VEGETATIONAL HISTORY AND ARCHAEOLOGY:
A STUDY OF TWO SITES IN WEST SCOTLAND

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Thesis submitted for the degree of M.Sc. in
the Faculty of Science, University of Glasgow.
May 1985.

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ACKNOWLEDGEMENTS

I would like to thank Professor M.~~A~~B. Wilkins for making possible the arrangement whereby I was able to work at the Department of Botany, University of Glasgow, whilst in the employment of the Scottish Development Department (Ancient Monuments), who funded the research. Also at the Department of Botany, I especially thank Dr. J.H. Dickson for his advice and helpful discussions during the work and Mrs C.A. Dickson for her help with macrofossil identification in particular. (The data of Table 3 are essentially the work of the former). It was a benefit to have the opinions of Drs. D.E. Robinson and W.E. Boyd on difficult pollen identifications and both provided ideas for the interpretation of results.

Mr J.N. Gillies assisted greatly with fieldwork in the area of Torrs Warren and Mr and Mrs T. Clark were very generous in the hospitality they gave at Sheshader.

Dr. W.G. Jardine (Department of Geology, University of Glasgow) kindly commented on Section IIi of Chapter 2 and also on the nature of the soil profile described in Section IIi of Chapter 3. On archaeological matters the advice of Mr.T.G. Cowie (National Museum, Edinburgh) is much appreciated. Dr. K.J. Edwards (Department of Geography, University of Birmingham) offered useful comments on Chapter 2. Mr. and Mrs. J.G. and M.M. Cruickshank (The Queen's University, Belfast) discussed how certain aspects of the main profile from Torrs Warren might be explained.

In the preparation of the text I am firstly grateful for the work of my sister, Liz (Computing Unit, Queen Elizabeth College, University of London) and to Mr. B. Meek (Director of the Unit) who made the word-processing facilities available to us. Mrs. M. Badrock contributed to the typing and Mr. P. Jackson supervised the printing. Finally, I thank Ms. J. Jones (Local Government Studies, University of Birmingham) for typing the Contents, Acknowledgements, References, Tables, etc.; also Mr. G.P. Dowling and Mr. S.J. Restorick (Department of Geography, University of Birmingham) for the photographic reductions of the two Maps and Diagrams, and Figs. 7 and 8).

ABBREVIATIONS AND CONVENTIONS

Radiocarbon Dates (b.p., b.c., a.d.)

Lower case letters are used for abbreviations following uncalibrated radiocarbon dates.

b.p. Before present; i.e. before 1950 A.D. calculated on the basis of the half life of ^{14}C being 5568 years.

± This prefixes the error on a mean date at one standard deviation.

Calendar Dates (B.P., B.C., A.D.)

Upper case letters are used for abbreviations following calibrated radiocarbon dates (after Clark 1975), or calendar dates given in the archaeological or historical literature.

Pollen Analysis

The pollen types identified in this work are generally named following the key in Faegri and Iversen (1975), but see p. 25. The depths of samples are given as the measurement from the top of the profile to the base of the sample (usually 1 cm thick) in cm, unless otherwise stated.

AP	Arboreal pollen.
NAP	Non-arboreal pollen.
TPS	Total pollen and spores.
TLP	Total land pollen i.e., excluding pollen of aquatics and spores.

Plant Nomenclature

The nomenclature for vascular plants, including the English name, follows Clapham, Tutin and Warburg (1981). In Chapters 2 and 3 the English name is given to a species or higher order at its first occurrence in the text, but not in the Sections describing the zonation of the diagrams or sediment description. The nomenclature for mosses follows Smith (1979).

Other Chronological and Stratigraphical Nomenclature

The term 'Post-glacial' refers to the period from c.10,000 b.p. until now, the equivalent of the Flandrian, which succeeds the 'Late-glacial', being the latest part of the last glaciation (the Devensian, formerly Weichselian, cf. Fig. 1).

A.O.D. Above Ordnance Datum.

SUMMARY

The results of pollen and macrofossil analyses of peat deposits at two sites in West Scotland are presented in two chapters following an introduction and a chapter describing the methods used in the investigations.

The Introduction broadly outlines how the research was funded, its principal aim and particular difficulties associated with the investigations at each site.

In Chapter 1 an account is given of the main assumptions of the techniques employed and aspects of their previous application to archaeological interpretation are considered. Some of the literature bearing on the interpretation of the pollen record from a site is reviewed so as to provide both a background for the inferences made from sequences from the two regions of SW and NW Scotland and for the two sequences of this study.

Chapters 2 and 3 are set out with roughly the same format, in sections, which may be subdivided (see Contents). The two chapters are not related in the sense that any conclusions from one site affect the conclusions from the other, and are two separate accounts. In each, the inferred vegetational history of the site is interpreted in terms of the known local archaeological record, but this necessarily entails explanations in which the history is perhaps only indirectly the result of man's activities in the areas, or primarily due to other causes.

INTRODUCTION

The Central Excavation Unit was set up within the Scottish Development Department (Ancient Monuments) in 1977 to serve the cause of 'rescue archaeology' in Scotland. As part of its programme , two sites in the west of Scotland have recently been surveyed prior to limited excavations. Pollen and macrofossil analyses of peat near to one site, Torrs Warren, Luce Bay, Wigtownshire and at Sheshader, Eye Peninsula, Isle of Lewis, have been carried out in an attempt to reconstruct the vegetation at, or around, the sites during various periods.

Both investigations have presented particular problems in relating the inferred vegetational history to the activity represented by the local archaeological record. In the first case, the period to which the recently excavated finds belong is earlier than that covered by the pollen sequence; in the second, there is the difficulty of determining the exact stratigraphical position of a prehistoric stone wall within the pollen record obtained from peat close to the wall.

There is no specific archaeological problem that is common to both sites, so the results from each are not compared and are discussed separately. That there is no such common aim is due to the manner in which the work arose. This is outlined for the individual sites in the sections headed 'Background'.

