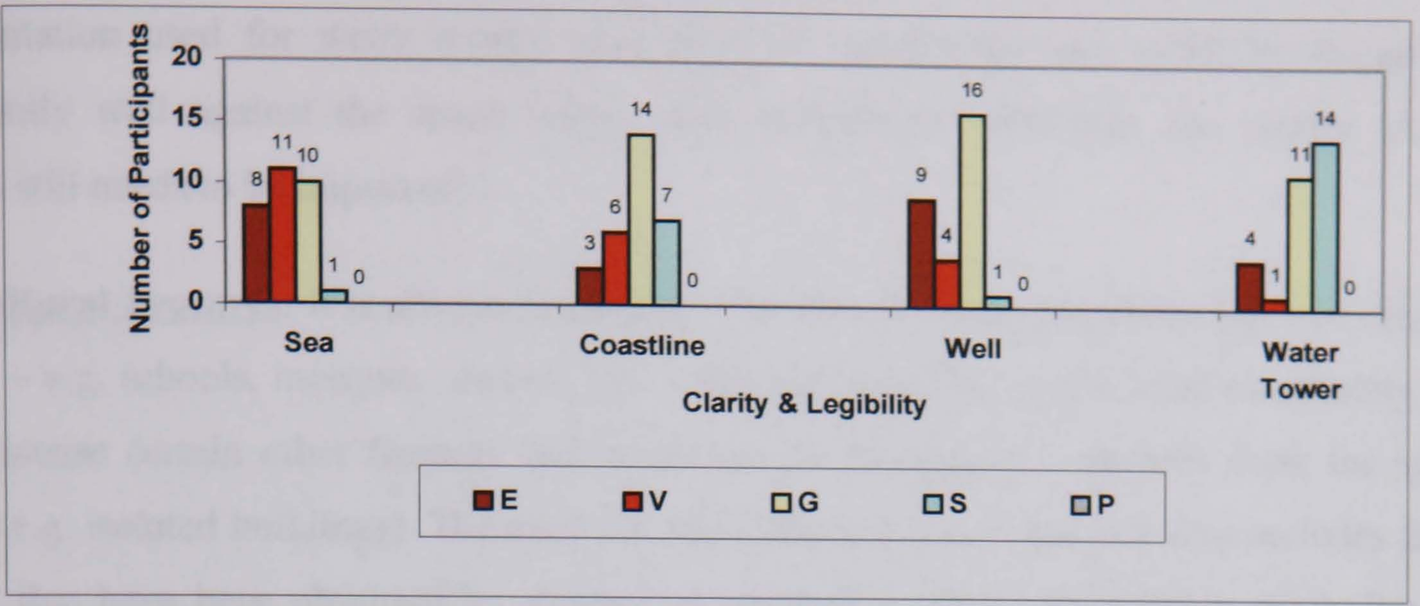

Figure 16-6: The results of the evaluation (in terms of clarity & legibility) for the symbolisation used to show water features given as a graphic representation.

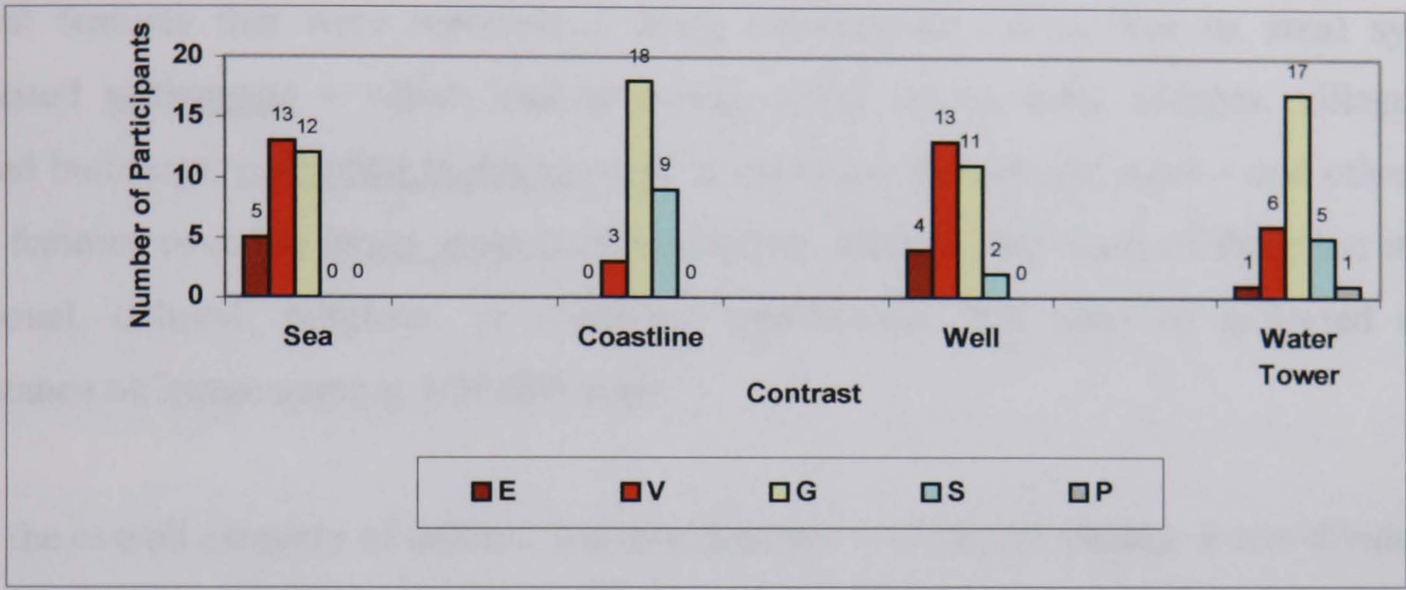

Figure 16-7: The graphic representation of the evaluation results (in terms of contrast) for the symbolisation used to show water features given as a graphic representation.

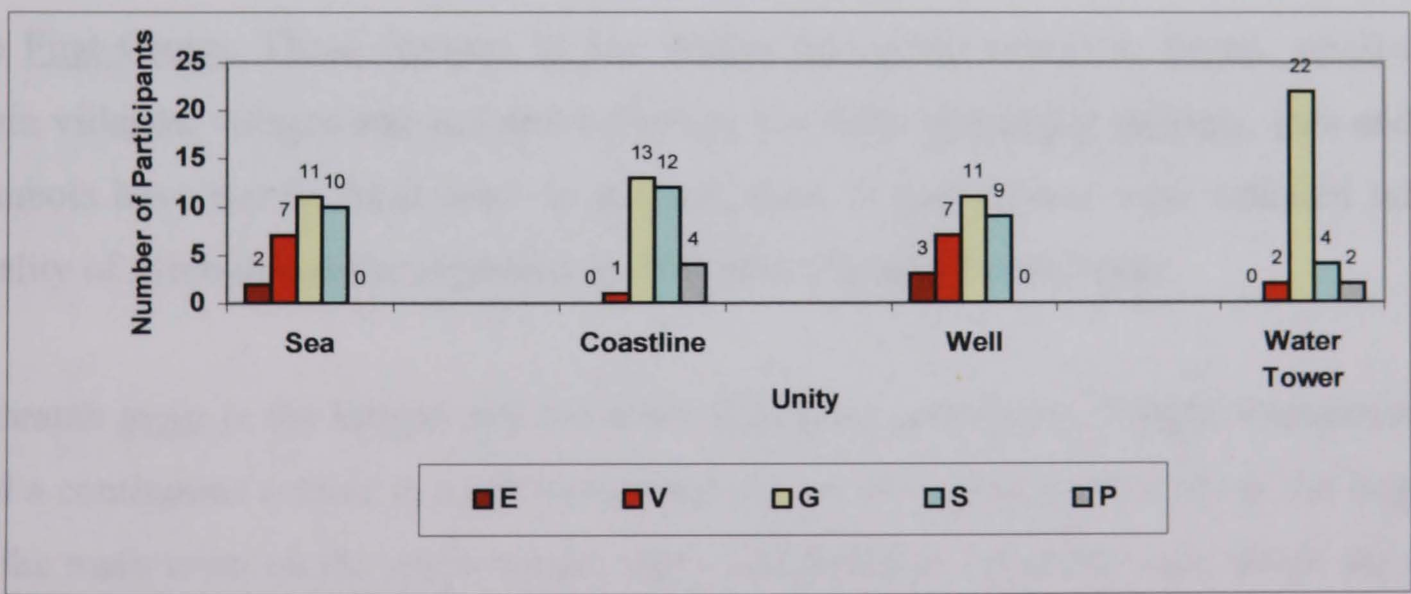

Figure 16-8: The results of the evaluation (in terms of unity) for the symbolisation used to show water features given as a graphic representation.

It will be recalled that water towers were represented using outlined solid squares. The actual outlines were shown in 100% cyan, whereas white was used for the solid squares. All of the participants thought that the wells had been given a much better representation – in terms of clarity & legibility, contrast and unity – than the water towers. However, as can be seen in

Table 16-4 & Figures 16-6, 16-7 and 16-8, most of these respondents still felt that the representation used for water towers was good or satisfactory and could be recognised sufficiently well against the space image. But nevertheless obviously the design of this symbol still needs to be improved!!

(iv) Cultural Features: It is always important to be able to locate particular types of cultural feature – e.g. schools, mosques, shrines, etc. – that are important to the local community and to emphasise certain other features that might not be immediately obvious from the space image (e.g. isolated buildings). The need for this enhancement of features also includes those objects that have been obscured by shadow or vegetation. Thus cartographic symbolisation was needed to supply more complete information about certain types of feature. Those cultural features that were represented using cartographic (point, line or area) symbols comprised settlements – which include towns, small towns, main villages, villages and isolated buildings; individual buildings such as mosques, shrines and ruins – and other man-made features covering larger areas such as quarries, airports, etc. Each of these has its own functional, cultural, religious, or economic significance that must be reflected on its appearance on image maps at 1:50,000 scale.

Since the overall category of cultural features contains 15 different classes, it was divided into three groups in an attempt to analyse the results of evaluating each group separately and more effectively.

(1) First Group: Those features falling within this group comprise towns, small towns, main villages, villages and isolated buildings. For these settlement features, area and point symbols have mostly been used. In general, most of participants were satisfied with the quality of symbols used to represent the different classes of settlements.

Misratah town is the largest and the more important settlement. A light transparent pink and a continuous outline in a 100% magenta colour have been used to show the large area of the main town on the space image map of Misratah at 1:50,000 scale. From the results presented in Table 16-5 & 16-9, it is apparent that the great majority of the participants felt that this symbolisation was clear and legible and could be easily recognised. The participants rated the clarity and legibility of this symbol as being excellent (in 4 cases), very good (in 11 cases), good (in 9 cases) and satisfactory (in 6 cases). Most of these participants had also believed that the use of light transparent pink was quite useful – in that it allowed the appearance of the town on the space image to be retained. They also believed that the area symbol had achieved a very good contrast against the background image and with the other items contained in the image map. As can be seen in Table 16-5 & 16-10, the ratings given by the evaluation were excellent (by 1 participant), very good (by 14 participants), good (by 8 participants) and satisfactory (by 7 participants). A large number of participants thought that the light transparent pink had integrated well with the space image, since the use of this colour did not disturb the realistic appearance of the natural image background and did not obscure its more important details. In their opinion, the light transparent colour was thoroughly appropriate and blended in well and appeared as an integral part of the image. The results in Table 16-5 & 16-11 reveal that the evaluation ratings given by the participants were excellent (3 respondents), very good (9 respondents), good (11 respondents) and satisfactory (7 respondents).

In their written comments or oral explanation, several participants felt that the use of the light transparent colour only helped their interpretation to a limited extent. However, they felt that the picking out of the network of road lines – using white infill and black casings – has enhanced the street structure very effectively and, in turn, resulted in a much easier recognition and interpretation of the town area. Moreover, others reported that the inclusion of the outline of the town's limits in a 100% magenta colour was very helpful in defining the extent of the town and in helping to discriminate it from the surrounding area features.

Apart from the main town of Misratah, there is another small town called Zawiyat Al Mahjub and two main villages, which are Zurayg and Abu Ruwayah. As the area of these built-up areas became smaller, the transparent pink had been made darker in order to achieve sufficient visual contrast against the black & white space image. Although continuous outlines in a 100% magenta colour have also been used to define the boundaries of these smaller built-up areas (small towns and main villages), the results of the evaluation – in Table 16-5 & Figures 16-9, 16-10 and 16-11 – indicate that the symbolisation used was less successful than that used for towns. However, as noted by a number of participants, the use of different letter sizes in the associated names has helped to differentiate between the small towns and the main villages and, in turn, this speeded up their recognition.

Since the other villages are so small and cannot be easily identified, as discussed previously, a geometric point symbol had been used for their representation – which took the form of a solid orange circle with black outline. The majority of participants, after having examined this symbol against the tonal space image, agreed that it was successful and appropriate in representing villages on the image map sample at 1:50,000 scale. This impression was borne out from the results of their evaluation (see Table 16-5 & Figures 16-9, 16-10 and 16-11), which showed that a large number of the participants considered that the symbolisation used for the representation of villages was very clear and legible. Furthermore, from these results, the opinion was that the use of orange proved to have a good contrast both against the background image and in relation to the other elements of the map. Table 16-5 & 16-9, 16-10 and 16-11 reveal that the symbol used for villages has also achieved a good unity with the space image.

To a large extent, the symbols used for settlements & isolated buildings were similar in terms of design – in which 100% magenta squares and black outlines were used. However, the variation was that aggregates of four squares were used for the settlements, whereas only a single square was used to represent an individual isolated building. The results given in Table 16-5 & Figures 16-9; 16-10 and 16-11 indicate that the use of the 100% magenta colour outlined with black for settlements & isolated buildings allowed the symbol to appear clearly against the space image. In the view of the participants, the combination of the 100% magenta and black colours has created a good contrast against the space image and the other symbolisation of the map. Furthermore, most of the participants felt that the symbolisation used had achieved a good unity with the space image. Several participants commented that the symbolisation of both the settlements & isolated buildings made them easy to locate and identify all over the sample map.

Several participants commented that the colours chosen for the different classes of this group were effective. They were easy to identify and achieved a good contrast both against the black & white space image and with respect to the other elements of the map. The participants were also satisfied with the method of classification used within this group of cultural features. They also expressed their satisfaction about the associated names being in different sizes, which, in their opinion, has facilitated the differentiation between towns, small towns, main villages and villages.

Cultural Features Representation Qs.	CLARITY & LEGIBILITY E	V	G	S	P	CONTRAST E	V	G	S	P	UNITY E	V	G	S	P
Town	4	11	9	6	0	1	14	8	7	0	3	9	11	7	0
Small Town	1	7	13	9	0	0	5	17	6	2	1	6	17	4	2
Main Village	0	2	7	17	3	0	1	12	11	6	0	4	12	9	5
Village	5	9	11	5	0	6	10	11	3	0	2	7	14	7	0
Settlement	4	7	12	7	0	5	11	8	6	0	3	8	12	5	2
Isolated Building	3	4	15	8	0	3	9	11	7	0	2	10	11	6	1

Table 16-5: The Results of the Evaluation of the Symbolisation Used to Show the First Group of Cultural Features Concerning Human Settlement – in Terms of their Clarity & Legibility, Contrast and Unity.

(2) Second Group: This group of cultural features comprises schools, mosques, churches, cemeteries (both Islamic and Christian), shrines and quarries. These small point features were all symbolised in much the same manner, in which outlined frames – that are oval in shape – were used as the background to each of these small point symbols. Both the outlines and the actual symbols were in black, while the oval shaped background was in white. Once again, their design and appearance on the map sample (at 1:50,000 scale) pleased the majority of participants. Therefore, most of these participants have rated highly their clarity and legibility, contrast and unity with the space image – see Table 16-6 & Figures 16-12, 16-13 and 16-14. In their general comments, several of the participants mentioned specifically that these point symbols were very successful in terms of their design and could be recognised easily all over the map. This was attributed mainly to the use of the oval-shaped frames in white against which the actual black symbols became clearer and achieved a good contrast against the space image.

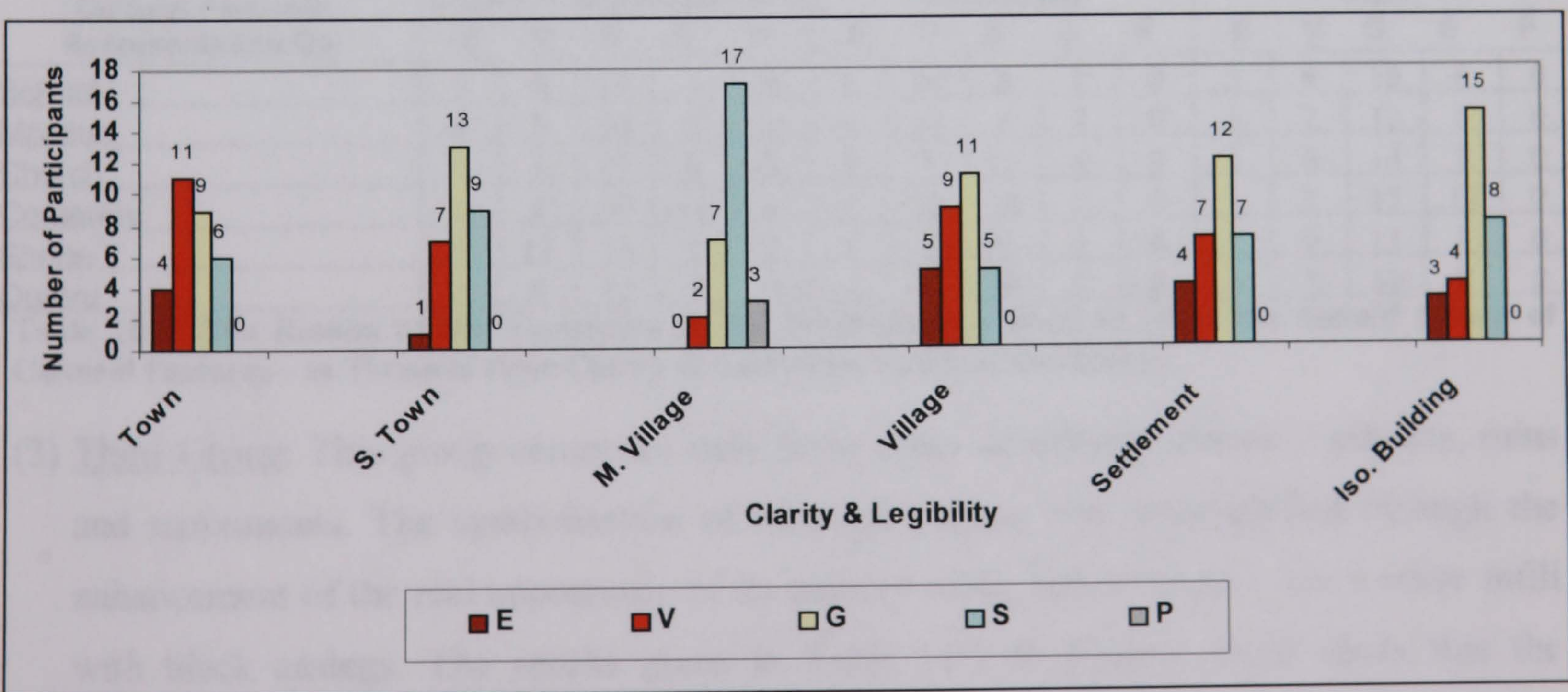

Figure 16-9: The results of the evaluation (in terms of clarity & legibility) of the symbolisation used to show the first group of cultural features given as a graphic representation.

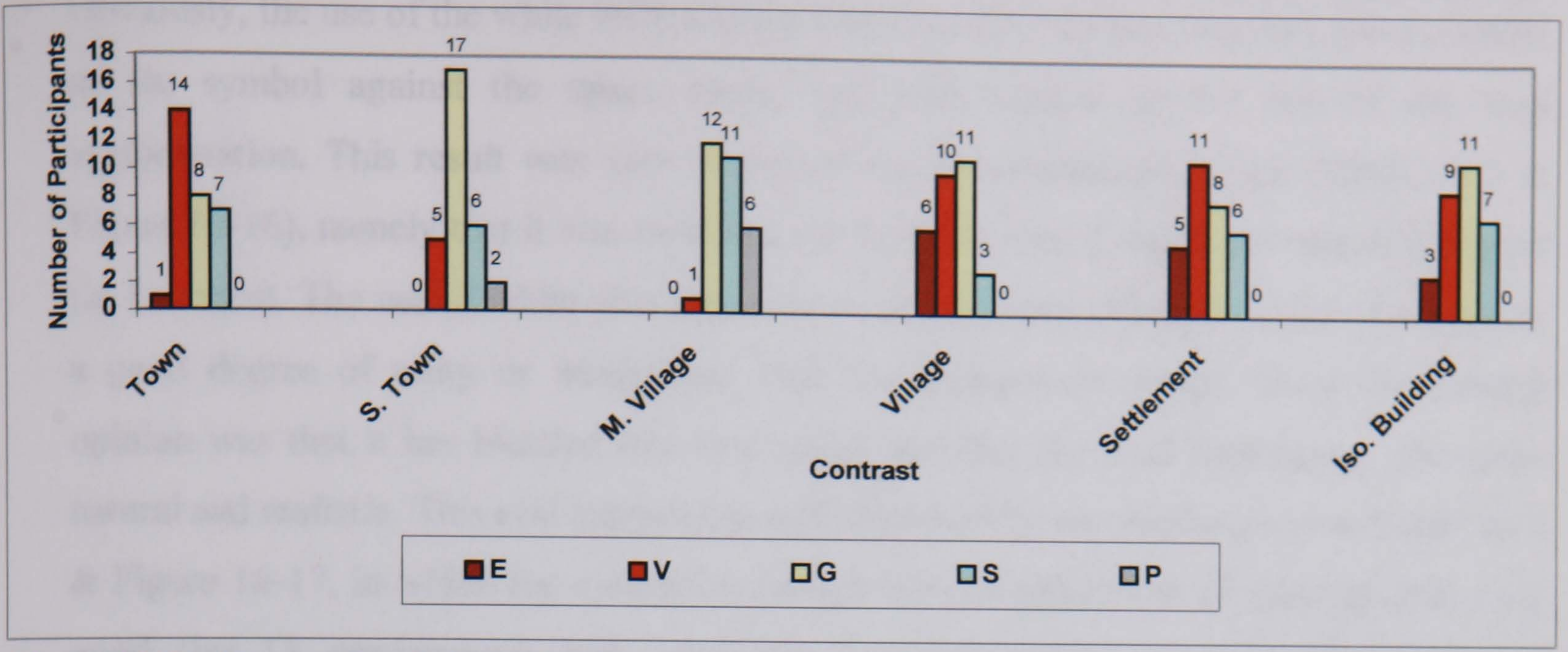

Figure 16-10: The results of the evaluation (in terms of contrast) of the symbolisation used to show the first group of cultural features given as a graphic representation.

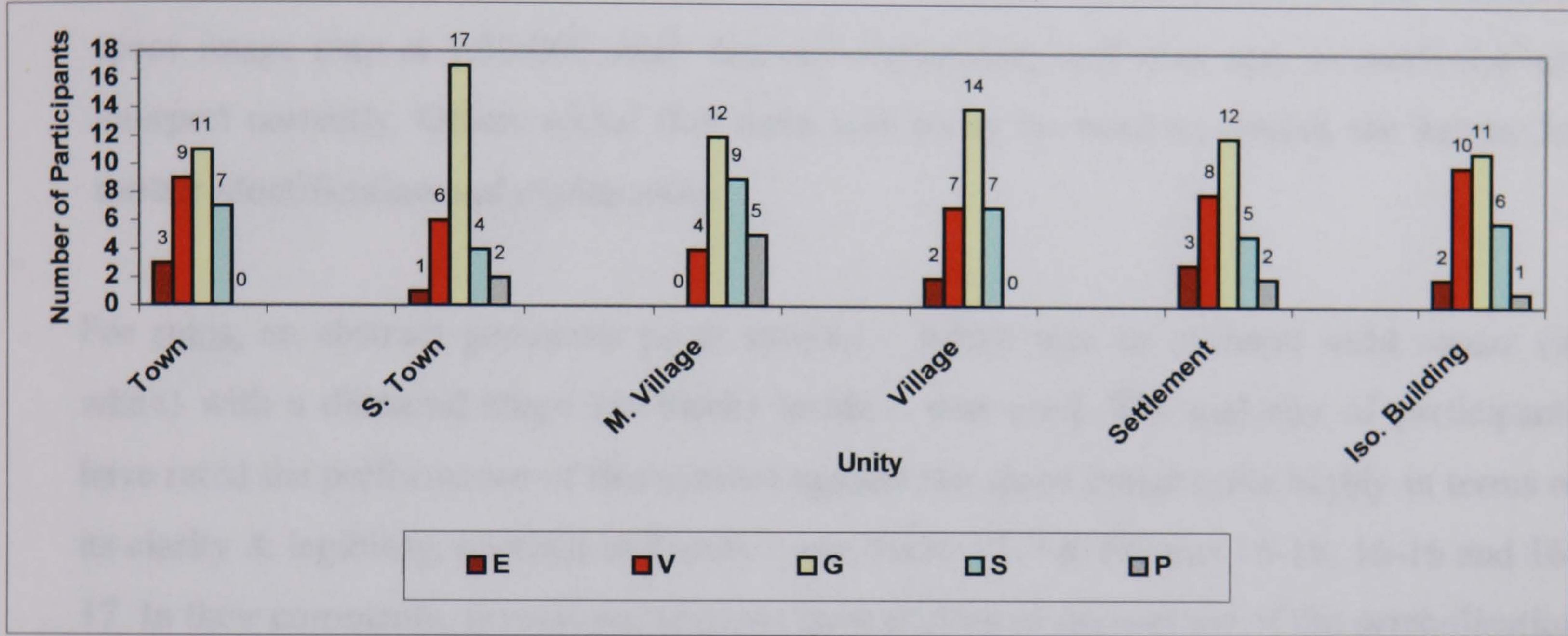

Figure 16-11: The results of the evaluation (in terms of unity) of the symbolisation used to show the first group of cultural features given as a graphic representation.

Cultural Features Representation Qs.	CLARITY & LEGIBILITY					CONTRAST					UNITY				
	E	V	G	S	P	E	V	G	S	P	E	V	G	S	P
School	5	9	12	4	0	6	14	8	2	0	5	9	10	6	0
Mosque	8	7	10	5	0	9	11	7	3	0	6	7	12	5	0
Church	3	5	13	9	0	5	8	11	6	0	3	6	14	7	0
Cemetery	1	8	9	11	1	3	10	14	2	0	1	2	17	10	0
Shrine	5	11	13	1	0	8	12	9	1	0	6	9	11	4	0
Quarry	2	9	12	7	0	4	7	10	9	0	4	5	13	8	0

Table 16-6: The Results of the Evaluation of the Symbolisation Used to Show the Second Group of Cultural Features – in Terms of their Clarity & Legibility, Contrast and Unity.

(3) Third Group: This group comprises only three types of cultural feature – airports, ruins and monuments. The symbolisation of Misratah airport was accomplished through the enhancement of the real appearance of its runway using line symbols – i.e. a white infill with black casings. The results given in Table 16-7 & Figures 16-15 show that the participants were highly pleased with the line symbol used for the airport. From these results, a rating of good or higher was given by all participants to confirm the fact that the symbolisation was clear and legible. Their actual evaluation ratings were excellent (given by 11 participants), very good (by 13 participants) and good (by 6 participants).

Obviously, the use of the white infill and the black casings resulted in a very good contrast of the symbol against the space image and with respect to the rest of the map symbolisation. This result was very evident from the evaluation ratings (Table 16-7 & Figure 16-16), namely that it was excellent (in 9 cases), very good (in 10 cases) and good (in 11 cases). The use of white also appeared to be very appropriate in terms of achieving a good degree of unity or integration with the background image, since the general opinion was that it has blended into this image and that the final appearance was quite natural and realistic. This oral impression was supported by the results given in Table 16-7 & Figure 16-17, in which the evaluation ratings were excellent (by 10 participants), very good (by 13 participants) and good (by 7 participants). Unsurprisingly, most of participants commented that the symbolisation adopted for the airport on the Misratah space image map at 1:50,000 scale was self-explanatory and very easy to recognise and interpret correctly. Others added that there was really no need to consult the legend for further identification and explanation.

For ruins, an abstract geometric point symbol – which was an outlined solid square (in white) with a diamond shape (in black) inside – was used. The majority of participants have rated the performance of this symbol against the space image quite highly in terms of its clarity & legibility, contrast and unity – see Table 16-7 & Figures 16-15, 16-16 and 16-17. In their comments, several participants have attributed the success of the symbolisation to the good colour combination of black and white that contrasted well against the background image. Thus the ruins were quite identifiable and easy to locate all over the map.

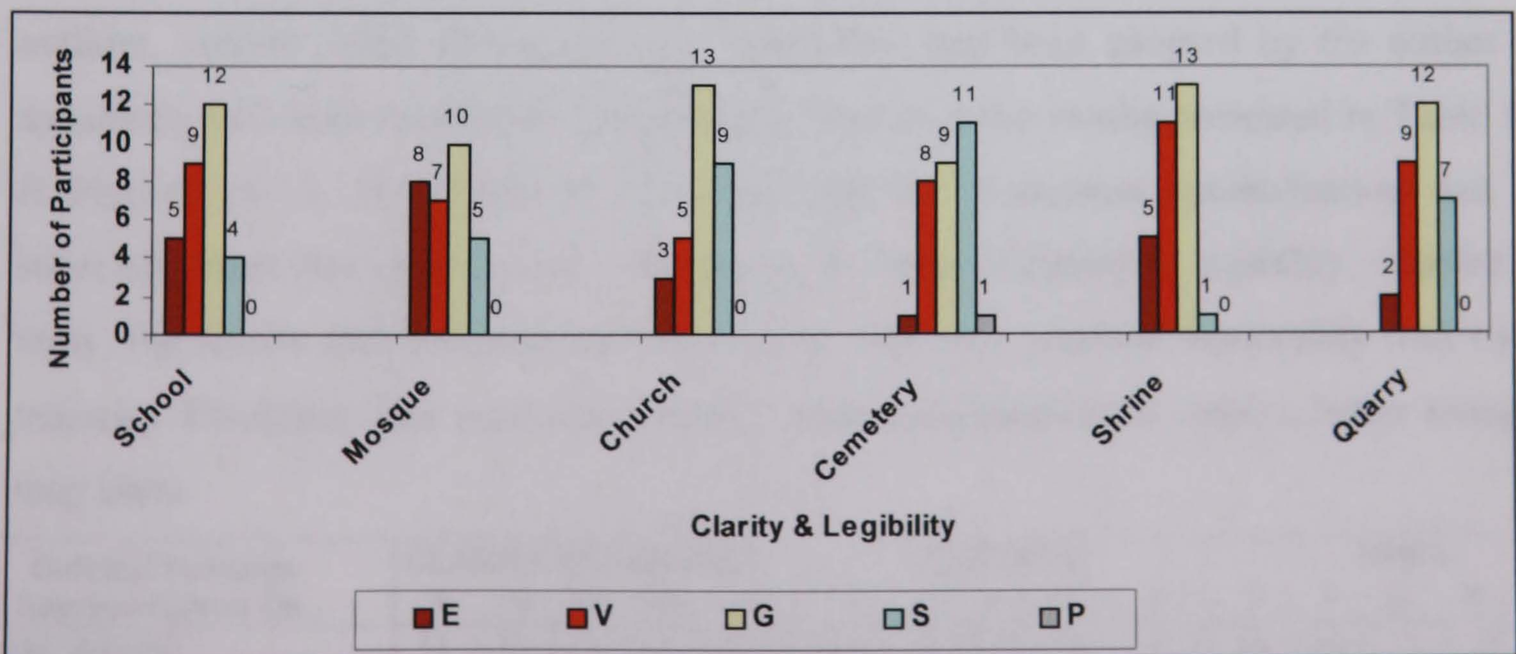

Figure 16-12: The results of the evaluation (in terms of clarity & legibility) of the symbolisation used to show the second group of cultural features given as a graphic representation.

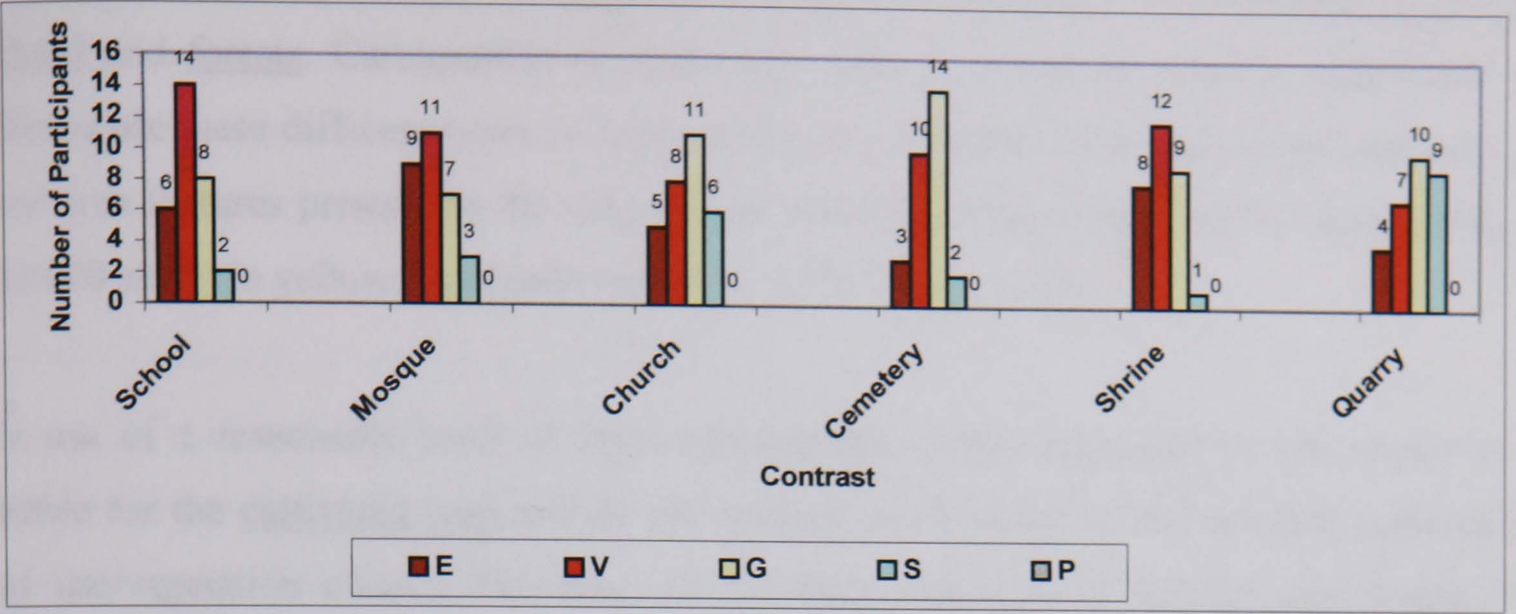

Figure 16-13: The results of the evaluation (in terms of contrast) of the symbolisation used to show the second group of cultural features given as a graphic representation.

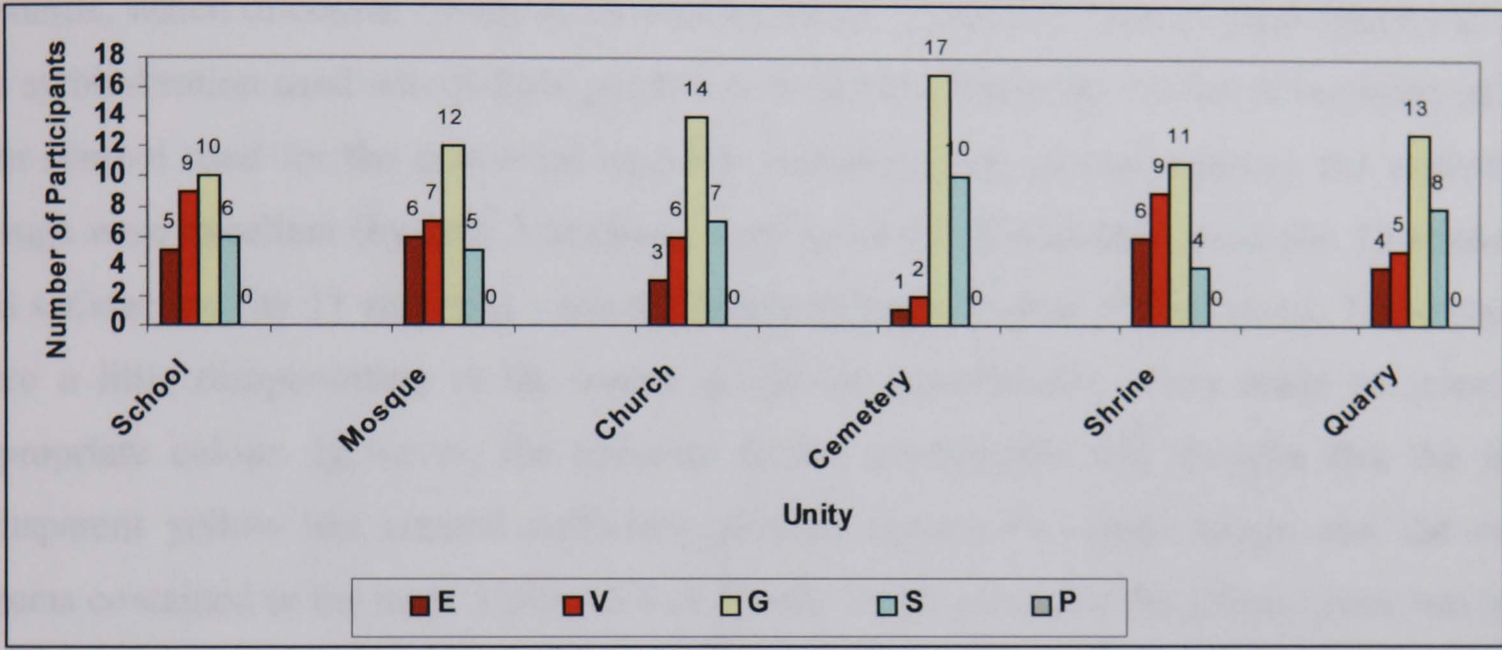

Figure 16-14: The results of the evaluation (in terms of unity) of the symbolisation used to show the second group of cultural features given as graphic representation.

Only two monuments were present in the area covered by the Misratah space image map at 1:50,000 scale. Again, a geometric point symbol – i.e. an outlined solid circle with a small dot inside – was superimposed on top of the space image. A combination of black (for the outline), yellow (solid circle) and red (small dot) had been adopted by the author and apparently provided reasonably good results. However the results presented in Table 16-7 & Figures 16-15, 16-16 and 16-17 reveal that the monument symbolisation was less successful than that used for ruins. However, in terms of clarity & legibility, contrast and unity, the results also indicate that the symbol was only received reasonably well by the majority. Obviously this particular symbol needs modification to reach a better rating by map users.

Cultural Features Representation Qs.	CLARITY & LEGIBILITY					CONTRAST					UNITY				
	E	V	G	S	P	E	V	G	S	P	E	V	G	S	P
Airport, Airfield	11	13	6	0	0	9	10	11	0	0	10	13	7	0	0
Ruins	6	4	16	3	1	4	7	14	5	0	3	8	15	4	0
Monument	3	7	11	7	2	2	5	13	9	1	1	3	9	16	1

Table 16-7: The Results of the Evaluation of the Symbolisation Used to Show the Third Group of Cultural Features – in Terms of their Clarity & Legibility, Contrast and Unity.

(v) **Land Cover/Vegetation**: This particular category of features comprises cultivated areas, orchard and forests. Cartographic symbolisation was necessary in order to emphasise and differentiate these different types of land cover and vegetation from each other and from the other area features present on the map. These area have been printed on the image map (at 1:50,000 scale) in yellow, light green and dark green, respectively.

The use of a reasonable level of light (transparent) yellow appeared to the author to be suitable for the cultivated land and its use made it much easier to differentiate between the land use/vegetation classes. However, as has been reported by several participants, this transparent colour (light yellow) was less pleasing to the eye than the light green used for orchards, which of course covers much smaller areas. Generally, most of participants felt that the symbolisation used was at least good or satisfactory. When the clarity & legibility of the area symbol used for the cultivated land was examined (by all participants), the evaluation ratings were excellent (by only 1 student), very good (by 5 students), good (by 13 students) and satisfactory (by 11 students) – see the results in Table 16-8 & Figure 16-18. These results were a little disappointing to the author given the considerable effort made to select an appropriate colour. However, the majority of the participants still thought that the light transparent yellow has created sufficient contrast against the space image and the other objects contained in the map. Table 16-8 & Figure 16-19 show that the rating given was very good (in 7 cases), good (in 9 cases) and satisfactory (in 13 cases). Only one participant felt the contrast of the symbol was poor. However, the results in Table 16-8 & Figures 16-20 show that the use of the light transparent yellow was more successful in terms of its unity or integration with background tonal image. This was largely because the area symbol used did not disturb the natural image or hide many of its important details. Several of the participants have commented that the use of transparent yellow had allowed the users to view the realistic appearance of the structure of the small fields of the cultivated land. In view of these rather disappointing results, obviously some more thought must be given to the representation of this most important category of feature.

On the other hand, the transparent light green used for orchards was more successful and apparently much more pleasing to the eyes of the map users. Most of the participants thought the symbolisation used was clear and legible and still allowed a realistic appearance of the natural background image. Indeed, the results given in Table 16-8 & Figure 16-18 reveal that the majority of participants were pleased since they rated this particular area symbol as being excellent (4 participants), very good (7 participants), good (16 participants) and satisfactory (3 participants). Most of the participants also felt that the transparent light green has created a sufficient contrast against the background image and in relation to the rest of the map symbolisation. The evaluation ratings that were given for contrast of the area symbol used were excellent (by 2 participants), very good (by 8 participants), good (by 14 participants) and satisfactory (by 6 participants) – see Table 16-8 & Figure 16-19. In general, the participants felt that the integration of the transparent light green (used to show orchards) with the space image was more successful than that of the transparent light yellow used for cultivated areas. However, from the oral explanations given by several participants, this success was partly explained by the fact that the size of the area covered by orchards was far smaller than that covered by the cultivated areas – which occupy more than 40% of the total map area. The results were really quite good since the evaluation ratings – that were given by all the participants – were excellent (in 5 cases), very good (in 11 cases), good (in 13 cases) and satisfactory (in only one case) – see Table 16-8 & Figure 16-20.

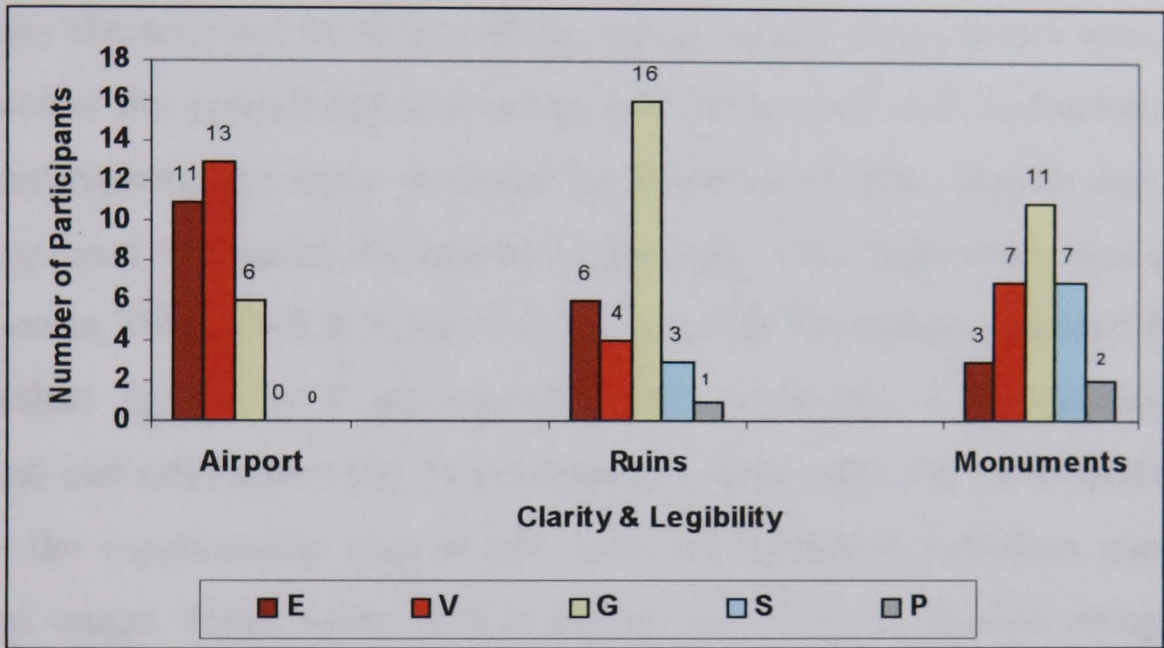

Figure 16-15: The results of the evaluation (in terms of clarity & legibility) of the symbolisation used to show the third group of cultural features given as a graphic representation.

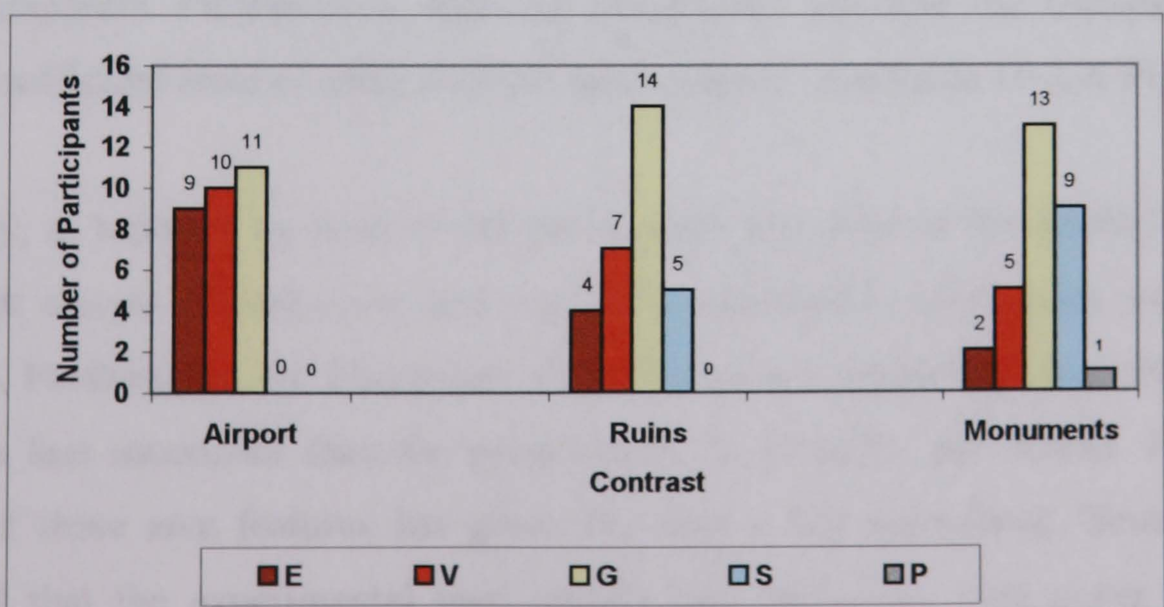

Figure 16-16: The results of the evaluation (in terms of contrast) of the symbolisation used to show the third group of cultural features given as a graphic representation.

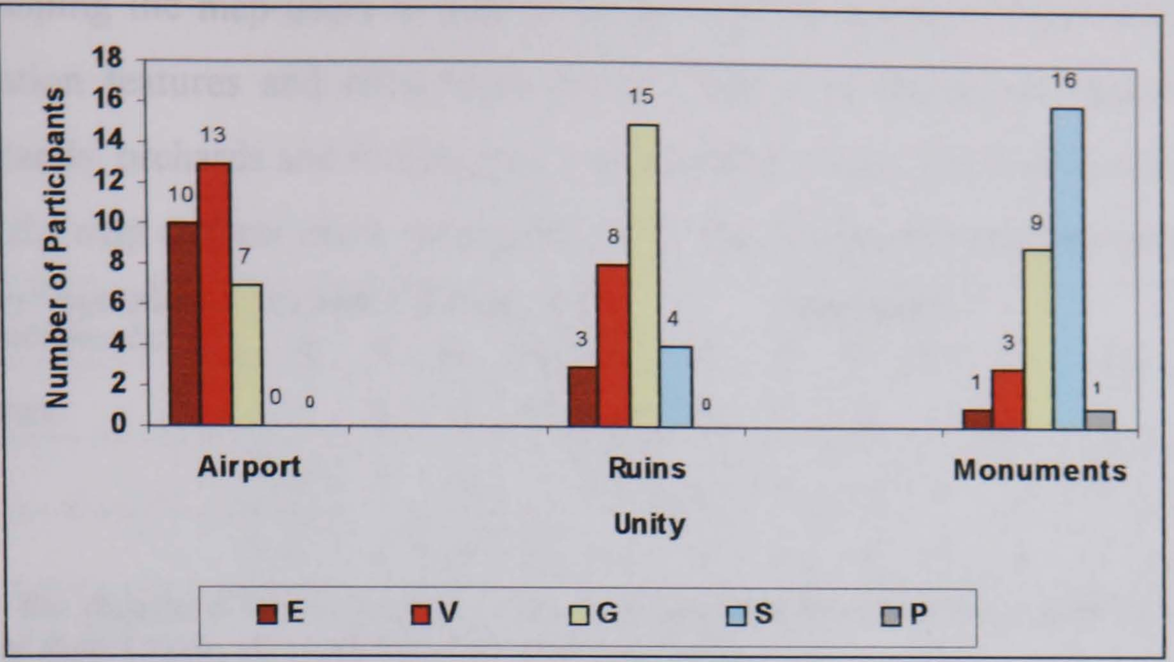

Figure 16-17: The results of the evaluation (in terms of unity) of the symbolisation used to show the third group of cultural features given as a graphic representation.

Although forests were represented using a transparent green, this important type of land use appeared very dark on the space image map of Misratah at 1:50,000 scale. Obviously, this is due to the black or near-black appearance of the forests on the actual space image. However, they are also characterised by their uniform regular shape, since, in this area, man has planted them to protect the agricultural land of the area from wind and sandstorms. As reported by most of participants, the areas occupied by forest were clear, legible and easy to identify without any need to consult the legend of the map. This impression was supported by the results given in Table 16-8 & Figure 16-18, in which the ratings provided by the evaluation were excellent (given by 2 participants), very good (by 4 participants), good (by 11 participants) and satisfactory (by 13 participants). Generally, the symbolisation used to show forests on the experimental map at this scale has achieved sufficient contrast against the background image. From Table 16-8 & Figure 16-19, the evaluation ratings were excellent (by 4 participants), very good (by 10 participants), good (by 9 participants) and satisfactory (by 7 participants). Furthermore, most of participants felt that the transparent green has achieved a sufficient level of unity with the space image – see Table 16-8 & Figure 16-20.

In summary, as reported by most of the participants, the most of the symbolisation used for the different classes of land cover and vegetation appeared to work quite well on the space image map. Furthermore, the transparent colours used were quite pleasing, although the light yellow was less successful than the greens used for orchards and forests. Furthermore the inclusion of these area features has given the map a full appearance. Several participants commented that the experimental map sample has shown the land cover and vegetation classes in a much more realistic manner than any line map, since the map users can still view the image details underneath the area symbols being used. Others, in their general comments, reported that the use of continuous outlines in solid colours was really quite successful in terms of helping the map users to define the boundaries between these different land cover and vegetation features and other open lands. They also mentioned that the inclusion of cultivated lands, orchards and forest gives much needed colour and body to the map and helps to balance the map content much more effectively than a conventional line map.