CHAPTER 1

METHODS

I Historical Introduction to Methods and General Approach Adopted for this Study

Pollen Analysis

Pollen that is identifiable to different taxonomic levels may be preserved in a stratified deposit for thousands of years. Since the communities of plants contributing to the pollen rain vary due to a number of interrelated factors (e.g. climate, soils, impact of man, disease etc.), the record of this variation was seen early on by von Post (1916) as potentially forming the basis of a method by which past distributions of vegetation (and hence climatic change) could be inferred on the principle of 'uniformitarianism'. With extended research parallel changes within certain geographical areas came to be recognised and the characteristic vegetation types were eventually defined by pollen zones. Whilst in von Post's view pollen analysis was mainly 'designed to serve as a means of determining geological time', to be fixed via the varve chronology of de Geer, its application of the study of vegetational succession remained one of its aims and was considered to give the best record of climatic change (von Post 1946). Used in conjunction with the evidence of peat stratigraphy and finds of fossil plants, it provided a more detailed record than the former two alone, which had been the main evidence for past climates as summarized in the scheme of Blytt and Sernander. A general account of the development and application of pollen analysis and related studies is given by Godwin (1975,25-33).

Many of the methodological problems of the technique were understood by the early workers, e.g. von Post (1916) in Sweden, and Godwin (1934a) in Britain. Since then, research has made some progress in substantiating the initial hopes for pollen analysis. A selection of this is briefly reviewed below, where the topics have been chosen as a preface to the discussion of the two sites investigated. The following is an outline of developments relating to the application of pollen analysis to archaeological interpretation, particularly in Scotland.

Archaeology and Vegetational History

Tansley (1939,147-170) had based his history of the Post-glacial vegetation on the same scheme (as yet unzoned) as that described, together with pollen evidence, by Godwin(1934b). An early application of pollen analysis, contributing to a picture of the natural background for the activities of prehistoric man is found in Clark's Mesolithic Settlement of Northern Europe (1936).

Once a scheme of pollen zonation had been established for England and Wales, although the distribution of sites was uneven, favouring the north and west with little work in Scotland (Godwin 1940), this was to be the basis of the description of broad vegetational change during the Late and Post-glacial periods (Godwin 1956, 1975 see Fig. 1). It thus became the main framework for interpreting the archaeological record of earlier people in an environmental setting. It could also be used as a means of dating (e.g. Durno 1961-2; 1962-3; 1963-4; 1965; 1970; for Scottish sites).

With the introduction of radiocarbon dating, zone boundaries were determined in radiocarbon years. The many more dates that have now been obtained from a diversity of sites allows the

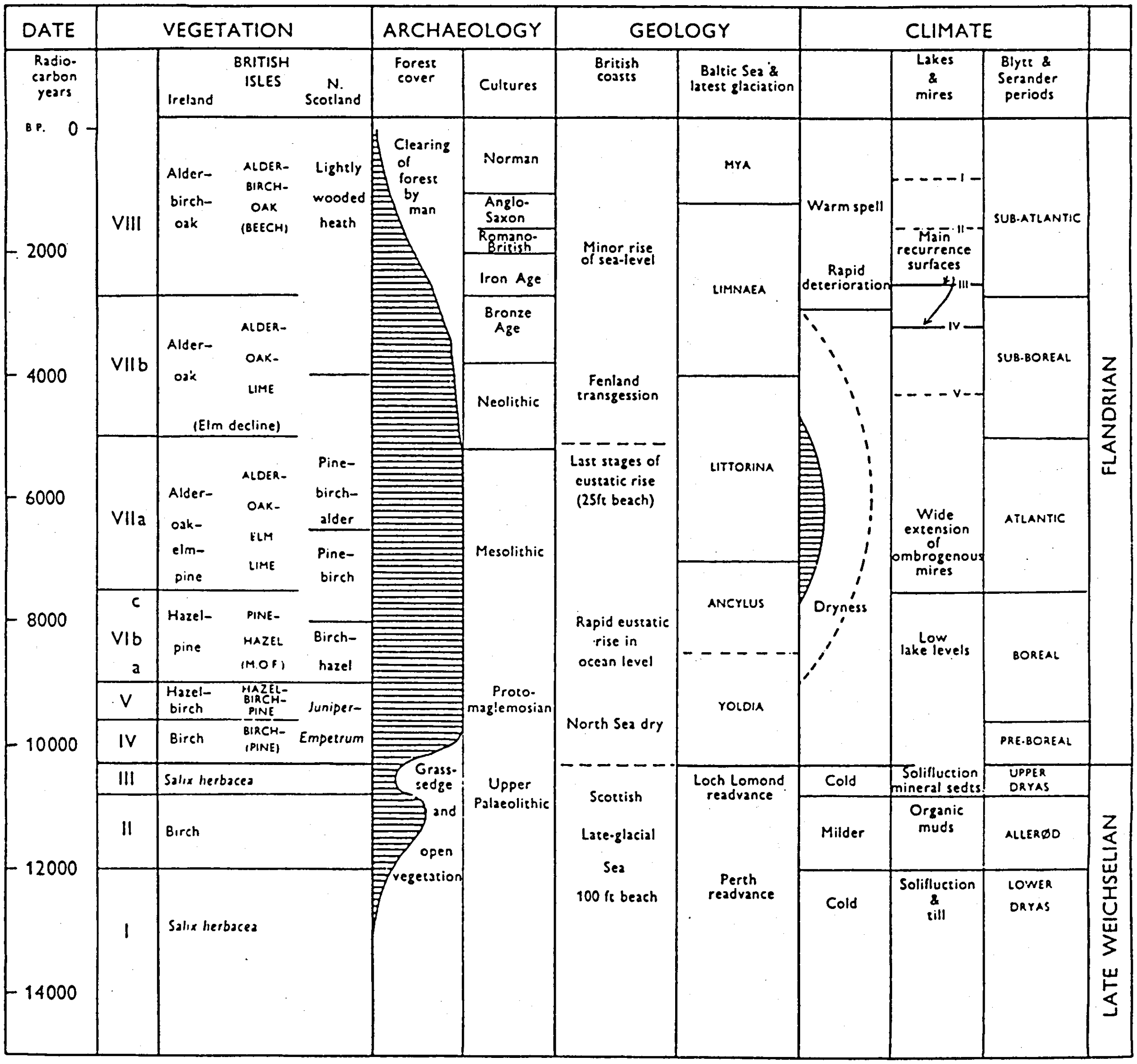


Fig. 1. Correlation table showing the main events of the Late Devensian (Late Weichselian) and Flandrian periods in the British Isles. From Godwin (1975).

dynamics of the changes in the dominant vegetation to be better understood (e.g. Smith 1965, Smith and Pilcher 1973, Huntley and Birks 1983).