Land Cover/Vegetation Representation Qs.	CLARITY & LEGIBILITY					CONTRAST					UNITY				
	E	V	G	S	P	E	V	G	S	P	E	V	G	S	P
Cultivated Area	1	5	13	11	0	0	7	9	13	1	3	7	11	7	2
Orchard	4	7	16	3	0	2	8	14	6	0	5	11	13	1	0
Forest	2	4	11	13	0	4	10	9	7	0	1	5	10	11	3

Table 16-8: The Results of the Evaluation of the Symbolisation Used to Show Land Cover and Vegetation – in Terms of their Clarity & Legibility, Contrast and Unity.

(vi) <u>Relief Information</u>: Relief is portrayed by a combination of contour lines and spot heights. The contours had been printed in light brown so that there was a clear distinction between them and the other line work used to represent other topographic features – such as the outlines bounding the different areas of land cover and vegetation. Whereas, the spot heights and the associated numerical elevation values had been printed in black.

The experimental image map at 1:50,000 scale carries contours with 20 metre contour intervals. This appears to be quite a suitable interval for representing the relief present on the experimental image map of Misratah – in the sense that the contours do not dominate the map, so making the map look less crowded, and therefore easier to read. Although the light brown colour used appeared to be suitable (in terms of representation) for the contour lines, most of participants found it not too easy to pick up the contours against the light yellow background of the cultivated land. However, it was much easier to see them against the black and white background of the open undeveloped land and against the green colour used for the orchards. The results in Table 16-9 & Figure 16-21 give some impression about how the participants evaluated the clarity and legibility of the line symbols used for contours on the experimental map. Their evaluation scores were very good (by 3 participants), good (by 11 participants), satisfactory (by 15 participants) and poor (by only one participant). Overall the majority of participants felt that these contour lines have achieved a good or satisfactory contrast against the space image and in relation to other items of the map – see the results in Table 16-9 & Figure 16-22. Obviously, the results in Table16-9 & Figure 16-23 indicate that most of participants were more pleased with the light brown contours as far as the unity of the symbol with the space image is concerned. These participants felt that these lines rather blended with this background image and appeared relatively to form part of it. In general, seen from the author's point of view, these results were somewhat disappointing and point to the need for further experimentation with the colour used for the contours.

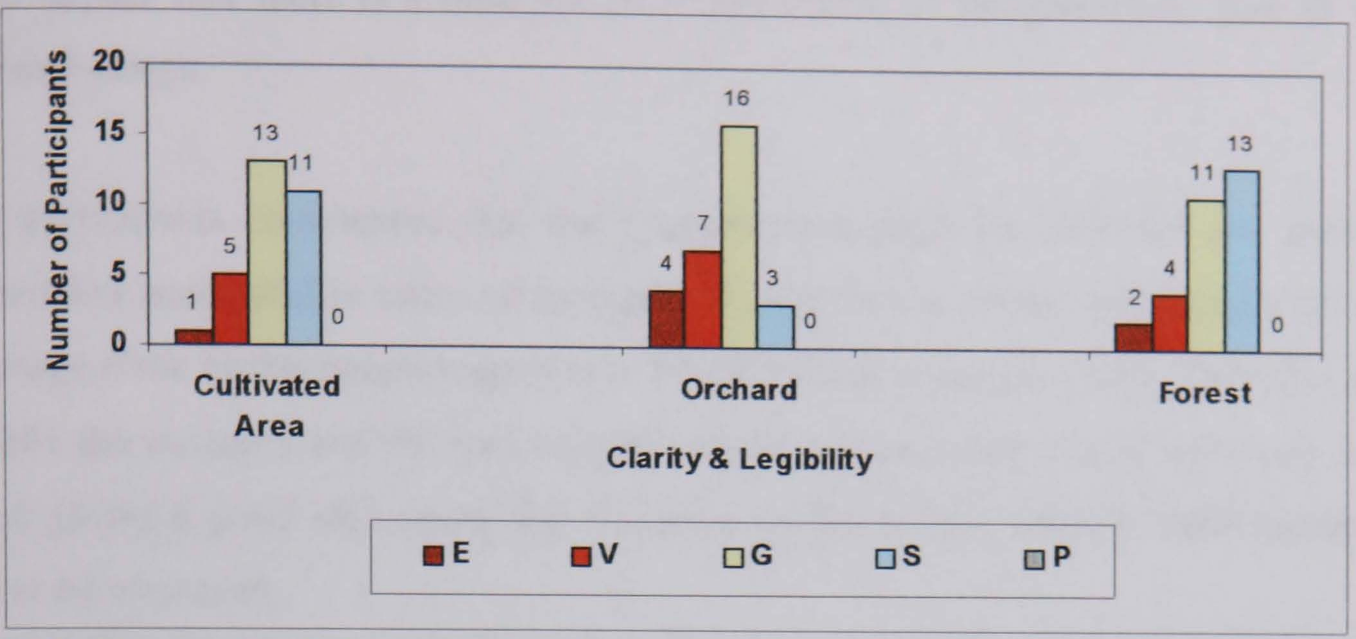

Figure 16-18: The results of the evaluation (in terms of clarity & legibility) of the symbolisation used to show the land cover and vegetation given as a graphic representation.

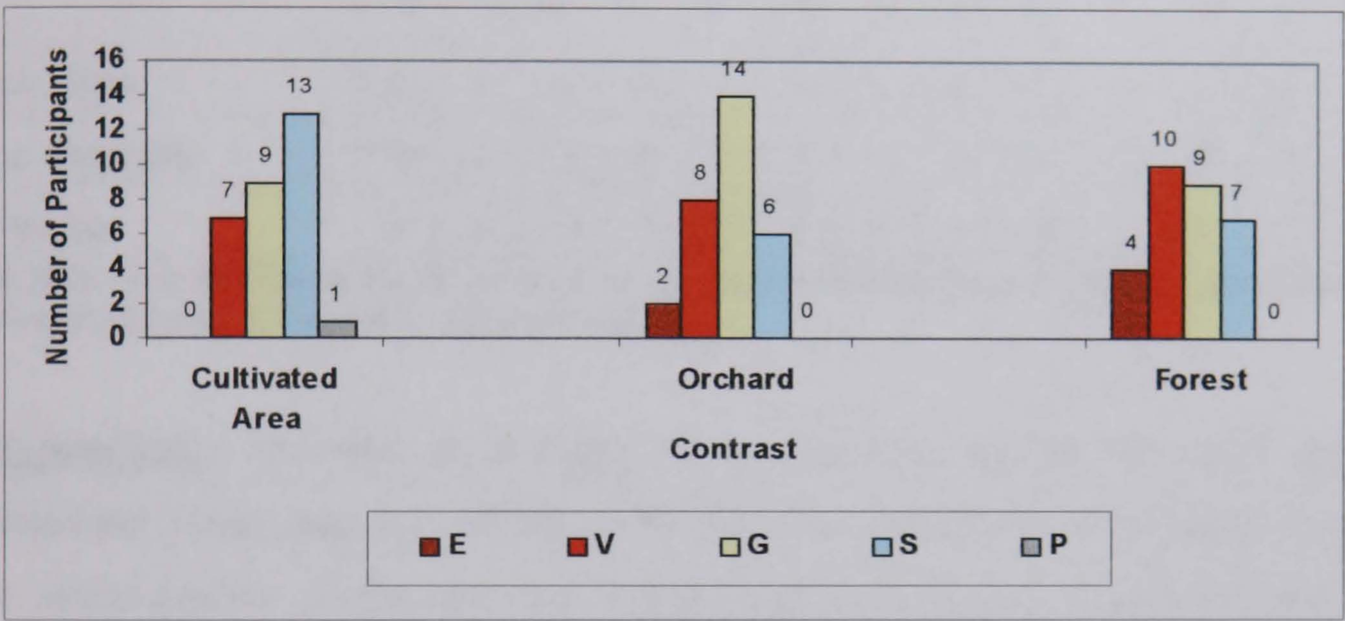

Figure 16-19: The results of the evaluation (in terms of contrast) of the symbolisation used to show the land cover and vegetation given as a graphic representation.

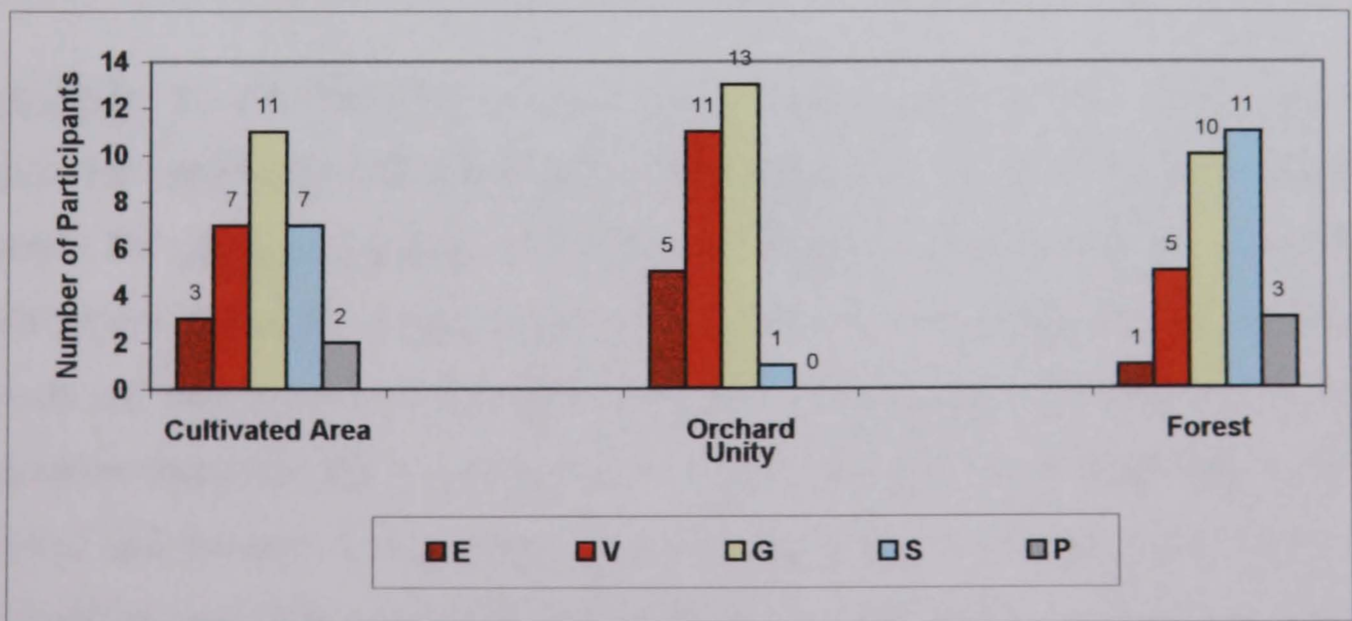

Figure 16-20: The results of the evaluation (in terms of unity) of the symbolisation used to show the land cover and vegetation given as a graphic representation.

Both the spot heights and the accompanying elevation numbers were printed in black. These black dots and numbers were very clear and legible in light areas, whereas they were not easy to see against dark areas of the background image. Table 16-9 & Figures 16-21, 16-22 and 16-

23 show how all participants felt about the symbolisation used for spot heights and elevation numbers in terms of their clarity & legibility, contrast and unity with the space image. Again it would appear that there is a need for an improvement in this particular area of the map content and design.

Several participants commented that the symbolisation used for contours and spot heights could be more successful in terms of its clarity & legibility, contrast and integration with the space image if the background image was in a light brown or sandy colour. They also reported that, while the contours and the spot heights printed on the space image were very useful in terms of giving a good idea about the elevation of the terrain surface, their representation needed to be improved.

Relief Representation Qs.	CLARITY & LEGIBILITY					CONTRAST					UNITY				
	E	V	G	S	P	E	V	G	S	P	E	V	G	S	P
Contour Lines	0	3	11	15	1	0	0	14	11	5	0	5	16	8	1
Contour Numbers	0	1	13	10	6	0	0	10	17	3	0	2	19	7	2
Spot Heights	0	0	21	7	2	0	0	8	20	2	0	0	12	11	5

Table 16-9: The Results of the Evaluation of the Symbolisation Used to Show Relief Information – in Terms of its Clarity & Legibility, Contrast and Unity.

4) Typography: In order to evaluate the performance of the text and names on the experimental image map at 1:50,000 scale, first the participants were asked to evaluate the basic characteristics of the text and names used on this map. Secondly, they were also expected to value the clarity and legibility, contrast and unity of these names with the space image.

(i) *Type Style*: In this mapping project, the major division in type style was between characters with serif forms and those without (sans serif). In this case, the serif type style was used mainly for physical features, while cultural features were named and identified using sans serif letters. From the results given in Table 16-10, it can be seen that the majority of participants felt that the type styles used were quite appropriate, since the evaluation ratings were given as excellent (by 4 participants), very good (by 11 participants), good (by 14 participants) and satisfactory (by only one participant). From the participants' point of view, the variations in type style – which is a cartographic necessity for creating hierarchies on the map – are much easily obtained from the use of sans serif styles (e.g. Helvetica) as compared with the alternative serif styles (e.g. Times Roman).

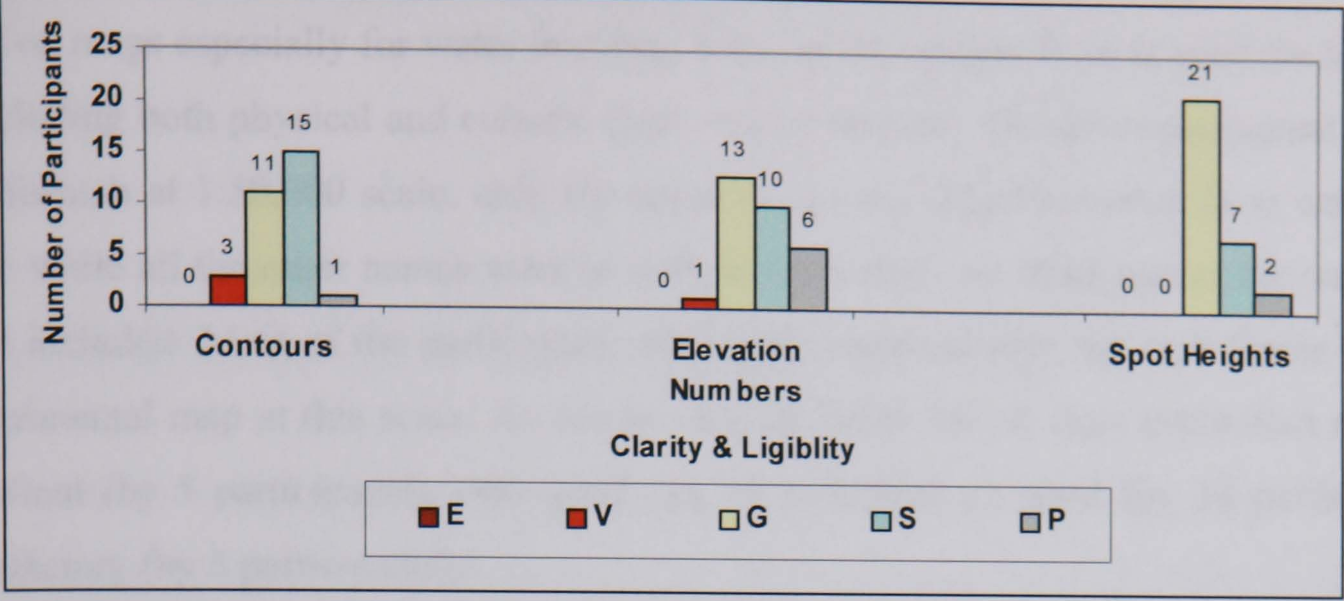

Figure 16-21: The results of the evaluation (in terms of clarity & legibility) of the symbolisation used to show the relief information given as a graphic representation.

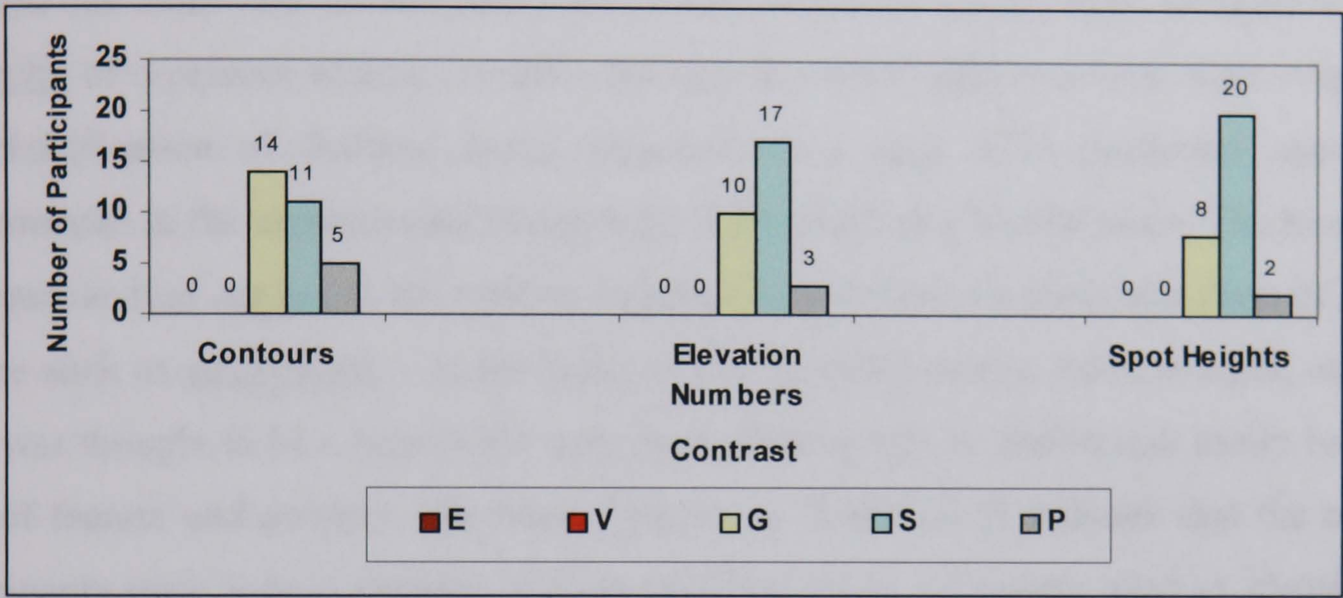

Figure 16-22: The results of the evaluation (in terms of contrast) of the symbolisation used to show the relief information given as a graphic representation.

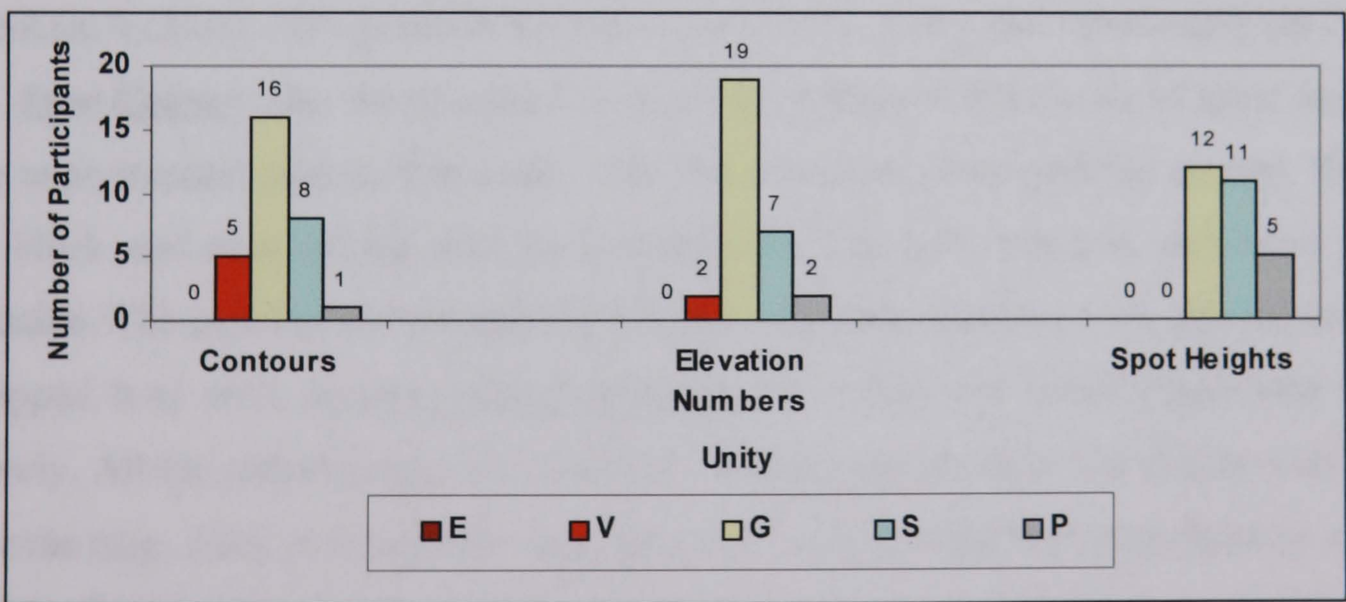

Figure 16-23: The graphic representation of the evaluation results (in terms of unity) for the symbolisation used to show the relief information.

(ii) *Type Form*: The Roman alphabet lettering system contains two quite distinct forms – i.e. upper case (or capital) letters and lower case (or small) letters. In this particular mapping project, the title, sub-title and the name of the sea have all been printed in capitals, while the other names on the map all have an initial capital letter as is expected with proper names. Furthermore, the orientation of the lettering gives two further possibilities in form, which are the upright (or Roman) form and the italic (or slant) form. Conventionally, the italic form is used on maps especially for water features, whereas the upright form is used for land features – including both physical and cultural (man-made) features. On the experimental image map of Misratah at 1:50,000 scale, only the name of the sea (Mediterranean Sea) was printed in italic while all the other names were in upright form since no other names for water features were included. Most of the participants were quite satisfied with the type forms used on the experimental map at this scale. As can be seen in Table 16-10, their evaluation ratings were excellent (by 5 participants), very good (by 10 participants), good (by 12 participants) and satisfactory (by 3 participants).

(iii) ***Type Size***: Variations in type size can often improve the differentiation and contrast between one name and another rather than using variations in type style. In many situations, a hierarchy of typefaces will be created – through the use of different type sizes – that will aid the classification of features being depicted on a map. This particular approach was implemented in the experimental image map of Misratah at 1:50,000 scale. The hierarchy that has been devised applies to the relative importance and size of a particular class of man-made feature such as settlements – in the form of towns, small towns, main villages, etc. This, in turn, was thought to be a help to the map user enabling him to distinguish easily between one type of feature and another. The results shown in Table 16-10 indicate that the majority of participants were indeed pleased with the different sizes of names used to identify various features on the map. This feeling was supported by their evaluation ratings, which were excellent (in 4 cases), very good (in 8 cases), good (in 11 cases) and satisfactory (in 7 cases).

(iv) ***Type Colour***: The use of colour in mapping is always of a matter of great importance. On the experimental map at this scale, only three colours were used for names; these were white, black and blue. Black was used mainly for the title, sub-title and other marginal information. The name of the sea and the UTM co-ordinate numbers were printed in blue. On the mapped land area, reverse (white) lettering on a relatively dark background was used effectively. All the participants in the user test reported that the text and names were readable all over the map. They evaluated the type colour as being excellent (2 participants), very good (9 participants), good (16 participants) and satisfactory (3 participants) – see the results in Table 16-10.

Basic Characteristics of typography	E	V	G	S	P
Style	4	11	14	1	0
Form	5	10	12	3	0
Size	4	8	11	7	0
Colour	2	9	16	3	0

Table 16-10: The Results of the Evaluation of the Basic Characteristics of the Typography Used to Name and Identify the Different Features on the Experimental Map at 1:50,000 Scale.

As several participants commented, the proper treatment of the basic characteristics of the typography used played an important role in achieving sufficient clarity and legibility, contrast and unity with the background image. Generally speaking, from the results presented in Table 16-11 & Figure 16-24, most of participants were pleased with regard to the printed text and names as they appeared all over the map sheet. They felt that the names and text used on the map were clear and legible due to the appropriate selection of type style, form, size and colour. The results support that conclusion since the evaluation ratings were excellent (5 participants), very good (7 participants), good (11 participants) and satisfactory (6 participants) with a poor rating given by only one participant.

Table 16-11 & Figure 16-24 show that the majority of participants felt that the names used have achieved sufficient contrast both against the space image and with respect to the other symbols that are present on the map. Some observed that the visual contrast between the type and its surroundings was a very significant factor in achieving a successful map design. Obviously the stronger the contrast, the more visible the names will be. Overall the evaluation ratings given by most of the participants were good, since they were excellent (in 1 case), very good (in 5 cases), good (in 14 cases) and satisfactory (in 8 cases) respectively and poor in one case only. From the general remarks made by several participants, the success in achieving good contrast has been attributed largely to the proper use of colour, since the white used in the land areas almost always contrasted well against the relatively dark tonal background. These results also indicate that the white colour used to show names on the space image has integrated well with the background image. The evaluation ratings given by the participants in this particular test were very good (8 participants), good (17 participants) and satisfactory (4 participants) respectively with only one participant stating that it was poor – see Table 16-11 & Figure 16-24.

Text and Names Representation	CLARITY & LEGIBILITY					CONTRAST					UNITY				
	E	V	G	S	P	E	V	G	S	P	E	V	G	S	P
Text and names	5	7	11	6	1	1	5	14	8	2	0	8	17	4	1

Table 16-11: The Results of the Evaluation of the Basic Characteristics of Typography Used to Name and Identify the Different Features – in Terms of its Clarity & Legibility, Contrast and Unity.

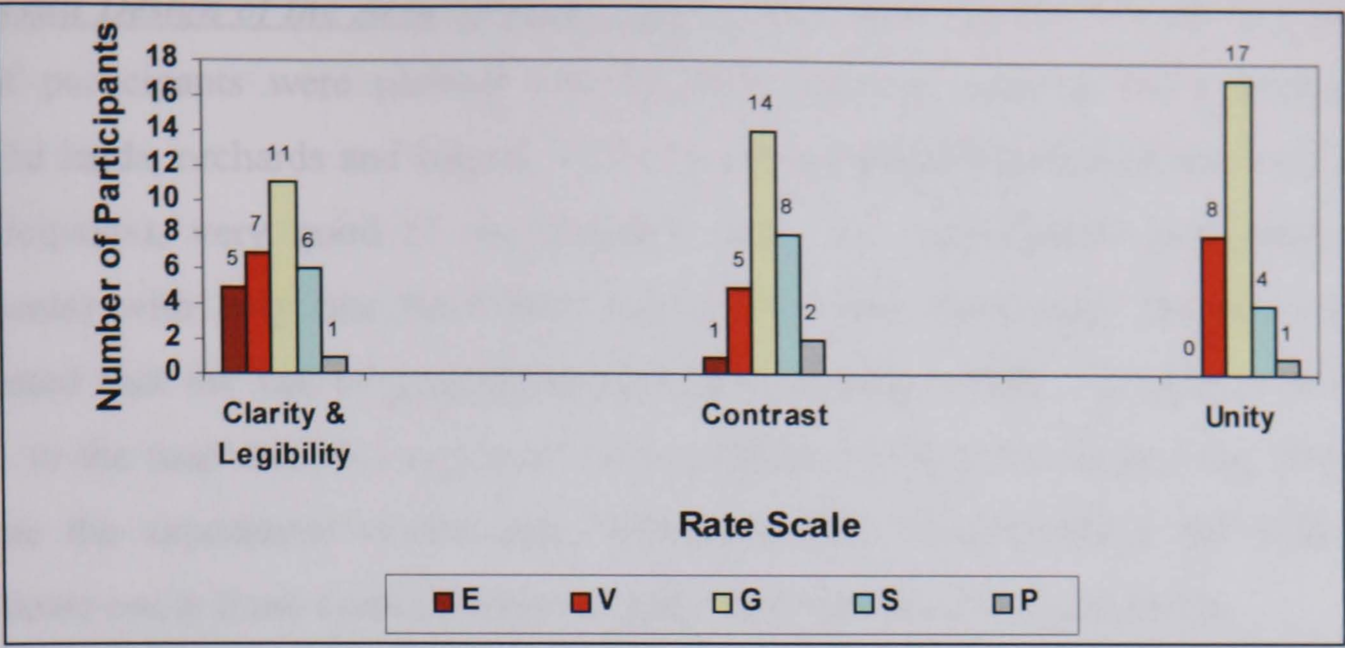

Figure 16-24: The results of the evaluation of the typography used to name and identify the different features – in terms of its clarity & legibility, contrast and unity given as a graphic representation.

5) Overall Representation in General: This sub-section of the evaluation form gave the opportunity to all the participants to examine and evaluate certain general but important elements of the experimental map produced at this scale. These were:

(i) ***Overall Design of the Point Symbols Used on the Map***: Although in image mapping in particular, point symbols are difficult to represent, the majority of participants appeared to be pleased with the design of the point symbols that had been used to show the various cultural features included on the experimental map. The results shown in Table 16-12 give a good indication that most of participants felt that the overall design of point features was quite successful. It will be seen that the evaluation ratings given were excellent (by 4 participants), very good (by 11 participants), good (by 13 participants) and satisfactory (by 2 participants). Both the abstract and pictographic point symbols were said to be quite clear and legible and have provided sufficient contrast against the other elements of the map. Moreover, the use of simplified versions of the pictographic symbols with oval frames allowed the symbols to contrast well against the space image background and has reduced the search time needed to locate the feature.

(ii) ***Overall Design of the Line Symbols Used on the Map***: In the participants' view, the design of the line symbols was quite good. This impression was supported by the results shown in Table 16-12, in which evaluation scores of excellent (7 participants), very good (9 participants), good (10 participants) and satisfactory (4 participants) were given. When all the participants examined the roads, they were all fairly satisfied and agreed that the linear symbols used for roads were effective and well designed. All the road symbols were thought to have been arranged within a good hierarchy through the appropriate use of the graphic variables (i.e. form, dimension and colour).

(iii) ***Overall Design of the Area Symbols Used on the Map***: As can be seen in Table 16-12, most of participants were pleased with the area symbols used to show built-up areas, cultivated lands, orchards and forests. The evaluation ratings that were given were excellent (2 participants), very good (7 participants), good (11 participants) and satisfactory (9 participants) with only one participant stating that they were poor. Several participants commented that the use of transparent area colours with outlines brought a better visual balance to the map and also appeared more realistic while, at the same time, they did not dominate the appearance of the map. Moreover, the outlines helped the map users to discriminate easily these areas of improved land from open undeveloped lands.

(iv) ***Name Placement***: Generally, the majority of participants felt that the number of names that had been included was appropriate and their placement on the image map were reasonably successful. The evaluation ratings that were given were excellent (by 3 participants), very good (by 8 participants), good (by 13 participants) and satisfactory (by 5 participants), only one participant giving a poor rating – see Table 16-12. However, several participants asked specifically why the author did not include Arabic names and lettering on this experimental map. To answer these participants, a full oral explanation had to be given by the author about the non-availability of adequate financial resources to buy the Arabic fonts needed to include Arabic names and text in this mapping project.

(v) ***Grid***: From the test, it appears that the selection of the grid size (5,000 x 5,000m) was appropriate and the participants felt that it did not dominate or disturb other elements of the map. The comments were that the blue lines could be clearly seen against the background image, while all the participants found that the inclusion of a full grid was very useful in allowing them to define the location of features on the experimental map using a grid reference. The relevant evaluation scores were excellent (from 10 participants), very good (from 8 participants), good (from 10 participants) and satisfactory (from 2 participants) as shown in Table 16-12.

(vi) ***Co-ordinate Numbers***: As stated by most of the participants in the test, the co-ordinate numbers for both the UTM and the geographical co-ordinate systems that had been printed around the body of the map were clear and legible. To aid the map user to differentiate between the co-ordinate systems, the UTM had been printed in blue, while black had been used to show the geographical co-ordinates. The results in Table 16-12 were in favour of this representation of these co-ordinate numbers, since the participants have rated them as being excellent (5 participants), very good (9 participants), good (11 participants) and satisfactory (5 participants).

(vii) ***Background Colour***: When compared to the other elements of the map, the colour of the background image (black and white) was less successful. The majority of participants felt it was merely satisfactory; and revealed in their comments that, if a light brown or sandy colour had been used, then the appearance of the image map would have been better in terms of being more realistic of the actual terrain. This impression was quite apparent since the participants have evaluated the background colour as being very good (only 1 participant), good (8 participants), satisfactory (19 participants), and poor (2 participants) – see Table 16-12. There was an obvious lesson to be learned from these comments, although initial trials to implement this suggestion have not been too successful.

The Overall Representation in General	E	V	G	S	P
Point Symbol Selection	4	11	13	2	0
Line Symbol Selection	7	9	10	4	0
Area Symbol Selection	2	7	11	9	1
Lettering Placement	3	8	13	5	1
Grid	10	8	10	2	0
Co-ordinates Numbers	5	9	11	5	0
Background Colour	0	1	8	19	2

Table 16-12: The Results of the Evaluation of the Overall Representation in General

6) **Arrangement & Layout**: This sub-section attempted to gain information from the users about certain other important aspects of the map design which, if not treated properly, might affect the appearance of the final map product. These elements such as title, scale, legend and marginal information should be clear and put together in a well-balanced manner, which would please the eye and make the map more successful. The questionnaire attempted to find out how the participants felt about these aspects of the map design.

(i) ***Title***: This was positioned at the top of the sheet and centred over the main body of the map. All the participants were pleased with the placement of the title and with the lettering used: it was judged to be very clear and very easy to read. It is obvious from the results in Table 16-13 & Figure 16-25 that the clarity of the title used on the map has been highly rated by all the participants. The evaluation rate given by these participants was excellent (11 participants), very good (13 participants) and good (6 participants). The appropriate selection of the basic characteristics (style, form, size and colour) of the type used to design the title gave the map a better appearance and good visual balance. In this respect, the respective evaluation ratings were excellent (14 participants), very good (11 participants) and good (5 participants) – see Table 16-13 & Figure 16-26.

(ii) *Scale*: Both the numerical expression and the relevant graphic scales were provided on the experimental map. The numerical expression has ensured that the map users would be aware of the scale of the map from their first inspection. However, as reported by the majority of participants, the graphic scale was more useful for measuring or estimating distances. Both sets of scale details were clear and legible, since the results in Table 16-13 & Figure 16-25 reveal that the relevant evaluation ratings were excellent (given by 7 participants), very good (by 14 participants), good (by 7 participants) and satisfactory (by 2 participant). Furthermore, the general opinion of the users was that the layout of the scale information on the map was well balanced and quite clear. Obviously, the results in Table 16-13 & Figure 16-26 confirm this impression with the ratings being given as excellent (by 12 participants), very good (by 9 participants), good (by 8 participants) and satisfactory (by only 1 participant).

(iii) *Legend & Marginal Information*: The legend was provided at the bottom of the sheet and contained the explanations of the symbols, scale, index to the adjoining sheets, etc. The marginal information has been kept as simple as possible. The neat line serves as the border of the map. The grid numbers lie outside the neat line, as do the five-minute values of latitude and longitude. From the users' point of view, the information provided by this arrangement of the legend and marginal information (including both the text and symbolisation) was said to be clear and legible and, in turn, easy to use. The results (see Table 16-13 & 16-25) show that most of participants found it easy to consult the legend whenever they needed to do so. The evaluation ratings given were excellent (by 9 participants), very good (by 11 participants) and good (by 10 participants). The results provided in Table 16-13 & Figure 16-26 also provide an indication that most of the participants were pleased with the balance of the map legend with the respective ratings given as excellent (by 6 participants), very good (by 12 participants), good (by 9 participants) and satisfactory (by 3 participants).

Arrangements & Layout Qs.	CLARITY					BALANCE				
	E	V	G	S	P	E	V	G	S	P
Title	11	13	6	0	0	14	11	5	0	0
Scale	7	14	7	2	0	12	9	8	1	0
Legend & Marginal Information	9	11	10	0	0	6	12	9	3	0

Table 16-13: The Results of the Evaluation of the Arrangement and Layout of the Map

7) Overall Appearance of the Image Map: The design of an individual map has an effect upon its usefulness as well as its general acceptability as a map. From the map maker's point of view, it is always necessary to involve the real users in assessing the readability, the balance in terms of contrast, and the use of colour and the practicality of the format size of the finally produced map. Of course, the map users' feed back will (or should) help to improve the design and production of the map in the future.

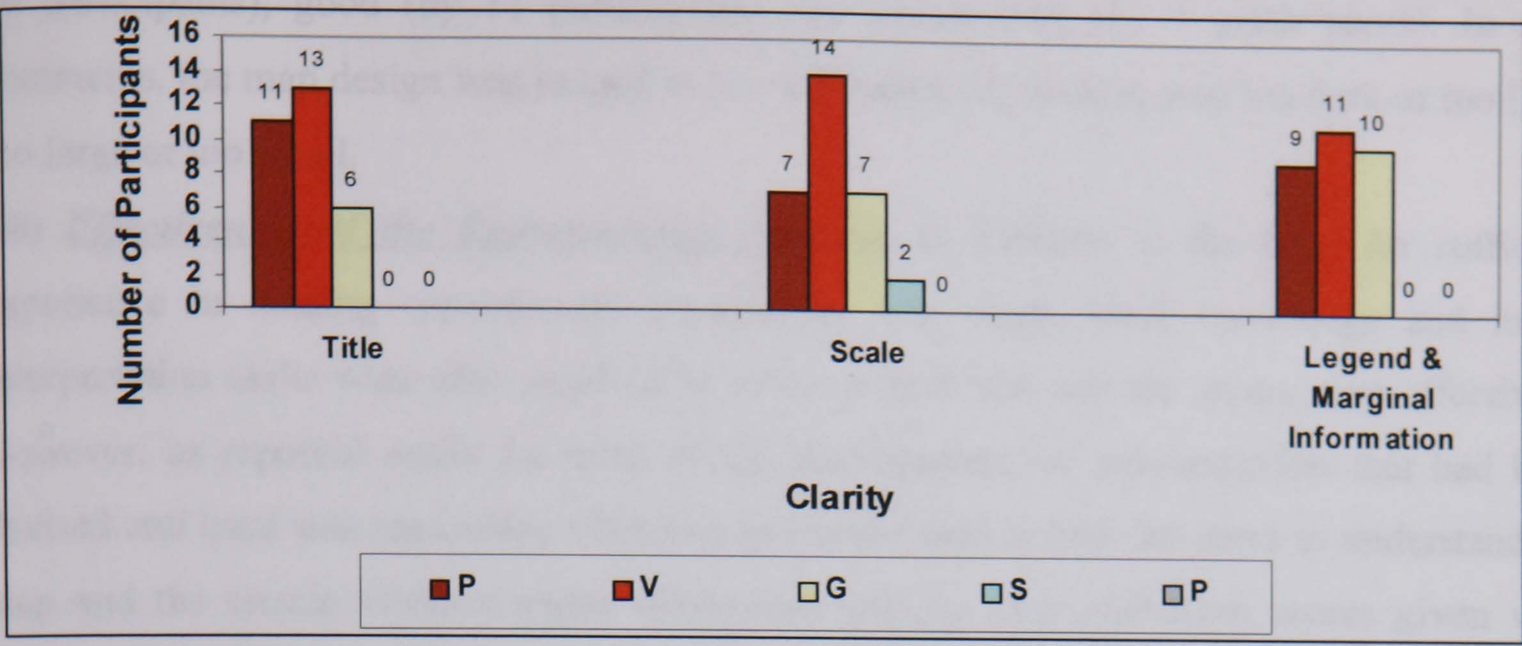

Figure 16-25: The results of the evaluation of the arrangement & layout elements of the map – including the clarity of the title, scale and legend and marginal information.

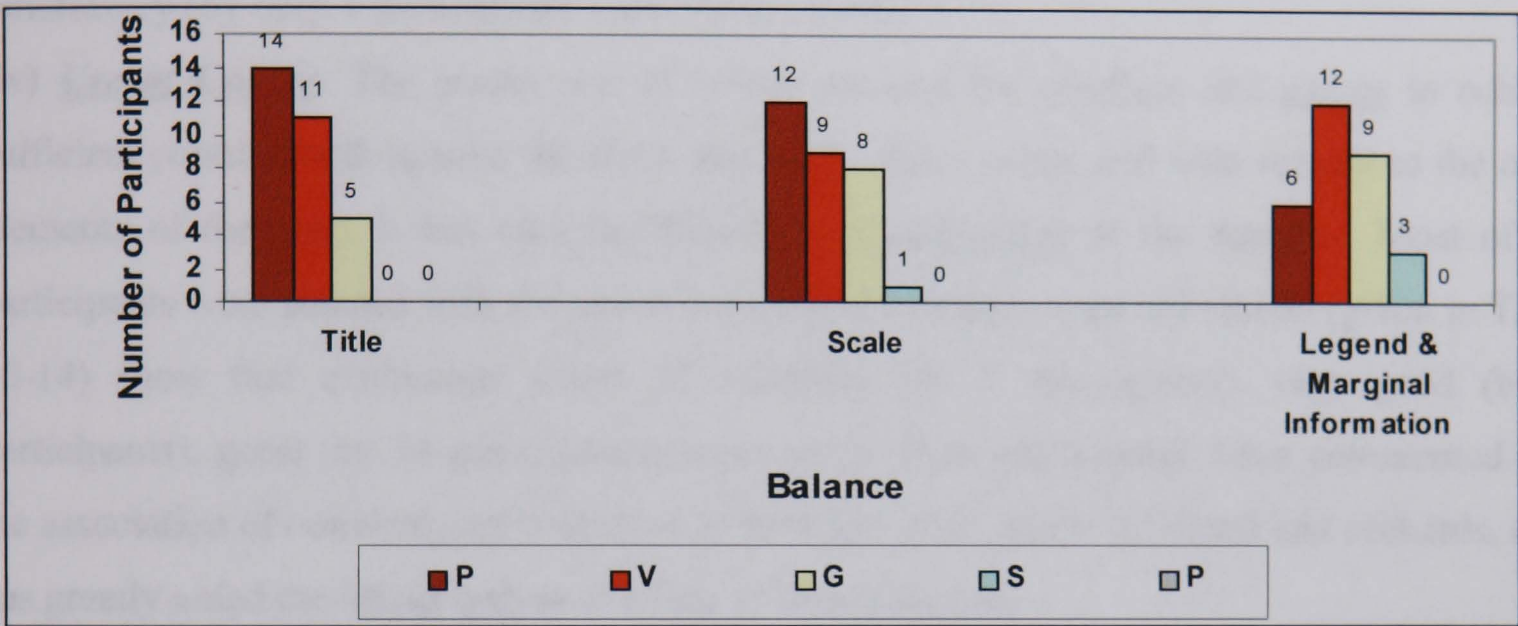

Figure 16-26: The results of the evaluation of the arrangement & layout elements of the map – including the balance of title, scale and legend and marginal information.

(i) ***Readability***: This particular point has been restricted to denoting the ability of the map reader or user to locate certain point, line and area information or specific names, that are generally associated with the ordinary topographic map. Generally, all participants found the experimental map at 1:50,000 scale reasonably clear and easy to read. In this respect, the evaluation scores (see Table 16-14) were excellent (in 4 cases), very good (in 9 cases), good (in 12 cases) and satisfactory (in 5 cases). Several participants commented that the legend was only consulted for more explanations on very few occasions.

(ii) ***Balance (Contrast)***: The question about balance was, in this case, more concerned with the overall contrast of all visual components (e.g. symbols, names etc.), both against the space image and in relation to the other items contained in the map. Since the map had been produced to meet general reference purposes, the domination of any group or class of features was avoided. From the results in Table 16-14, it was obvious that the majority of participants found the experimental image map (at this scale) to be well balanced in terms of its overall contrast. The respective evaluation ratings were excellent (by 6 participants), very good (by

10 participants), good (by 11 participants) and satisfactory (by 3 participants). In their comments, the map design was judged to be well balanced; nothing was too dark or too light, too large or too small.

(iii) ***Effectiveness of the Representation Method***: In addition to the need for sufficient experience in reading conventional topographic line maps, local knowledge and image interpretation skills were also required in order to read and use the image map effectively. However, as reported orally by most of the participants, the representation that had been devised and used was reasonably effective and useful and helped the users to understand the map and the terrain without undue difficulties arising. The evaluation scores given were excellent (by 3 participants), very good (by 7 participants), good (by 19 participants) and satisfactory (by only 1 participant) – see Table 16-14.

(iv) ***Use of Colour***: The proper use of colour allowed the symbols and names to achieve sufficient contrast both against the black and white space image and with respect to the other elements of the map. It has also facilitated the classification of the features. Most of the participants were pleased with the use of colour in the design, since the results (given in Table 16-14) show that evaluation scores of excellent (by 7 participants), very good (by 9 participants), good (by 14 participants) were given. Four participants have commented that the association of conventional colours (e.g. blue for water, green for forest and orchards, etc.) has greatly aided the identification of many of these features.

(v) ***Practicality of the Format Size***: The size of the map has been kept to the format that has been commonly used in Libya. Therefore, for the new image map series, the same rectangular formats and sheet sizes that have been used in the existing 1:50,000 scale topographic map series of the Surveying Department of Libya have been utilized. Thus, as might be expected, none of the participants faced any difficulties with regard to the sheet size while they were examining the experimental image map. From the results given in Table 16-14, it was quite clear that all the participants were thoroughly satisfied with the format or sheet size used for this image map at 1:50,000 scale. This impression was supported by the results of the evaluation with ratings of excellent (by 3 participants), very good (by 9 participants), good (by 11 participants) and satisfactory (by 7 participants). The general comment made by several participants was that the experimental map was quite easy to handle during the evaluation test. From their previous experience with the conventional topographic line maps of Libya at 1:50,000 scale (which had been printed using the same format size), most of the participants stated that the experimental map would be quite manageable both in the office and in the field.

Overall Appearance of the Image Map	E	V	G	S	P
Readability	4	9	12	5	0
Balance (contrast)	6	10	11	3	0
Effectiveness of method	3	-	19	1	0
Use of Colour	7	9	14	0	0
Practicality Of Format Size	3	9	11	7	0

Table 16-14: The Evaluation Results of the Overall Appearance of the Image Map

8) <u>Overall Rating of the Image Map</u>: At the end of **Section I**, the participants were given an opportunity to examine and evaluate the <u>overall design and appearance</u> of the experimental map of Misratah at 1:50,000 scale. The results in Table 16-15 indicate that overall the participants were quite pleased with the image map produced at this scale. These results reveal that the participants rated its overall design as being excellent (in 2 cases), very good (in 7 cases), good (in 16 cases) and satisfactory (in 5 cases). But with an average rating of good, it is plain that there is still room for improvement in the design of the map. The author will try to improve the score in future!

Over All Rating	E	V	G	S	P
	2	7	16	5	0

Table 16-15: The Results of the Overall Rating of the Experimental Space Image Map at 1:50,000 Scale.

16.5 <u>Section II</u>: Comparison between the Experimental Space Image Map and the Topographic Line Map (at 1:50,000 Scale and Covering the Same Area)

In this Section (II), the participants were expected to compare the performance of the experimental image map with the existing topographic line map at the same scale (1:50,000) covering the same area of Misratah. As can be seen in Table 16-16, many questions were included, which cover the design aspects of both map products. These included information content, representation, layout, suitability for depicting the terrain surface, etc.

1) <u>The Level of Detail Contained in Both Map Products</u>: Unsurprisingly, all participants reported that the <u>information content</u> of the experimental space image map is much higher than that of the conventional line map. Table 16-16 shows that the results were strongly in favour of the new type of space image map – as far as the level of detail is concerned. Obviously, when evaluating the <u>space image map</u>, the evaluation ratings given were excellent (by 8 participants), very good (by 10 participants) and good (by 12 participants) respectively. On the other hand, the corresponding scores given to the <u>topographic line map</u> were excellent (2 participants), very good (5 participants), good (8 participants), satisfactory (11 participants) and poor (4 participants) – see Table 16-16. As has been explained orally by most of these participants, the <u>space image</u> itself contains a much greater amount of detail, which can give a great deal of additional information regarding the characteristics of the terrain and the features present in the area. Furthermore, the introduction of additional information in the form of conventional symbols and names gave many of the qualities of a conventional line map, plus the detailed additional descriptive quality of the space imagery.

Comparison Questions	Exp. Space Image Map					Topo. Line Map				
	E	V	G	S	P	E	V	G	S	P
The level of detail in both map products.	8	10	12	0	0	2	5	8	11	4
The number of categories and classes of features in both maps.	4	9	13	4	0	7	11	12	0	0
The representation of point features in both types of map.	5	13	11	1	0	0	1	8	15	6
The representation of line features in both types of map.	6	10	13	1	0	0	0	6	16	8
The representation of area features in both types of map.	4	8	11	7	0	0	3	9	13	5
Relief depiction in both maps.	0	4	10	14	2	5	7	13	5	0
Text and Name placement in both maps.	3	8	11	7	1	1	5	16	5	3
The use of colour in both maps	6	10	12	2	0	0	0	0	9	21
Map Arrangements and Legend	5	9	16	0	0	0	3	10	16	1
The overall rating for both map products.	2	8	14	6	0	0	4	7	17	2
The use and suitability of both maps for the area and the users.	9	13	8	0	0	0	6	11	9	4

Table 16-16: The Results of the Comparison between the Experimental Space Image Map and the Topographic Line Map (at 1:50,000 Scale and Covering the Same Area).

2) The Number of Categories and Classes of Features in Both Maps: The results given in Table 16-16 confirm that most of participants felt that the number of categories and classes of features included in the experimental space image map were fewer than those included in the topographic line map of the SDL. However, in the case of the space image map, the inclusion of the maximum level of information had deliberately been avoided, since this would have disturbed the appearance and the final map design and concealed more of its valuable detail. On the other hand, the space image itself presents an enormous amount of basic information about the terrain, which has been represented in much more realistic manner than could be achieved by any line map.

3) The Representation of Point Features in Both Types of Map: From the results given in Table 16-16, it is clear too that all participants felt that the representation of point features on the space image map was far better than it was on the topographic line map. In the case of the space image map, the evaluation ratings given to the point symbolisation were excellent (by 5 participants), very good (by 9 participants), good (by 11 participants) and satisfactory (by only 1 participant). On the other hand, the evaluation ratings given to the topographic line maps were very good (by only 1 participant), good (by 8 participants), satisfactory (by 15 participants) and poor (by 6 participants). When examining the experimental image map, several participants reported that the good quality design (especially of the point symbols) resulted from the appropriate cartographic treatment of these objects. Particularly, the good use of colour seemed to be the essential factor involved in producing clear point symbols that have achieved a good contrast against the background image and with respect to other items of the map.

4) **The Representation of Line Features in Both Types of Map:** When the participants examined the representation of the line features included on the experimental space image map, they found the extensive use of line symbols where different colours had been used to show roads and to act as the outlines for the area features. From Table 16-16, the evaluation ratings given to the representation of the linear features on the experimental space image map, were excellent (by 6 participants), very good (by 10 participants), good (by 13 participants) and satisfactory (by only 1 participants). By contrast, most participants, when testing the topographic line map, felt that the lack of use of colour together with the use of less appropriate line forms had resulted in a less successful representation. In this particular respect, the evaluation ratings (see Table 16-16) given by the participants, for the topographic line map were good (by 6 participants), satisfactory (by 16 participants) and poor (by 8 participants). Several participants commented that they experienced confusion between some of the linear symbols and, quite often, they had to consult the legend of the conventional line map to identify them.

5) **The Representation of Area Features in Both Types of Map:** In certain types of topography, such as areas of sand dunes and tidal flats, swampy areas, and areas of distinctive land cover and vegetation, the space image provides a superior representation and gives far more information than is possible on the conventional type of line map. However, a proper cartographic treatment still needs to be added to identify and delineate less appropriate various areas and to aid their interpretation and speed up the search time needed to locate them. For example, in the case of the space image map, the majority of participants felt that the effective use of the transparent colours used on the map was far more realistic and effective in representing the various important areas of the terrain. The relevant evaluation ratings that were given were excellent (by 4 participants), very good (by 8 participants), good (by 11 participants) and satisfactory (by 7 participants). The representation of area features in the case of the topographic line map was far less successful than that of the space image map. The corresponding evaluation ratings that were given were very good (by 3 participants), good (by 9 participants), satisfactory (by 13 participants) and poor (by 5 participants).