The further definition of the term 'pollen zone' has made it easier to use the concept for individual sites whose pollen record is perhaps not typical of the general scheme for England and Wales. West (1970) proposed the hierarchy : Stage, Chronozone, Regional Pollen Assemblage Zone and Local Pollen Assemblage Zone. The last is likely to be most appropriate for subdividing the pollen record relating to an archaeological investigation and is the term employed below.

In Scotland, the increased knowledge of the present day vegetation and ecology, and also the number of pollen sequences, has made it possible for Birks (1977) to write a preliminary history of the vegetation, using the distribution of dominant vegetation types deduced by McVean and Ratcliffe (1962) as a starting point (see Fig. 2). With these and other sites a similar description for the British Isles as a whole has been attempted. It is based on isopoll maps and principal component analysis (Birks et al. 1975). The history given is that before c. 5000 b.p., when human disturbance of the natural vegetation was unlikely to have been appreciable and so not readily detected in a regional pollen diagram.

The extent to which pollen analysis has aided in reconstructing the environment of the British Isles, especially during the prehistoric period (before and after c. 5000 b.p.), is shown by the surveys of Evans (1975), Bradley (1978) and Simmons and Tooley (1981).

The approach that has been taken in investigating the sites of Torrs Warren and Sheshader is that of trying to gain as much useful

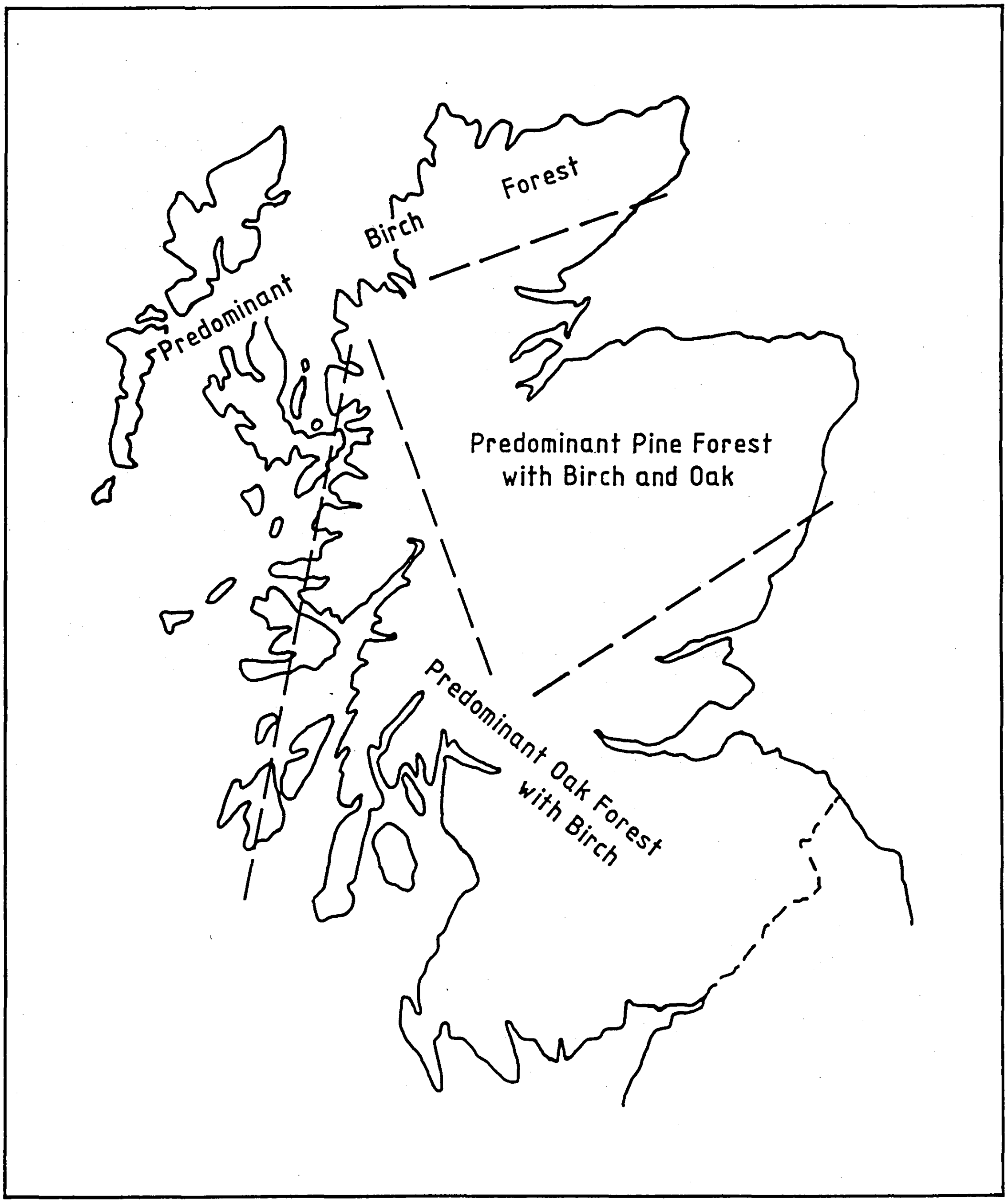


Fig. 2. Map showing the zones of the predominant trees of the forest as reconstructed assuming no interference by man and a climate such as prevails today in Scotland. From McVean and Ratcliffe (1962).

information within a given time from samples taken as a consquence of 'rescue' excavation and survey of threatened sites. This may be generally true of such work carried out at the Somerset Levels (e.g. Coles 1975-), Shaugh Moor(Balaam et al. 1982), Beaghmore(Pilcher 1969), or Ballynagilly (Pilcher and Smith 1979), although it has been possible to do much more detailed research at these sites.

This approach may be summarized as: firstly, to produce an outline diagram to discover the general trends of the pollen sequence; then to count levels at closer spacing where more detail would aid in interpretation. A basal radiocarbon date and additional determinations indicated the period to which the sequence belonged. Interpretations were then made which were based both on the current knowledge of the regional history of the vegetation as described in the literature, and on the basis of more local ecological considerations. There is no attempt made to discuss any wider implications of the results beyond the immediate area of the sites or to integrate them into the context of the prehistory or history of the region. This would hardly be possible in the case of Torrs Warren, and it would be premature for the results from Sheshader.