6) Relief Depiction in Both Maps: Relief was depicted on both map products using contour lines and spot heights. A large number of the participants thought that the symbolisation adopted to show these elevation informations on the space image map was reasonably successful. However, the majority of these participants pointed out that the use of black dots and black lines was more successful in the case of the topographic line map. Of course, this success was due to the presence of white space, against which the black symbols will always contrast well. The results of examining the relief depiction on the space image map given in Table 16-16 show that the evaluation ratings given were very good (by 4 participants), good (by 10 participants), satisfactory (by 14 participants) and poor (by 2 participants). In their general remarks, they mentioned that the representation of the fine lines against the black and white space image was not really successful. By comparison, the evaluation ratings given to the representation of relief on topographic line map was more successful being accorded excellent (by 5 participants), very good (by 7 participants), good (by 13 participants) and satisfactory (by 5 participants). As mentioned previously, this is a matter that will have to be attended to in the future if image mapping is to be adopted in Libya. An improved method of representation has to be found.

7) Text and Name Placement in Both Maps: For the experimental image map, the fact that there is a continuous background image has led to the necessity for much greater care and judgement in the depiction and placement of names, since the convenient white spaces of the conventional line map were absent. Generally, most of the participants felt that the level of names included in the space image map was appropriate. Furthermore, in their opinion, other elements such as name placement, the appropriate selection of the basic characteristics of type and the proper use of colour had been treated carefully and in a reasonably successful manner. Mostly the text and names were clear and legible all over the image map. The evaluation ratings given by the participants were excellent (by 3 participants), very good (by 8 participants), good (by 11 participants), satisfactory (by 7 participants) and poor (by only 1 participants) – see Table 16-16. On the other hand, although they felt that the topographic line map had the distinct advantage of having adopted a dual language approach (Arabic and English), in their opinion, the name placement was not handled properly. They also felt that the black colour used for text and names gave the map a rather heavy appearance and a crowded look.

8) The Use of Colour in Both Maps: As reported by nearly all participants, colour had been used effectively to show the different symbols of the experimental space image map of

Misratah at 1:50,000 scale. This allowed the symbols and names to be clear and legible and to achieve a good contrast against the space image and in relation to other symbols of the map. The use of colour also facilitated the classification and the differentiation of features and made it easier for the map user to read the map. From the results in Table 16-16, the evaluation ratings given to the use of colour (in the case of the space image map) were excellent (by 6 participants) very good (by 10 participants), good (by 12 participants) and satisfactory (by 2 participants). However, most of participants felt that the lack of use of colour gave the line map a poor appearance and made it much more difficult to read, so that the map users had to consult the legend continuously. This opinion was reflected in the evaluation ratings given to the topographic line map (see Table 16-16) which were said to be merely satisfactory (by 9 participants) and poor (by 21 participants).

9) Map Arrangement: From the results given in Table 16-16, there was the clear indication that the participants quite liked the map arrangement and layout of the space image map and thought that it rather more successful than the arrangement used with the topographic line map. According to them, all the elements were in the correct position and gave a good visual balance. The evaluation ratings given were excellent (by 5 participants), very good (by 9 participants) and good (by 16 participants) – see Table 16-16. In the case of the topographic line map, the ratings given were very good (3 participants), good (10 participants), satisfactory (16 participants) and poor (only 1 participant).

10) The Overall Rating of Both Map Products: Overall most of the participants felt that overall the performance of the experimental space image map was more successful in terms of its information content, representation and appearance. The results in Table 16-16 & Figure 16-27 support this impression, since the ratings given were excellent (by 2 participants), very good (by 8 participants), good (14 participants) and satisfactory (by 6 participants). While the corresponding evaluation ratings given to the topographic line map were very good (by 4 participants), good (by 7 participants), satisfactory (by 17 participants) and poor (by 2 participants).

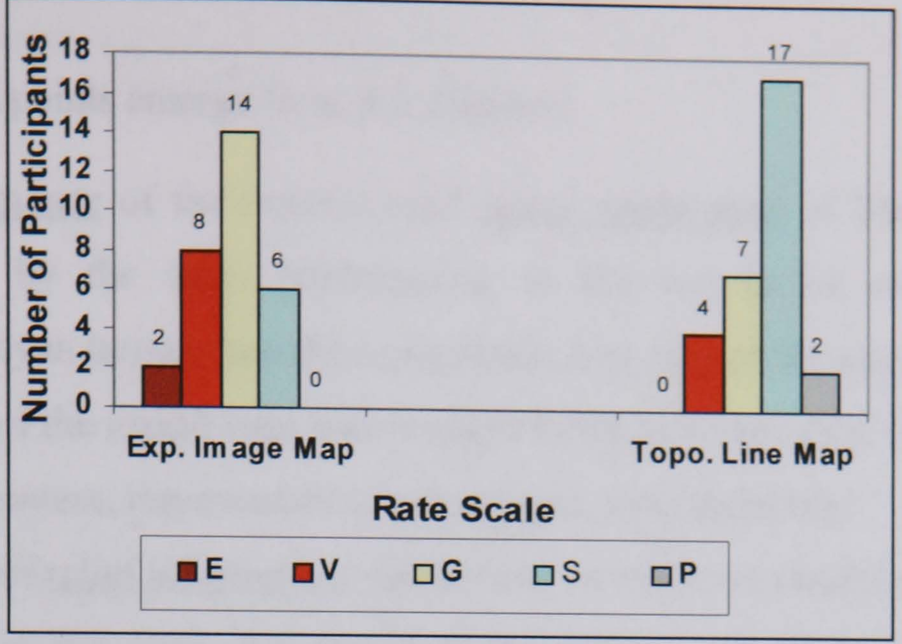

Figure 16-27: The results of the evaluation of the overall rating of both products shown as a graphic representation.

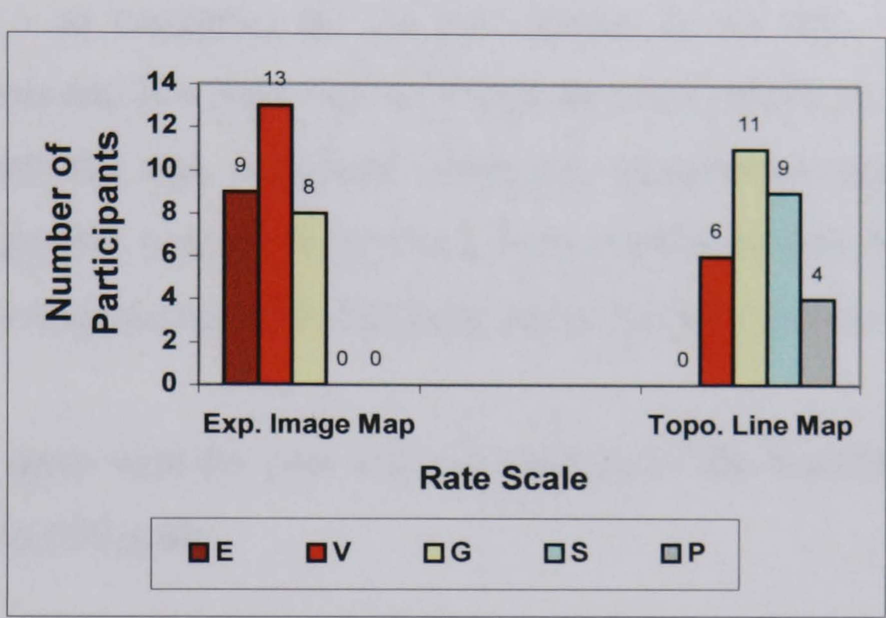

Figure 16-28: The results of the evaluation of the comparison between the experimental space image map and the topographic line map (at 1:50,000 scale and covering the same area) given as a graphic representation.

11) <u>The Use and Suitability of Both Maps for the Test Area</u>: In this particular user test, all the participants were pleased with the performance of the experimental space image map in showing the terrain through the use of the space image as a background together with the additional valuable symbolic information added on top of it. As can be seen from the results presented in Table 16-16 & Figure 16-28, the evaluation ratings that were given were in favour of the space image map, since it was rated excellent (in 9 cases), very good (in 13 cases) and good (in 8 cases). Whereas, the corresponding evaluation ratings given to the topographic line map were very good (in 6 cases), good (in 11 cases), satisfactory (in 9 cases) and poor (in 4 cases). Several participants made specific comments that the space image map really was a more suitable product to show the Libyan terrain surface, particularly in those areas where the landscape is dominated by physical features and contains relatively few man-made objects.

16.6 Conclusion

A number of important points emerge from this chapter:

(1) The overall performance of the experimental space image map of Misratah at 1:50,000 scale was judged by the users participating in the test to be more successful in representing the Libyan terrain than the topographic line map of the same area and at same scale. The success of the image map was its superiority as a cartographic product in terms of its information content, representation, appearance, and readability.

(2) The representation of relief information was held to be more successful on the topographic line map. Obviously this particular aspect of the space image map design needs to be improved. In this context, it may be that the use of a light brown or sandy (colour) background image – as suggested by the participants in the test – may improve the appearance of the dots and fine lines used to depict the relief details on the space image.

(3) All of the participants felt that, in general terms, the experimental space image map is a more suitable cartographic product for use in Libyan conditions and should be adopted to replace the 1:50,000 scale topographic line map series that is in present day use.

The next Chapter (17) deals with the user test and analysis of the experimental space image map of Misratah at 1:250,000 scale.

CHAPTER 17: USER TEST & ANALYSIS OF THE EXPERIMENTAL 1:250,000 SCALE SPACE IMAGE MAP

17.1 Introduction

The user test of the experimental space image map at 1:50,000 scale and the subsequent analysis of the results have been discussed in some detail in the previous Chapter (16). The experimental space image map was evaluated by a group of potential users (30 participants) both regarding its information content, representation and appearance and its use and practicality, as well as its suitability to show the different terrain features that are present in the test area. In general, as described in Chapter 16, the majority of participants were reasonably pleased with the overall performance of the experimental map, especially when compared with the existing topographic line map that covers the same area at the same scale (1:50,000). This new chapter deals with the corresponding user test and analysis for the second experimental space image map produced at 1:250,000 scale. Obviously, the level of detail that can be accommodated and its cartographic representation were both affected by the large reduction in scale from 1:50,000 to 1:250,000. Therefore, the same thirty participants were asked to evaluate the quite different space image map at 1:250,000 scale in an attempt to test its quality and overall performance. The results of their evaluation and the subsequent analysis will be described in the following sections.

17.2 The Design and Content of the Evaluation Form

The same evaluation form (Appendix VI) that had been used to test the 1:50,000 scale map, has also been used to evaluate the experimental space image map at 1:250,000 scale. However, due to the scale change, the participants were not asked to evaluate certain features – those marked with an asterisk sign (*) on the form – that were too small to be included in this smaller scale (1:250,000) space image map of Misratah. As noted before, the questions were very clear, simple and purely factual and could be answered in a straightforward and direct manner. The same evaluation scale (E, V, G, S and P) was used and the participants were encouraged to write general comments whenever they wish to justify, expand or modify their answers.

17.3 Material and Method

For the purpose of the test, each of these participants was given the following materials:

(i) The four page evaluation form;

(ii) The experimental space image map of Misratah at 1:250,000 scale that has been produced during the present project; and

(iii) Three map sheets from the existing topographic line map series at 1:50,000 scale, since no 1:250,000 scale line maps of the area were available for the purpose of the user test.

The test of the 1:250,000 scale space image map was carried out on 18th and 19th March 2000. As with the 1:50,000 image map, the evaluation test for this map was also conducted in ten individual sessions (five sessions a day). In each single session, the author was dealing with three participants only. Obviously from their experience with the previous map, all the participants were familiar with the evaluation form and the procedures to be followed in the user test. However, the author also gave some oral instructions and explanations to the participants during the time of the test. The author's intention in this chapter is not to repeat any of the discussion and analysis of the 1:50,000 scale space image map that was covered in the previous Chapter (16). Instead, the discussion and analysis will be concentrated on the more specific matters and differences occurring with the 1:250,000 scale image map.

17.4. Section I: The Evaluation of the Space Image Map (1:250,000 Scale)

As described in Chapter 16, this Section was also broken down into eight sub-sections, which were then divided into categories and classes of features.

1) Map Content: All the participants noted that the reduction in scale has affected the amount and type of information contained both in the natural space image and in the additional symbology added on top of it. This meant that, as the scale became smaller, the smaller details could not be identified on the space image. Furthermore, due to the large scale reduction, certain small man-made features such as schools, mosques, water towers, etc. were not included on this smaller scale image map – otherwise the map detail would become too crowded and difficult to read, especially in the built-up areas.

(i) *Question 1*: *The level of information displayed by the natural space image*. Although the space image mosaic covers a larger area than the image used in the case of 1:50,000 scale experimental image map, due to the scale change, this mosaic did not display many of the smaller features that are present in the terrain. As can be seen in Table 17-1 and Figure 17-1, the results show that the majority of participants felt that the level of information shown on this image was good (10 participants) or satisfactory (14 participants). However, in their general remarks, several participants commented that the image mosaic has provided a wider view of the terrain, which enables the map user to have a better idea regarding the overall topography, drainage system, land cover and vegetation, etc. of the test area.

(ii) *Question 2*: *The level of detail added through cartographic elements*. Several participants commented that, since the scale was much smaller, there was a greater need for cartographic treatment and the inclusion of additional cartographic elements in order to increase the readability of the image map and ease the interpretation task. As mentioned previously, only a medium level of detail could be added through cartographic symbolisation and annotation at this scale. However, this was still rated by the participants as being excellent (in 3 cases), very good (in 6 cases), good (in 13 cases) and satisfactory (in 8 cases) respectively. Several participants commented that the overlay of the symbology and names on top of the space image mosaic added considerably to its appearance and utility.

(iii) *Question 3*: *The number of categories included to emphasise important features*. As noted by all participants, no difficulties were experienced regarding the number of categories that had been utilized in the experimental image map at this smaller (1:250,000) scale. The results in Table 17-1 and Figure 17-1 indicate that overall the evaluation ratings that were given by these participants were good, since they were rated excellent (by 4 participants), very good (by 9 participants), good (by 12 participants) and satisfactory (by 5 participants). Actually, the ratings given by these participants were very similar to the corresponding ratings given when they evaluated the number of categories included in the 1:50,000 scale space image map of Misratah.

(iv) *Question 4*: *The level of classification made to distinguish or differentiate between features within the same category*. As the scale became smaller, certain small features have not been included in the 1:250,000 scale space image map. However, other small but very important features have been retained. This meant, for example, that, although features such as wells, minor roads and tracks are very small in dimension, they have still been shown on the experimental map because of their importance to the map users. Obviously, wells are the only source of water in the area; while minor roads and tracks are the only communication lines in the southern part of the area covered by the map. In general, most of participants were satisfied with the number of classes included within each individual category – see the results in Table 17-1 & Figure 17-1.

Question No.	Map Content Questions	E	V	G	S	P
Question 1	Level of information displayed on the natural space image.	0	4	10	14	2
Question 2	Level of detail added through cartographic elements.	3	6	13	8	0
Question 3	Number of categories included emphasising important features.	4	9	12	5	0
Question 4	The level of classification made to distinguish between features within the same categories.	3	8	10	9	0

E= Excellent V= Very Good G= Good S= Satisfactory P= Poor

Table 17-1: The Results of the Answers to the Four Questions Included in Sub-section Number 1.

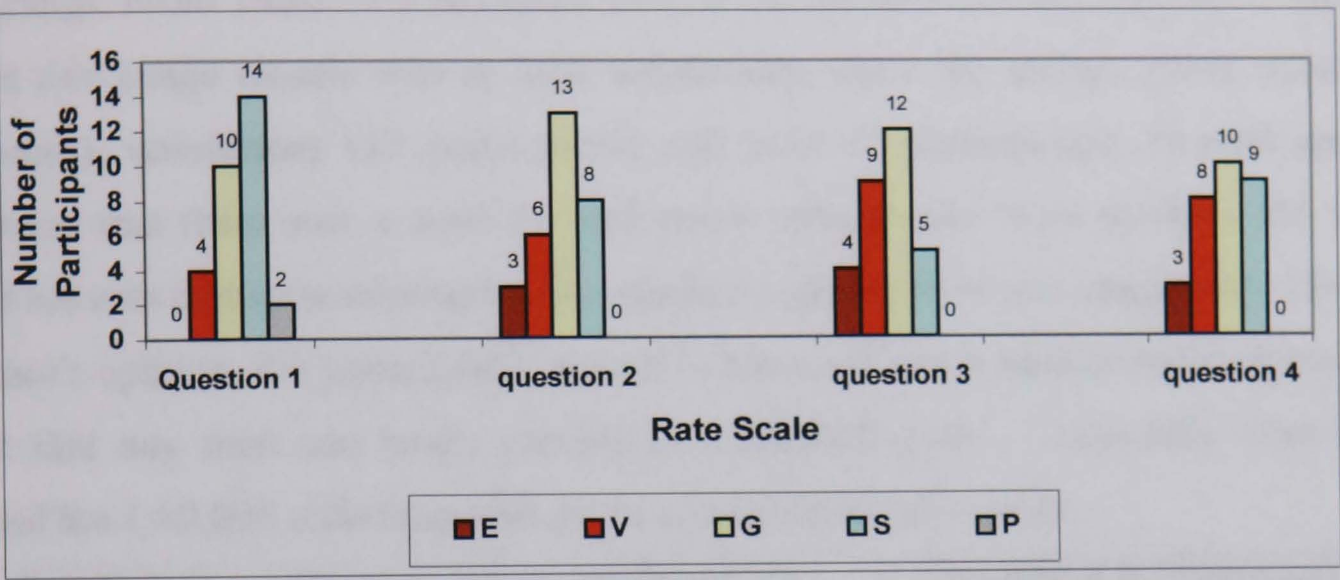

Figure17-1: The results of the answers to the four questions included in sub-section 1 shown as a graphic representation.

2) **Background Image**: Again, the reduction in scale has affected the image quality in terms of displaying both the physical and the cultural features that are present in the area. In fact, due to the scale change, many features that appeared on the 1:50,000 scale space image have simply disappeared on the 1:250, 000 scale image mosaic.

(i) ***Question 1***: *The quality of the space image mosaic in displaying physical features of the terrain*. All the participants noted that the appearance of the area's physical features on the space image mosaic at 1:250,000 scale was much less detailed than that of the space image used with the 1:50,000 scale image map. Thus this image mosaic was less successful in showing the smaller physical features (e.g. gullies) that exist on the terrain. However, most of participants still thought that the image mosaic was good in displaying physical features – in particular, in depicting the medium and large physical features such as the overall topography, the drainage system, and so on. In their opinion, the image mosaic gave them a good general view about the area covered by the image. Furthermore, most of this information would be very useful for all the various map users. As can be seen in Table 17-2 & Figure 17-2, the ratings given by the participants were very good (in 9 cases), good (in 12 cases), satisfactory (in 8 cases) and poor (in only 1 case) respectively.

(ii) ***Question 2***: *The quality of the space image mosaic in displaying the cultural (man-made) features of the terrain*. All the participants agreed that the representation of the cultural features on the space image mosaic was not very successful. Of course, this resulted from the scale reduction and the consequent lack of a high ground resolution. Also, in many cases, there was insufficient contrast between these cultural (man-made) features and their surroundings. From Table 17-2 & Figure 17-2, it can be seen that the majority of participants felt that this image mosaic was at least satisfactory, since the ratings given were good (6 participants), satisfactory (17 participants) and poor (7 participants). Several participants commented that there was a need for still more cartographic work to show the important cultural features that were missing on this smaller scale experimental image map. However, in the author's opinion, the participants seemed to have too much high an expectation as to the content that any map can really provide at 1:250,000 scale – especially after they had inspected the 1:50,000 scale map with all its greater detail previously.

Question No.	Background Image Questions	CLARITY & CONTRAST				
		E	V	G	S	P
Question 1	The display quality of physical features	0	9	12	8	1
Question 2	The display quality of cultural (man-made) features	0	0	6	17	7
Question 3	The display of all features in general	0	1	11	15	3

E= Excellent V= Very Good G= Good S= Satisfactory P= Poor

Table 17-2: The Results of the Answers to the Three Questions Included in Sub-section Number 2.

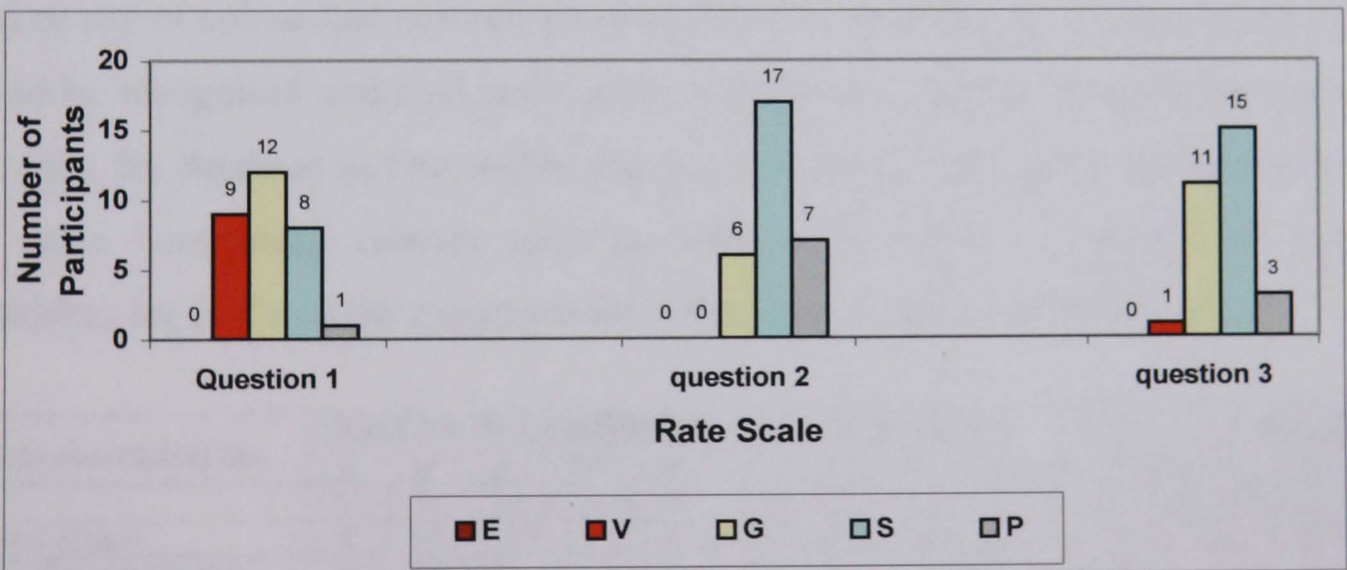

Figure17-2: The results of the answers to the three questions included in sub-section 2 shown as a graphic representation.

(iii) ***Question 3***: *The quality of the space image mosaic in displaying all type of features on the terrain*. Generally, although the image mosaic was not highly successful in terms of displaying all the different types of features present on the terrain surface, still the great majority of participants were reasonably pleased with its performance. As noted by many of these participants, the background image provided by the SPOT Pan scenes can still provide a considerable amount of detail regarding the terrain surface that is not provided by the traditional form of line map and would be very useful for the various types of user. The results in Table 17-2 & Figure 17-2 indicate that the ratings given were very good (by only 1 participant), good (by 11 participants), satisfactory (by 15 participants) and poor (by 3 participants).

3) **Symbolisation**: Although the reduction in scale has affected both the map information content and the method of representation, to a certain extent, the overall representational techniques that had been utilized by the author were similar to those used when designing the larger scale (1:50,000) space image map. Thus, the author sees no point in repeating the accounts given in previous chapters. Instead, only where different techniques of symbolisation had been used will the evaluation results be given in the next sections. As before, the evaluation regarding the design of the symbolisation of the different features was based on the clarity & legibility and the contrast of the symbol, both against the background image and also in relation to other map elements; and the unity or integration of each individual symbol with respect to the space image.

(i) **Road Detail**: Generally, as can be seen from the results in Table 17-3, the majority of the participants were pleased with regard to the symbols used for roads – this was in terms of their clarity & legibility, contrast and unity. In their general remarks, they commented that the appropriate use of colour had ensured good quality line symbols and a classification for roads that could be recognised and read quite easily without any need to consult the legend of the map. In fact, the decrease in line width, due to the scale change, has been balanced with the use of quite contrasting colours such as white and yellow to ensure an appropriate representation for roads on the experimental space image map at 1:250,000 scale.

Road Representation Qs.	CLARITY & LEGIBILITY					CONTRAST					UNITY				
	E	V	G	S	P	E	V	G	S	P	E	V	G	S	P
Highway	5	9	16	0	0	2	10	17	1	0	4	12	11	3	0
Main Paved Road	8	14	8	0	0	6	11	13	0	0	3	8	18	1	0
Secondary Paved Road	3	12	14	1	0	4	9	17	0	0	1	7	16	4	0
Unpaved Road	7	11	12	0	0	3	12	13	2	0	5	10	12	3	0
Track	4	9	17	0	0	1	10	14	5	0	3	12	10	5	0

Table 17-3: The Results of the Evaluation of the Symbolisation Used to show Roads – in Terms of its Clarity & Legibility, Contrast and Unity.

(ii) **Water Features**: Not too many differences were used in the representation of water features. The main difference was the non-inclusion of water towers due to scale limitations. Besides, since springs are a very important source for water and present on the terrain surface being covered by the image mosaic, this caused the author to include Ain (spring) Kaam –

which was shown using a geometric point symbol. In order to differentiate springs from wells, a solid circle in 100% cyan outlined with black was used to show the springs on the experimental image map at this scale.

Generally speaking, most of participants (see the results in Table 17-4) felt that the symbolisation adopted to show those water features was reasonably satisfactory. In particular, the comment was that, although the symbols used to show springs and wells were very small in size, these symbols were still easy to read all over the map. Actually, several of the participants commented specifically that the use of circles and the 100% cyan, white and black has provided a successful result in terms of their representation. The results in Table 17-4 indicate that the participants were reasonably pleased with the symbolisation utilized to show the various classes of water features.

Water Features Representation Qs.	CLARITY & LEGIBILITY					CONTRAST					UNITY				
	E	V	G	S	P	E	V	G	S	P	E	V	G	S	P
Sea	6	9	12	3	0	3	11	14	2	0	1	5	13	11	0
Coastline	2	5	15	8	0	0	1	15	12	2	0	0	10	17	3
Well	7	8	14	1	0	2	10	13	5	0	4	9	12	6	0
Spring	4	10	13	3	0	2	8	16	4	0	2	7	17	4	0

Table 17-4: The Results of the Evaluation of the Symbolisation Used to Show Water Features – in Terms of its Clarity & Legibility, Contrast and Unity.

(iii) Cultural Features: Inevitably the representation of certain cultural features has been affected by the scale reduction from 1:50,000 to 1:250,000. For example, the main villages and villages could no longer be represented using areal symbols, since these features are very small in size at the much smaller scale and it was more appropriate to show them using point symbols. The airport also became rather small and could hardly be recognised without additional cartographic treatment. This meant, using a point symbol to depict this type of cultural feature. Furthermore, other very small features such as schools, mosques, churches, isolated buildings and monuments have not been included in the specification for the 1:250,000 scale map due to the resulting scale limitations. Consequently this meant that the towns and small towns have been depicted through the use of areal symbols, while the rest of the cultural features have all been shown by point symbols.

For towns and small towns, again, a transparent magenta has been used, but, in this case, the transparent colour has been made darker since the area of the features became twenty-five (5x5) times smaller. In the author's opinion, although the map users could not view much of the underlying image detail, the use of the transparent magenta was still appropriate and appeared relatively natural and did not disturb the overall appearance of the experimental image map. When evaluating the symbolisation used for towns and small towns, most of participants thought the symbology used was good or satisfactory – see the results in Table 17-5. In their opinion, the symbolisation used was clear and legible and achieved a good contrast against the space image and in relation to other map elements; while still appearing sufficiently unified with the background image.

Cultural Features Representation Qs.	CLARITY & LEGIBILITY E	V	G	S	P	CONTRAST E	V	G	S	P	UNITY E	V	G	S	P
Town	0	7	13	10	0	3	9	12	6	0	1	8	17	4	0
Small Town	0	3	10	14	3	1	3	16	10	0	0	2	11	13	4

Table 17-5: The Results of the Evaluation of the Symbolisation Used to Show Towns and Small Towns – in Terms of its Clarity & Legibility, Contrast and Unity.

Both the main villages and the villages were depicted using solid orange circles and black outlines. While, the differentiation between these two classes of cultural feature was made through changes in the circle size. Large circles were used for the main villages, whereas small circles were to show villages. The results in Table 17-6 show that all the participants were fairly pleased with the symboliztation used to display these man-made features. The symbols used for main villages and villages were thought to be clear and legible, achieved a very good contrast with their background and integrated well with the space image. Indeed, according to their general remarks, these point symbols were easy to read all over the image map. Moreover the three solid magenta squares with black outlines were judged to be suitable in showing settlements on the map. Again, the majority of participants felt that the symbol used was reasonably successful and could be read easily – see the results in Table 17-6.

Cultural Features Representation Qs.	CLARITY & LEGIBILITY E	V	G	S	P	CONTRAST E	V	G	S	P	UNITY E	V	G	S	P
Main Village	10	14	6	0	0	7	11	12	0	0	5	9	13	3	0
Village	6	11	13	0	0	4	16	8	2	0	3	11	10	6	0
Settlement	4	8	16	2	0	2	10	13	5	0	1	8	11	10	0

Table 17-6: The Results of the Evaluation of the Symbolisation Used to Show Main Villages, Villages and Settlements – in Terms of its Clarity & Legibility, Contrast and Unity.

For the other cultural features (cemetery, shrine and quarry) that had been included in the map, white squares were used as frames for black symbols. All the participants rated the symbolisation used quite highly – see the results in Table 17-7. Several of the participants commented that the use of these white frames has increased the clarity and contrast of these black point symbols. Furthermore, they were regarded as being self-explanatory and easy to understand even without the help of the legend. A large number of the participants also felt that the successful selection of a good colour combination has provided well designed and point symbols that could be recognised all over the experimental map produced at this smaller scale.

Although the point symbol used to represent the airport on the experimental map at 1:250,000 scale was fairly successful in terms of both the form and the colour combination used, most of participants felt that the size of this point symbol was a rather smaller than it should be. However, it was quite evident from the comments that the symbol used was still fairly clear and legible against the space image; it also achieved a sufficient contrast and integrated well with the background image mosiac – see the results in Table 17-7.

For ruins, much the same form and colour of the point symbol that was used on the 1:50,000 scale map was also used on this smaller scale map. However, the scale change did force the designer to reduce the size of this point symbol. Still, notwithstanding this change, the results in Table 17-7 indicate that the majority of participants rated the performance of the symbolisation used to depict ruins on the experimental map as good.

Cultural Features Representation Qs.	CLARITY & LEGIBILITY					CONTRAST					UNITY				
	E	V	G	S	P	E	V	G	S	P	E	V	G	S	P
Cemetery	2	10	12	6	0	4	9	11	6	0	3	8	14	5	0
Shrine	4	9	14	3	0	7	10	9	4	0	2	7	11	10	0
Quarry	6	15	9	0	0	5	12	10	3	0	4	9	9	8	0
Airport, Airfield	3	8	12	7	0	2	9	12	7	0	1	5	17	7	0
Ruins	5	11	14	0	0	4	13	9	4	0	4	9	11	6	0

Table 17-7: The Results of the Evaluation of the Symbolisation Used to Show the Other Cultural Features – in Terms of its Clarity & Legibility, Contrast and Unity.

(iv) **Land Cover/Vegetation**: Due to the scale reduction, the areas of land cover and vegetation became much smaller than on the 1:50,000 scale. Consequently, the transparent colours used for the cultivated lands (yellow), orchards (green) and forest (dark green) have deliberately been made darker in order to achieve the required contrast. Actually, all the participants were happier concerning the transparent yellow used to show the cultivated areas at this scale than on the 1:50,000 scale map. According to their comments, this colour was more successful in terms of its representation of these areas and was more pleasing to the eye of the viewer. Indeed, the yellow used on this smaller scale image map was deemed to be clear and well balanced and achieved a good contrast and integrated well with the space image. Besides which, the appropriate selection of colour allowed the creation of a useful classification that increased the readability of the map and helped the map user to discriminate these area features from open land and the built-up areas, etc. Generally, most of participants were fairly satisfied with the symbology used to show the land cover and vegetation on the map – see the results given in Table 17-8.

Land Cover/Vegetation Representation Qs.	CLARITY & LEGIBILITY					CONTRAST					UNITY				
	E	V	G	S	P	E	V	G	S	P	E	V	G	S	P
Cultivated Area	5	9	13	3	0	6	10	12	2	0	3	8	16	3	0
Orchard	7	11	12	0	0	8	13	9	0	0	5	11	14	0	0
Forest	3	7	10	9	1	1	9	16	4	0	8	14	8	0	0

Table 17-8: The Results of the Evaluation of the Symbolisation Used to Show Land Cover and Vegetation – in Terms of its Clarity & Legibility, Contrast and Unity.

(v) Other Area Features: Obviously, the sabkhas or salt marshes cover a large area of the south eastern part of the Misratah region. Most of participants felt that the transparent colour that have been used has enhanced the appearance of the sabkhas and emphasised their contrast with the other open land. However, unfortunately, the dark appearance of these features on the space image did not permit the extraction of any useful detail within the marshy areas. Several participants commented that the use of the appropriate names in white has helped the identification of the sabkhas' location and extent. In general, as can be seen from the results in Table 17-9, a large number of the participants felt that the symbolisation used was good or satisfactory. In their opinion, it was quite easy to locate the sabkhas on the map and the cartographic symbolisation used did not disturb the appearance of the final map.

Other Area Features' Representation Qs.	CLARITY & LEGIBILITY					CONTRAST					UNITY				
	E	V	G	S	P	E	V	G	S	P	E	V	G	S	P
Sabkha (Salt March)	2	9	14	5	0	0	7	12	8	3	4	10	13	3	0

Table 17-9: The Results of the Evaluation of the Symbolisation Used to Show Other Area Features – in Terms of its Clarity & Legibility, Contrast and Unity.

(vi) Relief Information: From their first inspection during their examination of the experimental map at 1:250,000 scale, the great majority of participants noticed that no contour lines had been included on the map. Several participants through oral discussion complained about the non-inclusion of contours. Of course, the author explained fully the reasons behind not showing contours on this smaller scale map – namely the non-availability of data in the shape of contours in digital form or a topographic line map covering the same area. However, at the same time, the author would certainly ensure that contours would be shown if the suggested new space image map series of Libya at 1:250,000 scale is implemented.

As a result, only spot heights were available for relief information on the map: these were depicted in a black colour on the actual map. The results in Table 17-10 show that most of participants thought that the representation of these spot heights on the map was good or satisfactory. According to their general remarks, these spot heights were relatively easy to read and useful since they were the only means of relief information.

Relief Representation Qs.	CLARITY & LEGIBILITY E	V	G	S	P	CONTRAST E	V	G	S	P	UNITY E	V	G	S	P
Spot Heights & Elev. Numbers	0	5	17	8	0	0	6	14	9	1	0	10	13	7	0

Table 17-10: The Results of the Evaluation of the Symbolisation Used to Show Relief Information – in Terms of its Clarity & Legibility, Contrast and Unity.

4) Typography: To a large extent, the basic characteristics of the type used to specify and print names and text on the experimental map at 1:250,000 scale, were similar (in terms of type style and form) to those shown on the 1:50,000 scale map. The overall scale reduction forced the designer (i.e. the author) to reduce the size of all the names in order to ensure a sufficient visual balance and still meet the specifications for content. Consequently, the decrease in the size of names has made them more difficult to deal with in terms of their legibility, contrast and integration with the space image. However, most of participants were still reasonably pleased with the type style and form adopted for names on this smaller scale image map – see the results given in Table 17-11.

Basic Characteristics of typography	E	V	G	S	P
Style	6	9	13	2	0
Form	8	10	12	0	0
Size	4	7	10	7	0
Colour	5	11	14	0	0

Table 17-11: The Results of the Evaluation of the Basic Characteristics of Typography Used to Name and Identify the Different Features on the Experimental Map at 1:250,000 Scale.

(i) *Type Size*: A hierarchy of typefaces had been created using different type sizes in order to help facilitate the classification of various classes of feature. Again, this was mainly done to emphasize the relative importance and the real size of a specific class of man-made features – e.g. between the towns, small towns, main villages and villages. The results in Table 17-11 indicate that a large number of participants were reasonably happy with the different sizes of the names used to identify various features on the map.

(ii) *Type Colour*: The restrictions imposed by the scale led to a reduction in the size of the names in order to meet the specifications of the 1:250,000 scale topographic mapping. Therefore, to make these names legible and to create sufficient contrast against the black and white space image, a wider range of colours (such as blue, black, white and magenta) have been used. As noted by most of participants, the effective and successful use of these colours has made the names readable all over the experimental space image map. Obviously, the majority of these participants felt that the colours selected were very good or good – see the results given in Table 17-11. Actually, a number of participants noted specifically in their general comments, that the use of more colours did indeed facilitate the classification of features and helped the participants to distinguish one feature from another. As can be seen from the results in Table 17-12, a large number of participants were fairly satisfied with the performance of names in terms of their type colour. In turn, they considered these names as being legible; and had achieved a good contrast both against the background image and in relation to the other map elements. They felt too that they had integrated successfully with the background.

Text and Names Representation	CLARITY & LEGIBILITY E	V	G	S	P	CONTRAST E	V	G	S	P	UNITY E	V	G	S	P
Text and Names	6	11	13	0	0	2	9	12	7	0	4	9	14	2	1

Table 17-12: The Evaluation Results of the Basic Characteristics of Typography Used to Name and Identify the Different Features – in Terms of Clarity & Legibility, Contrast and Unity.

5) <u>The Overall Representation</u>: Again, the majority of participants were fairly pleased with the overall representation of the different features included in the map. The results given in Table 17-13 indicate that most of participants rated the selection of symbols (point, line and area), name placement, grid and co-ordinate numbers quite highly. They also attributed the success of the overall representation to the effective utilization of the graphic variables, which enable the designer to produce a successful map product. However the background colour used only achieved a satisfactory rating – so it is a matter that needs further attention.

The Overall Representation in General	E	V	G	S	P
Point Symbol Selection	9	11	14	0	0
Line Symbol Selection	6	11	11	2	0
Area Symbol Selection	3	10	13	4	0
Lettering Placement	5	9	14	2	0
Grid	8	12	10	0	0
Co-ordinate Numbers	4	7	16	3	0
Background Colour	0	3	6	17	4

Table 17-13: The Results of the Evaluation of the Overall Representation in General

6) <u>Arrangement & Layout</u>: No difficulties have been experienced concerning the map arrangement and layout. Again, the experimental map was designed to have a rectangular format; however, the longer side was in the horizontal direction instead of the longer side being vertical as had been done in the case of the 1:50,000 scale experimental map. Generally speaking, most of participants rated the whole elements of the map arrangement and layout (including the title, scale, legend and marginal information) quite highly – see the results in Table 17-14. In their opinion, all the elements were clear and put together in a well-balanced way.

Arrangements & Layout Qs.	CLARITY					BALANCE				
	E	V	G	S	P	E	V	G	S	P
Title	12	15	3	0	0	15	13	2	0	0
Scale	8	17	5	0	0	10	13	7	0	0
Legend & Marginal Information	11	13	6	0	0	9	16	4	1	0

Table 17-14: The Results of the Evaluation of the Arrangement and Layout of the Map

7) <u>Overall Appearance of the Image Map</u>: From the results given in Table 17-15, it can be seen that most participants were quite happy about the overall appearance of the image map and also rated its various elements or components fairly highly. In terms of <u>readability</u>, the majority of participants felt that all the map elements (symbols, names, etc.) were either very good or good – see the results in Table 17-15. These additional cartographic components were thought to be clear and legible and could be read successfully all over the map. They were also judged to be well-balanced in terms of their contrast – with nothing too dark or too light. In total, they had been put together in a successful manner – see Table 17-15. All the individual elements had been given relatively equal treatment to avoid the domination of one category or one class of features. In summary, the method of combining the two different types and levels of information – the <u>background space image mosaic</u> and the <u>additional cartographic symbolisation and annotation</u> – was thought to be quite effective, since most of the features included in the image map product have been represented with great deal of clarity and legibility. Also they have achieved a sufficient contrast both with the background and in relation to the symbols and names which have integrated well with the space image.

All of the participants agreed that the appropriate selection of <u>colour</u> had allowed the various symbols and names to achieve a good contrast and to be clear and legible all over the map area. Consequently, quite high evaluation ratings (see the results in Table 17-15) were given to the correct use of colour by all participants. Unsurprisingly, the majority of participants also felt that the <u>format size</u> was practical and can be handled easily both in office and in field. This impression was supported by the results in Table 17-15, in which the evaluation ratings were excellent (by 6 participants), very good (by 11 participants), good (by 12 participants) and satisfactory (by only one participant).

Overall Appearance of the Image Map	E	V	G	S	P
Readability	3	10	13	4	0
Balance (Contrast)	7	9	14	0	0
Effectiveness of the Representation Method	5	10	13	2	0
Use of Colour	9	11	10	0	0
Practicality Of Format Size	6	11	12	1	0

Table 17-15: The Results of the Evaluation of the Overall Appearance of the Image Map

Overall Rating	E	V	G	S	P
	4	11	14	1	0

Table 17-16: The Results of the Overall Evaluation of the Experimental Space Image Map at 1:250,000 Scale.

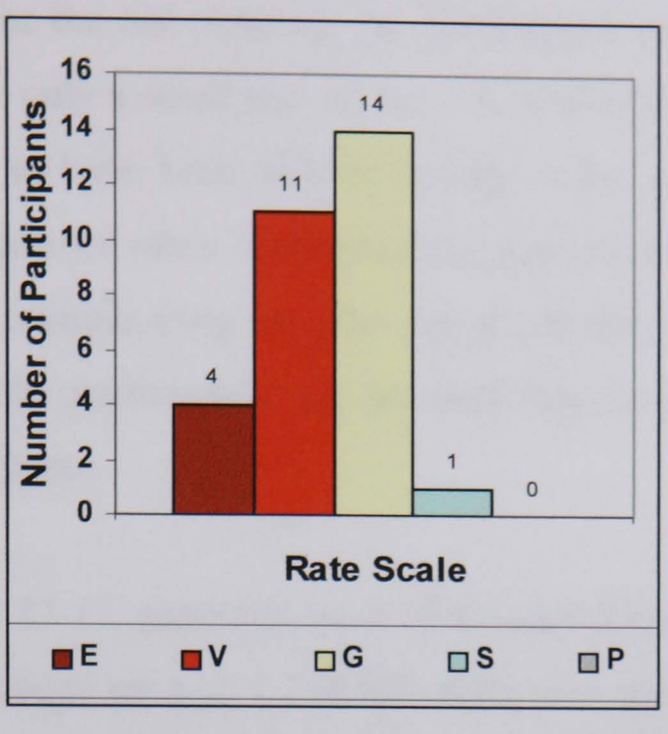

Figure 17-3: The results of the overall rating of the experimental space image map at 1:250,000 scale given as a graphic representation.

8) Overall Rating of the Image Map: From the results given in Table 17-16 and Figure 17-3, it seems that the overall rating of the experimental map at 1:250,000 scale was higher than that given for the larger scale map. Of course, the reduction in scale from 1:50,000 to 1:250,000 scale allowed a much larger area of the terrain surface to be covered in a single map sheet. As a result, this enabled the map user to obtain a much broader view of this terrain. Besides which, the scale restrictions had introduced more challenges in terms of map content and representation, to which more appropriate design solutions appear to have been found in trying to design and produce a good quality image map. Indeed, when designing the smaller scale experimental map, the author had found that there was a greater need to add the missing information through an appropriate cartographic treatment in order to ease the interpretation task and help the map user to understand this unfamiliar type of maps. From the general written remarks and oral exchanges with the participants, it was evident that the evaluation rating (of the overall performance of the map) given by the majority was quite favourable towards the smaller scale experimental map. This is really important since, in the author's view, a 1:250,000 scale image map series would be the most suitable for the basic national topographic coverage of Libya in terms of both its economy and its representation of the arid terrain.

17.5 Section II: Comparison between the Experimental Space Image Map and the Topographic Line Map (at 1:50,000 Scale and Covering a Small Part of the Area)

Unfortunately, the 1:250,000 scale topographic line map of the area covered by the image map was not available for the test. Instead, the participants were given three map sheets of 1:50,000 scale that cover only a small part of the whole area. It would have been much more appropriate and reliable to have been able to compare like with like – i.e. the comparison would have been more realistic when comparing maps produced at the same 1:250,000 scale. However, in the author's opinion, even with the use of 1:50,000 scale topographic line maps, a general idea about how the participants rate the performance of each of these two types of map products can be obtained.

From the results in Table 17-17, generally most of the participants felt that the performance of the experimental space image map at 1:250,000 scale was more successful than that of the topographic line maps. Since much of this had been explained in some detail in the previous Chapter (16), the author sees no point in repeating such explanations here.

Comparison Questions	Exp. Space Image Map					Topo. Line Map				
	E	V	G	S	P	E	V	G	S	P
The level of details in both map products.	5	8	10	7	0	3	7	10	9	1
The number of categories and classes of features in both maps.	3	10	14	3	0	4	13	11	2	0
The representation of point features in both types of map.	7	14	9	0	0	0	2	9	11	8
The representation of line features in both types of map.	9	12	7	2	0	0	0	7	17	6
The representation of area features in both types of map.	7	10	12	1	0	0	2	8	11	9
Relief depiction in both maps.	0	0	10	17	3	2	9	14	5	0
Text and Name placement in both maps.	6	10	13	1	0	2	4	13	7	4
The use of colour in both maps	8	12	10	0	0	0	0	0	5	25
Map Arrangements and Legend	6	11	13	0	0	1	5	8	10	6
The overall rating for both map products.	4	13	11	2	0	0	7	9	13	1
The use and suitability of both maps for the area and the users.	7	14	9	0	0	0	5	13	10	2

Table 17-17: The Results of the Comparison between the Experimental Space Image Map (1:250,000 Scale) and the Topographic Line Map (at 1:50,000 Scale and Covering Small Part of the Area).

17.6 Conclusion

The basic space image mosaic, which acted as the background for the experimental space image map at 1:250,000 scale, contains plenty of information. However, due to the large scale change, much of this disappeared and there was more need for additional symbols and names in order to provide the missing but important details.

The reduction in scale has affected both the information content and the method of representation of features on the map. This meant that a number of small (man-made) objects have not been included in the image map produced at 1:250,000 scale. However, certain small features – such as springs, tracks, etc. – have been included, since they are very important to the various map users. Moreover, as stated by most participants in this user tests, there is still an urgent need to show relief information using contour lines on the new image map series of Libya, since the contour lines together with the spot heights, are considered as the most appropriate way of depicting elevation detail on image maps.

Most of the results given in this chapter by the majority of the participants have indicated that the smaller (1:250,000) scale space image map of Misratah, which has been produced by the author in this project, was more successful than that of the 1:50,000 scale image map. However, these participants did not (indeed were not asked to) comment about the success, importance and suitability of this smaller scale image map as far as a huge country such as Libya is concerned – where most of the terrain is characterised by a bare physical landscape with few man-made features. In the author's opinion, the space image map that has been produced at 1:250,000 scale was much more successful in terms of both its information content, in its representation of the terrain and in the appearance of the final map. Furthermore, the smaller scale map covers a larger area of the terrain surface that, in turn, gives a broader view about the area of interest to the various map users. Moreover, the smaller scale map produced in this research project is very much more valuable than the image map series (comprising 127 sheets) that had been produced during the period 1978-80 by the American company Earthsat. This old series had been produced manually using the Landsat MSS images, which were characterised by a lower ground resolution (with an 80 metre ground pixel size) and suffered from the lack of any cartographic treatment and symbolization. Essentially it was a gridded mosaic and no other help was given to the map users since no symbols or names were added to the image. Thus the interpretation task was left solely to the users' knowledge ability and skills. Yet, even so, it was considered to be very useful – since there was no real alternative for most of Libya. The new type of space image map produced by the author is potentially an invaluable replacement. With all these considerations in mind, the author feels that he can recommend strongly the new small-scale (1:250,000) space image map that has been produced in this project as a replacement both for the small-scale conventional line map series and for the old space image map series which is now 20 years out-of-date. Of course what the user test has shown is that the representation of certain features on the new 1:250,000 scale image map needs to be improved, and, most certainly, the author will deal with all of these matters later when he goes back to his place of work (SDL) in Libya.

It is now necessary to make the final remarks and conclusion regarding the research work carried out by the author, and the recommendations with regard to the design aspects of space image mapping (at 1:50,000 and 1:250,000 scales) in Libya. All of these matters will be discussed in some detail in the next chapter.

CHAPTER 18: CONCLUSIONS AND RECOMMENDATIONS

18.1 Introduction

This chapter presents the general results and conclusions that can be drawn from this research project and discusses whether the original aims of the project have been reached or not. It also gives some recommendations for future research into this area of topographic mapping using high resolution space imagery, very much from the point of view of a cartographer.

18.2 Overall Conclusions

The detailed investigations carried out and the results acquired during the various stages of the present research project have been documented, discussed and analyzed in detail in the relevant chapters, so it is not necessary to repeat them in this concluding chapter. However, it is quite appropriate to make some concluding remarks on these investigations giving an overview that attempts to summarize the results from the large number of cartographic design experiments and tests that have been carried out in this research project – in an attempt to reach successful solutions to the design problems of producing space image maps of Libya at 1:50,000 and 1:250,000 scales.

The objectives of the author's research project were set out in Chapter 1. In general terms, the project has been successful in terms of reaching or satisfying most of the objectives stated previously. However, some objectives could not be achieved fully because of technical or financial limitations. A detailed discussion as to whether each of the six objectives stated above was reached will be given in the five sections (18.2.1 to 18.2.5) that follow.

18.2.1 The Systematic Analysis and Evaluation of the Existing Space Image Maps

As noted in Chapter 1, the first main objective was to carry out a systematic survey and analysis to evaluate the cartographic design aspects of the existing photo and image maps that have been published by different organisations. In the author's opinion, such a review and analysis was an essential preliminary to the main part of the project and one which has been carried out successfully. It has shown that a considerable amount and variety of space image maps have been produced, but mostly as one-off (i.e. individual) maps. However, with a few exceptions (e.g. the recent Baltic States series), they have not been adopted to form the whole or a part of a national series. It is a matter for discussion and debate as to whether or not this results from some fundamental shortcoming in space image maps in general or whether these types of map have not yet been developed sufficiently to be adopted by national mapping organisations. However, whatever the reasons, in those countries with vast areas of desert and semi-arid land (such as Libya), the use of space image maps certainly seems appropriate, since the space image background will allow the representation of the terrain surface in a manner that no other form of map can achieve.

As can be observed from the analysis conducted in Chapter 6, employing space images as a part of the map has, in general, added substantially to the map. These images can be highly informative and provide valuable details that cannot be shown by any conventional line map. Particularly, in certain types of topography – such as sand dunes, tidal flats, swampy areas and areas of complex woodland – even with a minimum level of additional information, the natural space image provides a superior representation of the physical landscape and much more information than is possible on the line map. However, the general disadvantage of most existing image maps is that most users find them difficult to interpret if they are left in a fairly raw state – as has been the case with many existing space image maps. Hence, it is always desirable to combine the images with relevant features that are either invisible or difficult to define or interpret on the image. These features need to be added or interpreted using cartographic symbolization. However, it was obvious from the analysis of the existing space maps that bringing together or combining these two quite different levels of information poses its own considerable problems – since the addition of symbols and names will obscure or eliminate part of the background space image. So the design and placement of such symbols and names require a high degree of skill and sensitivity on the part of those cartographers who are carrying out this task of supplementing the basic space image and adding value to the map.

The space image maps that have been reviewed during the author's investigation vary widely in scale, projection used, format and design, sensor and image type, etc. Their scales vary from 1:50,000 to 1,000,000 but the most common scales are 1:50,000; 1:100,000 and 1:250,000. In fact, the scale actually used mostly has a direct relationship with the ground resolution of the space image data that has been available and could be utilized to produce the space image maps. Furthermore, these types of map have been produced mainly for two rather different purposes, which are (i) general topographic mapping and (ii) land cover/land use mapping. However, the latter group have mainly been produced at smaller scales to give an overview of a large area for planning or monitoring purposes rather than act as a general-purpose base map.

The systematic analysis carried out by the author has also shown that the availability of high quality space image data in digital form and the recent advances in digital image processing technology and techniques have made it possible to join together several scenes to form a sharp and seamless image mosaic of a large area – which was certainly not the case with many earlier examples of space image maps. In addition, the improvement in this technology has also made it possible to enhance certain features contained in the image using well developed enhancement and filtering techniques. Nonetheless, the production of this kind of map is still restricted to certain scales; this is due largely to the limitations in the ground resolution of the space sensors. From a number of recent examples that have been included in the author's analysis, it is also obvious that the fusion or merging of multi-sensor image data can be an effective tool to increase the quality of space image maps through the combination of the higher geometric resolution of SPOT Pan image data and the colour information derived from Landsat TM image data or SPOT XS image data.

Nevertheless, in general terms, it can be concluded that many of the space image maps included in the author's review and analysis have not achieved a good level of success in terms of their cartographic design. These image maps have suffered from the lack of certain basic information such as names, contours, road classification, etc., which is important and needed for all users. However, as mentioned above, the application of space images in medium- and small-scale topographic mapping can be very useful and always has great value in those arid and semi-arid areas where the vast majority of the terrain features are those of the physical landscape with few cultural (man-made) details. Still, even in such areas, as has been observed through this analysis, the cartographic design aspects of the image map have not been treated adequately. In the author's opinion, these shortcomings have resulted largely from problems with the range of image contrast and those concerned with the integration of the cartographic elements (placement of symbols and names) with the complex background space image. Quite often too, the symbols that have been used are rather crude and poorly designed. Besides which, in many cases, the small but vital cultural details have been omitted from the maps. All of these matters provide enough justification for conducting research to solve the design problems of the space image map. On the other hand, it has to be said that, in the specific matter of conducting research into the design of the space image maps that are suitable for use in the Libyan context, some excellent pointers to a successful design solution have been given by the examples produced at different scales by the Technical University of Berlin – see Maps 14; 22; 29; 31 and 32 in Chapter 6.

By carrying out this systematic review and analysis, it has to be said that the author gained an enormous amount of knowledge and became much more familiar with image mapping and its various design problems as given by the many examples included in this analysis. Indeed, many lessons relevant to the design and production aspects of space image maps were learned which, in turn, increased the author's capability to solve these problems.

18.2.2 The Most Suitable Space Image Data for Medium- and Small-Scale Topographic Map Series in Libya

In Chapters 4 and 5, the various high resolution spaceborne imagers (including both photographic cameras and scanners) and the photography and digital imagery produced by them have been reviewed and their capabilities have been analyzed in detail in the context of national topographic mapping programmes in general and their application to the mapping of Libya in particular. The author has paid special attention to the different space photographs and images acquired by these satellite systems and their potential mapping capabilities in terms of (i) their geometric accuracy (both in planimetry and in height); (ii) the information content that can be obtained for medium- and small-scale topographic mapping (1:50,000 scale and smaller), especially in the desert and semi-arid areas of developing countries; and (iii) the suitability of these space images for image map production. As far as a new space image map series is concerned, the availability of the various types of space image data to the mapping community in Libya has also been a matter of great concern, especially given the embargo on supplying systems and services that has been applied by many Western countries.

Based on the above mentioned criteria, the author's analysis had shown that currently SPOT Pan images with their ground pixel size of 10m are the most suitable imagery available now for producing space image maps of Libya at medium- and small-scales. However although SPOT can provide images with sufficient horizontal planimetric accuracy for the compilation of 1:50,000 scale maps and smaller, its elevation accuracy is marginal, and generally, it cannot provide sufficient information required for the inclusion of the cultural detail that needs to be shown in 1:50,000 scale maps. Consequently, this would lead to the need for a fairly comprehensive field completion operation to acquire the missing details. However, in the Libyan context, with so little cultural detail occurring in the huge areas of desert that make up most of the country, this may not be a major problem. In the author's opinion, SPOT also shows much potential for the future since the new SPOT-5 satellite to be launched in 2001 will provide a much better ground resolution – 5m ground pixel with 2.5m in Supermode – while still retaining its wide 60 x 60km scene coverage. Furthermore the use of an along-track mode of data collection to collect stereo-image data removes all the difficulties associated with the acquisition of cross-track coverage and offers the possibility of producing DEMs and contour data for those areas lacking such data for the representation of their relief.

Nowadays, it is also obvious that the IRS-1C/1D satellites have achieved more coverage of Libya and will soon cover the whole country. In this case, it must be considered seriously as an alternative to SPOT Pan data. As described previously, many of its characteristics and capabilities are similar to those of SPOT – for example, its cross-track stereo-coverage and its similar heighting accuracy. But its superior resolution (5.8m v. 10m ground pixel size) could produce some substantial gains both in planimetric resolution and in the information content and features that can be extracted from the IRS images. However, although the IRS-1C imagery gives a better ground resolution than its current rivals, it also has less contrast, because of its lower radiometric resolution (limited to 6-bits or 64 grey levels). It remains to be seen whether this is an important point or not. Like SPOT, the next satellite (IRS-5P) in the Indian series, also called Cartosat, will provide a similar 5m/2.5m ground pixel size and along-track stereo-imagery. So the future prospects are quite bright in that both the SPOT and the Indian satellites will address one of the major shortcomings – the shortfall in ground resolution – of the present spaceborne imagers.

This new Landsat-7 imagery must also come into serious consideration, since it is still more up-to-date and its Pan imagery with its 15m ground pixel size offers a superior ground resolution in comparison with the TM imagery of the Landsat-4 and –5 with its 30m ground pixel size. While the SPOT Pan imagery has a ground pixel size of 10m, it seems from preliminary reports that, in practice, the Landsat-7 Pan imagery is of a near comparable quality both in terms of its actual ground resolution and of its radiometric quality. The Indian IRS-1C/1D imagery has a 5.8m ground pixel size, but it only has a 6-bit radiometric range. If one can establish that the Landsat-7 imagery is indeed of an equivalent or near-equivalent quality to that of its rivals in terms of the actual identification and extraction of the features needed for mapping, then, of course, the economics of conducting small-scale mapping from Landsat-7 are hugely compelling. This results from (i) its low cost to the user, and (ii) the large area coverage of a single scene – e.g. (185 x 185km) v. (60 x 60km) for SPOT and (70 x

70km) for IRS-1C/1D. Thus nine SPOT scenes are required to give the same ground coverage as a single Landsat-7 scene. Of course, the down side of all Landsat imagery is that it cannot provide a stereo-imaging capability for the production of DEMs and contours in the manner that is possible using the SPOT and IRS stereo-pairs.

The imagery from IKONOS-2 that is now becoming available and will also enter consideration. However the higher ground resolution (1m ground pixel size) of its imagery has only been achieved by a huge reduction in the ground coverage (11 x 11km) of a single scene. Therefore, a very much larger number (17,500) of images would be needed to cover the entire country. Thus the requirements for image processing and the provision of ground control points would escalate greatly so that the cost of the overall mapping operation would be substantially increased. Most probably, the value of IKONOS and the similar satellites (QuickBird and OrbView) that will appear soon, will be to provide high-resolution images of certain small areas, e.g. towns or oases or oil and gas production facilities – where the SPOT or IRS or Landsat images do not provide the information on cultural features that is required.

The overall conclusion from this part of the author's study is that, while the existing imagery from SPOT and IRS is, in certain respects, marginal for the production of space image mapping on a national scale, the future with the improved SPOT and IRS imaging sensors with their higher-resolution imagery and along-track stereo-viewing capabilities is decidedly bright – especially in respect of a national space image map series covering the whole of Libya.

18.2.2.1 Economic Aspects of Acquiring Space Imagery

Following on from this discussion, the economic aspects concerned with the acquisition of these different types of space imagery need to be considered. Libya is a huge country with an enormous area (1,750,000km^2) that requires a large number of space images in order to achieve the complete coverage of it. In total, 486 SPOT Pan images or 357 IRS-1C/1D images are required to cover the whole Libya. Thus the acquisition of total coverage of Libya will cost the SDL £972,000 (using SPOT Pan image data) or £785,400 (using IRS-1C/1D images). Indeed for the mapping of the whole country, it will not be too expensive to use either SPOT Pan or IRS-1C/1D imagery for small-scale (1:250,000) space image mapping purposes, especially when coverage of the whole country is required.

From the purely economic point of view, the Landsat-7 (ETM+) panchromatic images with their 15m ground pixel size and 185 x 185km ground coverage would be still more suitable for the complete coverage of the country needed to produce a national space image map series (at 1:250,000 scale) in Libya. This means that only 51 scenes of Landsat-7 are needed for the complete coverage of Libya. In this respect, Figure 18-1 gives a clear indication about the respective ground coverage of a single image of Landsat-7 when compared with those of the SPOT, IRS-1C/1D and IKONOS Pan images. Each single Landsat-7 scene covers 9 SPOT Pan images, 7 IRS-1C/1D images and 283 IKONOS images.

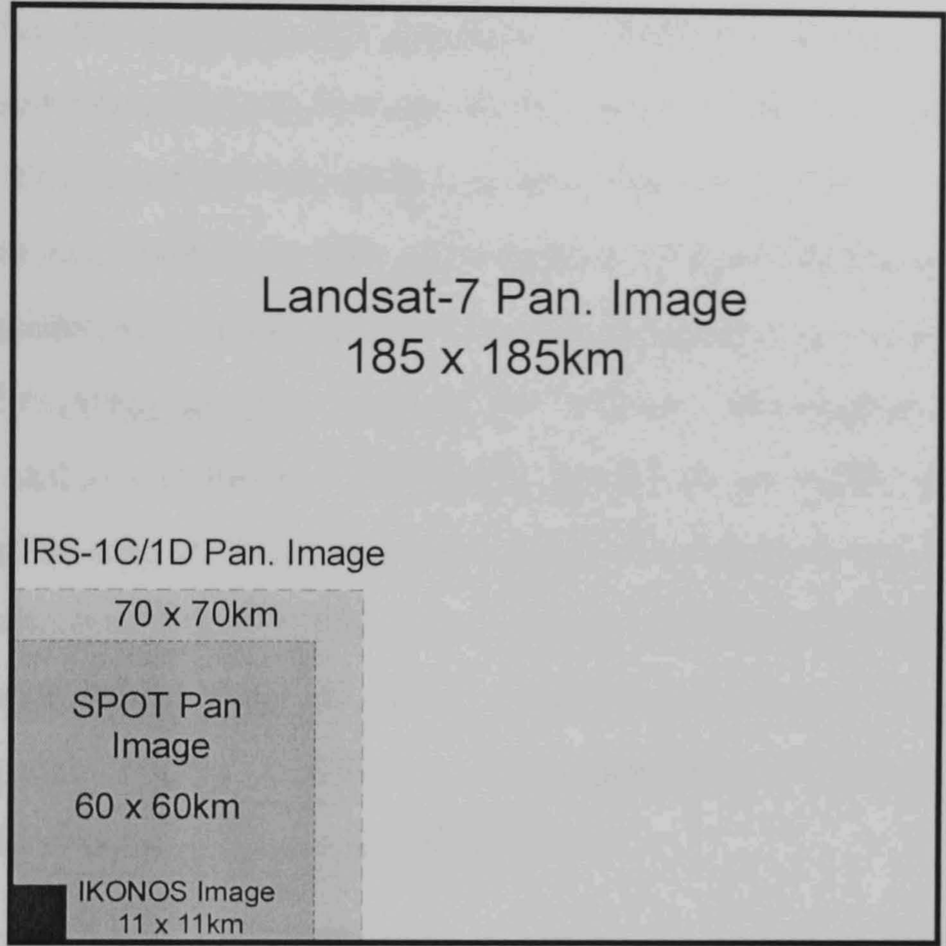

Figure 18-1: The ground coverage of Landsat-7 images compared to SPOT Pan and IRS-1C/1D images.

The author hopes that interpretation tests will show that the Landsat-7 imagery is of an equivalent quality to that of its rivals (SPOT Pan and IRS-1C/1D) in terms of the actual identification and extraction of the details needed for mapping. Certainly, if this proves to be the case, then the Landsat-7 images could be strongly recommended as the basis for a new national space image map series (at 1:250,000 scale) in Libya, since the complete coverage of Libya would only cost the SDL only £60,000. However, besides the possible lack of ground resolution, a matter of concern is that, so far, no plans have been announced for a follow-on satellite to Landsat-7 – whereas this is assured for the SPOT and IRS satellites. On the other hand, a total of 17,500 IKONOS Pan images would be needed to cover Libya. This would cost the SDL £45,000,000 for the whole coverage of the country –a sum which is impossible to justify.

18.2.3 Applying Appropriate Digital Image Processing Techniques to Produce a Seamless Mosaic for the Test Area.

During the present research, the methodology that has been developed and used in the production of the image mosaic to be used as the basis for the production of the experimental space image maps of the project area has been reported and discussed in Chapter 10. In addition, the results obtained from the various image processing activities have been represented and analyzed in that Chapter. From this work, some general conclusions can be reached. In particular, the commercially available EASI/PACE software system from PCI in Canada has been used extensively to execute all the various aspects involved in producing the background image mosaic of the Misratah test area. This involved the extensive use of the digital image processing techniques that are available in this software package. These have been used for the radiometric and geometric corrections and to join the six SPOT Pan images together to form the image mosaic covering the whole of the project area. Based on this experience, in the author's opinion, EASI/PACE proved to be highly capable of executing almost all the image processing tasks that were required to produce a good quality mosaic to act as the basis for the mapping of the test area. This in itself constitutes a big advance in that many previous image maps were produced using programs and routines that had been developed in-house and were not available to other organisations. Few have the sophistication and range of features that are available in EASI/PACE.

Although the quality of the six SPOT Pan images was fairly good, there were some flaws – such as line dropping and the presence of cloud – that had to be corrected through further processing. Fortunately, the availability of other SPOT Pan image data that covered the same area and the flexibility of the image processing techniques of the EASI/PACE software helped greatly to overcome the problems of cloud cover. These pre-processing techniques have produced a really good quality output image and indeed it was difficult for the human eye to recognise the merges and changes on the corrected image. Other radiometric enhancements, including contrast stretching and edge enhancement, have also been applied extensively. They helped greatly to produce better quality images that could be used later for the production of the space image mosaic of the whole test area, which acted as the background for the experimental space image map of Misratah at 1:250,000 scale.

The SPOT Pan images used in this project to form the mosaic were not affected by relief displacements, since the area of Misratah is characterized by low relief. Each of the six SPOT

Pan scenes was rectified and transformed into the desired map projection (e.g. UTM as the case in this project) using a two-dimensional polynomial transformation. The results obtained from the rectification and transformation procedures using GCP Works module were within the range of those results that has been achieved by the others and can meet the planimetric accuracy requirements of topographic maps at 1:50,000 scale. An overall histogram matching technique was also applied to the imagery. Through this procedure, the data contained in each individual SPOT Pan image was converted into a common homogenous grey scale in order to produce a seamless image mosaic covering the whole area. It has to be said that some difficulties have been experienced during the application of the histogram matching procedures. These difficulties resulted from the high reflection of the sand that covers a large part of the terrain area. To solve the problem, the author has spent a considerable period experimenting until good results have been achieved. Finally, all the enhanced images have been mosaiced and the final product was a very acceptable seamless homogenous image mosaic of the Misratah area.

Indeed, no major problems were encountered during the execution of the various image processing procedures to produce the final mosaic, but there were some minor difficulties to be overcome. The overall conclusion arising from the author's trials and his experience that the technology and the methodology now exist commercially to be able to carry out these basic procedures in a very satisfactory manner. This was certainly not the case in the past.

18.2.4 Planning the Content and the Actual Acquisition of the Information Required for Image Maps at 1:50,000 and 1:250,000 Scales

The proper way of establishing the actual map content of specific map series is to carry out a full-scale survey of user requirements in order to define either the present or the anticipated needs of the different map users. The wishes of the various map users have then to be translated into the actual content to be included in the map and the technical specifications of the different features that make up the content. Unfortunately, it was not possible to carry out such a survey within the scope of the current research project. Thus, the selection and specification of the features to be included in the two space image maps (at 1:50,000 and 1:250,000 scales) was based solely on the author's background and experience.

Since the nature of the basic image mosaic will not allow the map maker to add too much cartographic detail (in the form of symbols, names, grids, contours, etc.) - since that would obscure image detail and reduce the clarity of the map – only a medium level or number of features has been defined. Afterwards, these have been listed or placed into classes or categories (see Table 10-1) for the 1:50,000 and 1:250,000 scale space image maps respectively. The list of features, that has been included in Table 10-1, has formed the basis for the image interpretation and feature extraction that have been carried out using the SPOT Pan image data

The results of the interpretation tests (described in Chapter 11 of this dissertation) and those obtained from other similar tests and production experience in Africa show that the existing SPOT imagery is substantially deficient in terms of providing the information content – small man-made features in particular – needed to produce a new 1:50,000 scale map. This means that the available space images of wide ground coverage (such as SPOT and IRS-1C/1D, etc.) can only provide 70% of the features that need to be included on the map. Obviously these will constitute a larger percentage of the features required for maps at 1:250,000 scales. Therefore, an additional comprehensive field completion is necessary to derive the missing 30% of the total content of the 1:50,000 scale maps. Unfortunately, due to several problems and difficulties, field completion could not be carried out in this project, but still it is important to plan for this, if a new national space image map series is to be implemented for Libya – since such field activities require substantial time, cost and effort to undertake and complete. Hopefully, some of these problems will be solved in the near future, since the forthcoming developments with SPOT-5 and the Indian Cartosat satellites will provide space images of higher ground resolution (5m and 2.5m ground pixel size), which should allow the extraction of 90% of the required features. This will reduce the field checks on the ground substantially.

Some other points or conclusions that can be drawn from this part of the project are:

1) The experience of the author in using visual interpretation techniques to derive information directly from SPOT Pan and the fact that he is originally from the area and was familiar with it were of great help during the image map compilation stage. Obviously it would be much more difficult for cartographers based in other countries to extract the same information and features as cartographers who know the local terrain and conditions.
2) Although SPOT Pan imagery could not provide the total information required for mapping, the additional data obtained from small-scale aerial photographs and the existing topographic line maps (at 1:50,000) were very useful both to compile additional information and to confirm the identity of some other features.

3) The level of information content and specification; the methods and procedures used to acquire details directly from the SPOT imagery; and also those used to obtain from external sources (additional information) were suitable, as far as space image mapping at medium- and small-scale is concerned. The author can recommend the SDL to adopt them if it decides to produce the new space image map series for Libya.

18.2.5 Cartographic Design Aspects of the Space Image Maps of Misratah

Obviously, it is very important that the background space image should be of as high a quality as possible in terms of both its geometric resolution and radiometric quality In these respects, the SPOT images were of a reasonable quality rather than a very good quality, but it is apparent that, in the near future, with the availability of improved SPOT and Indian Pan imagery, this situation will improve. In the author's opinion, a light brown or sandy colour will be the most appropriate for the background image in Libyan conditions, since it will imitate the physical appearance of the desert and semi-arid areas in a more realistic manner. In addition, the use of this background image will then allow the superimposed symbols and names to achieve the required contrast against it. Unfortunately, due to some technical limitations of the software packages used in this project, the adoption of this particular colour (for the background image) was not possible. Instead the author was forced to accept the basic black and white colour of the Pan imagery to be used for the background of his space image maps – which was less successful. Consequently, this has complicated the design problems, since it was not easy to achieve sufficient contrast of the symbols, names, etc against this background colour. However, for the proposed new national space image map series, the author believes that this type of problem will be solved in the near future with quite minor development of the software.

As the author's experiments have shown, the scale that must be adopted for any image map series has a direct influence (i) on the level of information that can be included; (ii) on the methods of representation that can be used to show the different features; and (iii) on the time and cost that needs to be spent on the production process. Generalisation of the space image itself – other than that produced through a straightforward scale reduction – is impossible to implement Thus it is absolutely essential that the map design should be entirely related to the space image at the final scale of the image map For example, a number of very small cultural (man-made) objects which were incorporated successfully on the space image map at 1:50,000 scale, could not be included in the image map at 1:250,000 scale Indeed, not unexpectedly as the scale becomes smaller, there will be much more need for additional symbolisation and annotation, since many of the small man-made features will be wholly or partially invisible on the reduced scale and ground resolution of the space image. In turn, the scale reduction also affects the representation method that is required to show the various features on the space image map. In which case, certain topographic features (e.g. main villages, airports, etc.) that can be represented by area or line symbols on 1:50,000 scale maps, will become point symbols on the smaller scale map. Of course, many of such considerations also apply to line maps but they apply with special force when applied to space image maps with their complex and ever changing background tonal (or grey level) image.

In image mapping, the basic symbol design may follow many of the principles used in conventional line maps. However, the white space that is available on conventional maps is absent and the whole map area has to be printed with the space image as a background. Therefore, this background image must have sufficient contrast within itself to allow the detail that it contains to be clearly discerned. While, at the same time, any superimposed symbols must achieve sufficient contrast to stand out clearly against the variable tones (or grey levels) of the background and in relation to the other items present on the map. As the author has found during his experimental work, this means that the problems of symbol design in image mapping can be very difficult to deal with. The most obvious problem or task was how to combine two quite different levels of information – the natural image of the terrain, with the abstract conventional symbols that must be superimposed on top of it. The author was faced with many complicated problems the moment he started to combine these entirely different forms of representation.

To solve the symbol design problems of the new space image maps produced in this research project, the author followed what he considers to be a systematic approach to the design of the symbols of the different individual point, line and area features contained in the map. To reach the optimum symbol design and to test the integration of the symbol with the background image, alternative versions of each graphic symbol were created through variations in their form, dimension and colour. Indeed, the adopted approach was quite successful in the sense that it allowed the author to understand the problems of designing each individual type of map symbol and then to tackle it with a good deal of confidence and creativity. However, the achievement of clarity and legibility of both the space background image and the superimposed symbols and names proved to be the biggest challenge of all. Very careful control of the colour of both types of data proved to be essential. Quite small changes in the colour often resulted in great improvements in the clarity of the symbols against their background.

Again, the author's experience was that the cartographic design of symbols on space image maps proved to be a complex task and one where a successful outcome is difficult to achieve. Furthermore it depends very much on the physical nature of any particular area being mapped. Obviously, the need for symbols and names increases in the inhabited areas, and hence the problems of achieving clarity and legibility and sufficient contrast (while still retaining a good degree of integration) with the space image background are at their greatest in such areas.

18.2.5.1 Cartographic Design Aspects of a National Space Image Map Series for Libya

From a cartographic point of view, the requirements of a map series, as opposed to those of an individual map, are still more complex. As an example, a conventional map series, such as that produced by the SDL at 1:50,000 scale covering a large part of Libya uses the same standard conventional symbols and design over the whole area being mapped within the country. Taking into account the variety of landscapes likely to be encountered in Libya, it is possible that the same approach cannot be applied to space image maps. So to achieve similar national image map coverage, the cartographer may be forced to modify the design of individual map to suit the variety of landscape characteristics visible in the imagery.

In the author's view, based on the experience gained in this project, the design of each individual space image map requires very careful treatment. Obviously fewer problems will be encountered in those areas of natural terrain with small numbers of man-made features demanding little additional symbolisation and having few names. Moreover, it is in such regions that the space image map has its greatest advantage over the conventional line map – in particular, the ability of the space image map to show clearly and effectively the random patterns or natural objects which are so difficult to map and depict using the conventional line map forms.

The careful design treatment and the adoption of better solutions have helped the present author to overcome many of the difficulties and problems that are inherent in space image maps. For example, the use of different light transparent colours to represent the various areas has facilitated the classification task and, in turn, helped the map user to differentiate one area from another. This practice was found to be most appropriate, since, it did not obscure much of the important detail on the underlying image. Unlike the use of solid colour polygons, the transparent colours allowed the appearance of the terrain surface to show through and so represented it in a far more realistic manner.

The conclusion that can be reached is that the overall design of both experimental maps was good and successful and that all the map items were put together in a reasonably well balanced way. Besides having a good basic cartographic knowledge, the practical experience gained by the author during the project resulted in a real familiarity with the production process. These factors, together with good use of the graphic variables, have all helped him to design and produce good quality space image maps that are clear and relatively easy to read. However, some improvements are still needed to be done (in the near future) to increase the design quality of these map products. Nevertheless, the author feels that he has met the stated aims and objectives since the majority of the design experiments were successful – as shown by the results of the user tests.

18.2.5.2 User Tests & Evaluation of the Final Space Image Maps at 1:50,000 and 1:250,000 Scales

As stated in the Introduction to this dissertation, the evaluation of the design aspects of the experimental space image maps (at 1:50,000 and 1:250,000 scales) was one of the main objectives of this research project. As described in Chapters 16 and 17, it was necessary, as part of the overall strategy, to design and execute a test among a representative group of mostly experienced map users (i.e. geo-science graduate students) who were asked to examine carefully and evaluate the design quality of the two map samples that have been produced by the current author during this research project. Generally, from the results and analysis that have been given in Chapters 16 and 17, the space image maps of Misratah at 1:50,000 and 1:250,000 scales have been judged to be more successful in terms of their overall performance than the conventional line maps of the same area and at the same scales, that had been produced in the past by the SDL. It was very evident from the users' responses that these types of map are more appropriate and much more suitable in representing the Libyan terrain where so much of the land surface is a bare and non-vegetated physical landscape with relatively few man-made features. However they were also successful in the more inhabited and more highly developed coastal areas. The success of these image maps is attributed to their superiority as a cartographic product in terms of their information content, representation, appearance, and readability.

In the case of experimental 1:50,000 scale space image map of Misratah, due to certain technical difficulties and the non-availability of adequate financial resources, the author was forced to accept the black and white colour for the background image that acts as the base for the image map. Indeed, this complicated the design task and made it much more difficult to achieve the desirable contrast of the symbols against this image. As a result, the design of a few of the symbols was not very successful when compared to the other symbols on the map. For example, the representation of relief information was held to be more successful on the topographic line map. Obviously this particular aspect of the space image map design needs to be improved. In the near future, it may be that the adoption of a light brown or sandy colour for the background image may help to improve the appearance of the dots and fine lines that are used to depict the relief details on the space image map.

As mentioned above, the basic space image mosaic, which forms the base of the space image map at 1:250,000 scale, contains an enormous amount of detail. However, due to large scale change, some of this information that could be seen at the larger scale was not visible. Thus, there was an urgent need for additional symbols and names in order to provide or substitute for the missing but important information. In fact, the reduction in scale has affected both the information content and the method of representation of features on the map. This resulted in quite a number of small man-made objects not being included in the image map produced at 1:250,000 scale. On the other hand, small features such as wells; springs; tracks; etc. have been included in this smaller scale image map, since they are very important to many map users. However, from the user test, it was obvious that the representation of certain features on the experimental 1:250,000 scale image map needs to be improved. Most certainly, the author will deal with all of these matters later when he returns back to his place of work (SDL) in Libya.

Most of the participants in this user test have stated that there is still an urgent need to include relief information using contour lines in any new image map series of Libya, since the contour lines, together with the accompanying spot heights, are still considered as the most appropriate way of depicting elevation detail on image maps. In this context, the author wants to emphasize that the non-inclusion of contours on the smaller scale (1:250,000) space image map was simply due to the non-availability of the contour lines in digital form.

Largely, the results of the evaluation test given in Chapter 17, provide a clear indication that the experimental space image map of Misratah at 1:250,000 scale – that has been produced by the author in the present project – was indeed more successful than that of the 1 50,000 scale image map. The success was in terms of both its information content; in its representation of the terrain; and in the appearance of the final map. As a matter of fact, the smaller scale space image map covers a much larger area of the terrain surface, which gives a broader view about the area of interest to the different map users. Taking all of these matters into account, the author feels that he can recommend strongly the production of new small-scale (1:250,000) space image map series along the lines of that produced in this project as a replacement both for the small-scale conventional line map series and for the old space image map series which is now 20 years out-of-date. The 1:50,000 scale space image map covering the more inhabited areas is in a somewhat different situation and this will be discussed later in this Chapter.

One of the main issues that has been raised by all the participants in the user test was the non-inclusion of the Arabic language and its corresponding system of lettering on both space image maps (1:50,000 and 1:250,000 scales) of Misratah that have been produced through this research project. Unfortunately, it was not possible to do this during the present research project, since the inclusion of the Arabic lettering system required more facilities that, in turn, required more financial resources than those that were available for this part of the project. However, in image mapping in particular, the inclusion of two different versions of names and blocks of text will undoubtedly increase the potential for conflict and make the situation more complicated – since the placement of more names will conceal more important information and make the final appearance of the map more crowded. In the author's view, all of these problems and limitations that will result from the inclusion of two sets of names using two different languages and lettering systems simply point to the need for more experimental work to be carried out in the future to improve the design quality of any new space image map series of Libya.

Nevertheless, the main conclusion emerging from the tests is that basically all the participants felt that the experimental space image maps are more suitable as cartographic products for use in Libyan conditions than the existing line maps. Improved versions of these experimental image maps should be adopted to replace the 1:50,000 and 1:250,000 scale topographic line map series that are in present day use.

18.3 Proposal for New Space Image Maps of Libya

The main potential areas of space image maps in Libya have been mentioned previously in this dissertation. It is now necessary to outline and examine certain specific proposals – in particular, to discuss how new space image mapping at medium- and small-scales (i.e. 1:50,000 and 1:250,000) could be adopted for the production of a national map coverage. SDL already has surveying, photogrammetric and cartographic facilities and expertise, and any further investment in the image data, software, hardware and training needed to implement image mapping would have to be justified and recouped in terms of increased production and efficiency, besides offering a superior cartographic product. Obviously, the adoption of any space image mapping programme in Libya requires the purchase of the suitable high-resolution space imagery and the technology (both in terms of input and output systems). Training of personnel who are capable of executing the different image processing techniques and cartographic activities involved in image map production will also be important and provision would need to be made available for this.

18.3.1 Space Image Mapping of Libya at 1:250,000 Scale

The case for adopting space image mapping to provide national coverage at 1:250,000 scale seems quite strong.

(i) In the first place, the scale is very appropriate for full national coverage given the quite sparsely inhabited arid desert and semi-arid landscapes that make up most of Libyan's territory. Mapping the whole of this landscape at 1:50,000 scale would simply be too much, in that it would cost a huge sum of money and take a very long time to complete. Mapping the country at 1:250,000 scale would seem to be far more appropriate to the actual situation on the ground. If a specific area, e.g. around an oasis or a town in the desert area, requires mapping in greater detail, then an individual sheet can be produced at 1:50,000 scale for this specific area using aerial photography or high-resolution IKONOS (or other similar) data.

(ii) From the cartographic point of view, the space image map is the optimal vehicle for mapping and representing the huge areas of desert terrain. This has already been evident from the success of the existing very simple and unsophisticated series of image mosaics that covered Libya at the same scale. The use of modern digital image processing techniques in combination with the better cartographic design devised by the author will allow a superior product to be produced that should find wide acceptability among map users.

(iii) As discussed above in Section 18.2.3, the economic aspects of utilizing suitable space imagery for mapping at 1:250,000 scale are extremely favourable. The acquisition of suitable space imagery – e.g. the enhanced SPOT and IRS stereo-imagery with 5m/2.5m ground pixel size that will be available from next year (2001) – would cost under £1 million. This is not an outrageous sum to pay for the acquisition of the basic raw material required for the production of an up-to-date image map series covering the whole country. The Landsat-7 imagery can also be considered for the task. It is very much cheaper, but has a lower ground resolution and lacks a stereo-imaging capability.

(iv) While 1:250,000 scale mapping could be carried out from very small-scale aerial photography, the cost of such a programme over the whole country would be extremely high – since there is no prospect of achieving the very wide area coverage in a single image that is possible with the different space imageries.

(v) The vital matter of the ground resolution of the imagery – 6m to 10m for the present SPOT and IRS Pan imagery; and 2.5m to 5m for the forthcoming enhanced versions of these imageries – would seem to be thoroughly compatible with the requirements of mapping at 1:250,000 scale. Field completion will still be necessary to map missing features, but on a quite reduced and quite acceptable level, given the rather small number of cultural features that occur over most of the country's arid terrain. Similarly field survey work will be required for the establishment of the necessary ground control points (GCPs), but this can be based on the country's existing fairly comprehensive geodetic network. Furthermore it can be kept to the minimum through the use of block triangulation of the SPOT or IRS scenes – as is being done by Earthsat in its new GeoCover mapping project that is currently being carried out for Africa and the Middle East on behalf of NIMA and NASA.

18.3.2 Space Image Mapping of Libya at 1:50,000 Scale

As will have been obvious from the relevant discussion in various parts of this dissertation, the current opinion in Libya is that the coverage of a new map series of the country at 1:50,000 scale should be confined to the more settled and more highly developed areas of the country. Only for these areas – which lie mainly along the Mediterranean coast – can the larger scale be justified. However, the case for this being a space image map series is not quite so clear-cut as that for national 1:250,000 scale series. In particular, the requirements in terms of ground resolution, etc. for the 1:50,000 scale series are such that mapping from small-scale aerial photography may be a more economic and more viable solution – remembering that the final result can also be an image map series produced via orthophotos. Of course, a proper comparison of the relative merits and costs of the two methods needs a more detailed in-depth study than is possible here. But the following points are relevant.

(i) The need for higher ground resolution in the more highly developed areas is really the decisive point. As was discussed earlier, the use of present SPOT Pan imagery with its 10m ground pixel size resulted in a very considerable shortfall (of 30%) in the supply of the features required for 1:50,000 scale mapping. Obviously, the improved (5m/2.5m) ground pixel size of the forthcoming SPOT and IRS imagery should reduce this figure considerably. However this needs to be tested to see the actual extent of the improvement. In the meantime, there is little doubt that modern small-scale aerial photography can produce a still better ground resolution. Thus the 1:40,000 to 1:50,000 scale aerial photos routinely used for 1:50,000 scale mapping up till now, produce a ground resolution (not pixel size) of less than 1m. (At 50 lp/mm, the resolution = 0.02mm on the photo; with 1:50,000 scale photography, 1mm on the photo = 50m on the ground; so 0.02mm resolution on the photo = 1m ground resolution). The use of modern aerial cameras equipped with image movement compensation (imc) in conjunction with fine-grained emulsion' gives a still higher ground resolution. Thus results often in 95% to 98% of the required map detail being supplied from the aerial photos – with a large reduction in the requirements for field completion.

(ii) The IKONOS high-resolution imagery gives a comparable 1m ground pixel size (≡ 2m ground resolution) over an area of 11 x 11km. However at a current cost of $3,000 per scene, it simply does not compete with aerial photography in cost terms.

(iii) The detailed comparison of the respective costs and effectiveness of aerial photography versus space imagery can be conductive in Libya by SDL. However, whichever type of imagery is selected to produce the basic imagery needed for the 1:50,000 scale mapping, the final results and experience of designing and producing image maps at 1:50,000 scale that have been carried out by the author will still be highly relevant, even if the base is an aerial orthophoto instead of a SPOT or IRS image.

18.4 Recommendations for Future Research

During this research, the extensive work that has been carried out to develop the cartographic design aspects of the space image mapping at medium- and small-scales for Misratah area in Libya has already provided good results in terms of the information content, representation and appearance of final maps. With respect to remotely sensed data used in topographic map production in general and the situation regarding the use of high resolution space imagery for image mapping in particular, based on the experience gained in the present project, a number of specific points and suggestions may be made regarding the research work which could be undertaken in the future.

18.4.1 The Potential of New Earth Observation Satellites to Provide Geometric Accuracy and Information Content Required in Image Mapping

As described earlier in this chapter, a number of new space satellites – such as SPOT-5 and IRS-5P – will be made operational by the end of next year (2001). The Japanese ALOS satellite having a similar performance will be orbited a year or two later. These satellites will provide reasonably high-resolution imagery while, at the same time, retaining the wide coverage that will be useful for space image mapping at 1:250,000 scale and perhaps at 1:50,000 scale. When all these new satellite sensors do become operational, it will of course be very interesting (and necessary) to test these images and their potential to produce space image maps at 1:250,000 and 1:50,000 scales. Hopefully, if the new satellites are launched successfully and they do come into routine operation, this will lead to a large expansion in the use of satellite images for topographic mapping purposes. Of course, any decision to use these high resolution images for mapping purposes and for the production of medium-scale maps (at 1:250,000 and 1:50,000 scales) and for map revision will be largely a matter of cost.

18.4.2 The Cartographic Design Experiments Needed to Produce Better Quality Space Image Maps

It is clear that there is still much to be done both in the improvement of the final design of the space image maps and in general research in to the closely related fields of image map design, remote sensing and topographic mapping. The design of the space image maps of Misratah at 1:50,000 and 1:250,000 could and should be improved by further testing of alternatives for the representation of the different features and information content It would be also of value to evaluate different alternative scales (e.g. at 1:100,000, 1:25,000, etc.) for mapping which would allow the inclusion of various levels of information. Alternative symbol designs should also be investigated.

In general terms, space image map design is a field that, in the past, did not receive appropriate attention from cartographers. In the author's opinion, since this type of product is more suitable for mapping and representing desert and semi-arid areas, this whole area still needs a great deal of research to be undertaken in order to develop and improve this type of map product. Specific directions of investigation could include (i) the further definition of the appropriate information content, scale and representation; (ii) improvements in the clarity and legibility of the graphic image with specific reference to the map user; and (iii) the application of the most modern technology available to carry out the design and production of space image maps. Image map making is not a new task since it was known for a considerable period, but with the availability of new sensors and new image processing technology, it can now be approached with renewed interest. The needs for development and planning, oil and gas exploration, educational purposes and scientific studies, military operations, etc. will ensure a continued prominent role for space image mapping in the future development of cartography.

The inclusion of <u>dual languages</u> – e.g. Arabic and English – and the two corresponding systems of lettering was not possible (due to the non-availability of financial resources and facilities) on the space image maps of Misratah that have been produced in this research project. In image mapping in particular, the simultaneous use of two different versions of names and blocks of texts cannot be achieved without problems and complications. Therefore, in the near future, this will be an interesting subject for further research. Extensive experiments are planned by the author to solve the problems of name placement, legibility and clarity and their contrast against the space image – both in relation to the other elements on the map, and concerning the integration of names with the space image. All names should be clear, readable and well balanced and the obscuring of the image information should be minimize as far as possible – it represents a very serious challenge, but one that promises to be rewarding!

The present author feels that more research work should also be conducted in the area of <u>map use</u> in Libya. This will include carrying out more surveys to enable the map makers in the country to understand the real requirements of the various groups of map users. The research will also include designing and distributing more evaluation forms over large groups of map users to give them the opportunity to evaluate the design of the produced maps. In turn, this will allow Libyan cartographers to understand the design problems and then to find the possible solutions for these problems in order to improve the design quality and appearance of the country's maps.

18.5 Final Remarks

This research has given the author the opportunity to become familiar with a number of digital mapping and digital image processing systems and has also given him experience with these systems which will be invaluable in his future career as a senior staff member in the SDL. as a researcher and as a university lecturer. Furthermore, the extensive series of experimental tests carried out in this research project have greatly reinforced the knowledge of the author in the field of space image mapping and have also taught him how to deal with and overcome the many problems that have been encountered in the present research. In doing so, he has been able to deal with the detailed interpretation of small-scale aerial photographs and SPOT Pan images. The combination of the theoretical and practical aspects of this research project have allowed the author to gain the knowledge, experience and the confidence to tackle various complex cartographic tasks and to find proper solutions to different cartographic design problems. It has also increased his experience and knowledge of the production side of cartography. The difficulties resulted from dealing with symbols and names and solving problems of achieving sufficient clarity and legibility, contrast and integration with the space image have brought the situation that faces the practising cartographer into reality and raised his the appreciation of the cartographic tasks.

Finally, the project has greatly increased the author's ability to analyse the results of experimental tests, to derive conclusions from these results and to look at these from various angles of view and produce solutions to the many problems that arose during the research work. Hopefully too, the results of this project will be viewed as having contributed substantially to promoting the use of space image mapping of extensive areas of arid and semi-arid areas in developing countries. Undoubtedly too, the work will help to provide users with new and more suitable type of maps as a direct result of them having been properly designed by the author.

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PHOTO AND IMAGE MAP COLLECTION

Map No.	Scale	Date	Publisher
1	1:1,000,000	1970	University of California, LA
2	1:1,000,000	1972/73	U. S. G. S.
3	1:500,000	1969	U. S. G. S.
4	1:500,000	1972	U. S. G. S.
5	1:500,000	1972/73	U. S. G. S.
6	1:500,000	1979	World Bank
7	1:500,000	1993	Technical University of Berlin
8	1:250,000	1969	U. S. G. S.
9	1:250,000	1973	U. S. G. S.
10	1:250,000	1975	U. S. G. S.
11	1:250,000	1978	IGN France
12	1:250,000	1979	University of Glasgow
13	1:250,000	1981	U. S. G. S.
14	1:250,000	1987	Technical University of Berlin
15	1:250,000	1989	Lesotho Government
16	1:150,000	1986	NPA Ltd. UK.
17	1:100,000	1978	U. S. G. S.
18	1:100,000	1978	U. S. G. S.
19	1:100,000	1982	U. S. G. S.
20	1:100,000	1984	ERSAC Ltd. UK.
21	1:100,000	1986	U. S. G. S.
22	1:100,000	1987	Technical University of Berlin
23	1:100,000	1988	Technical University of Berlin
24	1:100,000	1991	Intergraph Co.
25	1:100,000	1998	I-Mage Consult Belgium
26	1:100,000	1998	I-Mage Consult Belgium
27	1:50,000	1990	ERA & Maptec International
28	1:50,000	1990	FBK & KAZ Berlin
29	1:50,000	1990	Technical University of Berlin
30	1:50,000	1990	Intergraph Co.
31	1:50,000	1990	FBK Berlin
32	1:50,000	1991	FBK Berlin
33	1:50,000	1992	SSC Satellitbild Sweden
34	1:50,000	1994	SSC Satellitbild Sweden
35	1:50,000	1998	I-Mage Consult Belgium
36	1:50,000	1999	Hunting & SDS UK
37	1:50,000	1999	Hunting & SDS UK

APPENDIX I: EASI/PACE AND ACE SYSTEM CHARACTERISTICS

I.1 EASI/PACE System Characteristics

EASI/PACE is a well-established image processing package that can carry out the radiometric and geometric pre-processing of a wide variety of remotely sensed images together with the classification of land-cover types, etc., traditionally associated with such packages. PCI has made this software available on a wide variety of computing platforms such as PCs (running Windows 3.1, 95 and NT and OS/2), UNIX-based graphics workstations (e.g. from SUN, SGI, HP, DEC, IBM, and DG), DEC VAX/VMS systems, and the Apple Machintosh. The EASI/PACE software package offers two classes of interface.

(i) The first class comprises three user interfaces – called X-Pace, EASI and SHELL. This type of software interface is a group or a collection of programs that serve as the communication channel or link between the user and the application programs (known collectively as PACE) which operate on the user's data (PCI manual, 1996).

(ii) The second class consists of the Graphical User Interface (GUI) with stand alone modules or tool boxes within EASI/PACE Version 6.0. These modules comprise Image Works, GCP Works, OrthoEngine, and Fly! modules.

(i) The First Class of Software Interface: As noted above, the first class of interface consists of three interfaces called EASI+, SHELL and X-Pace respectively.

a) EASI+ Interface: EASI+ (Environmental Analysis and Scientific Interface) is an application independent host environment that handles all interactions between the user and the system. EASI+ eliminates the differences between host operating systems, editors and file structures by presenting the user with a simple, powerful environment tailored to his application. Essentially, EASI+ is a command line interface to the PACE programs provided for those users who prefer this type of interface.

b) SHELL Interface: The SHELL is a menu-driven interface that has been designed for inexperienced or occasional users of the EASI/PACE software package. The SHELL interface provides menus of alternative commands, rather than a command line interface. These menus guide the user in selecting, setting up and running individual PACE procedures and tasks.

c) ***X-Pace Interface***: This interface is a graphical user interface for the PACE suite of programs. It is an alternative to EASI+ or SHELL. X-Pace is a mouse/windows oriented interface and is available both on graphical workstations or systems running the Open Windows or X11/Motif windowing systems, or on the desktop platforms (Windows 3.1, 95, OS/2, or Windows NT) running on PCs. The entire listing of EASI/PACE programs and their brief descriptions under different applications are available to the user employing this interface. The user enters selections and parameters mostly through the use of a mouse, and the software then executes multiple tasks either at the same time or in a rapid sequence. This last interface (X-Pace) has been chosen to carry out the image processing tasks used in this research work.

(ii) The Second Class of Modules with a GUI: These are the stand alone tool boxes or modules used in EASI/PACE. They consist of Image Works, GCPWorks, OrthoEngine, and Fly! As far as this particular research project is concerned, only the first two of these modules (i.e. Image Works and GCP Works) have been used.

a) Image Works can be considered to be the heart of the EASI/PACE system in terms of its useage during the author's research project. This module has been used extensively to display imagery, graphics and vectors on the display screen. It can be started in a number of different ways, and can be run from any of the EASI/PACE user interfaces.

b) GCP Works allows the user to carry out the collection of ground control points (GCPs) and the geometric correction of the images that this allows. This module provides an interactive, point and click environment for the user to carry the required processing steps. The GCP Works module has been used extensively for the geometric correction and mosaicing procedures carried out during the author's experimental work. It is run quite independently without employing any of the user interfaces (EASI+, SHELL or X-Pace) mentioned above.

1) PACE Applications

The EASI/PACE software package comprises over 370 application programs (sometimes called tasks) and procedures. Collectively these programs are referred to as the PACE (Picture Analysis, Correction and Enhancement) system. To run these programs, the software gives the user control over how the program will operate. This control is given by means of so-called program parameters. The idea of parameters is central when it comes to understanding and making use of the EASI/PACE software. A parameter is simply a program or system variable that controls the operation of a single aspect of a PACE program. This means that the user is able to specify the parameter values and hence control the operation of any particular PACE program. The specification of parameter values is possible using either alphabetic or numeric characters, however, each individual parameter is defined to recognise only one or other of these two data types. On this basis, parameters can be grouped into two data type categories – namely (i) character parameters, and (ii) numeric parameters.

Beyond this, parameters can perhaps be more meaningfully defined on the basis of their functionality. There are three such categories of parameters:

i) Program parameters;

ii) Output parameters;

iii) System parameters.

Regardless of the interface that the user is using, the interaction sequence remains the same. The user can always determine the **status** of the parameters of any program to see their current settings. Secondly, the user can **change** those parameters whose current values are not the desired ones. Finally, when the user **runs** the program according to these specified parameters, the software interaction process is illustrated in Figure I-1

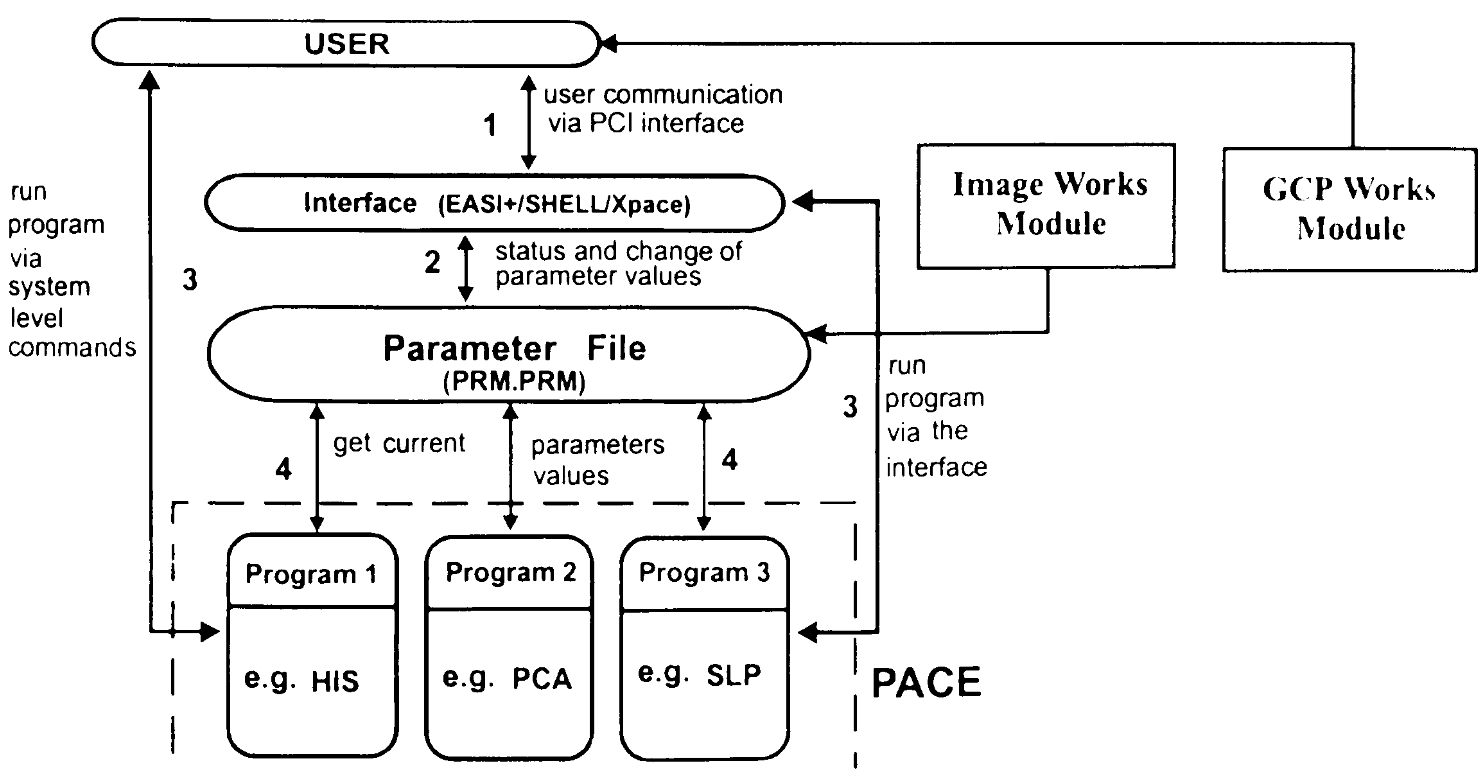


Figure I-1: Software/User interaction

As can be seen in Figure I-1 , the data that is central to the interaction sequence is the parameter file, which is a file stored on a disk that contains all of the parameters used by all of the PACE programs within the computer. All of these parameters are stored together in a separate parameter (prm.prm) file rather than in the PACE programs for efficiency reasons. The reason for doing so is that many parameters are common to several PACE prográms, and, through this arrangement, the user does not have to re-specify the values of the commonly used parameters for each program that uses them. Moreover, the user only needs to re-set the value of a specific parameter when he wants it to take on a different value from its last setting without affecting the other stored values.

2) Image Processing Programs

Only three of the main modules mentioned above as being available within the EASI/PACE software package have been used within this research project. These comprised some of the main PACE programs and the Image Works and GCP Works modules that have been employed to carry out the necessary pre-processing, radiometric enhancement, geometric corrections and mosaicing operations. These were required to correct the SPOT Pan images for the displacements, distortions or degradations introduced or occurring during the image data acquisition. Finally they produced a homogeneous and seamless image mosaic that covers the project area.

- **Pre-Processing Tasks**

The Image Works module provides an essential part of the image processing activities. Its **Main Window** gives the user the option to display, view and inspect each SPOT Pan image in order to assess and pre-process it. In this context, it has a useful zooming facility to magnify any part of the image so that the operator can look at its details more closely. He can also move to a new part of the image through the roaming facility. A full resolution viewing window is also available (as a sub-window) that helps the operator to view any part of the image at its actual full resolution. Using this facility, each SPOT Pan image has been examined carefully to detect any dropped lines, cloud effects, etc., besides providing general assessment of the image quality.