II Considerations Affecting the Interpretation of a Pollen Sequence - Selective Literature Review

Relative Pollen Productivity and Dispersal

Two factors determining the amount of pollen arriving at a site are the production of pollen by the various contributing plants and the method of dispersal. The results of the work by Pohl (1937) may contain inaccuracies, according to Birks and Birks (1980), but the order of decreasing pollen production of the important forest trees is given as : *Pinus sylvestris*, *Alnus glutinosa*, *Corylus avellana*, *Betula pendula*, *Quercus robur*, *Picea abies*, *Populus canadensis*, *Tilia cordata*, *Fagus sylvatica*, *Aesculus hippocastanum*. Wind-pollinated plants will tend to have their pollen much more widely dispersed than those pollinated by insects (e.g. most Compositae); and in self-pollinated plants the minimum of dispersal would be expected (e.g. cereals). A proportion of any pollen record may be the result of long-distance transport (e.g. Tyldesley 1973a, 1973b, 1973c).

A knowledge of the approximate relative magnitude of pollen production and the agent of dispersal, may be considered in relation to the type of model for pollen transport to a site devised by Tauber (1965). It may be possible to derive correction factors for the pollen percentages on a given diagram. Such were used by Iversen (1964) for interpreting the forest history at Draved, also by Andersen(1973) for Eldrup Forest, both in Denmark. However, numerical factors are not used in the discussions that follow, rather the various considerations are borne in mind when making particular interpretations.

Pollen Catchment

In order to assess the importance of man as an influence on the vegetation (and how widespread this was, in particular), the likely sources of the pollen rain have to be inferred. Two lines of evidence help towards this: the understanding of relative pollen productivity, types of dispersal and overall transport, combined with an understanding of the probable habitats of the contributing plants within the topographical setting of the site; and the method of obtaining surface sample spectra from locations at known distances from a selected vegetation type.

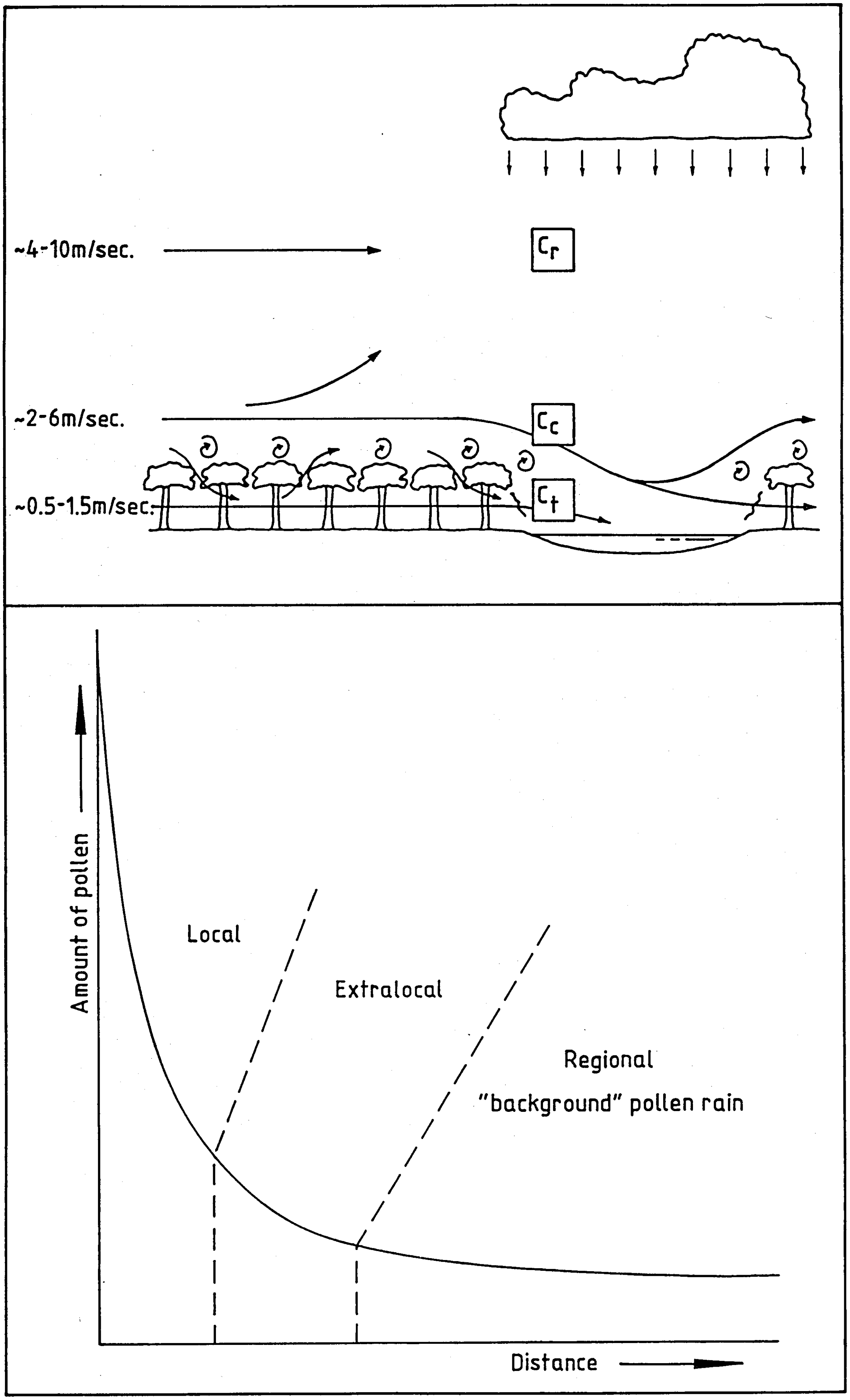


Fig. 3. Tentative model of pollen transfer in a forested area (C_r = rainout component, C_c = canopy component, C_t = trunk space component); and idealised relation between pollen rain and distance from pollen source. From Tauber (1965) and Janssen (1966).