In images where several adjacent pixels or an entire line are missing or appear noticeably different to their neighbours, the Line Drop Replacement (**LRP**) routine that is available within the **Image Processing Module** of PACE Programs can be used to replace those missing pixels or lines that have been located in some SPOT Pan images. Using this routine, lines may be replaced with the line before, the line after, or with the mean of the two neighbouring lines.

• Radiometric Enhancement Tasks

Radiometric enhancement encompasses a variety of operations designed to improve the visual interpretability of an image by increasing the distinction that is apparent between the features present in a scene. Using the appropriate routines that are available within EASI/PACE, two enhancement techniques – contrast stretch and edge enhancement – are those that have mainly been applied to each of the SPOT Pan images that have been utilized in this project.

If the pixel values are displayed in their original form, then often only a small range of grey level values will have been used, resulting in a low contrast image on which similar features might be indistinguishable from one another. A contrast stretch enhancement expands the range of grey level values that are used to display the image so that they are displayed over the full range of grey values available on the display. Two basic routines (**STR & LUT**) that are available in the **Image Processing Module** of the PACE programs have been used for the implementation of the necessary contrast enhancement operations.

The **Contrast Stretch (STR)** routine can be used to generate a suitable Lookup Table (**LUT**) to perform the contrast stretching of the image data available in any database file. The operator is given control of the input and output range limits and the region within the image that is to be operated upon. He is even provided with the capability to modify the **LUT** in a variety of ways interactively. In order to enhance the image permanently, the **LUT** produced for a particular image must be applied to the image in an appropriate manner. This can be done by employing the **Perform LUT Transformation** routine on the image. The routine will then physically pass all the image data through the Lookup Table (**LUT**) and write it back to disk. The result will be a contrast-enhanced image that is ready for further processing operations.

For the edge enhancement operation, a high-pass filter technique can be applied to emphasize the boundaries and edges of the local features that are present in images. The PACE programs of EASI/PACE system do offer one such edge enhancement routine named **Sharpening Filter (FSHARP)** that has been used by the author. The **FSHARP** routine computes the result of employing a high-pass differential edge detection filter on the image and then adds this result to the original image to produce the final edge enhanced image.

• Rectification and Resampling Tasks

Rectification deals with the removal of certain geometric displacements that are present in the image – mostly those due to the variations in altitude and attitude (roll, pitch and yaw) of the sensor platform at the time the data was being acquired. The techniques used to correct these errors involve the collection of ground control points (GCPs) distributed as evenly as possible over the whole of the SPOT Pan image. Based on this GCP data, each individual SPOT Pan image can be rectified and transformed into the desired map projection using a two-dimensional polynomial transformation. The procedure requires that the measured image co-ordinates of the GCPs be fitted to their known terrain co-ordinate values. The coefficients of the polynomial transformation parameters are determined through a comparison of the measured image and the known ground control point co-ordinates. Normally, a least squares procedure will be used with the solution – since usually there are more GCPs available than are necessary to determine the transformation parameters contained in the polynomial equations. One of several alternative polynomials may be chosen based on the desired accuracy and the available number of GCPs. The rectification procedure has been carried out using the **GCP Works** module that is available within the **EASI/PACE** software. After introducing an appropriate number of GCPs required for each SPOT Pan scene, the program carried out the least squares computation and adjustment and produced values for the coefficients of the polynomial transformation parameters together with the residual errors at each individual point and the value of the root mean square error (RMSE) of these residual errors.

The last phase of the process of geometric correction is resampling where, for each pixel of the geometrically corrected image, there must be an associated grey level value. Generally this involves an interpolation from the grey level values of the neighbours located around the pixel on the original image. For each pixel in the processed and rectified image, there is a corresponding set of co-ordinates in the original image that must be found. Once this has been done, it is necessary to calculate the grey level value of the pixel occupying that position from the values of its neighbours. In practice, normally this is executed by one of the three main resampling methods – either nearest neighbour, bilinear interpolation or cubic convolution. Since the use of the cubic convolution routine normally yields the best image quality, it has been used throughout this project. This method uses the nearest sixteen neighbours of the pixel in the original image, and can be carried out through the adoption of the appropriate routine available in the **GCP Works** interface of **EASI/PACE** software. In **GCP Works**, the re-sampling type can be set to run in the **Disk-to-Disk Registration** procedure.

- **Radiometric Matching and Mosaicing Tasks**

Since the test area is covered by six SPOT Pan scenes, some of which have been acquired at different dates, the final individual SPOT Pan images can differ quite significantly from one another in terms of their radiometric characteristics and appearance. Thus there is a requirement for the use of certain procedures to bring these images as far as possible to a common range or scale of grey level values. This is necessary to prevent any abrupt changes in the appearance of the terrain when the individual images are mosaiced together.

For the mosaicing of the SPOT Pan images, EASI/PACE has a number of very effective tools to carry out automatic contrast matching and the feathering of overlap areas without any obvious joins being visible between the individual component images. This can be accomplished through the use of histograms of the grey level values that can be calculated and displayed for each set of overlapping image data. Weighting can be assigned to the correction being made to the image data depending on its distance from the cutline between images. The matching and feathering of these different data sets will then produce a single homogeneous mosaic for the test area that will be ready for further experimental activities or operations.

I.2 ACE System Characteristics

ACE stands for Advanced Cartographic Environment. It is a natural extension to the EASI/PACE system, which is designed to edit and generate high quality output maps. Originally the package was written by a separate small company called 2+1, but such was its value that the company was bought over by PCI during the time that the author was engaged in this project. ACE is a multi-platform product designed to be run on a number of the operating system environments – Windows 3.1, Windows 95/NT 3.5x, OS/2, and Solaris 2.4/2.5 – that are available for use within EASI/PACE. In fact, it is a map design and production system designed specifically for use with EASI/PACE to provide the cartographer with a *turnkey* environment for designing and producing entirely digital maps, from data input to the generation of an output file, ready for printing

1) Data Types and File Types

ACE deals with two main data types – vector data and raster data.

Vector Data: Vector files store graphics data as a series of lines linking two or more data points, each identified by their co-ordinates (x, y) in the map co-ordinate system These lines are called ***vectors***. The position of each point in the vector data set is specified with respect to its neighbours. This means that geometric calculations on the graphic co-ordinate data can be performed easily and the data can be edited without difficulty. Furthermore, attributes can be assigned to each feature – for example, the height of a contour line or the orientation of a symbol or descriptive information.

Raster Data: A raster is a grid data structure, which can be used to represent the Earth's surface as a matrix of equal sized squares or picture elements (pixels). In raster data, points are represented as clusters of adjacent cells. Typical sources of raster data are aerial photos, space imagery, DEMs and scanned maps.

ACE also has its own specific method of storing data. Within ACE, the digital data for each map is stored in discrete elements called *representations*. Individual representations represent graphical features, which may be point symbols; line symbols; area symbols or graphic text strings. Each feature is categorised by a **Representation Code (RepCode)** and identified by a set of co-ordinates and one or more descriptive labels. The use of these RepCodes will be described later in more detail.

ACE also uses a number of different file types that must not be deleted under any circumstances. These files are:

- ***.mah**: Files with this extension are the map headers, which are the general working files of ACE, where all the information relating to the current mapping project is stored.
- ***.rst**: Files with this extension contain the **RepCode Setup Table**, which is the file containing the graphical representation for each feature.
- ***.sym**: Files with this extension contain the symbols used on the map. These symbols can be created or edited in the **Symbol Editor**.

- ***.pix**: Files with this extension store data in segments in a single file within the database. These files are created when the cartographer uses read-only files or when he tries to save data to a file format which cannot be saved to by ACE.
- ***.ma0, *.ma1, etc.**: Files with these extensions are backups of the main ***.mah** files.

2) Scale, Sheet Size and Areas

When creating a new Map Header within ACE, the **Map Setup Dialog Box** automatically pops up. Through this **Dialog Box**, ACE allows the cartographer to set the desired scale and sheet size for his map interactively. It also offers an easy way of changing the map scale or sheet size in one simple step, whenever needed. The map sheet can be divided into a number of ***areas*** (see Figure I-2).

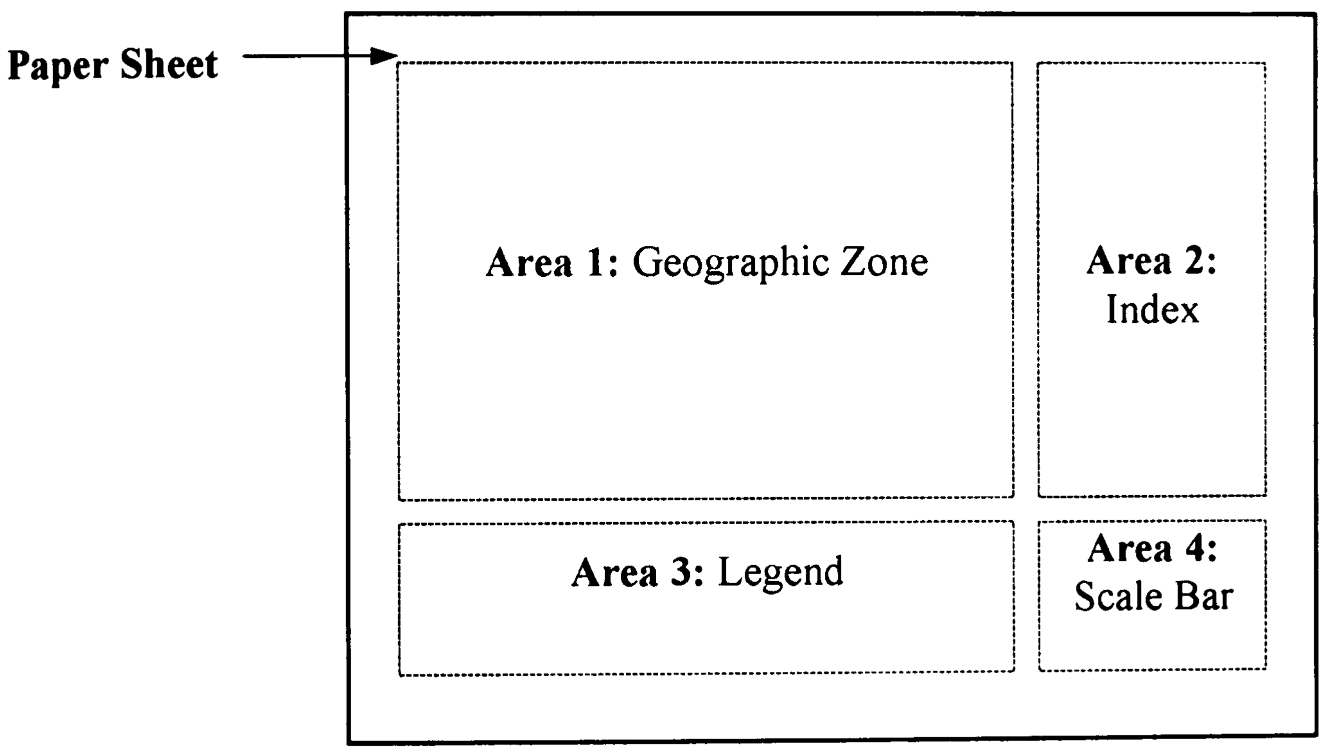


Figure I-2: Concept of areas within ACE

An ***area*** is defined as distinct physical region on the map sheet on which the final product will be printed. This map sheet may contain more than one area, each one representing different types of information: e.g. geographic zone, index, legend, scale bar, etc. One or more layers could be associated within each area, each one coming either from a ***vector*** or a ***raster*** file. These areas can also be edited, re-sized and new areas can be created if required.

3) Working with Raster Images

ACE allows the cartographer to load a new raster image to act as the backdrop to produce an image map. If required, this raster file can be separated into many layers. ACE provides support for 1-bit, 8-bit, 16-bit, RGB and grey scale imagery. It has also the facility to enhance the RGB and grey scale images using one of the contrast stretch routines – linear, equalize, root, or infrequency enhancement – that are available in ACE. In addition, the **Darken** and **Brighten** options are available and can be used for the raster images. These options move the whole Lookup Table (**LUT**) up or down in a smooth incremental way. As soon as the enhancement setting is changed within the option, the image is re-displayed in its new darker or lighter form.

4) Working with Vectors

Vectors are the prime working material that ACE uses to create a map. Each of the line and area features on a digital map is built up with vectors. Furthermore, various tasks and tools are available in order to facilitate the cartographic work with vectors. One of the most powerful features of ACE is the ability to create multiple layers to allow the separation of map features as they are created or imported from the digital database. The number of layers that can be created is limited only by the size of the memory of the PC. Each vector layer has its own geo-referencing information. Thus different layers of the same region will fit correctly on top of one another if they have been properly geo-referenced. In the case of loading more than one vector layer, the access mode of a vector layer can be changed to either the edit or the display only option. The active layer (which is editable on the screen) is the one on which new features will be created. It is also the one to which the options in the ***Vector menu*** will be applied. Indeed, this layer control has been used extensively during the design and production stage of the Misratah space image maps.

5) RepCode Setup Table (RST)

As noted above, the use of **RepCodes** is vital to ACE since they instruct the program how to draw and position all the features on a map. **RepCodes** are listed in ascending order with a description being given for each one. The **RepCode** can be created, modified, copied or deleted in any **.rst** file. Before creating and/or positioning any feature on the map, the cartographer must first define this feature. He does so by choosing its **RepCode**.

A graphical representation defines how these features are portrayed graphically (e.g. in the form of a point, line, polygon, symbol, vector-text, etc.). Each unique graphical representation has its own **RepCode**. This means that, for example, rivers and roads will be coded differently. Besides which, there may be different classes of roads that need to be shown on the map. In such a case, a separate **RepCode** is given for each class of road which ensures that these are distinct and that, for each class, a different graphical representation can be generated by the system.

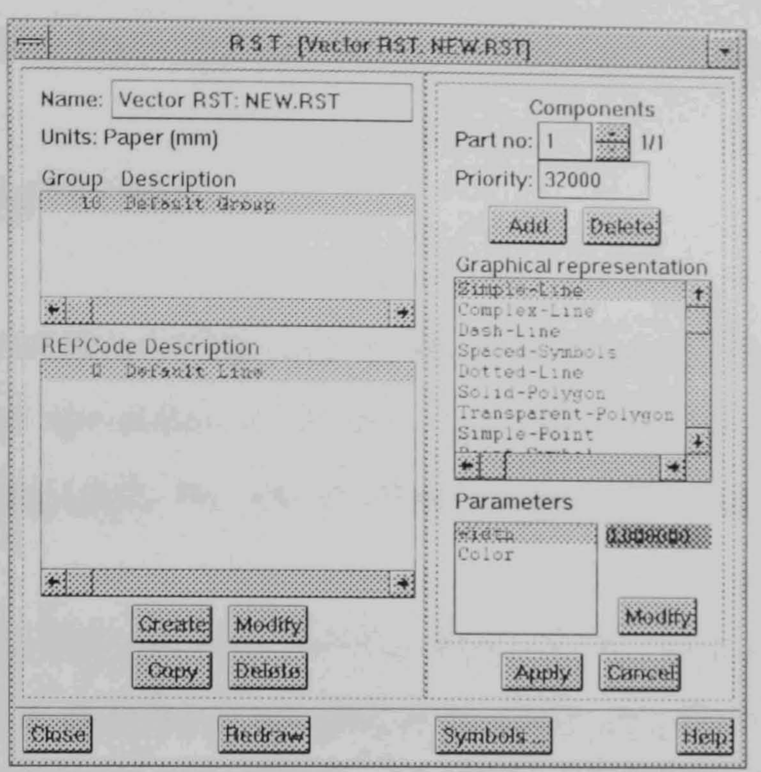


Figure I-3: The Dialog Box of the RST

In practice, a **RepCode** is a number that is attributed to each type of feature present on a map that the **ACE** software uses to differentiate one feature from another. These **RepCodes** are located in **RepCode Setup Tables** (**RST**) to provide the basic information required to draw and symbolize a feature. Associating a particular **RepCode** with its corresponding graphical representation provides the required display symbology in the feature representation scheme. Figure I-3 shows the **Dialog Box** of the **RST** that, in turn, contains the **RepCodes**, the **graphical representation** and their associated **parameters**. There is also a symbol library called **Symbols** that is available to provide standard point symbols.

The **RST** is the major tool that is used in any representation scheme since it contains the graphical representation for each individual feature. In ACE, there can be more than one **RST** opened in the application at a time. However, each loaded layer can only be linked to one **.rst** file, though **RSTs** can be shared between vector layers. These **RSTs** can be saved and used whenever they are required.

Different forms of graphical representation – such as a simple-line, dashed-line, solid-polygon, transparent-polygon, point-symbol, vector-text, etc. – are available in each **RST** together with their associated parameters of size and colour. These facilities allow the cartographer to create a variety of point, line and area symbols. Furthermore, a higher priority can be given to those features that should be displayed on top of other features. For example, a bridge should have a higher priority than a river. Besides which, a single feature can have more than one representation. This means that a highway could have two parts, the first being a thick black line and the second being a dashed red line.

6) Drawing and Editing Features

Building a map would not be possible without the capacity to create, add and edit features. In fact, the use of these operations is the most important aspect of creating a map. The main drawing and editing tools that are available in the ACE software package offer the following operations:

(i) Placing point, line and area features interactively in the required position with the mouse or in an exact geographical location by entering co-ordinates.
(ii) Zooming in or out or specifying a zoom location in order to display data.
(iii) Displaying data using full, partial or no **WYSIWYG** (what you see is what you get) representation.
(iv) Selecting the features to be displayed (e.g. only display the roads or rivers).
(v) Editing features with basic tools (cut, copy, paste, undo and duplicate).
(vi) Arranging features by grouping or ungrouping, attaching or detaching, rotating or mirroring them. For example, attaching an island to a lake so that only the water is coloured blue.
(vii) Interactively selecting one specific feature or selecting multiple features
(viii) Moving one or more features interactively using the mouse.
(ix) Digitising points, lines and polylines on-screen.
(x) Adding contour values (labels) from attribute information.

7) Adding and Editing Text

Text labels are very important items on any map: indeed the graphic will not be a map without them. For example, they are needed to show city names, wadi names, etc. Thus it is necessary to have good tools to work with text. In this respect, ACE provides a considerable number of text styles and fonts in various heights and colours to meet the cartographer's needs. In ACE, new names can be created in **Fixed** and **Curved** modes. As can be seen in

Figure I-4, in both modes, individual letters or entire words can be edited, moved or rotated. The system allows the cartographer to place text interactively using the cursor with a user specified angle. In addition, he can add his own fonts to the list of available fonts.

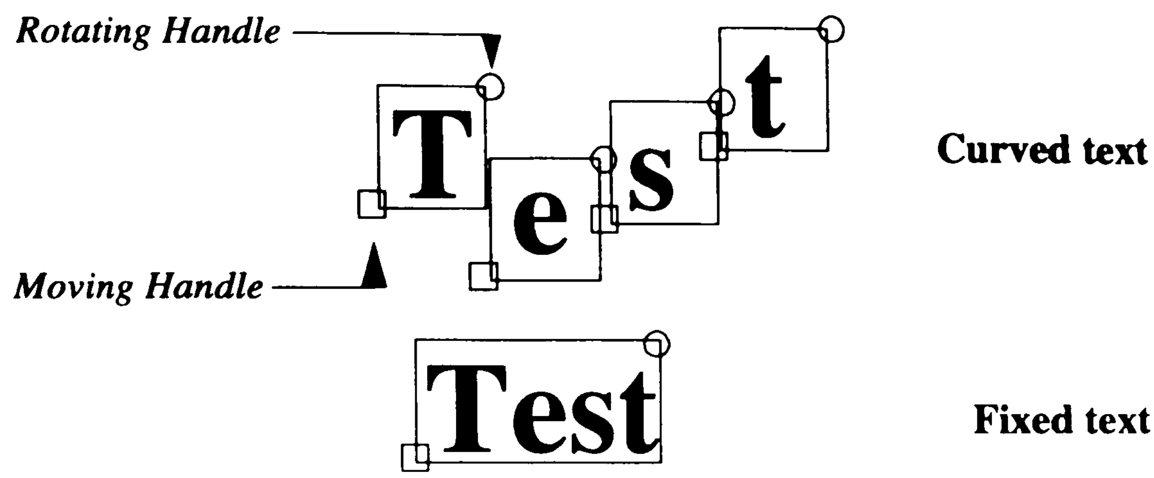


Figure I-4: Editing Fixed and Curved Text

8) Using ACE Special Tools

ACE offers the cartographer a variety of tasks or tools that are very helpful when creating his map. Only the **Symbol Editor** and the **Surround** tools will be described here.

(i) The **Symbol Editor** is employed to create, modify, or delete any symbol on the map. Figure I-5 shows the **Symbol Editor Dialog Box** with its drawing and editing tools and symbol library.

(ii) ACE has also the facility to generate the **Surround**, which comprises the descriptive information surrounding a map, including the neatline, grid, title, scale bar, legend, logo, etc.

All of these system characteristics of ACE described above have been used extensively in this project. However the ACE package is a comparatively new product and the present author has provided much help to the manufacturer of this software by providing the ACE technical staff with a great deal of feedback by reporting the problems and the shortcomings encountered using the software.

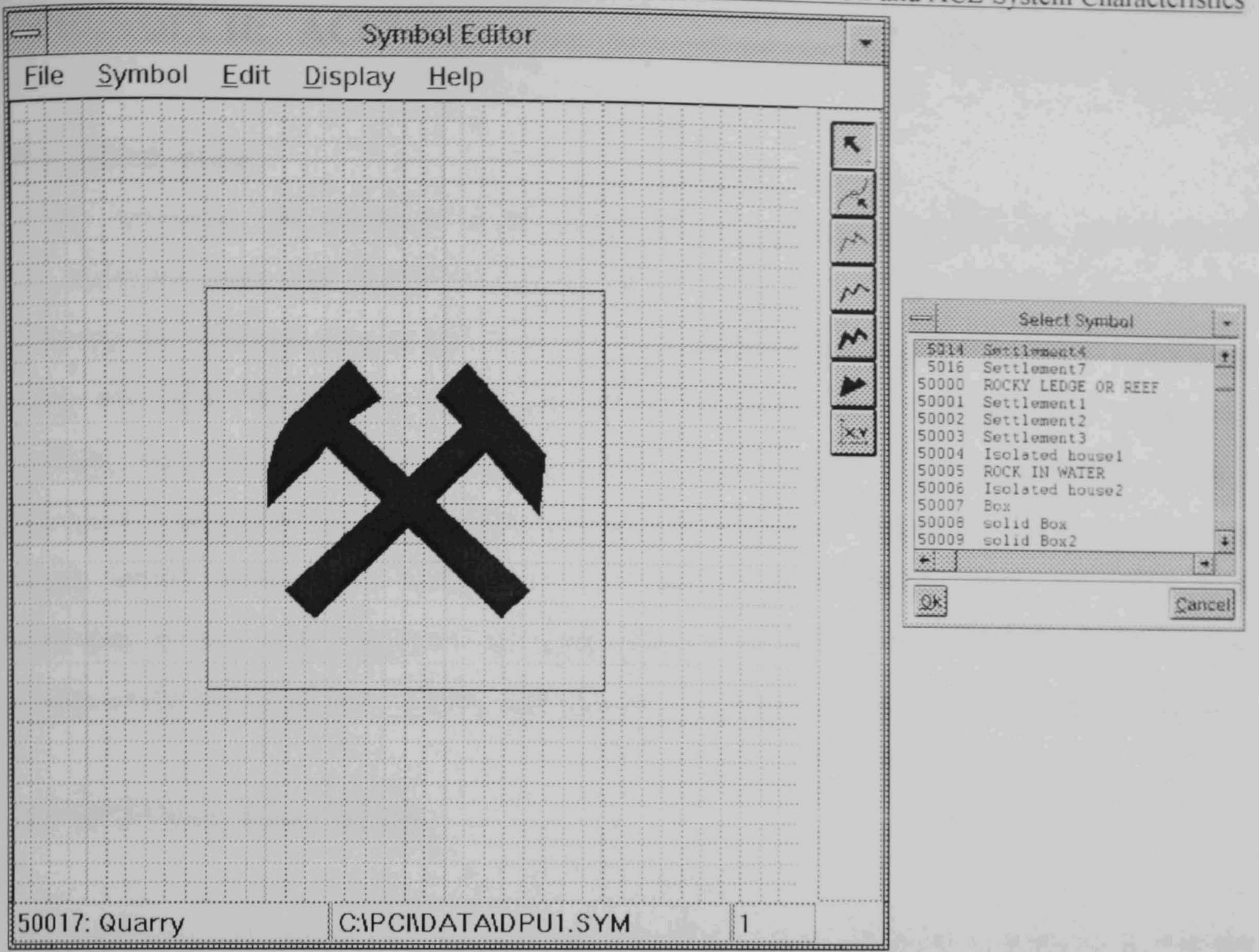


Figure I-5: The Symbol Editor with a Library to select symbols.

APPENDIX II: ACCURACY RESULTS AND VECTOR PLOTS

II.1 Introduction

In this Appendix, the results in terms of the planimetric accuracy after the application of the transformation and rectification procedure fitting the individual SPOT Pan images covering the Misratah area to the GCPs are presented first. This procedure was carried out using the GCP Works module of the EASI/PACE software package. The image co-ordinates have been measured from an origin at the top left corner of the image using a column (x) and row (y) co-ordinate system. All the error values are given in terms of pixels, which, in this case, are equal to 10 metres. The tabulated results are followed in each case by the vector plots of the residual errors (in planimetry) for all the SPOT Pan scenes of the Misratah area. These were produced using the FORTRAN (Vector) Program.

II.2 SPOT Pan Scene 76/285

The following are the results of the transformation and rectification procedure giving the planimetric accuracy of the SPOT Pan image for scene 76/285 using 29 control points and 20 check points:

1) Residual Errors at the Ground Control Points.

No.	Ground Control Point Co-ordinates (m)		Image Co-ordinates (Pixels)		Residual Errors (Pixels)		
	E (m)	N (m)	Column (x)	Row (y)	Δx	Δy	Vector
2	434460.0	3609950.0	1518.9	1056.9	-0.35	0.02	0.35
3	436610.0	3604225.0	1792.6	1592.6	0.28	0.61	0.67
4	447120.0	3597940.0	2759.3	2060.8	-0.20	0.72	0.74
6	423405.0	3584025.0	1070.6	3785.3	0.27	-0.93	0.97
7	427570.0	3611065.0	941.8	1047.3	-0.22	-0.49	0.54
9	460750.0	3581515.0	4172.1	3487.1	-0.23	-0.36	0.43
10	461490.0	3589650.0	4092.1	2670.2	0.33	0.01	0.33
11	460850.0	3594725.0	3949.6	2175.4	-0.76	-1.19	1.42
12	472250.0	3556910.0	5579..8	5755.9	0.40	0.19	0.44
13	481980.0	3585385.0	5892.2	2790..4	0.11	0.59	0.60
16	434460.0	3561700.0	2348.7	5839.3	-0.66	-0.18	0.69
17	468270.0	3573860.0	4936.8	4135.7	-0.43	0.52	0.68
19	463560.0	3567640.0	4652.8	4820.6	0.06	-0.80	0.80
20	465760.0	3558430.0	5004.3	5701.1	1.23	-0.59	1.37
22	448180.0	3558200.0	3539.4	5984.4	0.64	-0.35	0.73
23	450775.0	3565770.0	3619.5	5196.5	-1.03	0.93	1.39
24	451705.0	3578640.0	3472.3	3906.6	0.49	0.95	1.07
25	472760.0	3560100.0	5563.7	5431.4	-0.72	-0.68	0.99
26	462520.0	3559340.0	4713.3	5660.9	-0.89	1.40	1.66
28	466115.0	3586170.0	4539.7	2945.7	0.83	-1.19	1.45
35	415140.0	3592530.0	261.9	3064.4	0.01	0.36	0.37
36	421790.0	3563600.0	1289.3	5836.4	1.51	-0.21	1.52
37	437795.0	3568185.0	2509.7	5146.2	-0.32	-0.71	0.77
38	421210.0	3598145.0	652.5	2419.5	0.60	0.14	0.61
40	433285.0	3574680.0	2030.9	4569.1	0.83	0.46	0.95
42	468065.0	3590120.0	4632.8	2526.8	-0.37	0.23	0.44
45	434680.0	3586205.0	1943.9	3403.9	-1.22	-1.38	1.85
46	447755.0	3591490.0	2924.3	2691.1	1.37	1.20	1.82
48	419030.0	3570435.0	948.1	5199.1	-1.56	0.73	1.72
			RMSE		±0.77	±0.75	±1.08

The vector plot of the residual errors in planimetry at the individual ground control points using 29 GCPs is given in Figure II.1. These are random in terms of both extent and direction – i.e. there is no systematic error pattern visible.

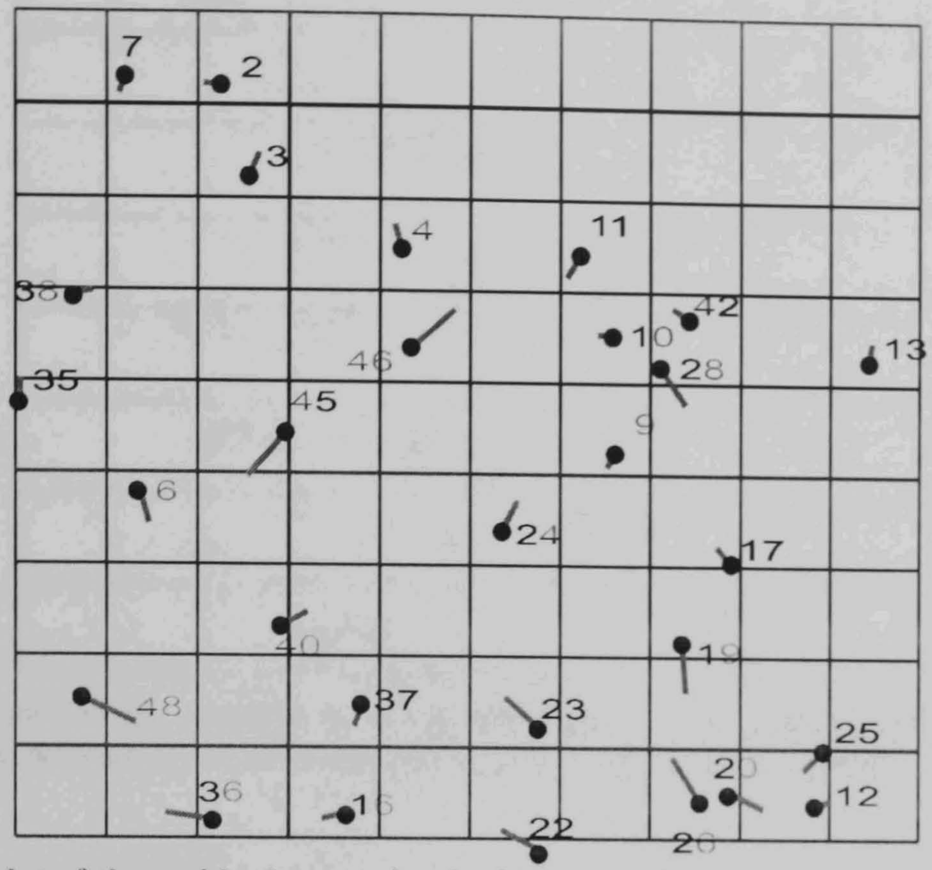


Figure II.1: Vector plot of the residual errors in planimetry at the ground control points for the SPOT Pan scene 76/285 after application of the transformation and rectification procedures.

2) Residual Errors at the Check Points.

No.	Ground Control Point Co-ordinates (m)		Image Co-ordinates (Pixels)		Residual Errors (Pixels)		
	E (m)	N (m)	Column (x)	Row (y)	Δx	Δy	Vector
1	433550.0	3608230.0	1475.9	1240.2	1.05	-0.29	1.09
5	427135.0	3587960.0	1304.3	3341.1	0.63	-0.64	0.90
8	460220.0	3584875.0	4070.3	3162.6	1.05	0.38	1.11
14	471995.0	3588570.0	4991.6	2621.2	0.99	-0.93	1.36
15	444925.0	3570830.0	3047.4	4780.1	-1.55	0.29	1.58
18	472375.0	3564550.0	5449.9	4998.3	-0.95	1.37	1.67
21	474380.0	3582370.0	5301.8	3201.1	0.82	-0.26	0.86
27	450935.0	3594775.0	3127.4	2316.4	-0.67	-1.24	1.41
29	442970.0	3577640.0	2769.7	4133.4	-0.31	0.37	0.48
30	448330.0	3586990.0	3047.7	3127.7	-0.45	0.27	0.53
31	438880.0	3562970.0	2689.4	5647.3	0.28	-1.16	1.19
32	456560.0	3571120.0	4007.4	4580.3	1.00	0.57	1.15
33	427750.0	3580310.0	1485.2	4092.3	0.66	1.17	1.35
34	433710.0	3565945.0	2215.6	5429.8	0.52	0.68	0.86
39	437910.0	3586460.0	2203.3	3333.2	-0.43	0.43	0.61
41	459150.0	3590590.0	3880.9	2610.1	0.31	-1.42	1.46
43	454070.0	3577750.0	3683.9	3960.2	0.80	1.13	1.38
44	444690.0	3597545.0	2565.4	2135.3	-1.47	0.40	1.52
47	424810.0	3572825.0	1373.8	4876.3	-1.08	-0.34	1.13
49	463870.0	3563065.0	4759.8	5268.9	-0.83	-1.34	1.58
				RMSE	±0.89	±0.87	±1.25

The vector plot of the residual errors in planimetry at the 20 check points is given in Figure II.2. Again, no systematic error pattern is visible.

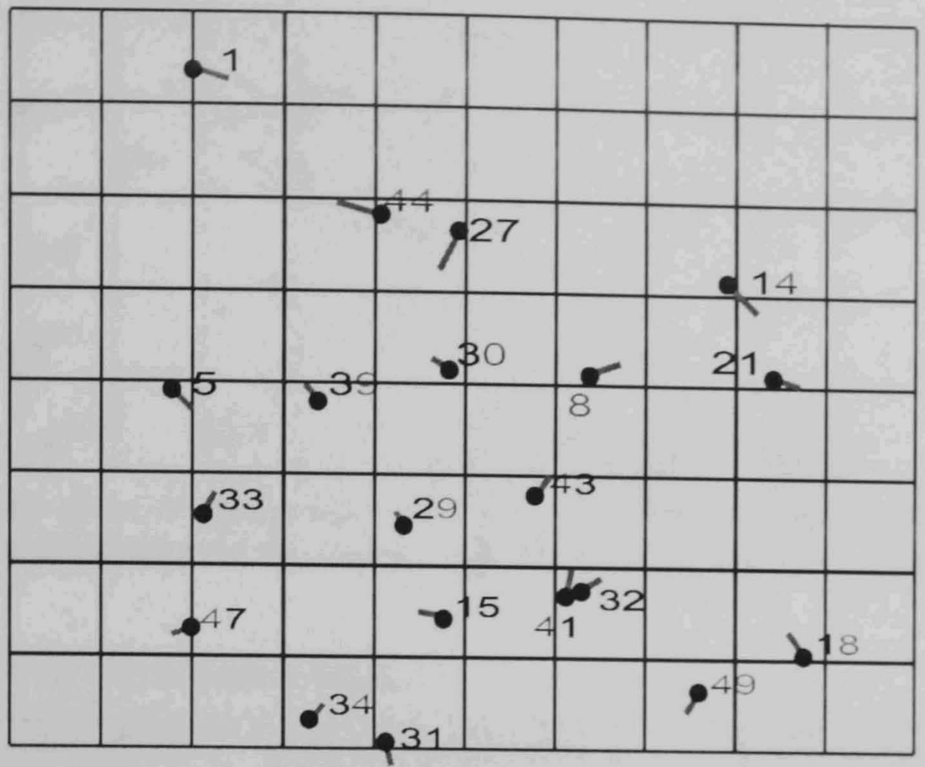


Figure II.2: Vector plot of the residual errors in planimetry at the check points for the SPOT Pan scene 76/285 after application of the transformation and rectification procedures.

II.3 SPOT Pan Scene 77/285

The following are the results of the transformation and rectification procedure giving the planimetric accuracy of the SPOT Pan image for scene 77/285 using 26 control points and 15 check points:

1) Residual Errors at the Ground Control Points.

No.	Ground Control Point Co-ordinates (m)		Image Co-ordinates (Pixels)		Residual Errors (Pixels)		
	E (m)	N (m)	Column (x)	Row (y)	Δx	Δy	Vector
1	490325.0	3574590.0	2694.4	4498.7	-0.67	-0.53	0.85
3	481115.0	3581420.0	1788.9	4031.3	2.02	-1.36	2.43
5	462850.0	3579825.0	312.8	4587.9	0.83	-0.32	0.89
8	463450.0	3588775.0	152.4	3698.4	-0.05	-0.69	0.69
9	493160.0	3584315.0	2700.8	3493.3	0.93	-0.11	0.94
11	499160.0	3575870.0	3377.3	4184.1	-0.06	-0.38	0.39
13	508010.0	3558525.0	4472.6	5684.2	0.82	1.59	1.79
16	479100.0	3573650.0	1800.8	4833.1	0.11	-0.53	0.54
18	503800.0	3566020.0	3969.9	5040.3	-2.06	-1.53	2.57
19	519790.0	3580410.0	4882.8	3303.9	-0.22	0.10	0.24
20	488310.0	3578980.0	2430.2	4116.3	-0.55	0.91	1.06
21	460035.0	3574500.0	204.9	5169.7	-0.49	0.39	0.62
22	493570.0	3563800.0	3201.4	5482.3	-0.57	1.47	1.58
24	469200.0	3583995.0	742.2	4041.4	-0.81	0.98	1.27
26	508810.0	3571885.0	4236.3	4361.9	1.08	-0.24	1.11
27	485115.0	3585395.0	2023.1	3560.3	0.40	0.87	0.95
28	491655.0	3580300.0	2671.4	3915.3	-0.07	0.02	0.07
29	497110.0	3586800.0	2957.9	3168.6	-0.60	-0.78	0.98
30	511275.0	3573130.0	4400.3	4188.7	0.45	0.75	0.88
32	495413.5	3559255.0	3451.7	5886.1	0.35	0.45	0.57
33	488540.0	3559665.0	2888.4	5992.8	0.03	-0.69	0.69
34	505385.0	3556230.0	4314.0	5965.0	0.66	-0.39	0.77
35	471665.0	3565350.0	1383.9	5802.1	-0.02	-0.39	0.39
36	459695.0	3568010.0	336.1	5805.9	0.07	0.17	0.18
39	515175.0	3554530.0	5120.8	5915.8	-0.57	-0.65	0.87
40	481620.0	3586540.0	1709.4	3523.4	-1.01	0.90	1.35
			RMSE		±0.81	±0.80	±1.14

The vector plot of the residual errors in planimetry at the individual ground control points using 26 GCPs is given in Figure II.3. The purely random pattern of errors can be seen.

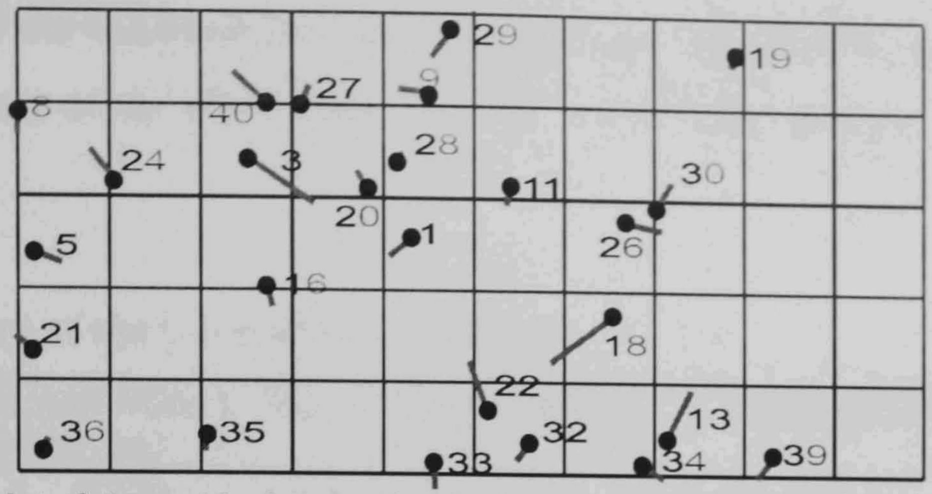


Figure II.3: Vector plot of the residual errors in planimetry at the ground control points for the SPOT Pan scene 77/285 after application of the transformation and rectification procedures.

2) Residual Errors at the Check Points.

No.	Ground Control Point Co-ordinates (m)		Image Co-ordinates (Pixels)		Residual Errors (Pixels)		
	E (m)	N (m)	Column (x)	Row (y)	Δx	Δy	Vector
2	511325.0	3569215.0	4495.3	4567.3	0.94	1.09	1.44
4	467190.0	3588430.0	473.4	3650.6	0.41	0.20	0.46
6	485370.0	3565540.0	2498.8	5488.2	-0.07	0.06	0.09
7	487470.0	3582850.0	2273.3	3757.3	0.08	0.44	0.45
10	489950.0	3571230.0	2741.7	4835.1	0.24	0.57	0.61
12	475085.0	3582760.0	1260.8	4033.4	1.38	0.90	1.64
14	493825.0	3575620.0	2955.1	4323.9	0.50	0.37	0.62
15	503885.0	3558290.0	4149.4	5796.8	-0.03	0.90	0.90
17	468275.0	3573880.0	903.6	5048.8	0.36	1.38	1.43
23	500825.0	3572205.0	3594.8	4505.3	0.17	0.88	0.89
25	508945.0	3565865.0	4382.6	4945.6	-0.63	1.24	1.39
31	476005.0	3564280.0	1764.1	5811.9	-0.19	-0.86	0.88
37	495305.0	3560270.0	3420.8	5789.9	0.64	1.46	1.60
38	468135.0	3566230.0	1073.8	5793.2	0.30	-0.50	0.58
41	501180.0	3578580.0	3475.2	3879.2	-0.53	0.82	0.98
				RMSE	±0.58	±0.91	±1.08

The vector plot of the residual errors in planimetry at the 15 check points showing the random distribution of these errors is given in Figure II.4.

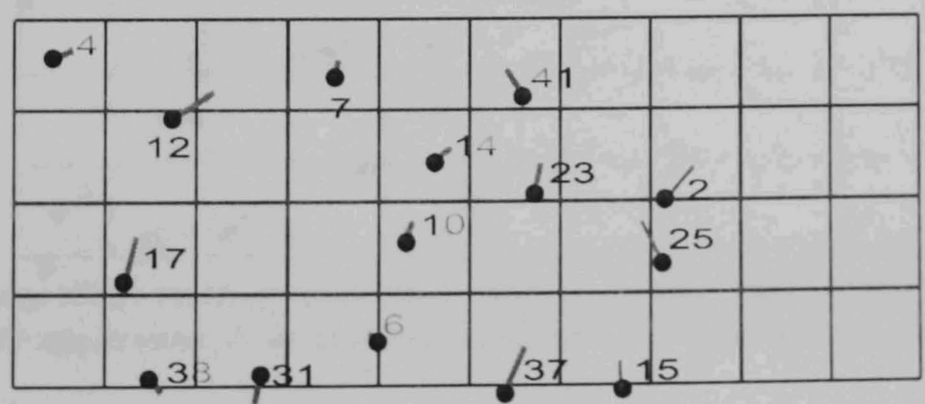


Figure II.4: Vector plot of the residual errors in planimetry at the check points for the SPOT Pan scene 77/285 after application of the transformation and rectification procedures.

II.4 SPOT Pan Scene 78/285

The following are the results of the transformation and rectification procedure giving the planimetric accuracy of the SPOT Pan image for scene 78/285 using 22 control points and 17 check points:

1) Residual Errors at the Ground Control Points.

No.	Ground Control Point Co-ordinates (m)		Image Co-ordinates (Pixels)		Residual Errors (Pixels)		
	E (m)	N (m)	Column (x)	Row (y)	Δx	Δy	Vector
1	510870.0	3563105.0	2968.8	5558.3	0.47	-0.55	0.72
2	511240.0	3573150.0	2814.7	4555.4	0.61	0.09	0.61
4	509170.0	3562020.0	2840.7	5690.1	-0.11	0.75	0.75
6	503810.0	3566010.0	2298.7	5367.1	-1.49	-0.85	1.71
9	497665.0	3586700.0	1386.2	3413.8	-0.47	0.83	0.96
10	515380.0	3581655.0	3021.9	3652.2	-0.52	0.48	0.71
11	503585.0	3580450.0	2014.3	3944.1	1.43	1.24	1.90
12	485110.0	3585375.0	335.4	3728.9	0.32	-0.42	0.52
14	493830.0	3575615.0	1259.4	4567.7	1.02	1.34	1.69
16	510660.0	3578910.0	2657.3	3991.3	-0.49	-0.59	0.77
19	479740.0	3564330.0	252.3	5901.2	-0.07	0.17	0.18
20	508775.0	3583355.0	2413.1	3578.7	1.03	-0.13	1.04
23	493705.0	3580690.0	1154.2	4066.1	-0.64	-0.41	0.76
25	506940.0	3568935.0	2517.4	5033.9	0.10	0.11	0.15
27	481040.0	3567425.0	308.3	5573.7	-0.02	0.14	0.14
28	486910.0	3563805.0	880.1	5838.7	-0.16	-0.73	0.75
29	493615.0	3563980.0	1456.9	5719.7	1.11	0.98	1.48
31	481140.0	3581440.0	66.8	4179.4	-0.01	0.37	0.37
33	504580.0	3584770.0	2019.9	3499.6	-0.60	-1.28	1.41
35	502050.0	3574065.0	1996.4	4596.6	-0.87	-0.22	0.90
37	489240.0	3581340.0	759.8	4068.6	-0.11	-0.37	0.38
39	489960.0	3571235.0	1005.3	5057.1	-0.52	-0.96	1.09
				RMSE	±0.72	±0.73	±1.03

The vector plot of the residual errors in planimetry at the individual ground control points using 22 GCPs is given in Figure II.5 and shows the random nature of these errors.

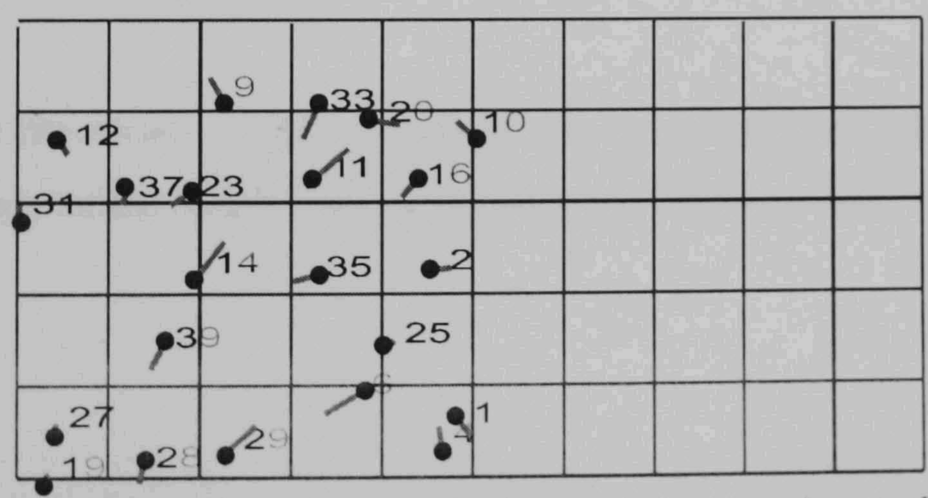


Figure II.5: Vector plot of the residual errors in planimetry at the ground control points for the SPOT Pan scene 78/285 after application of the transformation and rectification procedures.

2) Residual Errors at the Check Points.

No.	Ground Control Point Co-ordinates (m)		Image Co-ordinates (Pixels)		Residual Errors (Pixels)		
	E (m)	N (m)	Column (x)	Row (y)	Δx	Δy	Vector
3	510535.0	3574025.0	2737.8	4478.4	1.44	0.07	1.44
5	484025.0	3578500.0	363.6	4429.2	-1.42	0.53	1.52
7	505945.0	3574475.0	2329.2	4500.2	1.23	0.84	1.49
8	485375.0	3565540.0	715.7	5691.2	-0.17	-0.82	0.84
13	483575.0	3573535.0	414.6	4927.4	-1.00	-0.88	1.33
15	496860.0	3583570.0	1374.8	3735.3	0.79	0.81	1.12
17	508280.0	3571045.0	2594.3	4804.4	-0.42	-1.33	1.40
18	500825.0	3572210.0	1926.6	4798.6	0.99	0.37	1.06
21	499330.0	3578355.0	1683.9	4213.9	1.31	0.83	1.55
22	508990.0	3565775.0	2753.4	5319.3	-1.27	0.53	1.38
24	509440.0	3576865.0	2589.8	4212.3	1.25	0.09	1.26
26	512430.0	3580550.0	2781.9	3802.9	-1.11	-0.79	1.36
30	491340.0	3584460.0	883.9	3728.3	0.41	-0.28	0.49
32	487485.0	3582840.0	581.9	3946.2	-0.90	-0.11	0.91
34	490430.0	3577190.0	938.2	4462.7	0.98	0.73	1.23
36	507940.0	3581580.0	2371.8	3766.2	0.43	-0.66	0.79
38	490330.0	3574585.0	976.6	4721.7	0.38	0.53	0.65
			RMSE		±1.03	±0.71	±1.23

The vector plot of the residual errors in planimetry using 17 check points showing the random distribution of these errors is given in Figure II.6.

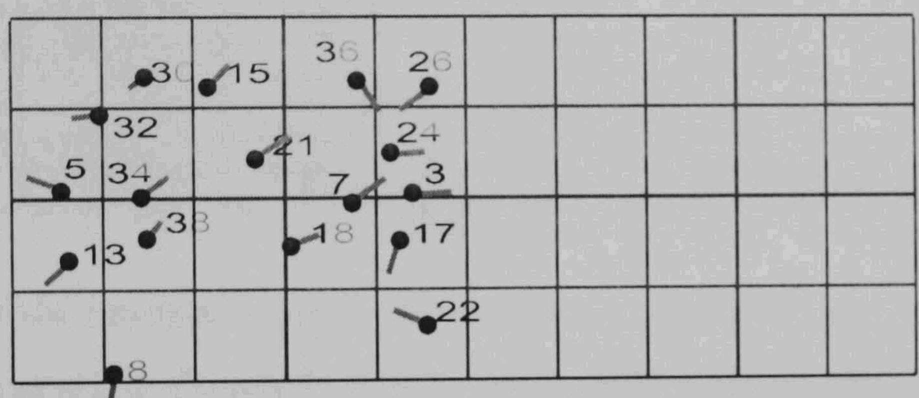


Figure II.6: Vector plot of the residual errors in planimetry at the check points for the SPOT Pan scene 78/285 after application of the transformation and rectification procedures.

II.5 SPOT Pan Scene 76/286

The following are the results of the transformation and rectification procedure giving the planimetric accuracy of the SPOT Pan image for scene 76/286 using 30 control points and 25 check points:

1) Residual Errors at the Ground Control Points.

No.	Ground Control Point Co-ordinates (m)		Image Co-ordinates (Pixels)		Residual Errors (Pixels)		
	E (m)	N (m)	Column (x)	Row (y)	Δx	Δy	Vector
2	435060.0	3552535.0	1628.8	1392.3	0.19	0.02	0.19
3	466425.0	3559290.0	3866.1	22.8	-0.61	-1.05	1.21
4	430045.0	3562370.0	1015.3	544.7	1.38	1.57	2.09
5	490956.0	3545661.0	5970.8	797.9	-1.07	-1.09	1.53
8	456425.0	3545430.0	3418.7	1601.2	0.65	-0.04	0.65
12	447985.0	3532190.0	3071.7	3082.7	0.68	1.34	1.50
13	465755.0	3519325.0	4678.4	3929.3	-0.55	1.19	1.31
14	442060.0	3546000.0	2314.9	1873.2	0.24	1.25	1.27
15	446730.0	3515280.0	3345.3	4749.6	-0.70	-0.83	1.09
17	435745.0	3565580.0	1387.3	103.4	0.47	-0.33	0.57
19	431385.0	3522205.0	2025.7	4426.8	-0.10	-0.91	0.92
20	462520.0	3559340.0	3571.9	108.9	-0.85	0.96	1.28
21	484525.0	3550425.0	5399.7	476.8	0.71	-0.53	0.89
24	472900.0	3504035.0	5531.2	5252.1	0.27	-0.20	0.33
25	406690.0	3514630.0	267.7	5715.7	0.12	0.35	0.37
26	489670.0	3553315.0	5715.5	80.5	0.49	0.77	0.92
27	487225.0	3542825.0	5757.8	1158.9	-1.21	-0.20	1.22
29	479950.0	3548417.0	5106.3	777.1	1.25	0.86	1.51
30	476190.0	3516150.0	5516.3	4004.1	0.25	-0.02	0.25
31	473720.0	3543470.0	4752.1	1398.8	1.13	-0.34	1.18
33	472245.0	3556900.0	4353.3	124.6	0.83	0.51	0.98
34	473500.0	3552910.0	4531.7	483.8	0.00	-0.42	0.42
40	456700.0	3556270.0	3200.1	539.1	-1.39	-0.36	1.43
42	446700.0	3561015.0	2335.6	303.8	-0.36	-0.09	0.37
45	418750.0	3555120.0	286.4	1497.8	-1.31	-1.06	1.69
46	467360.0	3534445.0	4473.6	2422.2	0.08	0.21	0.22
47	490395.0	3553780.0	5758.4	18.8	0.15	0.72	0.74
49	467135.0	3548815.0	4145.8	1026.8	-0.90	-1.02	1.36
51	448870.0	3552680.0	2686.4	1065.7	-0.20	-1.27	1.29
52	424075.0	3533285.0	1209.9	3514.9	0.37	0.02	0.37
				RMSE	±0.77	±0.79	±1.10

The vector plot of the residual errors in planimetry at the individual ground control points using 30 GCPs is given in Figure II.7. The vectors the random (non-systematic)nature of these residual errors.

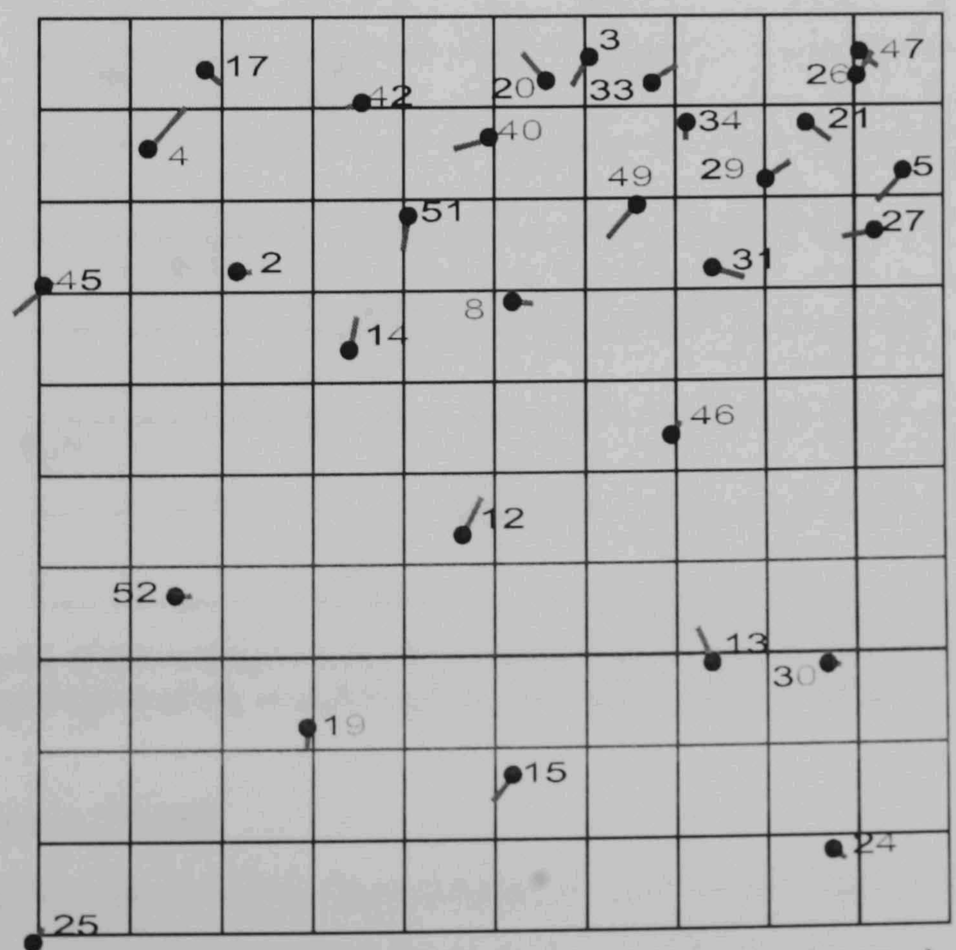


Figure II.7: Vector plot of the residual errors in planimetry at the ground control points for the SPOT Pan scene 76/286 after application of the transformation and rectification procedures.

2) Residual Errors at the Check Points.

No.	Ground Control Point Co-ordinates (m)		Image Co-ordinates (Pixels)		Residual Errors (Pixels)		
	E (m)	N (m)	Column (x)	Row (y)	Δx	Δy	Vector
1	430445.0	3538330.0	1592.1	2880.6	0.87	-0.30	0.92
6	427880.0	3551285.0	1097.6	1673.1	0.33	-1.01	1.06
7	438170.0	3557570.0	1757.2	831.4	1.04	-0.05	1.05
9	468780.0	3552385.0	4192.9	641.9	0.83	-0.75	1.12
10	449255.0	3552410.0	2721.8	1083.9	-0.10	-0.59	0.60
11	459240.0	3539300.0	3763.3	2133.8	0.29	0.00	0.29
16	441825.0	3563625.0	1903.7	160.8	1.04	1.75	2.04
18	448180.0	3558205.0	2511.3	544.2	-0.29	-0.10	0.30
22	481615.0	3554635.0	5095.2	131.3	0.23	-0.97	0.99
23	471375.0	3555770.0	4312.9	252.9	0.83	-0.79	1.15
28	469330.0	3525870.0	4804.1	3211.8	0.60	-0.02	0.60
32	468450.0	3546930.0	4285.4	1180.9	0.05	-0.60	0.60
35	488625.0	3546350.0	5788.1	782.2	1.44	-1.31	1.94
36	448985.0	3517960.0	3457.9	4440.8	0.56	1.17	1.30
37	467015.0	3555650.0	3989.8	364.1	0.06	-0.81	0.81
38	468000.0	3541560.0	4367.8	1713.7	0.03	-1.09	1.09
39	415085.0	3529395.0	592.8	4092.4	0.67	-1.11	1.29
41	454425.0	3558805.0	2973.3	345.3	-0.27	1.05	1.08
43	476075.0	3550325.0	4778.7	677.3	0.66	-0.44	0.79
44	459735.0	3546320.0	3646.1	1439.1	-1.36	-016	1.36
48	476010.0	3529195.0	5224.2	2738.7	-1.21	0.14	1.22
50	446250.0	3548240.0	2585.5	1559.5	0.25	0.63	0.67
53	463340.0	3508060.0	4741.4	5075.4	0.53	1.20	1.31
54	438030.0	3515715.0	2678.8	4906.4	0.81	0.47	0.93
55	443380.0	3531785.0	2729.6	3224.7	-1.05	-0.71	1.26
				RMSE	±0.76	±0.84	±1.13

The vector plot of the residual errors in planimetry at the 25 check points is given in Figure II.8 and shows that these errors are purely random in nature.

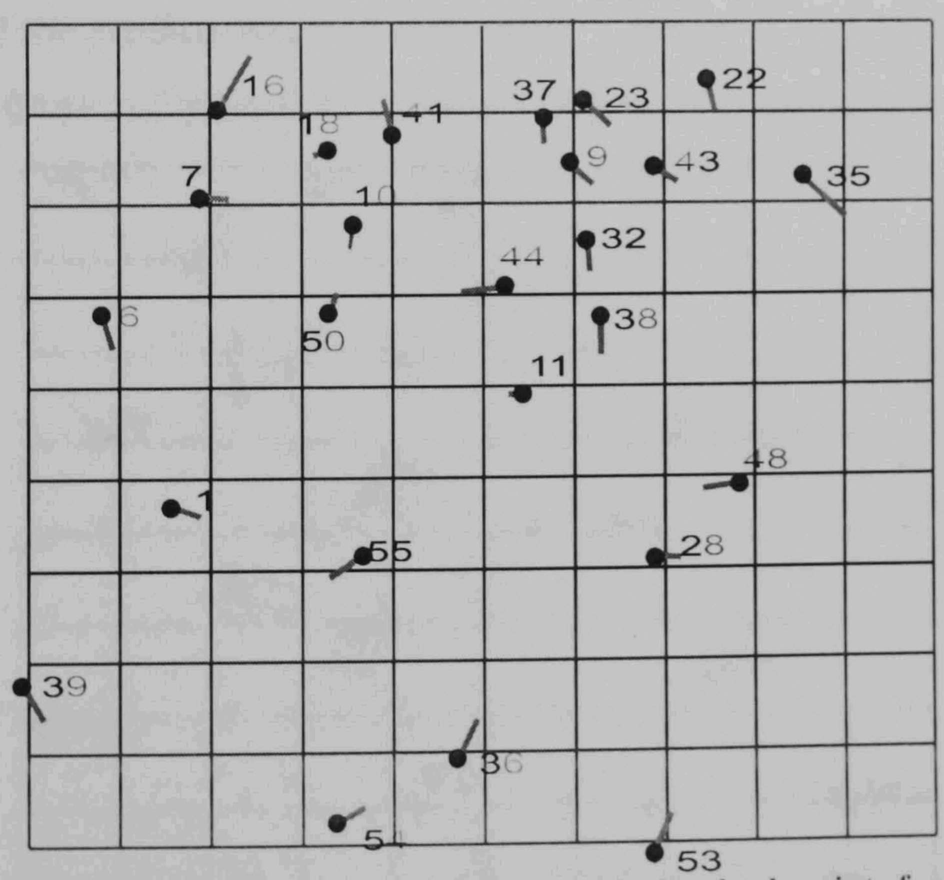


Figure II.8: Vector plot of the residual errors in planimetry at the check points for the SPOT Pan scene 76/286 after application of the transformation and rectification procedures.

II.6 SPOT Pan Scene 77/286

The following are the results of the transformation and rectification procedure giving the planimetric accuracy of the SPOT Pan image for scene 77/286 using 29 control points and 23 check points:

1) Residual Errors at the Ground Control Points.

No.	Ground Control Point Co-ordinates (m)		Image Co-ordinates (Pixels)		Residual Errors (Pixels)		
	E (m)	N (m)	Column (x)	Row (y)	Δx	Δy	Vector
1	507110.0	3558835.0	4252.0	9.5	-0.57	0.02	0.57
6	511280.0	3500350.0	5873.8	5623.4	1.01	-0.22	1.04
7	508900.0	3508965.0	5497.2	4833.8	-0.71	-0.65	0.96
9	468710.0	3539170.0	1602.1	2755.1	0.53	-0.83	0.99
11	480515.0	3563380.0	2013.7	139.7	0.24	0.17	0.30
13	472265.0	3552400.0	1589.7	1388.4	-0.03	0.70	0.70
16	484525.0	3550440.0	2632.7	1313.7	-0.28	-0.89	0.94
17	463520.0	3567660.0	520.9	90.2	0.78	-1.00	1.27
21	480105.0	3523370.0	2889.1	4052.8	0.08	0.05	0.09
24	512480.0	3539010.0	5112.7	1817.9	1.14	-0.95	1.48
25	479965.0	3542950.0	2432.3	2142.6	-0.75	-1.08	1.31
27	470180.0	3561375.0	1212.6	558.8	-0.63	0.98	1.16
28	460840.0	3552010.0	658.8	1676.9	-1.16	0.99	1.53
29	448985.0	3517960.0	466.8	5252.1	-1.54	-1.20	1.95
31	505200.0	3541825.0	4479.3	1707.9	0.09	1.42	1.42
32	511940.0	3514870.0	5601.4	4189.2	-1.36	0.85	1.60
34	504140.0	3525565.0	4758.2	3317.9	0.68	0.55	0.87
37	498350.0	3536400.0	4057.6	2385.6	-0.76	-0.49	0.91
38	492690.0	3552670.0	3241.2	920.2	-0.13	-1.37	1.38
39	491765.0	3560590.0	2989.2	171.2	0.39	0.97	1.05
41	446720.0	3515335.0	343.3	5559.1	1.16	1.15	1.64
42	478235.0	3534100.0	2495.4	3045.6	1.62	0.49	1.70
43	465555.0	3506725.0	2085.4	5984.2	0.28	-0.89	0.93
45	451160.0	3533580.0	287.9	3687.2	0.56	-0.42	0.70
46	463360.0	3508050.0	1874.4	5902.2	-1.21	-0.81	1.46
47	463429.0	3521439.0	1574.8	4599.8	-0.47	0.61	0.77
49	468580.0	3512810.0	2193.9	5329.7	0.74	0.84	1.12
51	462365.0	3510175.0	1746.4	5718.3	0.71	0.50	0.86
53	477105.0	3505305.0	3055.4	5879.6	-0.43	0.50	0.66
				RMSE	±0.83	±0.84	±1.18

The vector plot of the residual errors in planimetry at the individual ground control points using 29 GCPs is given in Figure II.9. These errors are non-systematic in nature.

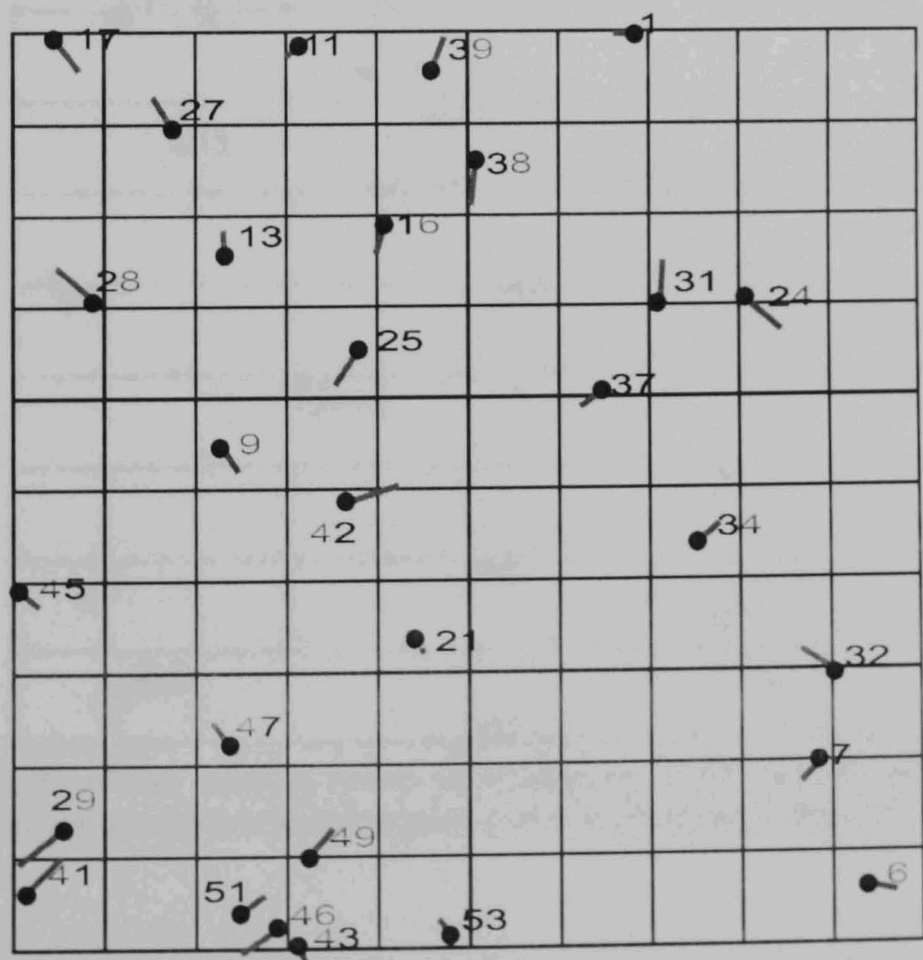


Figure II.9: Vector plot of the residual errors in planimetry at the ground control points for the SPOT Pan scene 77/286 after application of the transformation and rectification procedures.

3) Residual Errors at the Check Points.

No.	Ground Control Point Co-ordinates (m)		Image Co-ordinates (Pixels)		Residual Errors (Pixels)		
	E (m)	N (m)	Column (x)	Row (y)	Δx	Δy	Vector
2	489640.0	3557450.0	2887.9	520.9	-0.19	-0.50	0.54
3	490095.0	3533700.0	3459.4	2827.6	-0.61	-1.26	1.40
4	501515.0	3510210.0	4893.7	4876.7	0.33	0.11	0.35
5	500155.0	3532305.0	4294.1	2744.9	1.09	-1.59	1.93
8	485960.0	3555680.0	2629.2	772.7	-1.39	-0.15	1.40
10	504760.0	3517940.0	4976.1	4047.6	0.29	-1.46	1.49
12	501685.0	3539540.0	4253.9	2006.9	1.36	0.29	1.39
14	473200.0	3559750.0	1498.2	650.6	0.00	-0.15	0.15
15	496470.0	3556305.0	3461.6	487.3	-1.30	1.19	1.77
18	465700.0	3558385.0	913.6	948.3	0.11	1.15	1.15
19	483660.0	3542360.0	2746.3	2120.8	0.33	-0.92	0.98
20	474705.0	3530100.0	2300.1	3511.6	2.09	-0.01	2.09
22	483560.0	3550275.0	2559.6	1350.9	1.05	-0.49	1.16
23	454780.0	3515565.0	999.4	5357.7	-0.82	-0.42	0.92
26	505595.0	3554090.0	4239.2	504.2	1.15	0.59	1.29
30	472250.0	3556900.0	1485.6	949.9	0.03	0.78	0.78
33	467135.0	3548810.0	1250.8	1849.2	-0.57	-0.46	0.73
35	483310.0	3517030.0	3290.2	4602.4	-0.98	-0.88	1.31
36	472370.0	3564535.0	1319.5	203.5	-1.14	1.11	1.59
40	487765.0	3546415.0	2986.6	1637.3	0.71	-0.26	0.76
44	456395.0	3541535.0	534.6	2797.2	-0.75	1.27	1.47
48	452880.0	3522430.0	686.8	4733.9	0.61	0.73	0.95
52	478985.0	3506670.0	3178.1	5706.9	1.22	0.65	1.38
				RMSE	±0.96	±0.87	±1.30

The vector plot of the residual errors in planimetry at the 23 check points is given in Figure II.10 and shows non-systematic nature of these errors.

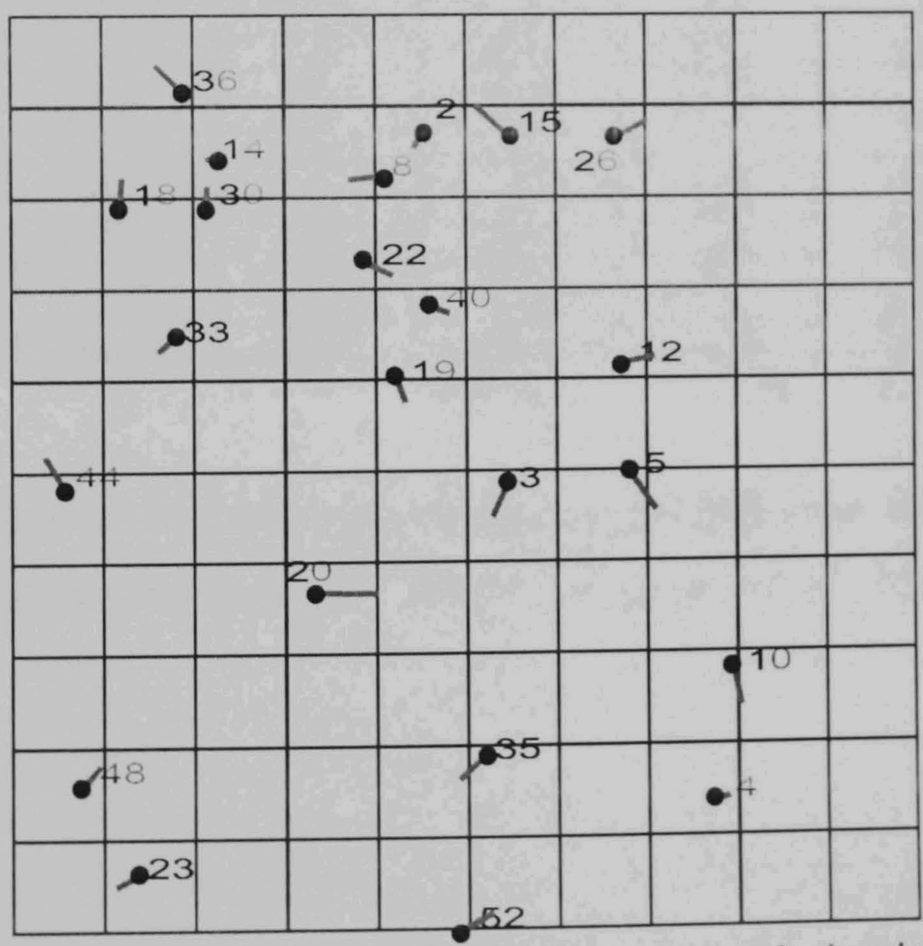


Figure II.10: Vector plot of the residual errors in planimetry at the check points for the SPOT Pan scene 77/286 after application of the transformation and rectification procedures.

II.7 SPOT Pan Scene 78/286

The following are the results of the transformation and rectification procedure giving the planimetric accuracy of the SPOT Pan image for scene 78/286 using 27 control points and 23 check points:

1) Residual Errors at the Ground Control Points.

No.	Ground Control Point Co-ordinates (m)		Image Co-ordinates (Pixels)		Residual Errors (Pixels)		
	E (m)	N (m)	Column (x)	Row (y)	Δx	Δy	Vector
3	477655.0	3559525.0	131.8	803.2	-0.49	0.48	0.69
6	475325.0	3526590.0	534.3	4109.7	0.14	-0.18	0.22
9	509530.0	3518065.0	3659.6	4436.4	-1.07	0.73	1.30
10	488860.0	3512460.0	1960.8	5290.1	-1.00	-1.81	2.07
11	524100.0	3500385.0	5291.6	5969.1	0.11	-0.04	0.12
12	505590.0	3554105.0	2642.4	926.7	0.98	-0.39	1.05
14	490660.0	3562910.0	1182.9	274.8	-0.14	-1.05	1.06
16	486430.0	3558685.0	899.7	756.9	0.86	1.09	1.38
17	495930.0	3551050.0	1858.3	1373.7	-0.50	0.01	0.50
20	495310.0	3531105.0	2177.8	3354.8	1.22	-0.77	1.44
22	476070.0	3550380.0	166.3	1736.6	0.88	-0.54	1.04
23	481405.0	3553670.0	560.9	1327.9	-0.60	0.08	0.61
24	479950.0	3542955.0	635.6	2413.6	1.09	0.11	1.10
25	496210.0	3556450.0	1782.1	834.7	-0.13	-0.51	0.53
26	512460.0	3539020.0	3526.3	2311.4	-0.67	-1.21	1.38
27	475640.0	3534110.0	424.8	3360.1	-0.65	0.46	0.79
29	497220.0	3536755.0	2235.6	2769.2	-1.33	0.37	1.38
33	499050.0	3545000.0	2241.5	1926.5	-0.35	0.21	0.41
35	485390.0	3565535.0	682.1	91.3	0.16	0.13	0.21
36	489075.0	3533400.0	1595.4	3221.4	0.13	0.73	0.74
38	483310.0	3517005.0	1398.8	4929.8	0.87	1.73	1.93
39	475255.0	3538880.0	305.2	2891.9	-0.53	-0.83	.098
43	487750.0	3546410.0	1239.4	1952.6	-0.94	-0.42	1.03
44	504785.0	3517890.0	3248.7	4523.7	1.30	0.29	1.34
45	508910.0	3508920.0	3776.9	5350.9	-0.49	-0.35	0.60
46	508040.0	3526080.0	3380.8	3664.8	1.22	0.82	1.47
47	509175.0	3562020.0	2808.6	88.8	-0.08	0.88	0.89
				RMSE	±0.78	±0.77	±1.10

The vector plot of the residual errors in planimetry at the individual ground control points using 27 GCPs is given in Figure II.11. There is no evidence of systematic errors being present.

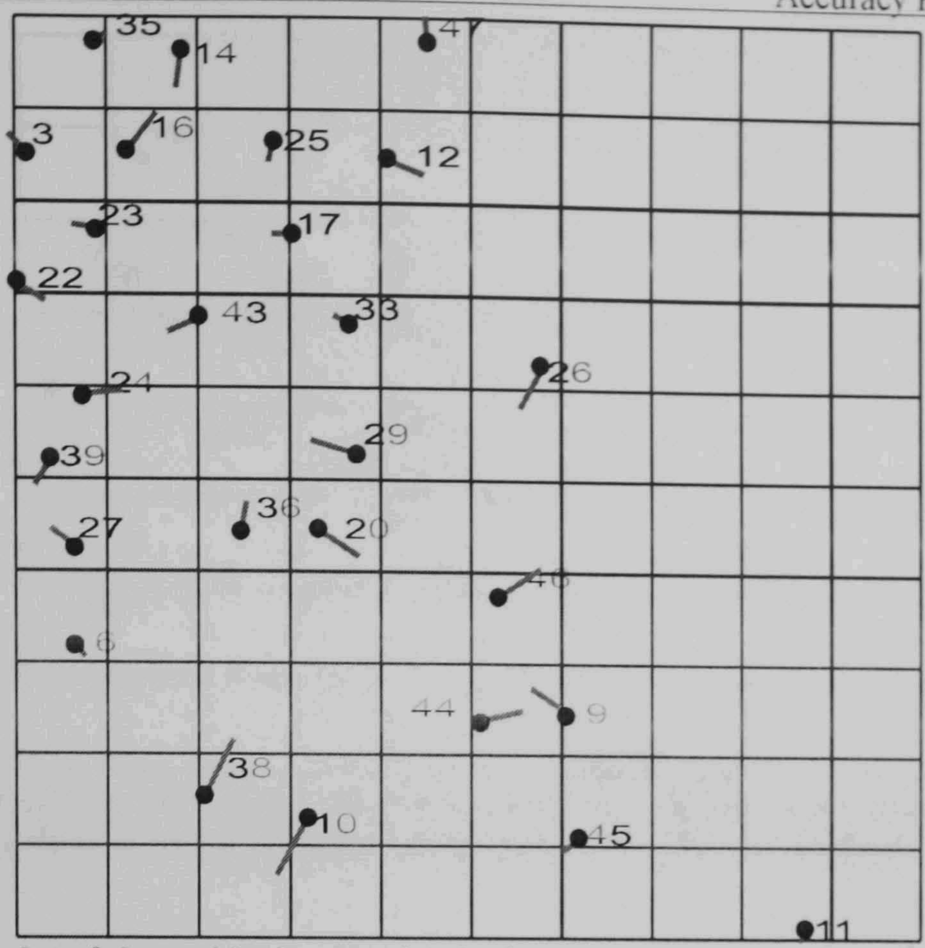


Figure II.11: Vector plot of the residual errors in planimetry at the ground control points for the SPOT Pan scene 78/286 after application transformation and rectification procedures.

2) Residual Errors at the Check Points.

No.	Ground Control Point Co-ordinates (m)		Image Co-ordinates (Pixels)		Residual Errors (Pixels)		
	E (m)	N (m)	Column (x)	Row (y)	Δx	Δy	Vector
1	484520.0	3550445.0	889.2	1601.8	0.95	0.67	1.17
2	483560.0	3550300.0	809.4	1629.8	0.84	-0.06	0.84
4	505225.0	3541845.0	2837.7	2147.6	-0.71	1.67	1.81
5	504175.0	3542940.0	2726.9	2053.2	0.71	-0.28	0.76
7	487010.0	3546770.0	1171.4	1929.6	1.33	1.27	1.83
8	500155.0	3532310.0	2575.1	3166.3	0.61	1.17	1.32
13	507105.0	3558820.0	2686.3	435.1	0.05	-2.07	2.07
15	485475.0	3557895.0	830.6	848.9	-1.12	0.78	1.37
18	503515.0	3537655.0	2768.4	2587.1	1.12	0.67	1.31
19	503210.0	3528410.0	2914.1	3505.9	0.77	0.23	0.80
21	491325.0	3544030.0	1592.4	2135.3	0.21	-0.55	0.59
28	498350.0	3536405.0	2340.4	2787.7	-0.94	0.90	1.31
30	493065.0	3553995.0	1557.3	1124.3	0.73	0.26	0.78
31	490515.0	3551240.0	1387.4	1433.4	-0.92	-0.58	1.08
32	503975.0	3548050.0	2613.3	1551.4	-0.05	0.58	0.58
34	494335.0	3547155.0	1794.6	1781.6	0.90	-0.91	1.28
37	487775.0	3538535.0	1388.2	2731.6	-0.20	-0.61	0.64
40	476070.0	3529210.0	550.4	3837.8	-0.78	-0.22	0.81
41	476870.0	3543030.0	369.6	2453.4	0.81	-1.20	1.44
42	511430.0	3513270.0	3918.2	4882.4	0.12	-0.22	0.22
48	498920.0	3561810.0	1916.8	266.9	0.16	1.85	1.85
49	493770.0	3541180.0	1855.1	2382.6	-1.05	0.67	1.25
50	492860.0	3528035.0	2022.1	3695.6	0.64	0.60	0.88
			RMSE		±0.79	±0.97	±1.25

The vector plot of the residual errors in planimetry at the 23 check points is given in Figure II.12 and shows the purely random nature of these errors.

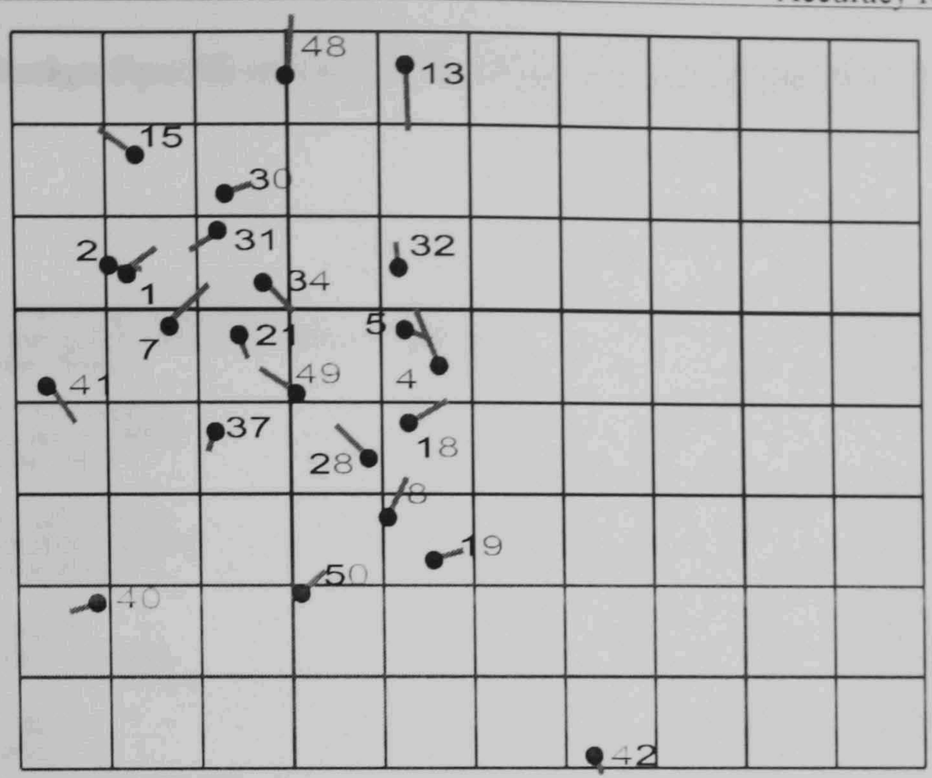


Figure II.12: Vector plot of the residual errors in planimetry at the check points for the SPOT Pan scene 78/286 after application of the transformation and rectification procedures.

APPENDIX III: Design Specifications for the Experimental Map at 1:50,000 Scale

0.20x0.35x0.10x0.35x0.20
Casings & Central Line: 100%Y + 100%M
Infill: White

0.15x0.60x0.15
Casings: 100%K
Infill: 20%Y

0.10x0.50x0.10
Casings: 100% K
Infill: White

0.40mm
50%Y + 50%M

0.30mm
White

1.60mm, 50%Y + 50%M
Width: 0.80mm, Dash Length:5.0mm,
Space: 3.0mm, Dot:0.80mm
100%K

Width: 0.80mm, Dash Length:4.0mm,
Space:2.0mm
100%K

Outline: 0.20mm, 100%M
Transparent: 50%Y + 80%M
Opacity: 35%

Outline: 0.20mm, 100%M
Transparent: 50%Y + 80%M
Opacity: 40%

Outline: 0.20mm, 100%M
Transparent: 60%Y + 90%M
Opacity: 40%

Outline: 0.3mm, 100%K
Circle: 2.5mm (dia.), 100%Y + 50%M

Outline: 0.3mm, 100%K
Square: 1.1 x 1.1mm , 100%M

Outline: 0.3mm, 100%K
Square: 1.1 x 1.1mm , 100%M

15%C

Outline: 0.2mm, 100%C
50%C

Waadi Kaam

Times Roman, Normal–Italic, 2.0mm Height
100%C

Outline: 0.2mm, 100%K
Circle: 1.5mm (dia.), white
Dot:1.1mm (dia.), 100%C

Outline: 0.2mm, 100%K
Circle: 1.5mm (dia.), 100%C

Outline: 0.6mm, 100%C
Square: 0.80 x 0.80mm , White

20

0.3mm, 100%Y + 50%M
Helvatica Oblique, 1.8mm Height, 100%K

115

Dot: o.6mm (dia.), 100%K
Helvatica Oblique, 1.8mm Height, 100%K

Outline: 0.2mm, 100%K
Symbol: 2.3 x 2.3mm, 100%K
Frame: 2.5 x 2.5mm, White

0.3mm width, 100%K

1.2mm width, 100%K

Outline: 0.2mm, 100%K
Symbol: 2.3 x 2.3mm, 100%K
Frame: 2.5 x 2.5mm, White

Outline: 0.2mm, 100%K
Symbol: 2.3 x 2.3mm, 100%K
Frame: 2.5 x 2.5mm, White

Outline: 0.2mm, 100%K
Symbol: 2.3 x 2.3mm, 100%K
Frame: 2.5 x 2.5mm, White

Outline: 0.2mm, 100%K
Symbol: 2.3 x 2.3mm, 100%K
Frame: 2.5 x 2.5mm, White

Outline: 0.2mm, 100%K
Symbol: 2.3 x 2.3mm, 100%K
Frame: 2.5 x 2.5mm, White

Outline: 0.2mm, 100%K
Symbol: 2.3 x 2.3mm, 100%K
Frame: 2.5 x 2.5mm, White

Outline:0.2mm, 100%K
square: 2.1 x 2.1mm, White

Outline: 0.3mm, 100K
Circle: 1.5mm (dia.), 100%Y
Dot: 0.8mm (dia.), 100%Y + 100%M

80%Y
Opacity: 40%

90%C + 90%Y
Opacity: 35%

100%C + 90%M + 100%Y
Opacity: 35%

100%C + 70%M + 50%Y
Opacity: 35%

Original Colour of the Image
Opacity: 0%

30%C + 70%M + 100%Y
Opacity: 35%

APPENDIX IV: Design Specifications for the Experimental at 1:250,000 Scale

0.15x0.30x0.10x0.30x0.15mm
casings & Central Line: White
Infill: 100%M + 100%Y

0.15x0.60x0.15mm
casings:100%K
Infill: White

0.10x0.40x0.10mm
casings: 100%K
Infill: 50%Y

Width: 0.30mm, Dash Length: 2.25mm
Space 1.20mm
White

Width: 0.25mm, Dash Length: 1.40mm
Space 0.80mm
White

1.20mm, 100%M + 100%Y
Dash Width: 0.60mm, Dash Length: 5.00mm
Space 3.00mm
100%K

Width: 0.60mm, Dash Length: 3.0mm
Space 1.0mm
100%K

Outline: 0.20mm, 100%M
Transparent: 90%M + 60%Y
Opacity: 40%

Outline: 0.20mm, 100%K
Circle: 2.3mm (dia.), 100%M + 100%Y

Outline: 0.20mm, 100%K
Circle: 2.3mm (dia.), 100%M + 100%Y

Outline: 0.30mm, 100%K
Square: 0.9 x 0.9mm, 100%M

20

0.3mm, 50%M + 100%Y
Helvatica Oblique, 2.0mm Height, 100%K

117

Dot: 0.6mm (dia.), 100%K
Helvatica Oblique, 1.6mm Height, 100%K

Outline:0.2mm, 100%K
Symbol: 1.7 x 1.7mm, 100%K
Frame: 2.0 x 2.0mm, white

Outline:0.2mm, 100%K
Symbol: 1.7 x 1.7mm, 100%K
Frame: 2.0 x 2.0mm, white

Outline:0.2mm, 100%K
Symbol: 1.7 x 1.7mm, 100%K
Frame: 2.0 x 2.0mm, white

Outline: 0.2mm, 100%K
Square: 1.6 x 1.6mm, white

Outline:0.2mm, 100%K
Symbol: 1.7 x 1.7mm, 100%K
Frame: 2.2 x 2.2mm, white

2.2 x 3.0mm, 100%K

Outline: 0.3mm, 100%K
Circle: 3.0mm (dia.), White
Symbol: 1.7 x 1.7mm, 100%M + 100%Y

Outline: 0.2mm, 100%K
Circle: 1.3mm (dia.), White
Dot: 0.7mm (dia.), 100%C

Outline: 0.3mm, 100%K
Circle: 1.2mm (dia.), 100%C

Wadi Sasu

Times Roman, Normal-Italic, 1.6 Height
100%C

15%100%C

Outline: 0.2mm, 100%C
50%C

Outline: 0.2mm, 100%Y
90%Y
Opacity: 40%

100%C + 10%M + 100%Y
Opacity: 40%

Outline: 0.2mm, 50%C + 50%Y
100%C + 70%M + 100%Y
Opacity: 40%

100%C + 70%M + 50%Y
Opacity: 40%

APPENDIX V: THE FINAL SPACE IMAGE MAPS OF MISRATAH

V.1 The Final Space Image Map of Misratah at 1:50,000 Scale
V.2 The Final Space Image Map of Misratah at 1:250,000 Scale

APPENDIX VI: USER TESTS OF THE FINAL SPACE IMAGE MAPS

IMAGE MAP EVALUATION FORM

VI.1 Introduction

The author has designed and produced two experimental maps (at 1:50,000 and 1:250,000 scales) for the Misratah area in North Libya. The main subject of this research work has been to analyse, develop and evaluate the design aspects of space image maps, in particular for the arid and semi-arid areas that are typical of the Libyan terrain. In such areas, these map products are thought to be more suitable to show, in a more realistic fashion, the terrain surface – most of which is a physical landscape with few or no cultural (man-made) features.

The nature of the space image map is quite different to that of the conventional line maps in the sense that there are two different levels of information – the un-generalised natural space image and the superimposed cartographic elements. These are combined together to produce a more realistic representation both for general purposes and for various users. To help to evaluate the design aspect of the produced maps, I would appreciate some of your time to inspect the two map products and complete the accompanying evaluation forms, to allow the current author to draw better conclusions. Your feedback will be helpful in evaluating the different design aspects that were involved in designing and producing the experimental image maps of the study area.

The rating scale will be as follows:

E = Excellent **V** = Very Good **G** = Good **S** = Satisfactory **P** = Poor

VI.2 The Evaluation Form

Participant: ----------------------- **Scale: -----------------------**

Background:---------------------- **Date:-------------------------**

VI.2.1 Section I: Image Map Evaluation

1) MAP CONTENT:	E	V	G	S	P	GENERAL COMMENTS
Level of information included and shown by the natural space image.						
Level of detail added through cartographic elements.						
Number of categories that had been included emphasizing important topographic features.						
The level of classification made to distinguish between features within the same categories.						

2) BACKGROUND IMAGE:	CLARITY & CONTRAST* E	V	G	S	P	GENERAL COMMENTS
Image Quality in showing:						
Physical Features						
Cultural (Man-made) Feature						
All Features						

3) SYMBOLISATION:	CLARITY & LEGIBILITY E	V	G	S	P	CONTRAST E	V	G	S	P	UNITY E	V	G	S	P	GENERAL COMMENTS
Road Detail:																
Highway																
Main Paved Road																
Secondary Paved Road																
Unpaved Road																
Track																
Boundary Information:																
International Boundary																
Provincial Boundary																
Water Features:																
Sea																
Coastline																
Water Body																
Wadi																
Spring																
Well																
Water Tower *																
Cultural Features:																
Town																
Small Town *																
Main Village																
Village																
Settlement																
Isolated Building *																
School *																
Mosque *																
Church *																
Cemetery																
Shrine																
Airport, Airfield																
Bridge *																
Dam *																
Dam with Road *																
Quarry																
Ruins																
Monument *																
TV Tower *																
Vegetation:																

Cultivated Area																
Orchard																
Forest																
Other Area Features:																
Sabkhah (Salt Marsh)																
Hummock and Ridges *																
Sand Hummock with Low Growth *																
Relief Information:																
Contour Lines																
Contour Numbers																
Spot Heights																

UNITY = Unity or integration of the cartographic elements (foreground) and the space image (background).
Contrast = Contrast of cartographic symbols against one another.
Contrast* = Contrast of image features.
Note = Features associated with asterisk sign (*) are not included in 1:250,000 scale image map.

4) TYPOGRAPHY: **a) Basic Characteristics of Type**	E	V	G	S	P	GENERAL COMMENTS
Style						
Form						
Size						
Colour						

b) Text and Names Representation	CLARITY & LEGIBILITY					CONTRAST					UNITY					GENERAL COMMENTS
	E	V	G	S	P	E	V	G	S	P	E	V	G	S	P	
Names and Text																

5) OVERALL DESIGN:	E	V	G	S	P	GENERAL COMMENTS
Point Symbol Selection						
Line Symbol Selection						
Area Symbol Selection						
Lettering Placement						
Grid						
Co-ordinates Numbers						
Background Colour						

6) LAYOUT:	CLARITY					BALANCE					GENERAL COMMENTS
	E	V	G	S	P	E	V	G	S	P	
Arrangement:											
Title											
Scale											
Legend & Marginal Information											

7) OVERALL APPEARANCE:	E	V	G	S	P	GENERAL COMMENTS
Readability						
Balance (Contrast)						
Effectiveness of Representation Method						
Use of Colour						
Practicality Of Format Size						

8) OVERALL RATING:	E	V	G	S	P	GENERAL COMMENTS

VI.2.2 Section II: Comparison between the experimental image map and the topographic line map (at the same scale and of the same area) in terms of content, representation, use and suitability for the area covered by the map.

1) COMPARISONS	Exp. Space Image Map					Topo. Line Map					GENERAL COMMENTS
	E	V	G	S	P	E	V	G	S	P	
The level of detail contained in both map products.											
The number of categories and classes of features in both maps.											
The representation of point features in both types of map.											
The representation of line features in both types of map.											
The representation of area features in both types of map.											
Relief depiction in both maps.											
Text and name placement in both maps.											
The use of colour in both maps											
Map arrangements											
The overall rating for both map products.											
The use and suitability of both maps for the test area.											

APPENDIX VII: THE NEW 3-D VISUALISATION TECHNIQUE

VII.1 Introduction

The display and visualisation of the three-dimensional (3D) data sets derived from both aerial and space imagery is currently one of the most interesting topics of research in the field of topographic science. It employs image processing techniques in combination with geometric transformations to produce the required visualisation and has various applications related to the analysis and extraction of spatial information. In fact, more research needs to be carried out into the integration of the display and visualisation process into remote sensing and cartographic operations.

In this context, different methods have been developed and used to recreate depth perception of the terrain surface. In particular, stereoscopic depth perception is of fundamental importance for data collection within the fields of photogrammetry and remote sensing, for it enables the formation of a 3-D stereo-model by viewing a pair of overlapping photographs or images that have been taken from different view points. This stereo-model can then be studied, interpreted, measured and mapped. Since viewing photographs or images stereoscopically without the aid of optical devices is an extremely difficult matter, instruments called stereoscopes are normally used to overcome these difficulties in stereo-viewing. In addition, there are other techniques that provide the user with a 3-D viewing facility – e.g. the use of anaglyphic or polarising filters and spectacles that allow the individual left and right images to be viewed respectively by the left and right eyes only. More sophisticated devices such as alternating shutters are also used; with these, the opening and the closure of the shutters through which the viewing takes place are synchronised with a screen displaying alternately left and right images at high speed. All of these 3-D viewing methods utilize the horizontal parallax that is present between the two images to create the depth perception, but most need a specific and sometimes expensive device or system in order to view the terrain surface in three dimensions. With some techniques such as the anaglyphic filter and spectacle technique, the 3-D stereo-model cannot be displayed in colour, and there are occasions where the 3-D image can only be viewed in digital form on the monitor screen rather than in printed hard-copy form.

VII.2 Existing Stereo-Viewing Techniques and Devices Used in Photogrammetry & Remote Sensing

In photogrammetry and remote sensing, stereo-viewing is regarded as an absolute necessity, both for measuring the ground control points needed for absolute orientation and for subsequently extracting those features required for topographic map compilation and the 3-D digital data needed for use in a GIS/LIS environment (Sarjakoski and Lammi, 1992). Besides which, the technique is also very useful in carrying out map revision and editing the digital elevation data produced by automatic image matching techniques. As reported by Petrie (1984, 1997b), all Digital Photogrammetric Workstations (DPWs) feature stereo-viewing and measuring capabilities – except one or two systems introduced by companies that specialize primarily in the field of remote sensing and appear to be less aware of the attributes of stereo-viewing.

Petrie (1984, 1997b) has stated that six main methods are currently in use in photogrammetric and remote sensing systems, though others are possible. These are:

- ***Twin monitors viewed with a mirror stereoscope or using polarizing filters and spectacles***: The first method involves the use of two flat-screen monitors, displaying the left and right images of the stereo-pair, respectively. The mirror stereoscope is used to present one of these images to one eye only and the other image to the other eye only. In the second variation of this method, the operator wears appropriate spectacles with horizontal and vertical polarizing filters to allow the stereo-viewing of the images on the display monitors which have the corresponding polarizing filters placed in front of them.
- ***Single monitor viewed with a simple mirror stereoscope***: This alternative approatch is to display the left and right images side by side on a single monitor and to view these through a simple mirror stereoscope – the so called split-screen stereo method.
- ***Anaglyphic filters and spectacles***: This involves simply superimposing the two component images of the stereo-pair on the screen of a single colour monitor, with the one image displayed in red and the other in green, using the anaglyphic technique familiar to photogrammetrists from early analogue stereo-plotting instruments based on optical projection. Users wearing spectacles with the corresponding red/green filters view the resulting stereo-model on the monitor screen.
- ***Alternating images on the monitor screen with alternating shutters for stereo-viewing***: This system alternates the left and right component images on a single

monitor screen at high speed (e.g. 50 to 60 Hz per image). Viewing is carried out using (active) spectacles equipped with alternating shutters synchronised with alternating images on the monitor – the left eye sees only the left image and the right eye sees only the right image.

- ***Alternating images on the monitor screen with an electronic prism in front of the screen; stereo-viewing using polarizing spectacles***: This last method also uses alternating (left/right) corresponding images displayed on a single monitor screen. In this situation, each image has a different polarization pattern (clockwise/anti-clockwise) induced by an electronic prism mounted in front of the display monitor. Users viewing the stereo-model wear (passive) spectacles equipped with the corresponding polarizing filters.

More details about how each of these methods operates are given by Petrie (1984 and 1997b). From this discussion, it can be seen that existing 3-D viewing methods present two images, a left image and right image, to the observer either at the same time on a screen or using a binocular optical train or on a printed hard-copy image or sequentially at high speed on a screen. Conventional stereoscopic processes selectively pass one of the two images to each eye by blocking the unwanted image from view. Since each eye sees a different view, the brain can then generate the perception of depth.

VII.3 Chromo-Stereoscopy

Quite recently, a new technique for data visualisation and analysis has been developed using the effect known as chromo-stereoscopy. This technique, as described by Toutin and Rivard (1995) and Toutin (1997a), combines colour vision and depth perception. The chromo-stereoscopic method is straightforward – depth is encoded into a range of colours within a single image rather than the two images involved in all the techniques mentioned above. This image then decoded by means of quite simple and cheap prismatic optics to produce depth perception. At the time of viewing any colour-encoded composite image (using chromo-stereoscopy), the resulting stereo impression will be based on certain physiological and psychological factors pertaining to colour and depth.

In the next section of this chapter, a more detailed description will be given covering the basis of the new method and the actual procedures that have been devised and were carried out to generate a coloured image using the new 3-D chromo-stereoscopic visualisation method. In particular, the techniques that have been applied to control the input parameters of the required geometric and radiometric processing of space images over the author's test area in Libya will be discussed and analysed.

VII.4 Depth Perception

One of the most important features of any 3-D visualisation environment is the perception of the third dimension (depth). Normally the human visual system creates the 3-D impression of an object from the 2-D patterns projected onto the retinas of the observer's two eyes. Nevertheless, some impression of depth can be seen with only one eye when the other one is closed. This suggests that the use of two eyes is not necessary to create some sense of depth – although most methods of 3-D viewing do require the use of both eyes.

As described by Okoshi (1976), McAllester (1993) and Toutin (1997b), the human visual system interprets depth in the sensed images based on both physiological and psychological cues. Thus depth cues are divided into these two major categories – physiological and psychological. Some physiological cues need both eyes to be used (e.g. when binocular vision needs to be used); others are available when an observer uses only one eye to look at images (monocularly). By contrast, the psychological cues are entirely monocular. Most authorities define four cues that are physiological and while the other six are psychological. The physiological depth cues are accommodation, convergence, binocular disparity, and motion parallax. Convergence and binocular disparity are the only binocular depth cues; all the others are monocular. The psychological depth cues are retinal image size, linear perspective, texture gradient, aerial perspective, overlapping, and shades and shadows. More details about the subject can be found in Okoshi (1976), McAllester (1993) and Toutin (1997b).

In the real world, the human visual system automatically uses all available depth cues to determine distances between objects. In modern psychology, these cues have been treated as additional elements of information which, when added to the 2-D image located on the back of the human eye, make depth perception possible. The human brain then combines these cues with the flat image to enable the observer to make judgements about objects and their relationship in space. These cues can also be combined together to provide an enhanced depth sensation. In photogrammetry and remote sensing, certain of these cues (perspective, binocular disparity, shades and shadows, etc.) are generally found to be the most useful cues for depth perception.