The model for pollen transport to a site postulated by Tauber (1965) is illustrated in Fig. 3. It takes into account the likely impedence of the pollen rain by the surrounding vegetation, which was given further attention (Tauber 1967) with regard to the possible filtering effect of common sallow (*Salix cinerea*). Janssen (1966) distinguished a 'local', 'extralocal' and 'regional' pollen rain, and in these terms the regional rain is probably made up from Tauber's 'canopy' and 'rain-out' components; the extralocal from the 'trunk space' component. As defined, the extralocal rain is not so susceptible to change with distance from the vegetation as the local, but it makes a greater contribution than the regional (see Fig. 3).

Surface sample analyses have demonstrated the change in the amount of pollen arriving at a site as a function of distance. The findings for three British studies are summarized by Edwards (1982) in a discussion of their implications for interpreting the influence of early activity. The earliest of these examined the pollen spectra from points along two 500m transects from a plantation (on Cameron's Moss, Ayrshire) of mainly *Pinus sylvestris*, with some *Betula pendula* and *Sorbus aucuparia*, across an area of open bog without further planted trees (Turner 1964). After showing that the *Betula* pollen from the plantation was not affecting the percentages of *Pinus* when the calculation sum of total tree pollen (AP) was used, these percentages were plotted against the distances of the samples to the plantation on both transects. An exponential decay curve (of the form $y = a + be^{cx}$) was fitted to these points and the maximum component of *Pinus* pollen deriving from the plantation found to be 49% AP, the constant b; with a maximum value for y of between 80 - 90% AP. Another transect at Bloak Moss, Ayrshire from a larger pine plantation showed that this component was not dependent on the size or shape of the woodland and is mainly derived from the woodland edge. Expressed as percentages of total land pollen (TLP), the maximum pine component, the constant b, is only 18% or 10% on the respective transects, reducing to 5% and 2% within a distance of 100m. If the open grassland of today's landscape was covered by trees and assuming that these produced an amount of pollen comparable to the open habitat plants, the component deriving from the trees would have been about 10% to 18% of the total tree pollen, in contrast to the 50% at present. Thus in interpreting the extent of clearance evidenced in a pollen diagram, it would seem that only if a clearance was made within approximately 100m of a coring site would it be detected. Most of the diagrams prepared from bogs of larger dimensions are therefore recording the cumulative effect of a number of clearances in the landscape, accepting that other tree pollen grains would not have travelled as far as those of pine. Work has been carried out at Bloak Moss to produce 'three-dimensional' pollen diagrams so as to try and locate the areas of clearance as previously recorded in a 'regional' diagram (Turner 1965, 1970, 1975).

The study by Tinsley and Smith (1974) was in part concerned with the dispersal of oak, birch and alder pollen over a variety of heathland communities from oak (Quercus petraea) dominated woodland on the Nidderdale Moors, West Yorkshire. The results from the randomly selected sites on an area of predominately Calluna and Vaccinium heath will be referred to in Chapter 3 below. The woodland was of fairly open canopy and the average tree pollen value of 51% TLP reflects this. The reduction in overall tree pollen was seen to be mainly that of oak pollen, and it was the trees on the edge of the woodland (in this case oak) that contributed to the decreasing values of tree pollen plotted against distance along the transects. The equation fitted to the decay in each case, was of the form $y = a + b/x$. The curves are levelling off by 100m, with the greatest rate of reduction in tree pollen occurring near to the woodland edge. The birch was growing in the interior of the wood and the percentages of birch pollen were not observed to decrease in this way, being approximately constant in two transects at c. 5% TLP. The representation of alder pollen was erratic, with peaks of c. 10-15% TLP being recorded at various distances to beyond 500m from the wood. On the basis of the figures obtained it was thought that for this type of site, percentages of over 50% (TLP) of tree pollen probably indicate woodland within 100m of the site; percentages of between 25% and 50% as being derived either from a woodland edge, or a site surrounded by dispersed trees.

Caseldine (1981) similarly based the percentage calculations of his results from Bankhead Moss, Fife, on total land pollen. Here it was the change in birch pollen percentages as recorded at 10m intervals from a birch wood that was a principal object of the investigation. The woodland surrounded a small open bog (c. 200m x 50m) and included an element of Pinus sylvestris planted along most of one side. The woodland was in turn surrounded by a variety of vegetation types (more planted pine; Filipendula carr, some with Salix and long grass) which separated it from open farmland. The graph chosen to fit the decline of pollen values with distance was of the form $\log y = a - b \log x$. Two of the three transects from the centre of the bog outwards provided sufficient points for this, although the pattern of the percentages levelling off at 30m and only gradually reducing during the next 50m or more, was a feature of all three. It is suggested that it may be the choice of equation that is showing a more 'rapid' levelling off of the birch values, than the rate determined for those of oak by Tinsley and Smith (1974). The reduction of birch pollen percentages was from c. 25-60% to 5%; 45-90% to 10%; and 50-80% to 10% over 30m.

The point made by Edwards (1982) from these studies and already alluded to by Turner (1964) is that unless the sampling site is comparatively close to the edge of woodland being cleared (within 100m and possibly even within 30m) an individual clearance may not be detected.

Absolute Pollen Analysis

Another factor affecting the pollen record, as it is usually presented, is the percentage calculation for the values at each level. If the representation of one type is increased, then other values must decrease as a function of the calculation, since the amount of a taxon appears both in the numerator and the denominator (1).

(1) Level 1 No. of grains of A = 100, of B = 400

$$\%\text{age of A} = \frac{100}{100 + 400} \times 100 = 20\%$$

Level 2 No. of grains of A = 400, of B = 400

$$\%\text{age of A} = \frac{400}{400 + 400} \times 100 = 50\%$$

From the percentage figures it might appear superficially that the amount of A in Level 2 has increased by 2.5 compared to Level 1. The absolute increase, however, assuming a constant density and volume of sediment, is by 4.0; B has remained the same on this assumption, though the percentage of B has fallen from 80% to 50%.

The method of absolute pollen analysis in attempting to overcome this effect has a known physical quantity as the denominator: either weight or volume of sediment. The results are then expressed as the amount of a taxon/unit volume or weight. Exotic pollen of known quantity, within statistical limits, is added to the preparation of known volume or weight, thus (2):

(2) No. of fossil grains/unit of sediment = Nf
No. of exotic grains/unit of sediment = Ne
No. of fossil grains counted = cNf
No. of exotic grains counted = cNe

Since $\frac{Nf}{Ne} = \frac{cNf}{cNe}$,

the no. of fossil grains/unit of sediment = $\frac{cNf}{cNe} \times Ne$.