VII.5 Basic Concepts of the New 3-D Visualisation Technique

US researcher, Richard A. Steenblik, first invented the ChromaDepth 3-D process after he noticed that the bright colours on the screen of a TEMPEST video game seemed to lie in different depth planes. This observation opened the door to him developing this effect, known as *chromo-stereoscopy*, using a quite simple but elegant technique into a practical method for producing 3-D images. As mentioned above, chromo-stereoscopy is a method for converting colour into stereoscopic depth. The most interesting thing about this process is that the encoding of depth is accomplished in a single image – which opens the door to its use as a cartographic technique. In this respect, it is therefore very different from the conventional stereoscopic technique based on the use of pairs of photographs or images containing parallaxes (or displacements) related to elevation or depth which have a perspective geometry that is different to that of the map. Instead a chromo-stereoscopic depth-encoded image retains its map geometry and all of its 2-D usefulness. Although special but inexpensive optics are needed in order to produce a really useful depth separation, a small chromo-stereoscopic effect can sometimes be observed without the aid of the special glasses purely as a result of commonly experienced physiological and psychological conditions. However the new 3-D visualisation technique described in this chapter is based on the ChromoDepth 3-D process and the requisite simple glasses are needed for this particular purpose. Steenblik (1986-1991) has developed the technique taking into consideration the following two main phenomena:

(i) As described by Toutin (1997a), the concept of this new 3-D display method (chromo-stereoscopy) is first based on Enthoven's theory in 1985, by which co-planar stimuli are perceived as being different in terms of their apparent depth. In other words, a red object is perceived as being in front of a blue body, in which case, chromo-stereopsis is deemed as being positive. Whereas the opposite perception results in negative chromo-stereopsis. This phenomena has been credited to transversal chromatic dispersion and the asymmetrical relation of the visual and optical axes.

(ii) Through the physical property of refraction, chromo-stereopsis can be enhanced. The amount of refraction of a ray of light passing from air to glass depends on its speed in these two different media (air and glass), the two speeds depending on wavelength (λ). A typical example occurs when white light enters a glass prism, in which case, the differing refractions of the various component wavelengths spread them apart and each can be seen as a band of coloured light (i.e. or spectral colour), see Figure VII-1.

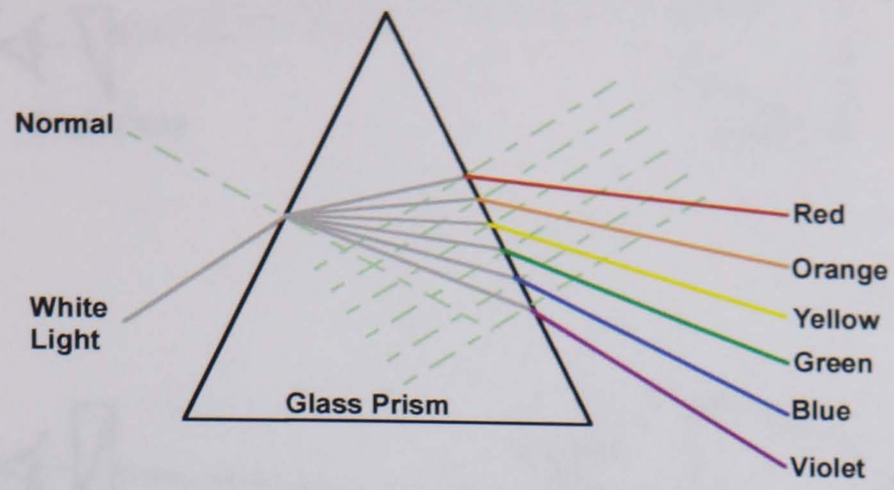


Figure VII-1: The refraction of white light through a glass prism.

In summary, Toutin and Rivard (1995) have stated that "the basic concept of this technique is straightforward – encoding depth into an image by means of colour, then decoding the colours by means of optics producing the depth perception". Since colour is used to represent depth information, the generation of only a single image is required. The artificial depth can then be related to any quantitative theme such as altimetry or gravimetry.

VII.5.1 The Optical Elements Used for 3-D Chromo-Stereoscopic Viewing

After many years of experimentation, Mr. Steenblik created several alternative types of viewing spectacles, including those equipped with plastic prisms; glass double-prisms; and Fresnel prisms; and those using liquid optics employing glycerine and Chinese cinnamon oil held in wedge-shaped glass cells. These liquid-based spectacles worked extremely well, but were expensive to construct and not suited for mass production.

Although a pair of single-prisms can be used to view enhanced chromo-stereoscopic images, unfortunately, the use of this method creates more problems than those using a pair of double prisms. Furthermore, single-prism spectacles bend all the colours of the light coming from the object; in this case, the image appears much closer to the observer than the object because the lines of sight converge at a point closer in space (Figure VII-2a). The solution is to push the mean or average image distance back to coincide with the actual object distance; this effect can be achieved through the use of double-prism spectacles (Figure VII-2b).

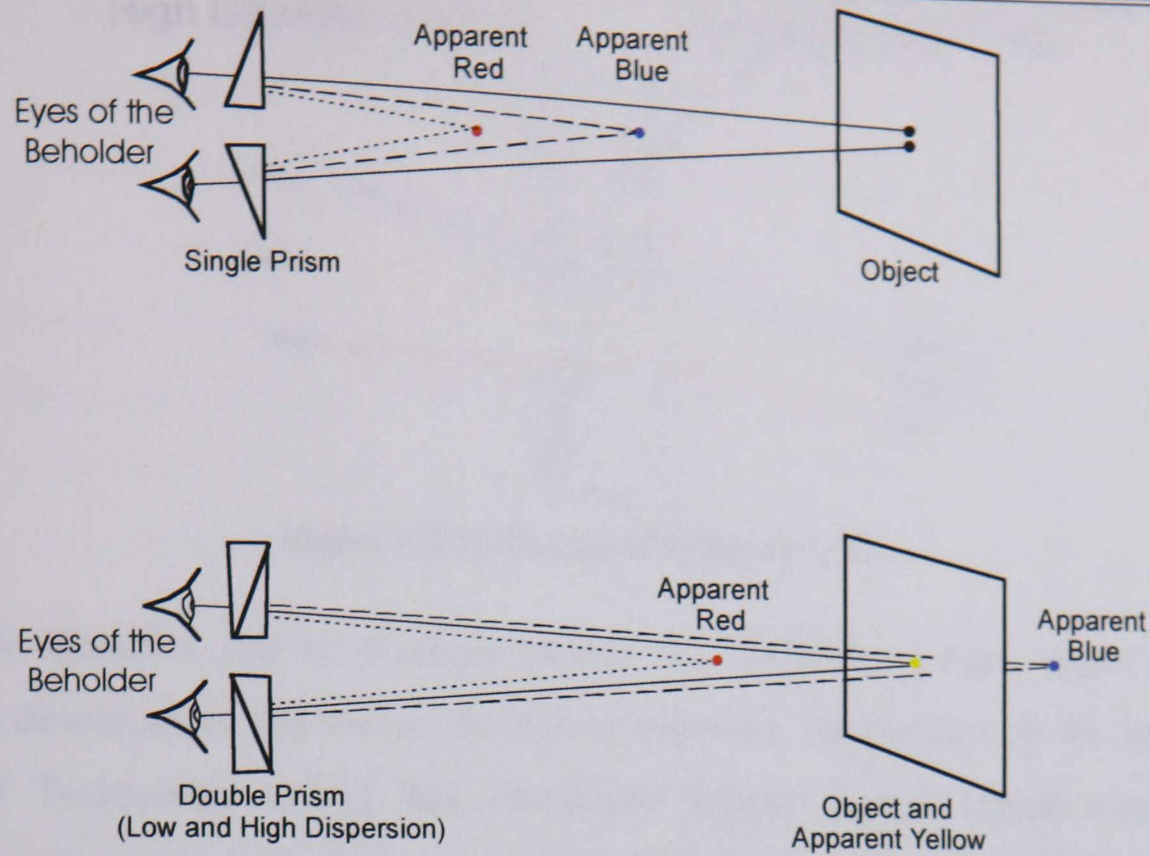


Figure VII-2: (a) Single prism viewing spectacles and (b) double prism spectacles

The optical element that results from this double-prism arrangement is called a superchromatic prism. As illustrated in Figure VII-3, it consists of two prisms placed face-to-face with their bases pointing in opposite directions. The first is a high-dispersion prism made from a material that has a high coefficient of chromatic dispersion. In such a case, the refractive index of the material is strongly wavelength-dependent. The second prism is a low-dispersion prism, which is made from a material having a low coefficient of chromatic dispersion. The refractive index of this material is nearly invariant across the visible spectrum. In this case, a single colour is selected and is made to appear at the same distance as the actual object plane. A medium colour (such as yellow) is usually chosen; in which case, the other colours are designed to appear in front of or behind the selected colour in the object plane. Foreground objects are coloured red; background objects are coloured blue, and objects lying in-between are positioned relatively in accordance with their position in the electromagnetic wave spectrum. As noted above, a variety of optical materials are suitable for the creation of these prisms, including glasses, plastics, and liquids.

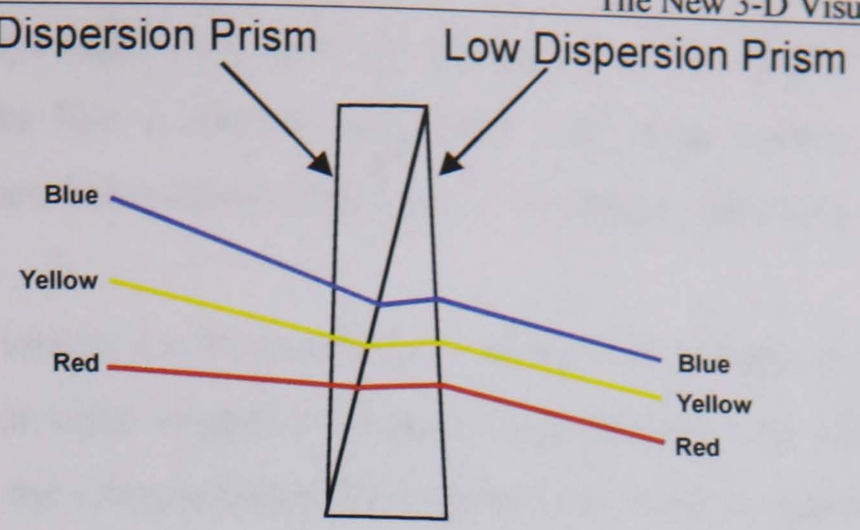


Figure VII-3: The superchromatic prism

In 1990, Mr. Steenblik and his business partner, Dr. Frederick Lauter, began to explore a new optical development that had come to their attention. Researchers at the Massachusetts Institute of Technology (MIT) had developed binary optics; which resulted in the introduction of a method of making very thin diffractive optics that had the efficiency of refractive optics. Obviously, the use of this type of binary optics provided a practical answer to the problems of viewing in 3-D using the chromo-stereoscopic technique. The binary optics used in the ChromaDepth 3-D spectacles are made as very thin prisms – which allows them to be handled easily during the viewing process – yet they act like thick glass prisms. After two years of development work in collaboration with MIT, the ChromaDepth 3-D spectacles were first used commercially in June 1992. They are inexpensive, mass-producible chromo-stereoscopic spectacles, and can be reproduced in the form of plastic film through proprietary techniques.

VII.5.2 The Use of ChromaDepth 3-D as a Visualisation Technique

Generally speaking, human beings see objects in 3-D every day of their lives because their two eyes see two slightly different views of the world. Their brains then interpret the subtle differences between these views and build a 3-D image of the real world. As described above, chromo-stereoscopic spectacles perform their function in a completely different manner to that utilized in conventional stereoscopic image depth-decoding devices.

Obviously, the ChromaDepth 3-D process does not begin with two images; it only requires a single image. Depth information is encoded into the image through a choice of colour. Foreground objects are coloured red, background objects are coloured blue, and objects in-between are coloured according to their position in the rainbow of colours in the visible part of the spectrum; thus an orange object would appear behind red but in front of green. The binary optics in the ChromaDepth 3-D glasses decode this depth information to create a left view for the left eye and a right view for the right eye. The final ChromaDepth 3-D compatible image looks like a normal individual 2-D image when viewed without ChromaDepth 3-D glasses, but suddenly becomes a 3-D image when viewed with them

The ChromaDepth 3-D images can be presented in the form of printed, overhead projected, computer screen, film, or video images or in laser show formats. As will be described in the following sections, the ChromaDepth 3-D process can also be applied to continuous tone imagery (e.g. space imagery). Essentially it is used for visualisation after the stereo-photogrammetric operations for the extraction of the terrain elevation data have been completed. Thus it occupies a quite different place in the overall mapping process, falling much more into the area of cartographic representation or visualisation of the terrain surface rather than in the photogrammetric part of the overall mapping process.

VII.6 Applying the ChromaDepth 3-D Technique to Remotely Sensed Image Data of Libya

Image interpretation is an important technique in utilizing the images that result from remote sensing and photogrammetric operations. However, in order to accomplish this task, the interpreter must have his own specialised tools and systems to make further judgements and decisions about the object of study. From the interpreter's point of view, the perception of colour and stereo are such tools. Colour is an effective way of displaying three-dimensional data, and can significantly help users to extract detailed information and make judgements about it. Furthermore, the exploitation of certain types of cartographic information such as elevation data can be facilitated by its stereo-visualisation in 3-D when compared to its 2-D representation. It is clear that the ChromaDepth 3-D visualisation technique is an interesting and inexpensive tool that can aid an interpreter's understanding of the terrain surface characteristics and obtain information. Particularly in a country such as Libya, where most of the terrain is a bare physical landscape with few cultural features, the ChromaDepth 3-D display method could be very useful for geo-scientists working both in office and field applications when used in the context of space imagery.

For this technique to be implemented with remotely-sensed space image data, two quite separate (geometric and radiometric) processing steps must be implemented to generate a good quality ChromaDepth 3-D image to allow the final product to be seen using the special glasses. These two processing steps are required to ensure that the ChromaDepth

3D image maintains both the geometric integrity and the radiometric information contained in the SPOT Panchromatic images.

VII.7 The Study Site & Data Sets

Once again, the already processed SPOT space imagery covering Misratah area has been used as the test data set for research into the exploitation of the newly-developed ChromoDepth technique.

VII.7.1 Study Site

A test site (47 km x 55.6 km) was selected lying within the Misratah area already used by the author for his work on the cartographic design of the space image maps: it is covered by four topographic maps at 1:50,000 scale. This area represents a typical example of a semi-arid region with no major water courses existing in the area. Instead, the area is characterised by a number of the dry stream channels called wadis that fill up with water for short periods during the occasional rainstorms. There is an agricultural project, a small town, two or three villages, etc., occupying the north and the northeast corner of the Misratah area. The highest point in the area lies in the southwest corner of the area and has an elevation of about 275m. The lowest point is located in the northeastern part of the area towards the sea and has an elevation of 20m. Thus there is an elevation difference of 255 m across the study site.

VII.7.2 Data Sets

The remotely sensed image data comprises four of the SPOT monoscopic images taken in panchromatic mode with a ground pixel size of 10m. The four scenes were acquired during the 1980s from a descending orbit. Table VII-1 provides some information about the acquisition date, scene number and the viewing angles of these particular images.

SPOT Scene No.	Acquisition Date	Viewing Angle
76-285	17/9/1986	-24.8°
77-285	14/10/1986	-14.8°
76-286	03/3/1989	+28.6°
76-286	26/9/1986	+25.1°

Table VII-1: The acquisition dates and the viewing angles of the SPOT data.

The cartographic data includes the following:

i) Four topographic maps at 1:50,000 scale covering the test area. The contours of these maps had interval values of 20m. The planimetric accuracy (R.M.S.E) of these maps is ± 15m, whereas the contour accuracy is estimated to be ± 7.5m.

ii) A digital elevation model (DEM), with grid spacing of 10m, was generated from the contour lines of the 1:50,000 scale topographic maps. As noted above, the terrain elevation in the study site varies from 20 to 255m.

VII.7.3 Data Capture for Digital Elevation Model (DEM)

In order to carry out experiments using chromo-stereoscopy over the study site, a Digital Elevation Model (DEM) was required. In this case, the DEM was needed both for use in the ortho-rectification process for the ortho-mosaic production, as well as being needed (together with the SPOT Panchromatic ortho-mosaic) for the generation of the chromo-stereoscopic image of the test area.

The DEM is a data file that contains a matrix of elevation values of the terrain at a fixed grid interval over a specified area of the Earth's surface. The location and the intervals between each of the grid points will always be referenced to the terrain co-ordinate system. This could be either the geographic latitude-longitude, UTM (Universal Transverse Mercator) or one of the national (local) co-ordinate systems that have been established by some countries. The closer together the grid points, the more detailed the elevation information about the terrain surface will be. Usually the details of the peaks and valleys in the terrain will be better modeled with a small grid point spacing than when the grid intervals are very large.

The DEMs can be extracted using one of the following sources:

i) Cartographic source: This refers to the process of extracting digital elevation data by interpolation from the contours shown on existing hard-copy cartographic products, such as topographic maps and bathymetric charts.

ii) Photogrammetric and remote sensing sources: These refer to the process of extracting DEMs from stereo-images (e.g. aerial stereo-photos or space stereo-images) using either an analogue or analytical stereo plotter or digital photogrammetric workstations.

For the current project, unfortunately stereo-pairs of SPOT imagery were not available, so the digital elevation data had to be derived from the contour lines contained in the topographic maps at 1:50,000 scale (constituting a cartographic source) to create the DEM of the study area.

VII.7.3.1 Manual Vector Digitizing

Manual vector digitizing was used to digitise the contour lines at 20m intervals. Each of the 1:50,000 scale topographic maps has been placed on a large-format tablet digitizer and digitized utilizing the **MAPDATA** software package.

The **MAPDATA** interactive digitizing and editing package is designed to undertake the task of manual vector digitizing and interactive editing and has been used extensively for the digitizing of contour lines both in the Department and elsewhere. In this particular case, **MAPDATA** was installed on a standard **386PC** linked to a large-format **CalComp 9100** tablet digitizer (see Figure VII-4). This software package functions within its on-screen graphical interface and operates within the **MS-DOS** environment. It relies on the entry of a series of two-character keywords that can be input directly through the keyboard or pre-programmed as digitizer cursor button commands. The program incorporates a built-in (affine) transformation procedure to allow the direct conversion of the digitizer co-ordinates to the corresponding terrain co-ordinates. One of the most important cartographic functions available within **MAPDATA** system is the ability to assign feature codes to digitize points or line segments. This function enables similar map features to be captured, grouped, or separated in a logical order by numeric code and sub-code, e.g. an index contour = 2.1; an intermediate contour = 2.2; and a supplementary contour = 2.3. It is also possible with **MAPDATA** to attach a height value or text comment to digitized point and line segments to create a digital terrain model or generate text at a later stage. Kassim (1988) and Shand (1997) have given more information about **MAPDATA**, and its initialisation and set-up procedures.

Figure VII-4: The 386 PC linked to CalComp 9100 tablet digitizer.

As mentioned above, the contour lines on four adjacent topographic maps at 1:50,000 scale have been digitized. The co-ordinate limits of these maps are as shown on Table VII-2.

Topographic Map Sheet Number	Lower Left E	Lower Left N	Upper Left E	Upper Left N	Upper Right E	Upper Right N	Lower Right E	Lower Right N
2189 I	429325	3568450	429525	3596150	453025	3596025	452900	3568325
2189 II	429150	3540750	429350	3568450	452925	3568325	452775	3540600
2289 III	452775	3540600	476425	3568225	452925	3568325	476375	3540500
2289 IV	452900	3568325	453025	3596000	476500	3595925	476450	3568225

Table VII-2: The four corner co-ordinates of each of the 4 topographic maps at 1:50,000 scale.

The digitizing units were in metres. **MAPDATA** allows the capture of data as discrete points or line segments. The end of a segment is signalled from the keyboard, and the procedure is then continued until the data capture operation has been completed. The digitized co-ordinates may be stored as (X, Y) or as (X, Y, Z) co-ordinates. In this work, the digitized data were stored as X, Y, Z co-ordinates. **MAPDATA** allows digital data to be saved and output in several different raster and vector formats for further processing either within **MAPDATA** or in some other suitable package. The two output formats that are most commonly used are compressed binary and readable **ASCII**: both are given the suffix **.MAP** when saved in **MAPDATA**.

After 350 hours of hard work, the whole digitizing job needed for the DEM extraction has been completed. A total of four files were created for the digitized contours and saved in the readable **ASCII** format for further processing. Figure VII-5 illustrates the digitized contour lines of one of these files. A check proof has been produced in the form of line plots for each digital file using a **Hewlett Packard DraftPro** vector plotter. Then all the outputs of these files were checked and edited as required.

Finally, it is worth mentioning that, although this work was laborious and time consuming, the author gained a great deal of experience using the **MAPDATA** software package, the tablet digitizer and the **Hewlett Packard DraftPro** vector plotter that will be very useful when supervising digital map production on his return home.

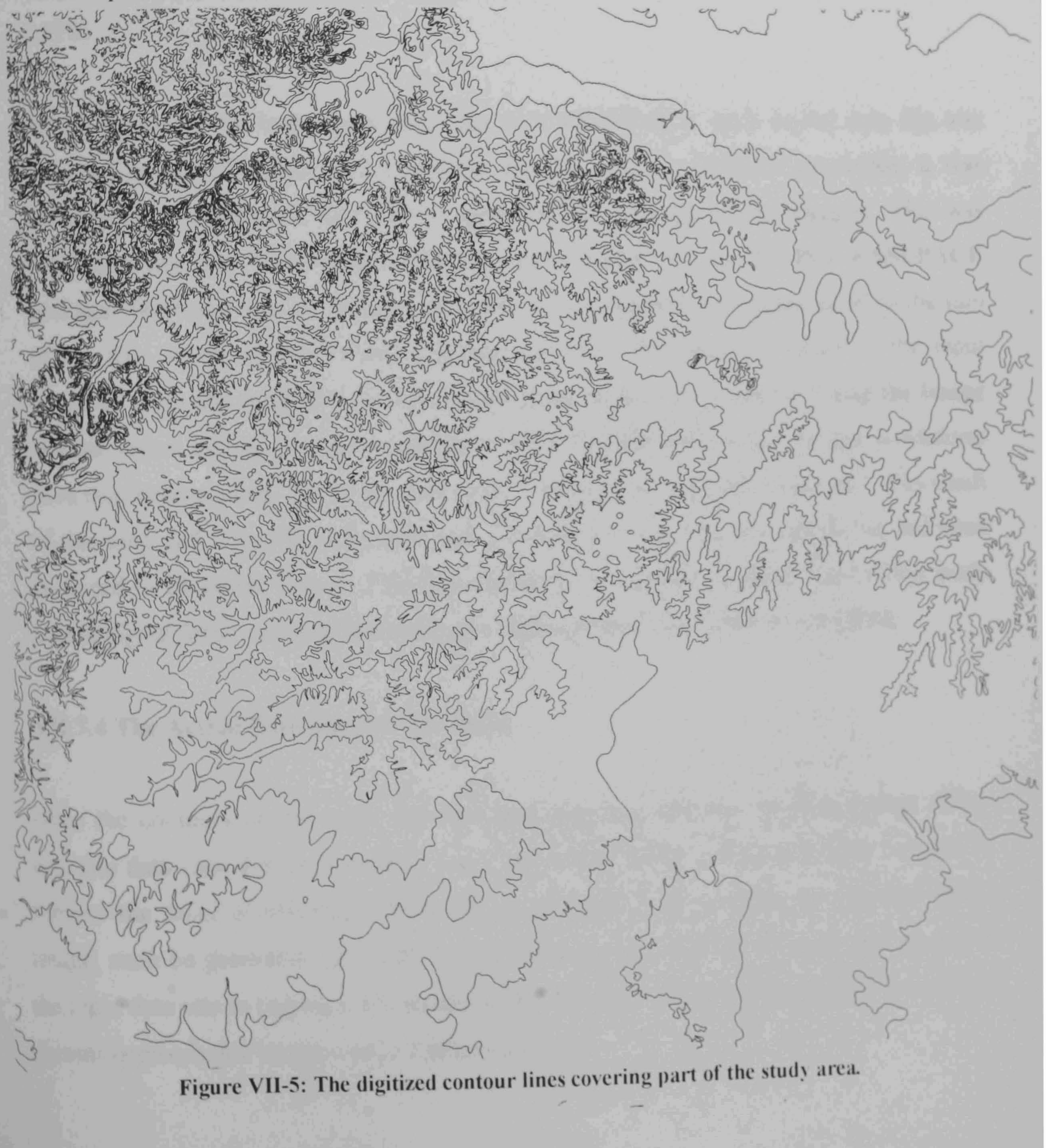


Figure VII-5: The digitized contour lines covering part of the study area.

VII.7.3.2 Vector Data Transfer and Import

At this stage, **MAPDATA** had produced the measured contour data in readable **ASCII** format which allowed the data to be re-formatted and output in a format suitable for import to other digital mapping and graphics software packages. Unfortunately, a problem that then arose was that the **PCI EASI/ PACE** software package does not support the **MAPDATA** format. The solution was to convert the four digital data files (one file for each map) to the **ARC/INFO** ungenerated (**.UGN**) format using a small **FORTRAN** program that is available in the Department. The four new digital data files with the **.UGN** extension could then be imported using the **FIMPORT** tool available in the **PACE** programs of **PCI EASI/PACE** and then changed into its own native **PCIDISK** format (**.PIX**).

When importing the four digital data files into **EASI/PACE**, each digital data file was imported as an individual vector segment. For the purpose of DEM generation, it was preferable to combine all four vector segments into a single vector segment. This was achieved using the **VECMERG** (Merge Vector Data) tool of the **PCI EASI/PACE** package. The result was the creation of a new vector segment with a size equal to the sum of the four vector segments that has been merged. The attribute tables of the input segments were also merged to create a single table for the new segment. Using the **Image Works** vector editing module available in **PCI EASI/PACE**, some editing procedures have then been applied, e.g. to connect contour lines of the same elevation, etc. The result of this long and complex procedure was a vector data file (**contours.pix**) that had been produced in **PCIDSK** format. This file contained the digitized contour lines of the study area in digital form, and was then ready for further processing to extract the DEM.

VII.7.4 The Actual Extraction of the DEM

Once the contours of the study site had been digitized and converted to strings of co-ordinate data (one for each contour line), the actual DEM, which will then be used to remove the relief displacement from the space images and produce the required ortho-image, must be generated. In addition, the extracted DEM would be used later as one of the input data sets to represent the terrain within the area of interest when the 3-D coloured chromo-stereoscopic image would also be generated.

This DEM was generated to give elevations at a 10m grid interval using two tools available in the **X-PACE** module of the PCI **EASI/PACE** software package. These tools were:

1) Grid from Vector (**GRDVEC**) Tool: This was necessary to convert vector data into a raster form. In other words, this tool was used to carry out gridding of the vector data. The attribute value associated with each line and point in the vector segments was placed into the image channel. In this particular case, GRDVEC was used to convert the elevation contour lines into an 8-bit image channel. Luckily, it was possible to use an 8-bit image channel (with 0-255 grey level values), since the highest point in this particular DEM is 255m. This means that each grey level value was equal to 1 m.

2) Grid Interpolation of an Image (**GRDINT**) Tool: This routine was used to fill in raster values between the vector values contained in the image channel. In other words, it interpolated elevation values for each pixel lying between the encoded isolines.

Once the **GRDVEC** and **GRDINT** tools have been run – the time was taken to run each of these routines with this data set was about 15 minutes – respectively, the end product was a DEM covering 47 km x 55.6 km (Figure VII-6) ready for further processing.

Figure VII-6: The extracted DEM of the test area.

VII.8 Ortho-Image Generation

The four SPOT Pan images that were used for the ortho-image generation, had already been geometrically corrected and radiometrically enhanced in the early stages of this research project – see Sections 10.3, 10.4 and 10.5 in Chapter 10. Afterwards, these SPOT images were joined together – to form the mosaic of the whole test area – using the same mosaicing procedures described in Chapter 10 (see Section 10.6). At this stage, the image mosaic was ready for further corrective processing. However, the area covered by the space mosaic was larger than that area covered by the extracted DEM. Thus it was necessary to select the image area that matched the DEM area. This was carried out using the **Subset** tool available in the **Image Works** module of the **PCI EASI/PACE** package. The DEM data set formed part of the base data needed for the ortho-rectification process, since the relief displacements had not yet been removed from the SPOT image mosaic.

Figure VII-7: The generated ortho-image of the test area.

Thus, for the area to be covered by an ortho-image, a digital elevation model (DEM) providing the XYZ co-ordinate values for all the DEM points had been produced. Which meant that an elevation value had been derived for each pixel of the final ortho-image. Using the **SORTHO** program of the **PCI EASI/PACE** package, the SPOT panchromatic mosaic covering the study site was used to generate the corresponding ortho-image utilizing the DEM with elevation values created at a 10m grid interval. In the input to the **SORTHO** program, the particular digital elevation channel that is to be used must be specified. In addition to this, the input database file must be specified, this file should contain the actual imagery. Also the output file should be specified; if not, the program will create a new image database and the user will have to geocode it using the **GEOSET** program. The database file name that contains the DEM data also needs to be specified, together with the specific resampling technique to be applied. For the production of the ortho-image generated in this project, the cubic convolution technique has been used – for more details regarding this resampling techniques, consult Section 10.5.1.3 in Chapter 10. Figure VII-7 shows the ortho-image created from the SPOT panchromatic mosaic of the test area.

VII.9 Colour Image Generation

The next and final step was to generate the elevation encoded multi-coloured image needed for the new 3-D chromo-stereoscopic visualisation technique from the multi-source (ortho-image and DEM) data. This image could then be viewed in stereoscopic 3-D using the ChromoDepth spectacles. To establish this image, two major steps were required:

i) A geometric step was needed to produce accurate co-registered images – which have been joined together to form the whole mosaic of the area – with the same ground resolution.

ii) A radiometric step was required in which the appropriate colours were created in a direct relation to the elevation data derived from the input image. This was carried out through the use of intensity-hue-saturation (**IHS**) encoding to modulate the red-green-blue (**RGB**) display.

It was important to ensure that the output colour image maintained the geometric coherence and radiometric detail of the input grey tone image. Since the space images had been geometrically corrected applying the same procedures discussed previously in Chapter 9, only the radiometric step will be explained in the following paragraphs. In fact, the depth information is related in a quite simple manner to the DEM elevation information contained in the input image and is encoded in the hue that controls the colour (from blue to red). Whereas the ortho-image is encoded in terms of the intensity and saturation components of the 3-D colour image.

In most computer-based image processing, colours are produced as combinations of the additive primary colours (red, green and blue) that will be displayed on the monitor screen of the computer. Another means of colour definition is in terms of intensity, hue and saturation (IHS) values. This is the way cartographers normally think of and manipulate colour. In fact, IHS values can be used to enhance and more easily control the output colours for any three channels in an image database file. ***Intensity*** is the lightness of a colour – as the intensity is increased, the lightness increases and the darkness decreases Full intensity in an 8-bit (256) scale shows no colour and would be white. ***Hue*** refers to the actual wavelength of the colour that is visible. The following table (Table VII-3) shows the ranges of the selected hues scaled against the equivalent wavelengths and elevation values as used in this particular test.

Hue	The Ranges of the Selected Hues within the 8-bit Channel (0-255)	Wavelength (λ) (nanometres)	Elevation (metres)
Blue	0-43	400	0
Cyan	43-85	490	65
Green	85-128	560	130
Yellow	128-170	590	190
Red	170-200	700	255

Table VII-3: The ranges of the selected hues in 8-bit image data associated with the equivalent wavelengths and elevation values.

Saturation defines the purity or greyness of the colour. Zero saturation for 8-bit (0/255) data shows no colour and would appear as a grey shade depending on the associated intensity. Full saturation for 8-bit data (255/255) would show the full colours for red, green and blue. Intensity-hue-saturation is an easier means of controlling the output colour than red-green-blue. For example, it is in many ways easier to comprehend lightening an image (increasing the intensity) or adding more colour (increasing the saturation) than it is to increase or decrease the red-green-blue values.

VII.9.1 Radiometric Processing Procedures

The radiometric processing started with the creation of a three-channel database file. This file includes the following data sets as inputs:

- channel 1: the *ortho-image* given in terms of intensity;
- channel 2: the *DEM values* applied to hue; and
- channel 3: the *ortho-image* given in terms of saturation.

Next, using the **IHS** colour transformation tool available in the **Adobe PhotoShop** software package, the author has controlled and varied the processing parameters - mainly through the use of Look-Up Tables (**LUTs**) - independently and interactively for each individual component (I, H, S) and visually checked their effect on the chromo-stereoscopic image and depth perception. This experimental procedure has been repeated until a good quality colour image was produced. Several points need to be discussed arising from the experience gained during this experimental part of the work.

(i) First of all, it was difficult to balance the intensity of the full mosaic, since the hilly part (in the southwest corner) of the image mosaic appeared very bright as compared to dark appearance of the city area (northeast corner) of this image resulting in a loss of the details contained in the SPOT panchromatic image. A pinkish 3-D image (instead of red) was the direct result of this problem because the use of too high intensity values washes out the colour, so reducing the depth perception. Thus the image mosaic had to be darkened in order to produce the deep red part of the 3-D chromo-image. This problem was a consequence of the high reflection of the sand in the area of interest. For this area, the radiometric normalisation done before mosaicing was insufficient. This resulted in too large a contrast between the low land and high land. Thus the city area appeared too dark when compared to the hilly area. Indeed overall, the whole mosaic had to be darkened to avoid pale colours, which reduce depth perception. Since the characteristics (type, quality, dynamic range, etc.) will always be different for each image, based on the author's experience, an interactive radiometric pre-processing stage will always need to be carried out by the cartographer. This also means that some type of compromise in the processing has to be implemented in order to generate a good quality chromo-image. For this particular area, the hilly part had to be darkened without darkening the city area. Thus a mask had to be made over the sea, the city and the low rivers (comprising mainly the blue components) and two Look-Up Tables (**LUTs**) were applied as follows:-

1) The first LUT was only applied to the city part of the SPOT Pan image (input) with original grey level values lying in the range from 80 to 250. The result was an enhanced city part of the image (output) with grey level values of 0 to 200; this had the effect of lightening the image in the city area.
2) The second LUT was only applied to the hilly part of the SPOT Pan image (input) with original grey level values from 155 to 255. The result was an enhanced hilly part of the image (output) with grey level values between 55 and 255, which had the effect of darkening the image in the hilly area.

Consequently, the hilly area became darker than the city area so that a better radiometric balance was obtained in the full output image.

(ii) For the image shown in Figure VII-8, the full dynamic range over 8-bits (256 grey level values) was used; this also resulted in some certain effects on the elevation visualisation being produced over the whole area of the chromo-image. Although these effects can be controlled, enhanced or eliminated, it is always a matter of the cartographer having to make a judgement as to what should be done depending on the desired result.

- The first effect was the result of using the entire dynamic range of the intensity channel that utilized the ortho-image grey level values. This produced a chromo-image having pale colours that reduced the depth perception and caused more loss of the image detail. The solution was to compress the intensity channel LUT from 0 to 255 to 0 to 200 grey level values to keep the same colour balance – after IHS transformation – between the three channels in this situation. The compression from a 255-value LUT to a 200-value LUT resulted, in general, in a chromo-stereoscopic image that is darker and sharper, with a more realistic depth perception when viewed with the spectacles.

- The second effect, that may have helped to invert the depth perception at the highest part of the area, was due to the use of the full range (0-255) of the hue channel (used with the DEM). The **IHS** colour system is usually thought of or represented as a three-dimensional colour, in which system the hues are arranged in a circle around the circumference. In this case, the hues go from blue-to-blue going through cyan, green, yellow, red and magenta. Therefore, when the IHS colour system was used to generate the 3-D chromo-stereoscopic image, a full range (0 to 255) of grey level values of the DEM LUT (the hue channel) were assigned from blue-to-blue. However, this would be of no value to the new 3-D visualisation technique, since no depth perception could be created – in this situation, blue (as a background colour) would have been encoded to lowest and highest elevation at the same time. The solution adopted was again to compress the DEM LUT to 0-200 grey level values and only to use the blue to red range – see Table VII-3. In addition, since the majority of the elevation values contained in the DEM were generally low, an equalisation LUT processing has been applied in an attempt to increase the use of the yellow to red colours. This procedure resulted in a little loss of the reality since the 3-D spectacles are more-and-less linearly coded. The impact was mainly noticed on the slopes or between the relative elevation variations, but never between the colours. After the IHS transformation, the depth perception at the highest parts became more and more realistic when viewed with the spectacles.

- Finally, the last processing parameter was related to the saturation channel in the IHS transformation. Saturation was given a constant value (150), since only one ortho-image has been used for the intensity values.

As can be seen in Figure VII-9, after considerable experimentation, all the various negative features in terms of the 3-D stereo-viewing of the test area were removed. The final product was a sharper chromo-stereoscopic image with more realistic depth perception when viewed through the spectacles.

The final result of all this processing was written on film using a small format (8 x 10 inch) film writer and then printed on to photographic paper. Enlargements could be produced using a photographic enlarger. The results could be viewed stereoscopically in 3-D very well through the use of the ChromaDepth spectacles.

Figure VII-8: The chromo-stereoscopic image with effects.

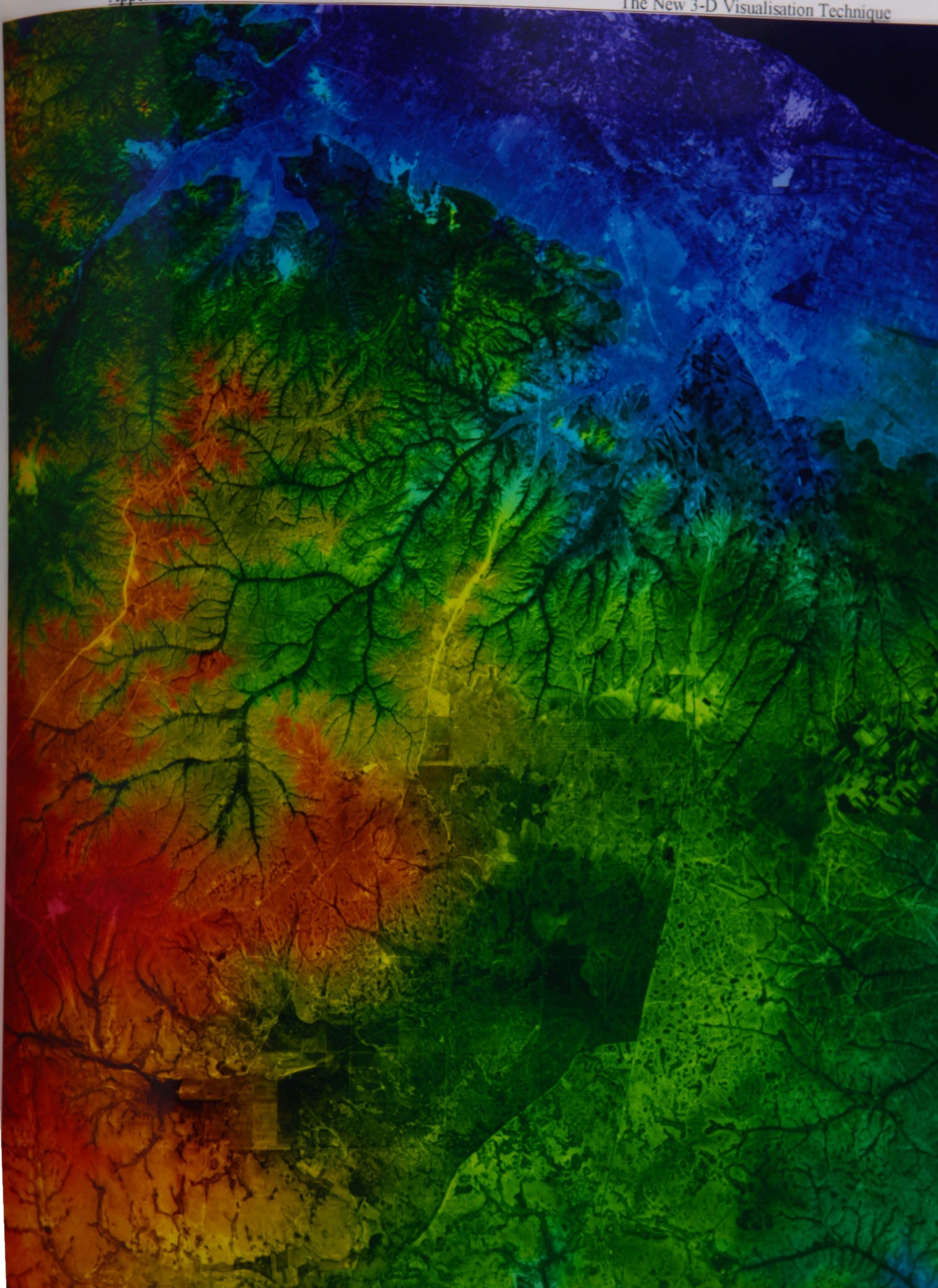


Figure VII-9: The chromo-stereoscopic image without effects.

VII.10 Conclusion

This Chapter has described a valuable new tool to help visualise, perceive and interpret multi-source spatial data. This new 3-D visualisation technique combines physiological and psychological aspects of the depth perception and colour vision processes. In this process, the effect known as chromo-stereoscopy has been used, in principle, it is a relatively straightforward procedure to implement and can be applied by first encoding depth into an image by means of colour, then decoding the colours by means of 3-D ChromaDepth spectacles, providing depth perception. Various types of data such as gravimetric data, GIS polygon data, etc. can be used to produce a 3-D stereo-representation of the data set as well as elevation data. The end product is a normal flat colour image that can be viewed without the ChromaDepth spectacles, but when viewed with the spectacles, it jumps into a 3-D stereoscopic representation of the data.

From the cartographic point of view, the use of this technique has certain advantages in depicting the relief better than some alternative methods (such as hypsometric colours, hill shading, etc.), since, through the use of colour, it can show the slope and elevation of the terrain in an area characterized by lowlands and highlands at the same time.

While the basic principle of chromo-stereoscopy is relatively simple to comprehend, its actual implementation using elevation data needs considerable care and judgement on the part of the cartographer. The author feels that he has devised a simple procedure for encoding the elevations making use of commonly used software packages (**EASI/PACE** and **Adobe PhotoShop**) that were available. However, based on the experience gained during this experiment, it is apparent that a purely automated procedure may not produce the best results from the terrain visualization point of view. Almost certainly, the judgement and experience of the cartographer must be employed through an interactive and iterative procedure if the best representation of the terrain is to be achieved.

The generation of the chromo-stereoscopic image of the Misratah area has showed that the use of relatively high resolution space imagery together with the adoption of suitable digital image processing techniques to produce chromo-stereoscopic images can be used to represent the terrain surface in a faster, cheaper and more realistic manner than alternative methods of representation. In particular, this new 3-D visualisation technique appears to be very suitable for application in arid and semi-arid areas where most of the terrain is a bare (non-vegetated) physical landscape with very few man-made (cultural) features. This technique represents the relief (both the elevation and the slope) and the various landform features – such as the drainage pattern, wadis, sand dunes, lowlands, highlands, etc. – in a good quality manner. Thus, in the Libyan context, it would be of great benefit if used as a complementary tool together with the space image maps to give a more realistic idea about the relief of the area.

In the next chapter, the evaluation of the results of this new 3-D visualisation technique will be discussed and analysed in more detail.

APPENDIX VIII: THE EVALUATION TEST OF THE NEW 3-D VISUALISATION TECHNIQUE

VIII.1 Introduction

Recently, as a part of his Ph.D. study, the author has generated an experimental 3-D image product using SPOT satellite panchromatic images, a digital elevation model (DEM) and advanced digital image processing techniques. The new display technique that is being used to view this image in 3-D is based on the effect known as chromo-stereoscopy. Depth is encoded into an image by means of colour, and depth perception is produced by means of spectacles equipped with thin prismatic optics — the so-called ChromaDepth 3-D glasses — which decode the colour and act as thin glass prisms to create the depth perception. In this colour composite image (with a 10 m pixel size) of an area covering 47 km x 55.6 km of the Misratah region located in the north of Libya, the depth perception is related directly to the terrain elevations occurring in the area.

A 2-D SPOT panchromatic (black and white) mosaic for the same area covered by the colour image is also attached which can be used for comparative purposes. To help to evaluate this new 3-D display product, I would appreciate a few minutes of your time to answer the various questions set out below. Your feedback will be helpful in evaluating the method as a tool to represent elevations and to aid the interpretation of landscape features.

The evaluation scale will be as follows:

E = Excellent V = Very Good G = Good S = Satisfactory P= Poor

Title	
Name	
Occupation	
Background	
Organisation	

VIII.2 SECTION IA TERRAIN ANALYSIS

Various terrain characteristics are important to geologists, geographers, hydrologists, etc. The principal terrain characteristics that can be estimated by means of image interpretation are landforms, bedrock, drainage, etc.

1) The size and shape of a landform are probably its most important identifying characteristics. To what extent can the lowlands and the highlands and the associated landforms be identified in both images?

A) 3-D Chromo-stereoscopic Image (Colour)

--------- E
--------- V
--------- G
--------- S
--------- P

B) 2-D SPOT Panchromatic Ortho- Image without contours (Black and White)

--------- E
--------- V
--------- G
--------- S
--------- P

2) How well can you recognise the slope in both image products?

A) 3-D Chromo-stereoscopic Image (Colour)

--------- E
--------- V
--------- G
--------- S
--------- P

B) 2-D SPOT Panchromatic Ortho- Image without contours (Black and White)

--------- E
--------- V
--------- G
--------- S
--------- P

3) A dendritic drainage pattern is found in the area; how well do the images display and represent this pattern?

A) 3-D Chromo-stereoscopic Image (Colour)

--------- E
--------- V
--------- G
--------- S
--------- P

B) 2-D SPOT Panchromatic Ortho- Image without contours (Black and White)

--------- E
--------- V
--------- G
--------- S
--------- P

4) Erosion refers to the size and shape of the gullies or wadis which are the smallest drainage features that can be seen on the images. How well do these images show these features?

A) 3-D Chromo-stereoscopic Image (Colour)

--------- E
--------- V
--------- G
--------- S
--------- P

B) 2-D SPOT Panchromatic Ortho- Image (Black and White)

--------- E
--------- V
--------- G
--------- S
--------- P

5) Through a careful study of the images, interpreters are able to identify <u>different types of rocks</u>. An interpreter must consider topography, drainage, and erosion characteristics to distinguish between these different types of rocks. How well do the images help to distinguish the bedrock type?

A) 3-D Chromo-stereoscopic Image (Colour)

--------- E
--------- V
--------- G
--------- S
--------- P

B) 2-D SPOT Panchromatic Ortho-Image (Black and White)

--------- E
--------- V
--------- G
--------- S
--------- P

VIII.3 SECTION I B.

1) The size and shape of a landform are probably its most important identifying characteristics. To what extent, can the <u>lowlands</u> and the <u>highlands</u> and the associated landforms be identified in both images?

A) 3-D Chromo-stereoscopic Image (Colour)

--------- E
--------- V
--------- G
--------- S
--------- P

B) 2-D SPOT Panchromatic Ortho- Image with contours. (Black and White)

--------- E
--------- V
--------- G
--------- S
--------- P

2) How well can you recognise the slope in both image products?

A) 3-D Chromo-stereoscopic Image

(Colour)

--------- E
--------- V
--------- G
--------- S
--------- P

B) 2-D SPOT Panchromatic Ortho- Image with contours

(Black and White)

--------- E
--------- V
--------- G
--------- S
--------- P

3) A dendritic drainage pattern is found in the area, how well do the images display and represent this pattern?

A) 3-D Chromo-stereoscopic Image

(Colour)

--------- E
--------- V
--------- G
--------- S
--------- P

B) 2-D SPOT Panchromatic Ortho- Image with contours

(Black and White)

--------- E
--------- V
--------- G
--------- S
--------- P

VIII.4 SECTION II. FEATURE INTERPRETATION

1) How can you rate the chromo-stereoscopic image quality from the point of view of its ground resolution and its ability to distinguish the features present on the terrain?

--------- E
--------- V
--------- G
--------- S
--------- P

Comments:

2) Which image characteristics can be used to interpret the chromo-stereoscopic image?

	Yes	No
- Tone	---	---
- Shape	---	---
- Size	---	---
- Colour	---	---
- Shadow	---	---
- Pattern	---	---
- Texture	---	---
- Site	---	---

Comments:

3) What do you think of using the chromo-stereoscopic image for interpretation of the following features classes?

	E	V	G	S	P	Comments
- Physical	---	---	---	---	---	
- Cultural	---	---	---	---	---	

VIII.5 SECTION III. IMAGE PRODUCT USE

1) Using the chromo-stereoscopic image, how well can the depth be perceived without the use of the glasses?

--------- E Comments:
--------- V
--------- G
--------- S
--------- P

2) From the physical geography point of view do you think that this product will be of great help to the user in the office?

Yes = -----------
No = -----------

If yes, please answer how?

--------- E Comments:
--------- V
--------- G
--------- S
--------- P

3) Again from the physical geography point of view do you think that this product will be of great help to the user in the field?

Yes = -----------
No = -----------

If yes, please answer how?

--------- E Comments:
--------- V
--------- G
--------- S
--------- P

VIII.6 SECTION IV. ADDITIONAL COMMENTS

Any additional comments may be written below.

APPENDIX IX: THE EVALUATION TEST OF THE NEW 3-D VISUALISATION TECHNIQUE

IX.1 Introduction

In order to evaluate the new 3-D visualisation product that has been produced in this project, a questionnaire or evaluation form (see Appendix VII) was distributed to over 20 post-graduate students having a geo-science background. Among these students were geologists, hydrologists, geographers and planners. Ten of the students were Libyans who are familiar with Libyan terrain conditions; the other ten came from Middle Eastern countries, most of which are characterised by similar terrain characteristics. However, although these twenty participants all have a geo-science background, they have different levels of experience in photo and image map interpretation. In fact, eight of these participants are very experienced in photo and image interpretation, while the others have gained some experience during their previous work. The main objective of this test was to evaluate the chromo-stereoscopic image as a method of representing elevations with a view to aiding the interpretation of landscape features. This was carried out on a comparative basis against the corresponding conventional space image products likely to be available to users.

IX.2 Materials Available for the Test

When the test was administered, each of the test participants was given the following materials:

(i) the five page evaluation form;

(ii) the 3-D colour composite elevation encoded image produced for the test area in the Misratah region (47 km x 55.6 km; 10m pixel size);

(iii) a pair of ChromaDepth 3-D spectacles;

(iv) the 2-D SPOT Pan. (Black and White) ortho-image mosaic covering the same area as the coloured image; and

(v) a SPOT Pan (Black and White) ortho-image with contours superimposed on top

IX.3 The Design of the Evaluation Form

The questionnaire or evaluation form was divided into three main sections, which cover (i) terrain characteristics; (ii) feature interpretation; and (iii) image product use. Each of these sections contains a group of related questions that had to be answered by the participants (post-graduate students). A summary of the questions is given in Tables IX-1a to IX-7. As will be seen, most of them were purely factual, straightforward and direct questions. Instructions to the participants were printed at the top of the first page of the evaluation form. These were reviewed orally prior to the actual test to ensure that the participant clearly understood the test procedure and the method of recording his response. The oral briefing included instructing the participants how to use the spectacles and giving them a general idea about the area being covered by the images. A five-point evaluation scale (Excellent, Very Good, Good, Satisfactory and Poor) was provided, and the participants were given the possibility of making comments whenever they wish to justify, expand or modify their answers. Since only one film copy of the colour image was available, the evaluation was conducted in individual sessions, so that, in each session, the author was dealing with one interpreter only. Although no time limit was imposed, in practice, each participant generally took no more than thirty minutes to complete the test. In fact, the evaluation took place over three weekends to be answered by all the twenty participants.

As mentioned above, the evaluation form was divided into three distinct sections.

I. The first section comprised five questions (numbers 1, 2, 3, 4 and 5) which, in general, were concerned with the **terrain characteristics** of the study area and how well did the images display the lowlands, highlands, slope, drainage patterns and other landforms. The first three questions (numbers 1, 2 and 3) of this section have been used to compare the performance of (a) the corresponding 2-D SPOT Pan ortho-image without contours, and (b) the SPOT Pan ortho-image (with the overlaid contours) and (c) the chromo-stereoscopic image in visualising landforms. For the remaining two questions (numbers 4 and 5), only the 3-D chromo-stereoscopic image and the corresponding 2-D SPOT Pan ortho-image without contours were used to compare the performance of the both images. This second comparison was to examine how well the two images displayed small features (such as gullies and wadis), and how well they helped to distinguish between the bedrock type

II. The second section included three questions (numbers 1, 2 and 3) that dealt specifically with the **feature interpretation** side of the chromo-stereoscopic image and associated matters. In particular, it attempted to establish how well the chromo-stereoscopic image could be used for the interpretation of the physical and man-made (cultural) features that were present in the test area.