If a time-scale for the rate of deposition of the sediment has been derived, then the pollen influx may be expressed as the number of grains/cm^2/year.

The main difficulty of the method is the uncertainty of whether the absolute basis of volume or weight actually applies. It is most suited to lake sediments of a uniform composition, though it has been used by Beckett (1979) for two peat deposits (one mainly *Sphagnum* peat; the other mainly *Sphagnum* and *Cladium* peat). It was considered that the results were sufficiently valid to aid in the interpretation of the sequences. Absolute counts have been made at certain levels at both of the sites discussed below. Some other difficulties of the method and the preparation technique are given in Section III.

Soil Pollen Analysis

There are two main problems associated with the pollen analysis of soils. The best conditions for the preservation of pollen are seldom met with in a mineral soil profile, which may be alkaline in reaction, and comparatively dry and so aerobic. Secondly, the activity of earthworms sorting the soil by ingestion and excretion and possible movement of the pollen grains by percolating water give rise to the question of how truly stratified the pollen is in relation to its original order of deposition.

The first of these problems has been the subject of research by Havinga (e.g. 1964, 1967, 1971). In the earliest paper the order of susceptibility to corrosion (caused other than by oxidation experiments) was tabulated on the basis of previously published work by other authors. The order is given in Table 1. This correlated well with the order obtained from Havinga's (1964) experiments designed to observe the effect of oxidation on the corrosion of spores and grains. It was concluded that oxidation susceptibility was a good indication of corrosion susceptibility. This was in turn apparently related to the sporopollenin content of pollen and spores, see Table 1. Exines that were easily oxidised were more liable to attack by micro-organisms (in these experiments, both bacteria and yeasts). In natural conditions, especially in a well aerated soil, autoxidation might also be related to the sporopollenin content of the exine walls, as was suggested by a further experiment to compare the effects of oxidation on <u>Lycopodium</u>,and <u>Pinus</u> and <u>Picea</u>(affected after two and a half years) left exposed to light in an exsiccator.

The type of corrosion was not described in detail, although reference was made to the phenomenon of perforation corrosion as reported by Andersen. The other two papers (Havinga 1967, 1971)

Order of corrosion susceptibility based on previously published work. (fr. Havinga 1964)	Order of susceptibility to oxidation (fr. Havinga 1964) Least ↓ Most	Sporopollenin content (%) in pollen & spores (fr. Havinga 1964, after Kwiatkowski and Lubliner-Mianowska 1957).	Sequences of increasing susceptibility to decay (fr. Havinga 1971).	
			River Clay Soil	Leaf Mould
Lycopodium	*Lycopodium clavatum*	*Lycopodium clavatum*	*Lycopodium, Polypodium*	*Lycopodium, Polypodium*
Conifers	*Polypodium vulgare*	*Pinus sylvestris*	*Taraxacum*	*Taraxacum*
Tilia	*Pinus sylvestris*	*Tilia* sp.	*Fagus*	*Fagus, Juniperus, Quercus*
Corylus	*Tilia* sp.	*Alnus incana*	*Juniperus, Quercus*	*Tilia, Pinus*
Alnus, Betula	*Alnus glutinosa, Corylus*))	*Corylus avellana*	*Tilia, Pinus*	*Taxus, Salix, Carpinus,*))
Quercus	*avellana, Myrica gale*)	*Betula pendula*	*Taxus, Betula, Populus*	*Ulmus, Acer*)
Fagus	*Betula* sp.	*Carpinus betulus*	*Salix, Carpinus, Ulmus,*))	*Betula, Populus, Fraxinus*
Also:	*Carpinus betulus*	*Ulmus* sp.	*Fraxinus, Acer*)	*Alnus*
Carpinus > *Tilia*	*Populus* sp., *Quercus* sp.))	*Acer negundo*	*Corylus, Alnus*	*Corylus, Myrica*
Salix > *Corylus*	*Ulmus* sp.)	*Quercus petraea*	*Myrica*	
Fraxinus,)) > (*Alnus,*	*Fagus sylvatica,*))	*Populus alba*		
Populus,) ( ) (*Betula*	*Fraxinus excelsior*)			
Ulmus)	*Acer pseudoplatanus*			
	Salix sp.			

Table 1. Data Relating to the Differential Preservation of Pollen and Spores.

are more concerned with corrosion types and give the results of an experiment in which known proportions of pollen and spores were enclosed in nylon pouches and buried in five different soil types: *Sphagnum* peat, *Carex* peat, podsolised sand, river clay and leaf mould in a greenhouse. The pollen and spores in the peaty soils were subject to aerobic conditions for some of the year. Only the river clay and leaf mould had intense biological activity and only in these was there a significant decline from the original percentages of uncorroded exines after 20 months. *Alnus* and *Corylus* had declined in number, which was not to be expected from the orders of susceptibility published earlier and although it had been considered possible to separate *Corylus* and *Myrica* at the start of the experiment, this became more difficult. All three types contributed to the indeterminable pollen category. Perforation-type corrosion was observed in many of the identified grains of *Corylus*, *Myrica* and *Alnus*, as it was to a lesser extent in other species. The effect was not seen in *Lycopodium clavatum*, *Polypodium* and *Taraxacum officinale*. The perforation-type corrosion is not expected in a podsol unless corroded pollen from another, peaty soil has latterly been incorporated. The usual corrosion type is a thinning of the exine wall. The nylon pouches were left for a longer period. From the results obtained from those buried in the river clay soil and leaf mould, a general sequence of increasing susceptibility was drawn up, bearing in mind the arithmetical manipulation used to express the degree of decay; see Table 1. A rough classification of the degree of corrosion was given under three headings: unaffected, intermediately affected, and severely affected. A more comprehensive system has been devised by Cushing (1967), which is further discussed below (pp. 16-17).

The second of the problems may be summarized as one resulting from the processes of soil formation. Writing at a time when soil pollen analysis was not recieving much attention, Dimbleby (1961a) sought to emphasize the value of such work. He maintained that in cases where a soil is sufficiently acidic to preserve pollen and inhibit earthworm activity, the stratified pollen record can give information about the general vegetation types during the sequence, provided that the interpretation is based on an understanding that the spectra have been obtained from a soil and not a bog peat. The presence of pollen stratification in a soil argues against mixing and is therefore a suitable record for making deductions about the past vegetation (cf. Dimbleby 1957). However, there may be little indication of the time-span that the sequence represents.

Dimbleby's observation that pollen is bound in aggregates in the soil is supported by Munaut (1967, 138), which evidence is cited by Havinga (1974) in summarizing the prevailing theories as to how pollen is incorporated into a mineral soil. Downwash of individual grains of pollen is not thought to be the mechanism of incorporation. Rather, two processes are at work: the homogenisation of biologically active mull soil, which may be followed by the downwash of freed grains or even aggregates after mixing has decreased due to the increased acidity of the soil. Downwashing will depend to an extent on the particle and pore size of the mineral soil, but a relatively clear passage through the soil can allow this process to take place.

Keatinge (1983) suggested from this and other results (Guillet 1971, Stockmarr 1975, Andersen 1979a) that the faunal mixing is the most important mechanism in giving rise to the pollen stratigraphy, with downwashing a less important factor. He demonstrated that the distribution of soil particle sizes was related to the changes in pollen spectra and frequency in four profiles, and therefore to earthworm activity. If his interpretation that the pollen stratigraphy, indicating a change from forest to heath vegetation, is to be explained by the change in the depth to which groups of earthworms burrow, then the stratigraphy is not formed so as to produce a direct relationship between depth and time.

Pollen Identification

In spite of the number of available pollen identification keys and photographs that may be used in conjunction with modern reference material, there still remain difficulties in identification. Of relevance to the discussion below are grains in a poor state of preservation, which may accentuate the problem of separating *Betula* from Coryloid type. Within the Coryloid type, even if well preserved, there is uncertainty in assigning any grain to either *Myrica* or *Corylus*. Pollen of the Gramineae presents a problem of distinguishing types of grain, even if they are in a good state of preservation, and various measurements of grains have been used to identify cultivated grasses (cereals) as opposed wild grasses.

Cushing (1967) defined six categories of pollen preservation: *corroded*, *degraded*, *crumpled and exine thinned*, *crumpled but exine normal*, *broken* and *well-preserved*. There was also a category for indeterminable pollen that was *concealed*. In *corroded* grains the exines were 'affected by a distinctive etching or pitting'; in *degraded*, the exines 'appear to have undergone a structural rearrangement, so that sculptural and structural details are resolved only with difficulty'. Rather than combine categories, Cushing had a hierarchy whereby if more than one category was applicable, the one highest up the order was the single term used;

the six categories were applied to the condition of every grain encountered during routine analysis, whether determinable or not. (See below, pp. 24-25, for procedure adopted here.)

That it may be hard to distinguish *Betula* from Coryloid was noted by Godwin (1934a), as was also the distinction between *Myrica* and *Corylus*. A recent experiment by Edwards (1981) illustrates the uncertainty of the latter, although various workers have separated the Coryloid type, for instance in the experiments by Havinga discussed above, or by Dimbleby (1961b). Moore and Webb (1978) have a *Myrica* type in their key, whereas Faegri and Iversen (1975) do not.

In a study of wild grass and cereal pollen Andersen (1979b) summarizes the principal characteristics that have been used to describe these: 1) pollen size, 2) annulus and pore diameter, 3) thickness or protrudence and delimitation of the annulus, 4)surface sculpturing.

It may be particularly significant if it can be shown when cereals first appear in any pollen diagram. The presence of a comparatively large size of grass pollen grain is at least indicative of this. However, in practice the grains tend to crumple and the measurement may only be approximate. The preparation technique may cause the average sizes of grains to vary: especially after a period, if the mounting medium is glycerol. It is more practicable to measure the annulus diameter than the pore diameter with a normal light microscope having a graticule division of about 1µm, since the pore diameter is only of the order of a few microns. The annulus thickness can only be measured when grains are suitably orientated. To identify surface sculpturing requires phase contrast, or scanning electron microscopy for detailed study, as well as good preservation of the grains.

Thus measurements were made of the largest diameter of a grain and at right angles to that; and the average of these taken as the 'pollen size', even if the fossil material is crumpled (Andersen 1979b, 72; 84). Since Corylus grain size has been shown to vary similarly with other pollen types, all the preparations of modern pollen were made with Corylus mixed in and the sizes of the grass grains adjusted to the variation in Corylus from the standard size (24.5μm). Annulus diameter was the preferred criterion for characterizing the pore, since it is not affected by crumpling and is large enough for measurement. Because of the natural variation in pollen size, 100 grains of each collection of grass pollen (80 species) were counted.

There are two general points of interest from this for the interpretation of the pollen diagrams presented below. Firstly, unless there is an adequate number of large grass grains, the ranges of their sizes in nature prohibit definite identification on the basis of size alone, since the pollen size ranges of some wild grasses overlap with those of certain cereals. Table 2 lists measurements of grass and cereal pollen selected from the data published by Andersen (1979b), Beug (1961) and Andrew (1980). The mounting medium used is given in the table and the definition of pollen size in the case of Andersen's figures. Secondly, some of the large wild grass pollen (e.g. Ammophila arenaria, Elymus farctus and Leymus arenarius are plants found on sand dunes, the environment of Torrs Warren; also Elymus repens is a common grass of waste places and fields and so a likely contributor to the pollen rain in any area cleared for agriculture.