III. The third section (questions 1 and 2) was the last but not least and it was designed to establish the **potential use of the chromo-stereoscopic image** both in the office and in the field. The author feels that it would be more suitable to analyse each of the three sections of the evaluation form separately, since each section was concerned with different types of information.

IX.4 Results and Analysis

The results of the evaluation carried out by the participants together with their associated questions have been summarised, organised in tabular form and also represented graphically (through the use of bar diagrams) for comparative purposes. Representing the results of the questionnaire in this systematic manner was quite helpful in establishing a clear picture of the results. In turn, this has allowed the author to extract more useful information and carry out a much more thorough analysis of these results.

IX.4.1 Section I: Terrain Characteristics

Various terrain characteristics are important to geologists; hydrologists; geographers; planners; etc. The principal terrain characteristics that could be established by means of an interpretation of the chromo-stereoscopic image were landforms, bedrock, drainage, etc. All the participants have gained a good impression regarding the suitability of the chromo-stereoscopic image in displaying the terrain surface: none of them had ever encountered this technique before.

Tables IX-1a and -1b both summarize the questions and give the results of the evaluation for all three images – which are the chromo-stereoscopic image; the SPOT Pan ortho-image (with the overlaid contours); and the plain SPOT Pan (black and white) image with no elevation encoding.

The Results of the Evaluation Form Section I: Terrain Analysis

Que. NO.	Summary of the question	The Number of Participants within Each Class (Total Number=20) Chromo-Image					The Number of Participants within Each Class (Total Number=20) SPOT Pan. Image With the Overlaid Contours					The Number of Participants within Each Class (Total Number=20) SPOT Pan. Image Without Contours				
		E	V	G	S	P	E	V	G	S	P	E	V	G	S	P
Q1	The extent of identifying lowlands and highlands and associated land forms in the image.	10	7	3	0	0	0	7	10	3	0	0	0	4	8	8
Q2	Recognition of the slope in the image.	10	3	6	1	0	0	1	13	6	0	0	0	1	9	10
Q3	The representation of the dendritic drainage pattern in the image	11	8	1	0	0	0	12	8	0	0	0	1	12	5	2
The Total		31	18	10	1	0	0	20	31	9	0	0	1	17	22	20

Table IX-1a: The summary of questions 1, 2 & 3 and their results: Section I

Que. NO.	Summary of the question	The Number of Participants within Each Class (Total Number=20) Chromo-Image					The Number of Participants within Each Class (Total Number=20) SPOT Pan. Image Without Contours				
		E	V	G	S	P	E	V	G	S	P
Q4	The display of the smallest features such as gullies and wadis in the image	6	9	4	1	0	0	1	4	6	9
Q5	The distinction of the bedrock type in the image	7	5	5	2	1	0	0	6	6	8
The Total		13	14	9	3	1	0	1	10	12	17

Table IX-1b: The summary of questions 4 & 5 and their results: Section I

1) Question 1 - ***To what extent, can lowlands and the highlands and the associated landforms be identified in the three images?***

It was obvious to all the participants that the 3-D chromo-stereoscopic image was more realistic and more informative in visualising the lowlands, highlands and associated landforms. The results in Table IX-1a support this impression. Furthermore, most of the participants in their answers rated the new 3-D visualisation technique highly – as being excellent (10 participants), very good (7 participants) and good (3 participants) – in terms of representing these landforms. By contrast, although 4 participants have evaluated the 2-D SPOT Pan image as a good tool to display lowlands, highlands and associated features, the majority of them have rated this 2-D black and white image as only being satisfactory (8 participants) or poor (8 participants) in terms of depicting such features. Thus the overall performance of the 3-D coloured image was far better than that of the 2-D black and white image with no contours overlaid on top. Although the 2-D SPOT Pan image has displayed the characteristics of the terrain surface in a natural and useful manner, unfortunately, from this type of image, it is not possible – even for experienced interpreters – to extract much information about the relief and the elevations of the area being covered by the space image.

In the previous paragraph above, the comparison was between the 3-D chromo-stereoscopic image and the corresponding 2-D SPOT Pan without contours or any other means of providing elevation information. Obviously the results would be more significant and more convincing if the comparison was between one method of representing elevation and another. The suitable way to achieve this was to superimpose the existing contours on top of the corresponding SPOT Pan ortho-image (see Figure IX-1) of the test area in order to compare the relief features in both images. Thus the SPOT Pan ortho-image with contours was also compared with the 3-D chromo-stereoscopic image. From this Figure, it was apparent that the contours were rather close to one another and, as a result, the area in the north western part of the ortho-image in particular, was heavily masked by the contour lines. This situation arose because the available digital contour lines had been digitized from the 1:50,000 scale topographic maps with 20m contour intervals and then reduced to a smaller scale – that of the ortho-image – in order to match the background image when superimposed on top of it.

Figure IX-1: The SPOT Pan ortho-image with un-generalised contours.

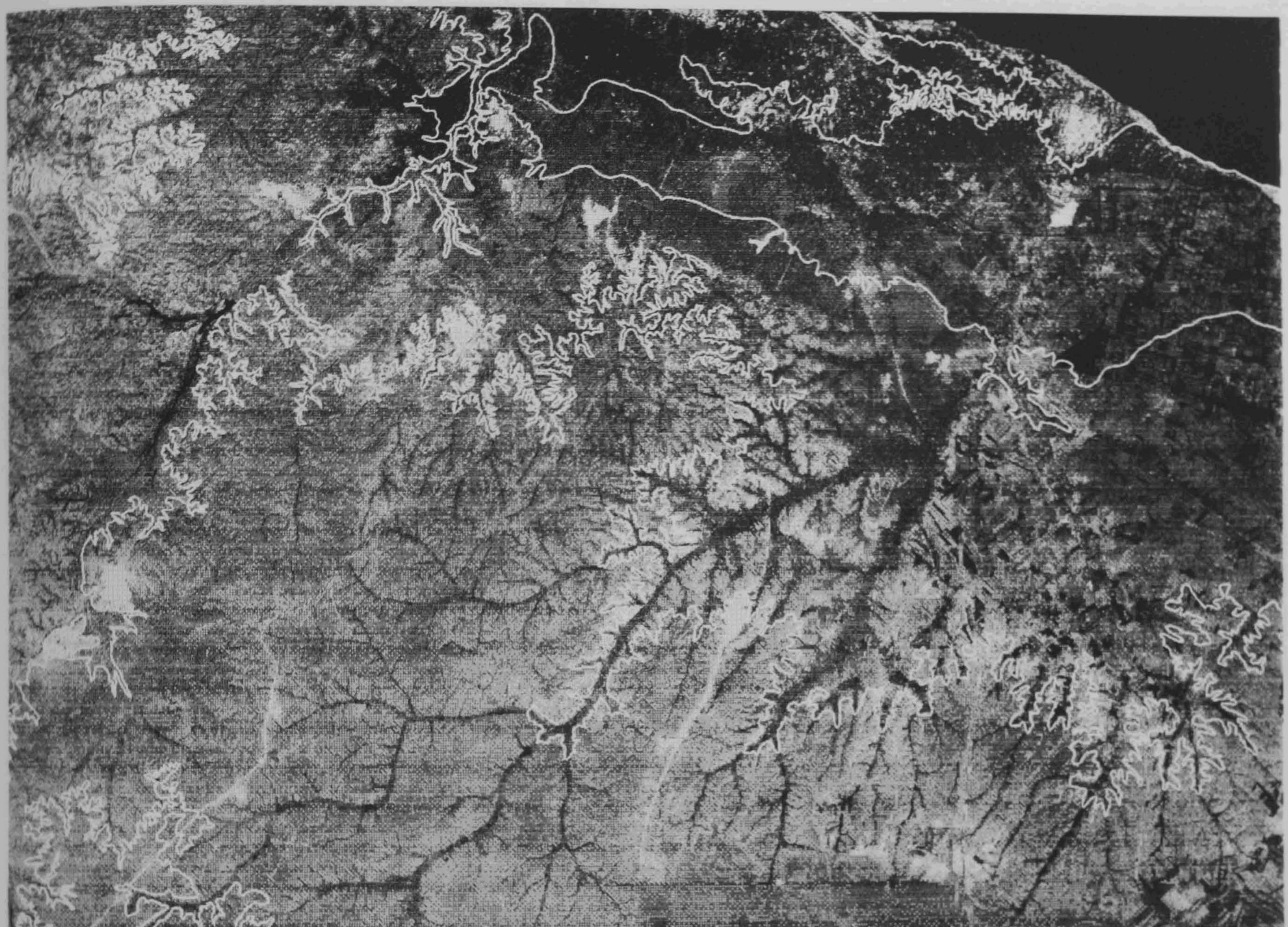


Figure IX-2: The SPOT Pan ortho-image with generalised contours.

The result of this method of deriving contours is quite similar to that of deriving contours by photographic reduction techniques, in that no generalisation took place. In the author's opinion, without any generalisation process (e.g. selective omission) being applied, this representation would only be of limited help to the interpreters. It would not allow them to fully identify the terrain characteristics and extract valuable relief information. With these important considerations in mind, some generalisation has been applied to the contours in that certain contour lines have been omitted. Therefore, the contour intervals became 40m instead of 20m – see Figure IX-2.

Figure IX-3: Comparisons of the evaluation results of question number 1.

It is clear from the results given in Table IX-1a and Figure IX-3 that the 3-D chromo-stereoscopic image has shown a better performance even when compared with the SPOT Pan ortho-image with contours. In fact, the identification of lowlands, highlands and associated landforms on the ortho-image with contours relies greatly on the map user's experience, which also have a considerable effect on how well the relief information is perceived and interpreted. Abstract symbols generally require more familiarisation or learning, and the contour is one such type of abstract representation of relief in that it uses lines that have no physical appearance on the ground to represent the surface. Certainly it represents elevation data, but its value lies in its elevation value and in the user's ability to make quantitative assessments of the terrain features from the forms depicted by these lines. Therefore relief depiction on the basis of contours is not usually immediately apparent or imageable for inexperienced users. Whereas the 3-D chromo-stereoscopic employs a technique that gives a 3-D stereo impression that is immediately imageable since it uses a more natural or image-related representation that allows a better and faster visual impression of the terrain features.

However, it must be noted that the ortho-image with contours has achieved better results than the 2-D SPOT Pan image without contours, since it was difficult for most of the participants to extract relief information from the purely 2-D space image.

2) Question 2 - ***How well can you recognise the slope in the three images?***

By applying the chromo-stereoscopic visualisation technique, the entire terrain surface of the study area has effectively divided into an easily recognised series of elevation zones when the 3-D coloured image was produced. Furthermore, through the use of colour and the special 3-D spectacles, the chromo-stereoscopic image product has produced a very much stronger visual effect in displaying the slopes of the study area than the 2-D SPOT Pan (black and white) image. Most of the participants reported orally that the image product was quite fascinating to inspect. In particular, the sharp slope that rises from the coastal plain in the north to the plateau that covers much of the rest of the area was quite striking, as was the steep-sided wadis that are incised into this slope and into the plateau. Once again, the evaluation results came out strongly in favour of the 3-D chromo-stereoscopic image.

As can be seen in Table IX-1a, the evaluation scores given to the recognition of the slopes in the 3-D colour image were rated excellent (by 10 participants); very good (by 3 participants) and good (by 6 participants). Indeed, the use of the range of colours used to generate the image and having the spectacles to view it in 3-D has clearly helped the participants to recognise more easily the slopes that are present in the area. Figure IX-4 gives a graphical representation of the evaluation results for the three images.

From these results, it can be seen that the 3-D chromo-stereoscopic image was also more successful than the ortho-image with contours in allowing the interpreters to recognise the slope of the study area – see Table IX-1a and Figure IX-4. According to Keates (1989), contour lines do not represent either slope or landforms. In fact, they provide factual statements about elevation, from which the map user can then attempt to judge the extent and the angle of slope relating to the relief features. This was supported by the oral comments of the participants. Obviously they feel that, although it is not possible to recognise the slope immediately from contours, the presence of contour lines and certain other specific terrain features (i.e. the drainage pattern) can help to point out the lowlands, highlands and recognise the slope – which is determined by noting the relationship of the change in height with respect to the corresponding plan distance. Thus it was obvious from the results that the performance of the ortho-image with contours was more successful than that of the 2-D SPOT Pan image without any means of elevation. But still the 3-D chromo-image came out as being the best of the three representations.

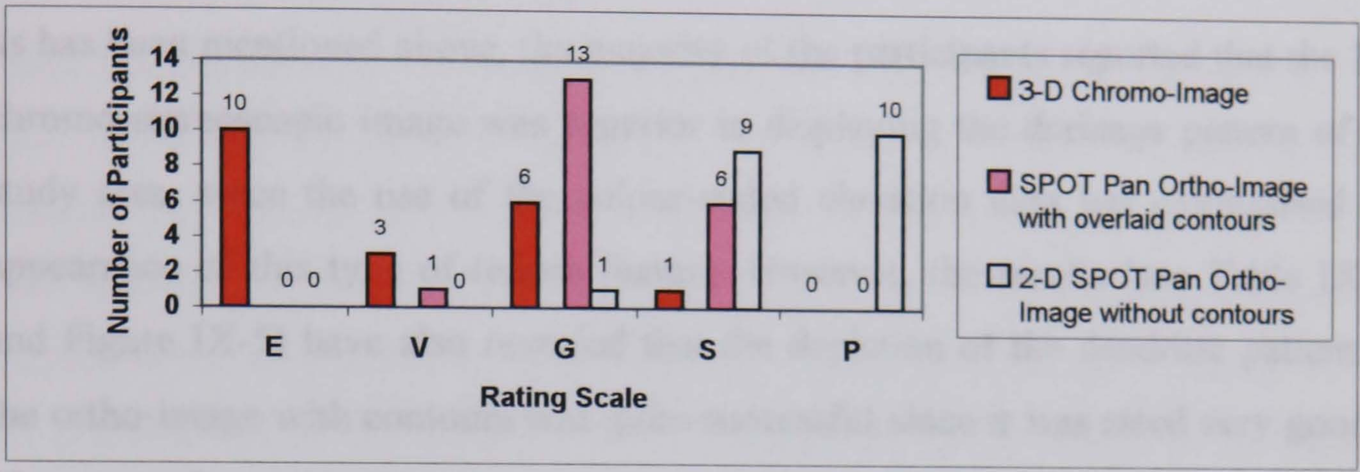


Figure IX-4: Comparisons of the evaluation results of question number 2.

3) Question 3 - ***How well do the three images display the <u>drainage pattern</u>?***

The drainage pattern that is present in the study area is basically dendritic, which is a characteristic of a terrain showing a lithological, structural and topographic homogeneity. In fact, this drainage pattern is one of the most obvious elements of the physical landscape of the test area and reveals a lot of significant information about the terrain surface to geologists, hydrologists, geographers, etc. In particular, besides the actual drainage of water across the landscape, the drainage system can help to reinforce the visual impression regarding the relief and slope of the study area, since water always flows downhill. Hence geo-science users are always keen to have a more realistic impression of the drainage in order to extract valuable details about the terrain surface that can be of great benefit to them.

The results given in Table IX-1a and Figure IX-5 indicate that the majority of the participants felt that the drainage pattern representation on the chromo-stereoscopic image was excellent (11 participants) or very good (8 participants). On the other hand, the results have also revealed that depiction of the dendritic pattern on the 2-D SPOT Pan image was simply good in 12 cases.

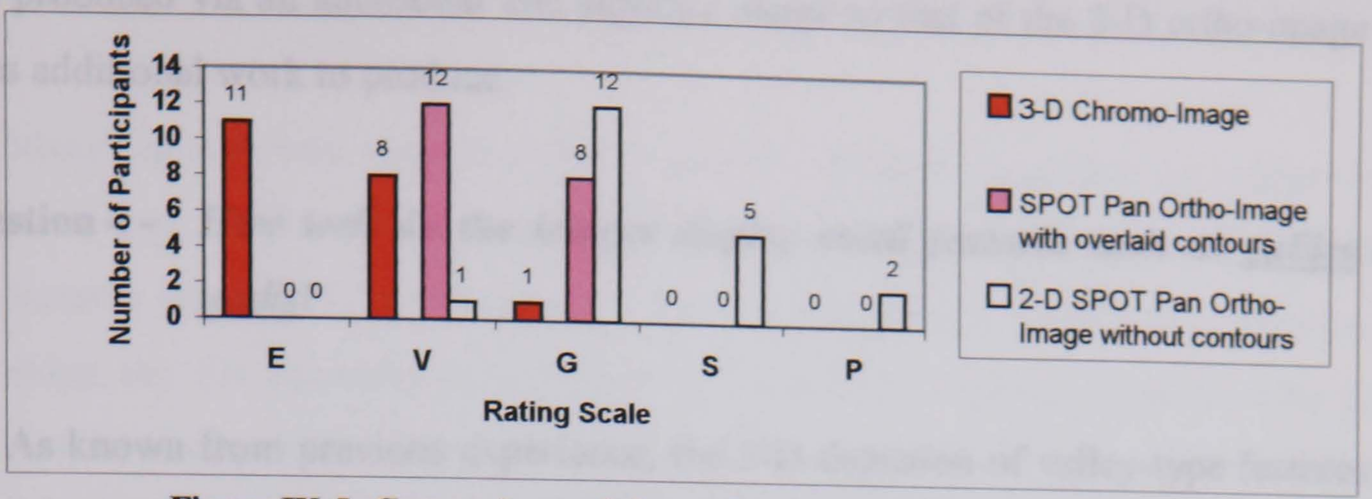


Figure IX-5: Comparisons of the evaluation results of question number 3.

As has been mentioned above, the majority of the participants reported that the 3-D chromo-stereoscopic image was superior in displaying the drainage pattern of the study area, since the use of the colour-coded elevation data has emphasised the appearance of this type of terrain feature. However, the results (see Table IX-1a and Figure IX-5) have also revealed that the depiction of the dendritic pattern on the ortho-image with contours was quite successful since it was rated very good in 12 cases and good in 8 cases.

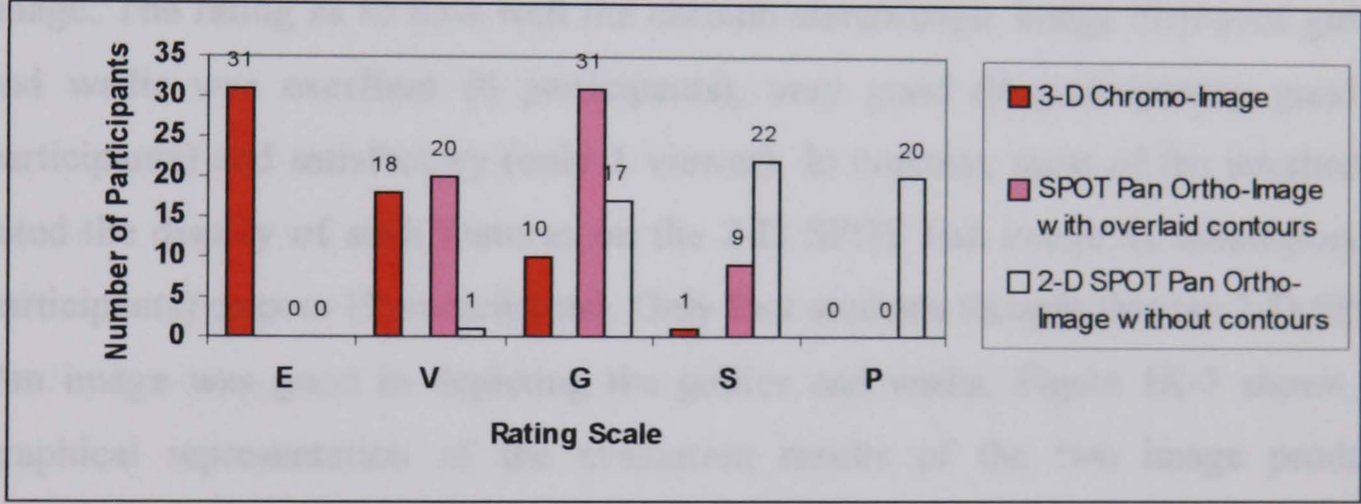


Figure IX-6: Summary Diagram – The total number of participants for the first three questions in Section I with their evaluation classes regarding the three images.

In summary, for the first three questions in Section I, all the responses falling in each rating class have been calculated. From Table IX-1a and Figure IX-6, it is evident that the overall performance of the new 3-D chromo-stereoscopic image was much better than the SPOT Pan ortho-image without contours, particularly in depicting relief features such as lowlands, highlands, slope and drainage pattern. However, the SPOT Pan ortho-image with contours came in between and could be considered as the second possibility of showing elevation, especially for experienced users who have the ability of interpreting and extracting useful relief details from such representation method. The advantage of this technique over that of the 3-D chromo-stereoscopic representation is that it can be accommodated easily within a single image – whereas the 3-D chromo-stereoscopic image is only produced via an additional and separate image to that of the 2-D ortho-image and requires additional work to produce.

4) Question 4 - ***How well do the images display small features such as <u>gullies</u> and <u>wadis</u>?***

As known from previous experience, the 3-D depiction of valley-type features can help by displaying them in a more realistic way that will aid their identification. After viewing and comparing both images, it appeared that the chromo-stereoscopic image has displayed the small valley-type features – such as gullies and wadis – in a much better manner than the 2-D SPOT Pan image. Obviously, the application of the new 3-D visualisation technique has enabled the interpreters to have a much more realistic visual impression that has helped them to understand these particular features in less time and in more detailed way. It was so clear from Table IX-1b that the performance of the coloured 3-D chromo-stereoscopic image in representing these smaller features was much better than that of the other purely planimetric image. The rating as to how well the chromo-stereoscopic image displayed gullies and wadis was excellent (6 participants), very good (9 participants), good (4 participants) and satisfactory (only 1 viewer). In contrast, most of the interpreters rated the display of such features on the 2-D SPOT Pan image as satisfactory (6 participants) or poor (9 participants). Only four students thought that the 2-D SPOT Pan image was good in depicting the gullies and wadis. Figure IX-7 shows the graphical representation of the evaluation results of the two image products regarding small valley-type features.

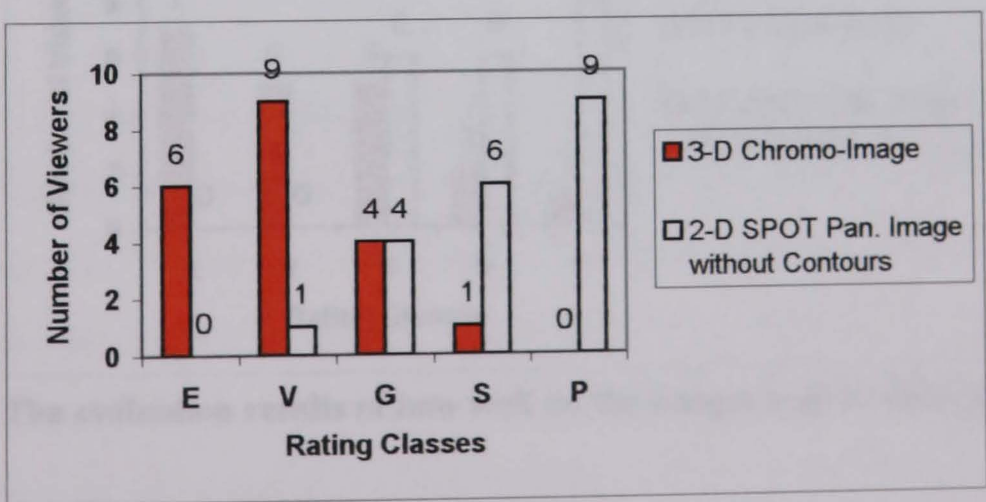


Figure IX-7: The evaluation results regarding the display of small valley-type features such as gullies and wadis in the chromo-stereoscopic image and the 2 D SPOT Pan image without contours.

5) Question 5 - ***How well do the images help to identify the rock type in the area?***

Many features help the interpreter to identify the rock types that are present in the area – e.g. whether it is a sedimentary, igneous or metamorphic rock. Among those features that help in this respect are the drainage pattern, the extent of erosion, the slope, etc. For example, the existence of the dendritic drainage pattern in the image gives a strong indication to the interpreter that sedimentary rocks may be dominant the area. Nevertheless, the performance of the interpreter in distinguishing between the different bedrock types is always reliant on the resolution and the quality of the image used for interpretation. If the image is of a good quality, it will display the small features such as gullies and wadis, the drainage pattern and the slope in a sharper manner that could help the interpreter to make his decision – though this will still need to be confirmed through field work.

It was evident from the results (Table IX-1b and Figure IX-8) that, once again, the responses were in favour of the chromo-stereoscopic image. Obviously, the participants were given much more information to help them identify the rock types that exist in the area, since the 3-D coloured image was sharper and more realistic. This impression was obtained when the 3-D chromo-stereoscopic image was rated excellent (7 participants), very good (5 participants) and good (5 participants). While in contrast to these ratings, six, six and eight participants have rated the 2-D SPOT Pan image as good, satisfactory and poor respectively.

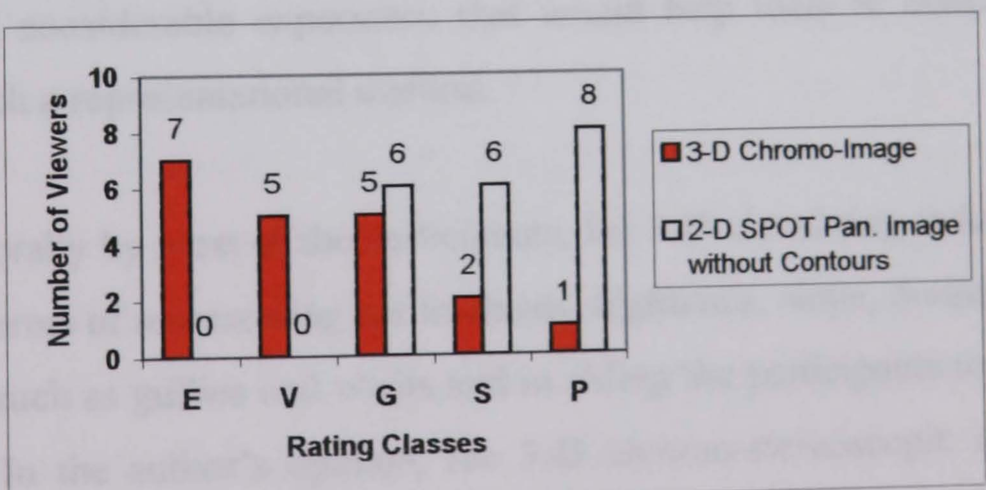


Figure IX-8: The evaluation results of how well do the images help to distinguish the bedrock type.

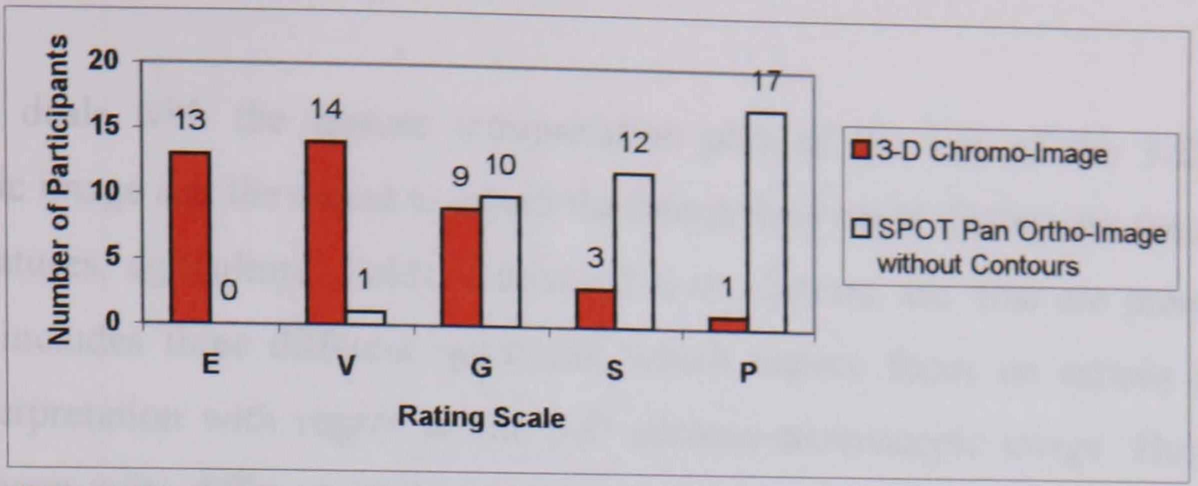


Figure IX-9: The total number of participants for question numbers 4 & 5 in section I with their evaluation classes regarding the 3-D chromo-image and the 2-D SPOT Pan image without contours.

The results in Table IX-1b and Figure IX-9 show that, when the participants answered questions 4 & 5 in Section I, the total number of responses was very much in favour of the chromo-stereoscopic image. This means that the 3-D coloured image was a better product in displaying small features such as gullies and wadis. This also indicates that the 3-D chromo-stereoscopic image is more helpful in distinguishing the bedrock type..

In summary, for all five questions in Section I, the totals of all the responses falling in each rating class (E, V, G, S or P) have been calculated. From the calculated results shown in Table IX-1a and -1b and in Figures IX-3 and IX-9, it is obvious that the overall performance of the 3-D chromo-stereoscopic image was far better than the 2-D SPOT Pan image without contours in visualising the various relief features. However, the SPOT Pan ortho-image with contours can still be considered as the second possibility for depicting elevation, especially for these specialist users with good local knowledge and considerable experience that would help them to obtain useful relief details from such a representational method.

As mentioned orally by most of the participants, the 3-D visualising technique was very impressive in terms of representing the lowlands, highlands, slope, drainage pattern, and small features such as gullies and wadis and in aiding the participants to distinguish the bedrock type. In the author's opinion, the 3-D chromo-stereoscopic image can be a useful product even for the inexperienced or non-specialist person interested in the landscape, since it gives a good visual impression about the terrain characteristics of any area.

IX.4.2 Section II: Feature Interpretation

Section II deals with the feature interpretation part of the test of the 3-D chromo-stereoscopic image and the extent to which the interpreters could distinguish the man-made cultural features, agricultural fields, cultivated areas, forests, etc. that are present on the terrain. It includes three different questions, which mainly focus on certain aspects of feature interpretation with regard to the 3-D chromo-stereoscopic image. However, the questions were quite different to those asked in Section I, in the sense that there was no need to compare the 3-D coloured elevation encoded image with the 2-D SPOT Pan black and white image. Moreover, the participants were given the opportunity to make their comments whenever they wished to do so.

1) Question 1 - ***How can the chromo-stereoscopic image quality be rated from the point of view of its ground resolution and its ability to distinguish the man-made features, agricultural fields, cultivated areas, forests, etc. that are present on the terrain?***

The results given in Table IX-2 and Figure IX-10 indicate that the ground resolution of the chromo-stereoscopic image was rated as being excellent (6 participants), very good (6 participants) and good (8 participants). However, only five of the twenty participants supplemented their answers with written comments regarding the quality of the ground resolution produced by the new 3-D visualisation technique. It has been mentioned in their comments that the technique was particularly useful for depicting relief features, since the colour was only used to display elevation information instead of the features. Apart from this fact, they have also mentioned that the small physical features of the terrain could still easily be seen on this image. It has been pointed out by the participants in the test that, although colour has only been used to represent elevation, features such as roads, cultivated areas, agricultural fields, built-up areas and forests could still be identified sufficiently well for feature extraction purposes.

Que. No.	Summary of the Question	The Number of Participants within Each Class (Total Number=20)				
		E	V	G	S	P
Q1	The quality of the ground resolution and the ability to distinguish features present on the terrain.	6	6	8	0	0

Table IX-2: The results regarding the quality of the ground resolution of the 3-D coloured image.

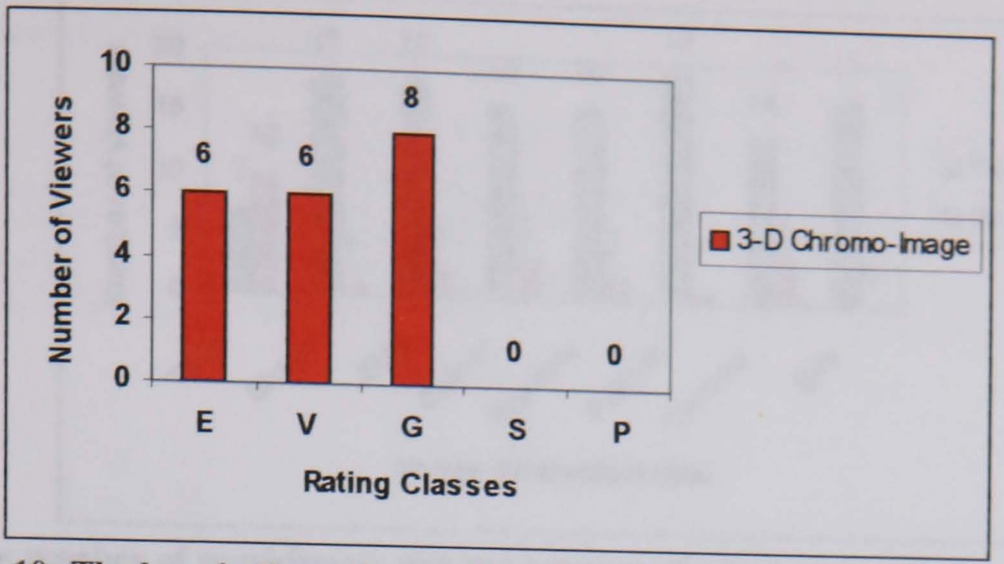


Figure IX-10: The bars indicate the number of participants in each rating class of the chromo-stereoscopic image.

2) Question 2 - *Which image characteristics can be used to interpret the chromo-stereoscopic image?*

In general, for image interpretation using visual techniques, there are several well-recognised aids to interpretation of which the interpreter should be aware. These are generally known in the literature as the image characteristics, the most useful of which are the following:- tone, shape, size, colour, shadow, pattern, texture and site. Indeed interpreters should be thoroughly familiar with the uses of all these image characteristics and be skilled at exploiting them. To answer whether these various image characteristics could be used in interpreting the chromo-stereoscopic image, the participants were given a group of image elements (such as tone, shape, size, etc.) and they were expected to answer using ***yes*** or ***no*** to whether each of these image characteristics could be used to interpret features from the new 3-D chromo-stereoscopic image. As can be noticed from Table IX-3 and Figure IX-11, apart from tone, the majority of all participants had answered yes to the use of all other image characteristics for the interpretation of the chromo-stereoscopic image. However, there was a small number of participants who did not provide any answers to some of the image elements since they were not experienced interpreters and were not sure about how to answer the question that had been set. It would seem that they were not really aware of these individual image elements or characteristics that lie behind the interpretation process.

Que. No.	Summary of the Question	Tone		Shape		Size		Colour		Shadow		Pattern		Texture		Site	
		Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N
Q2	Which image characteristics can be used to interpret the chromo- image?	7	10	19	1	18	2	16	3	16	2	19	1	14	4	17	0

Table IX-3: The results regarding the use of each individual image characteristic used to interpret the 3-D coloured image.

Figure IX-11: The number of participants and the answers of yes or no to the use of each individual image characteristic in chromo-stereoscopic interpretation.

In fact, most of the participants think that tone can only be used in conjunction with black and white images. Although a great number of participants answered yes to the use of colour, they mentioned in their comments that colour was only being used to represent elevation. Obviously colour or false-colour imagery cannot be used together with the chromo-stereoscopic image and this prevent the use of multi-spectral space imagery in conjunction with the 3-D technique and the additional information that this would give the interpreter.

3) Question 3 - ***What do the participants think of using the chromo-stereoscopic image for the interpretation of physical and cultural features?***

As reported by all the participants, the chromo-stereoscopic image has provided a better visual impression for the relief in particular. Since the cultural (man-made) features were mostly located in the lowest part of the image, they have been represented using the background colour for low elevation values – which was dark blue. However, the use of such a dark colour to underlie the different man-made features – e.g. buildings, roads, etc. – has reduced their contrast and appearance and obscured important information in the image. The results given in Table IX-4 and Figure IX-12 show that a large number of the participants think that, although the physical features were much easily recognised, the cultural features were less easily recognised due to the overlaid colour (deep blue) in the area where most of the man-made features were created. Undoubtedly this is a negative result coming out from the test.

Que. No.	Summary of the Question	Physical Features Total Number=20					Cultural Features Total Number=20				
		E	V	G	S	P	E	V	G	S	P
Q3	The use of the chromo-image for interpretation of physical and cultural features.	11	7	2	0	0	0	1	9	8	2

Table IX-4: Results of the use of chromo-stereoscopic image for interpretation of physical and cultural features.

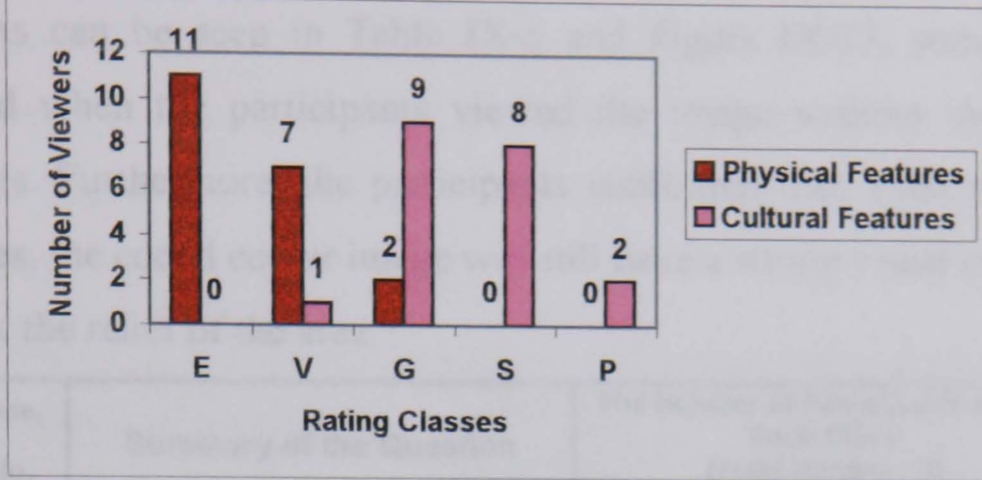


Figure IX-12: These bars show the number of participants against each rating class for interpretation of physical and cultural features on the chromo-stereoscopic image.

Once again, from all answers in Section II regarding feature interpretation, the great majority of the participants were highly satisfied with the information obtained from the chromo-stereoscopic image. Particularly in those areas with very few man-made features, where most of the terrain surface is a purely physical landscape, the image ground resolution is sufficient to extract the required information that can be used for geo-scientific activities. Moreover, the results obtained gave the impression that all the image characteristics could be used in interpreting the new 3-D coloured image – except for the tonal element, which could only be used in black and white images. In this context, the use of the colour element for interpretation is entirely different, since it has only been used to represent elevation. In fact, as reported by all the participants, this image product has been a great success in depicting the different physical features. However the same cannot be said about the man-made objects in the particular circumstances of the Misratah test area.

IX.4.3 Section III: Image Product Use

In the third section, the participants were asked questions about the image product use. This includes the possibility of depth perception without the use of the 3-D spectacles, and the potential use of the chromo-stereoscopic image both in the office and in the field.

1) Question 1 - ***How well the depth can be perceived without the use of the spectacles?***

To a certain extent, viewing the chromo-stereoscopic image without the use of the 3-D spectacles, is similar to the depiction of relief using the hypsometric colour method on medium- and small-scale topographic maps – in the sense that the colours used divide the entire land surface of the map into a series of elevation zones. As can be seen in Table IX-5 and Figure IX-13, some depth could be perceived when the participants viewed the image without the use of the 3-D spectacles. Furthermore, the participants confirmed that, even without the use of spectacles, the coded colour image will still have a strong visual effect when used to represent the relief of the area.

Que. No.	Summary of the Question	The Number of Participants within Each Class (Total Number=20				
		E	V	G	S	P
Q1	Can the depth be perceived from the chromo-image without the use of the spectacles?	2	5	6	6	1

Table IX-5: Results of how well depth can be perceived from the chromo-stereoscopic image without the use of the 3-D spectacles

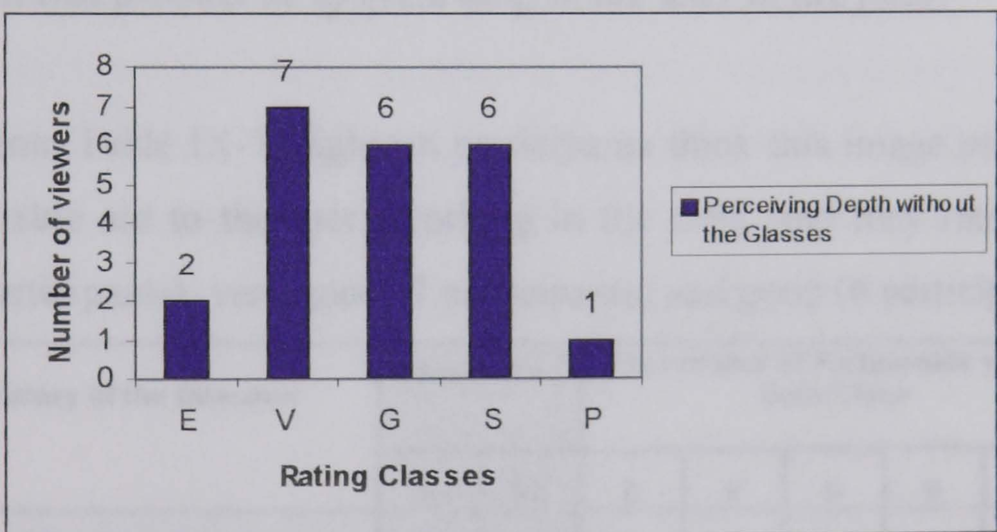


Figure IX-13: The number of participants against rating classes of perceiving depth from the stereoscopic image without spectacles.

2) Question 2 - ***Will this product be of great help to the user in the office?***

The answer of this question was divided into two parts; in the first part, the participants were prompted to answer this question using a simple **yes** or **no**. While, in the second one, if the participants thought that the chromo-stereoscopic image would indeed be of great help to the user in the office, they were asked to estimate how well and to what extent, it could be used in the office. From Table IX-6, nineteen participants out of twenty that think the chromo-stereoscopic image could be of great help for many users in the office – for example during preliminary studies and the planning and preparation for field work. This Table also indicates that the participants have rated the use of this product in the office as excellent (8 participants), very good (7 participants) and good (4 participants) These participants have mentioned in their answers that the product could provide a great deal of help for all the various users – geologists, geographers, planners, military officers, hydrologists, etc. – who might be expected to use space imagery in the office. Since this type of image visualizes the terrain surface in a more realistic and informative manner, a general idea about the relief and the different landforms existing in the terrain could be obtained in the office before actually visiting the area to carry out field work.

Que. No.	Summary of the Question	Office Use		The Number of Participants within Each Class				
		Yes	No	E	V	G	S	P
Q2	The use of the chromo-image in the office.	19	1	8	7	4	0	0

Table IX-6: Results of the use of the chromo-stereoscopic image in the office.

3) Question 3 - ***Will this product be of great help to the user in the field?***

Once again, from Table IX-7, eighteen participants think this image product would be of considerable aid to the users working in the field, and they rated its use as excellent (5 participants), very good (7 participants) and good (6 participants).

Que. No.	Summary of the Question	Field Use		The Number of Participants within Each Class				
		Yes	No	E	V	G	S	P
Q3	The use of the chromo-image in the field.	18	2	5	7	6	0	0

Table IX-7: Results of the use of the chromo-stereoscopic image in the field.

Figure IX-14 shows the graphic representation of the evaluation results for the use of the chromo-stereoscopic image in the office and in the field.

From the user's point of view, it was evident from most of the responses that the chromo-stereoscopic image could give a good general idea regarding the terrain, in particular its relief, even without the use of the special 3-D spectacles. Obviously, due to the use of colour to depict elevation, some depth can be perceived with purely naked eye viewing, but equally obviously the use of the ChromoDepth spectacles aided greatly in this respect. In general terms, this evaluation test has revealed that this type of image product could be of great benefit to the various users – the image providing valuable information that could be of great help for both office and field use.

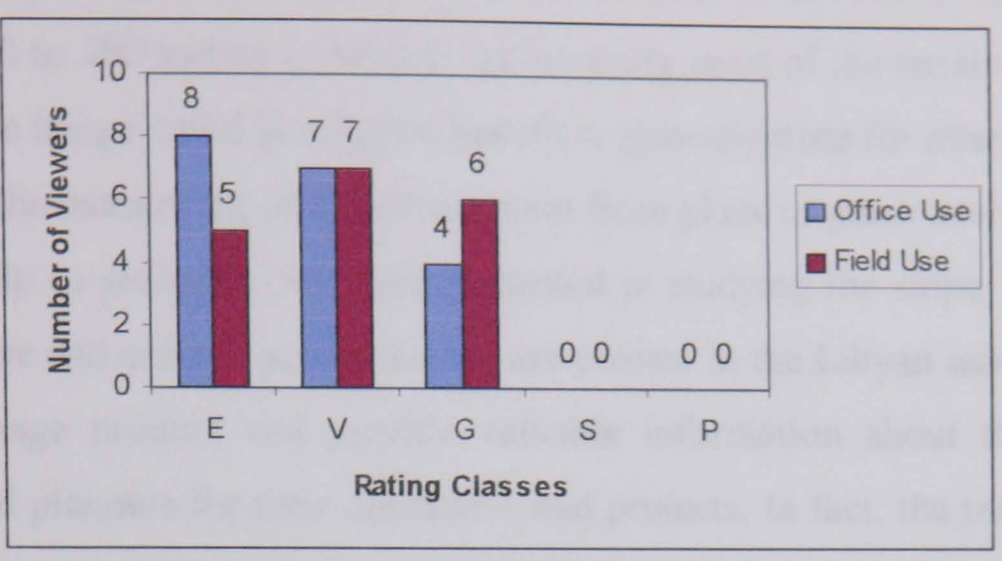


Figure IX-14: The bars show the evaluation results of using the chromo-stereoscopic image in the office and in field.

IX.5 Conclusion

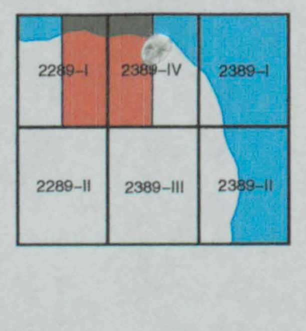
From the results obtained in this detailed study, it would appear that the new 3-D visualisation technique could be very suitable for application to the desert and semi-arid areas which constitute so much of the unmapped areas of Africa in general and Libya in particular. In the author's opinion, those developing countries with this type of terrain are good candidates to adopt this new image product as a complementary tool to their image maps and conventional line maps, since the method is comparatively easy to learn and realise, and it is cheap and fast to implement, resulting in an attractive as well as useful image.

However, it must be realised that the method is better suited for adoption with panchromatic space imagery where the colour can be used for the 3-D stereoscopic representation of the terrain elevations. If the basic space images are in colour or false-colour, then to allow these colours to be used for interpretative purposes, then the 3-D colour stereoscopic image must be provided as separate image. In which case, the interpreter would need to handle two separate images instead of one.

Notwithstanding, the limitations when using multi-spectral imagery, the author strongly recommends the use of this method in the Libyan context as a complementary tool to maps to give a general view about the physical terrain in the country. For various geo-scientists, information about the elevation and slope of the land surface is necessary, and thus a suitable technique, such as the new 3-D chromo-stereoscopic image, is required. In particular, this method can be used to study geomorphologic phenomena and processes. For example, in the desert area in the southern part of Libya, in which large sand dunes (around 200 to 300 metres in height) are covering most of the terrain surface, the chromo-stereoscopic image could be of great benefit to geo-scientists for observations of these sand dunes and the monitoring of their movement from place to place over time. It could also be of great help to geologists who are interested in studying the slope, drainage pattern, and bedrock type and erosion processes that are present in the Libyan terrain. Furthermore, this type of image product can provide valuable information about the terrain to military officers and planners for their operations and projects. In fact, the technique is very useful in that both experienced and inexperienced users can use the 3-D coloured image, since it is more realistic and gives much better and faster visual impression of the terrain surface.

MISRATAH

INDEX TO ADJOINING SHEETS



MAIN SOURCES:

SPOT IMAGE

HRV2 (SPOT1)	1986 – 1989
Scenes	76–285, 77–285, 78–285, 76–286, 77–286, 78–286
Panchromatic	0.51–0.73 um

Libyan 1:50,000: Topographic maps sheet 2289–I (Zawiyat Al Mahjub) and sheet 2389–IV (Misratah) produce by Surveying Department of Libya (SDL) 1979.

Libyan 1:40,000: Aerial Photographs covering the test area produced by2389–IV (Misratah) by Surveying Department of Libya (SDL) 1989.

Cultivated Area

Orchard

Forest

Sabkha (Salt Marsh)

Hummocks and Ridges

Sand Hummocks with Low Growth

Scale 1:50,000

1000 500 0 1000 2000 3000 4000 Metres

Contour interval 20 metres

Projection: Universal Transverse Mercator (UTM)

Spheroid : UTM 33S International 1924

Blue numbered lines indicate the 5,000 metre Universal Transverse Mercator Grid, Zone 33, International 1924 Spheroid.

Image processing, compilation, and cartographic processing by Hasin Mohammed Rammali, Surveying Department of Libya, February 2000.

Produced in the Department of Geography & Topographic Science, University of Glasgow.

Sea

Water Body

Wadi (Dry Stream Channel) Name — Wadi Kaam

Well, Spring

Water Tower

Contours — 20

Spot Height — 57

Shrine, Mosque

Church, School

Cemetery: Christian, Islamic

Ruins, Monument

Quarry

Bridge

Airfield, Airport

Highway

Main Paved Road

Secondary Paved Road

Unpaved Road

Track

International Boundary

Provincial Boundary

Town

Small Town

Main Village

Village

Settlement

Isolated Building

S.P.L.A.J. SPACE IMAGE MAP 1:250,000

MISRATAH

PARTS OF SHEETS NI 33–14/NI33–15/NH 33–2/NH 33–3

MAIN SOURCES:

SPOT IMAGE

HRV2 (SPOT1) 1986–1989

Scenes Panchromatic 76–285, 77–285, 78–285, 76–286, 77–286, 78–286; 0.51–0.73 um

Libyan 1:50,000 Topographic maps covering the test area of Misratah produced by Surveying Department of Libya (SDL) 1979.

Libyan 1:40,000: Aerial photographs covering the test area of Misratah produced by Surveying Department of Libya (SDL) 1989.

NI 33-13	NI 33-14	NI 33-15
NH 33-1	NH 33-2	NH 33-3
NH 33-5	NH 33-6	NH 33-7

Scale 1:250,000

5 4 3 2 1 0 5 10 15 Km

Projection: Universal Transverse Mercator (UTM)

Spheroid: UTM 33S International 1924

Blue numbered lines indicate the 25,000 metre Universal Transverse Mercator Grid, Zone 33, International 1924

Image Processing, compilation, cartographic design and production by Hasin Mohamed Rammali, Surveying Department of Libya, March 2000.

Produced in the Department of Geography & Topographic Science, University of Glasgow.

Cultivated Area
Orchard
Forest
Sabkha (Salt Marsh)
Sea
Water Body
Wadi (Dry Stream Channel) Name — Wadi Sasu
Well, Spring

Contours — 100
Spot Height — 18
Shrine
Cemetery: Islamic, Christian
Ruins
Quarry
Oilfield
Airport, Airfield

Highway
Main Paved Road
Secondary Paved Road
Unpaved Road
Track
International Boundary
Provincial Boundary
Town
Main Village
Village
Settlement