Species and likely habitat	Source: Andersen 1979b mounting medium: silicone oil				Beug 1961 (from Rohde 1959) glycerine jelly							Andrew (1980)			
	size, (M+ + M-)/2		anl-D		size, M+		anl-W	anl-T	pore-D	anl-D	)*	s.oil M+	a-D	g.jelly M+	a-D
	m	range	m	range	av	min max				av	range)	m	m	m	m
Waste ground or fields															
Avena fatua	44.2	42.3-46.2	11.9	10.7-13.2	50.3	43.8-65.0	3.3-4.7	2.7-2.9	4.7-5.4	13.1	11.3-14.8	42	12	54	14
Elymus repens (Agropyron repens)	37.3	34.5-40.1	9.1	7.8-10.4	43.9	37.2-49.1	2.0-2.7	2.9-3.3	4.0	8.7	8.0- 9.4	38	9	48	10
Hordeum murinum	39.1	36.6-41.6	8.8	7.3-10.2	54.3	37.2-53.7	2.7-4.0	3.3-4.3	3.7-5.3	11.2	9.1-13.3	36	10	45	12
Sand dunes															
Ammophila arenaria	32.0	29.5-34.5	8.4	6.2- 9.7	38.4	31.9-43.8	3.3-4.0	2.4-2.8	3.3-4.0	11.0	9.9-12.0	36	-	40	9
Elymus farctus (Agropyron junceiforme)	39.1	36.6-41.6	8.8	7.3-10.2	54.3	37.2-53.7	2.7-4.0	3.3-4.3	3.7-5.3	11.2	9.1-13.3	36	10	45	12
Leymus arenarius (Elymus arenarius)	42.6	40.1-45.0	8.4	7.1- 9.6	49.0	37.8-57.7	2.7-4.0	2.7-3.3	2.9-4.9	10.6	8.3-12.9	44	10	46	12
Slowly-moving water															
Glyceria fluitans	34.5	32.0-37.0	9.1	8.3-10.9	38.7-40.3	30.5-43.8	2.7-4.0	2.7-4.0	4.0-5.3	8.0	9.4-13.3	36	10	45	12
Fields of cereals															
Avena sativa	40.9	37.3-44.6	10.7	9.2-12.2	49.1-55.0	41.8-62.4	2.7-4.0	2.0-4.0	4.0-6.6	12.0	9.4-14.6	-	-	52	14
A. strigosa	ND	-	-	-	45.4	37.8-66.4	2.7-2.9	2.0-2.7	4.0-4.8	10.0	9.4-10.6	36	9	38	12
Hordeum distichon L.	ND	-	-	-	44.8-47.8	37.8-58.4	3.3-4.7	2.7-3.3	2.7-4.3	11.5	9.3-13.7	-	-	-	10
H. vulgare L.	37.3	35.2-39.3	8.2	7.2- 9.2	44.6-47.0	35.2-53.7	3.1-3.7	2.1-3.0	3.1-5.0	10.9	9.3-12.4	-	-	45	12
Secale cereale L.	40.1	37.4-42.8	8.9	7.8-10.1	50.8-55.8	31.9-65.0	2.7-4.0	2.4-3.3	2.7-5.3	11.2	8.1-15.3	45	11	50	12
Triticum aestivum L.	45.0	42.2-47.9	11.8	10.4-13.3	55.2-57.6	39.8-69.0	4.0-5.3	3.3-4.7	5.3-9.3	16.6	13.3-19.9	45	15	48	17
T. compactum Host.	47.2	44.9-49.5	14.2	12.4-16.0	54.8-56.7	44.5-66.4	3.7-5.3	3.7-4.7	5.3-9.3	16.3	12.7-19.9	ND	-	-	-
T. dicoccum Schrank.	45.8	43.3-48.2	13.5	12.0-15.1	49.2-57.6	38.5-71.0	4.0-5.3	2.9-4.0	4.0-6.6	14.6	12.0-17.2	-	-	-	14
T. monococcum L.	36.7	34.1-39.4	8.3	7.3- 9.2	43.2-46.6	32.5-59.1	2.7-4.0	2.7-3.3	2.7-6.6	10.6	8.1-14.6	-	-	-	13
T. spelta L.	46.0	43.8-48.1	12.6	11.1-14.1	53.8-63.7	41.8-72.3	3.3-5.3	3.3-6.0	5.3-9.3	15.9	11.9-19.9	-	-	50	16
Moorland															
Agrostis tenuis	25.9	24.1-27.8	6.7	5.8- 7.5	ND	-	-	-	-	-	-	24	-	-	-
Anthoxanthum odoratum	29.7	26.8-32.7	6.7	5.7- 7.5	32.2-36.0	23.9-48.4	2.0-3.3	2.0-2.7	2.7-4.0	8.7	6.7-10.6	30	-	-	-
Deschampsia flexuosa	24.6	22.9-26.2	5.5	4.6- 6.3	28.5	21.2-32.5	2.7-2.9	1.5-2.4	2.5-3.3	8.5	7.9- 9.1	27	-	30	-
Festuca ovina	24.0	22.3-25.7	6.1	5.2- 7.0	ND	-	-	-	-	-	-	30	-	-	-
F. rubra	29.6	27.7-31.4	6.8	5.8- 7.7	ND	-	-	-	-	-	-	29	-	-	-
Molinia caerulea	24.5	22.3-25.8	5.9	4.8- 7.0	ND	-	-	-	-	-	-	24	-	30	-
Nardus stricta	27.3	24.9-29.7	5.2	3.9- 6.4	28.7-28.8	19.9-42.5	1.6-2.7	2.0-2.7	1.6-3.7	7.0	4.8-9.1	-	-	30	-

M+, largest diameter of a pollen grain
M-, diameter at a right angle to M+
(M+ + M-)/2, av. diameter, standardised to *Corylus* (24.5µm)
anl-D, a-D, annulus diameter
anl-W, annulus width
anl-T, annulus thickness
N.B. No annulus measurements standardised, nor M+ from Beug or Andrew

m, arithmetic mean , or average of groups of means
range, 1 standard deviation
av*, calculated from 2 x ½ (anl-W_{min} + anl-W_{max}) + ½ (pore-D_{min} + pore-D_{max})
range*, calculated from (2 x anl-W_{min} + pore-D_{min}) and (2 x anl-W_{max} + pore-D_{max})
given as *Agropyron* cf. *repens* in Beug.
from Grohne (1957)
species selected from list 11 in Hubbard (1968, 30)
ND, no data

Table 2. Selected Measurements of Wild Grass and Cereal Pollen, from Andersen (1979b), Beug (1961) and Andrew (1980).

III Experimental Methods

Introduction

Where the above considerations relating to certain problems and assumptions of pollen analysis are relevant to the interpretation of the pollen diagrams from either of the two sites, these will be referred to within the individual accounts. The methods outlined here mainly concern the laboratory procedures used.

Sample Preparation

Standard method - All samples were prepared for pollen analysis by essentially the same method (cf. Birks and Birks 1980, 157). After treating c. 1-2 ml of sediment with 10% NaOH, the tubes being left in a boiling water bath for c. 3 minutes, the deflocculated peat was sieved whilst stirring and washing the debris with a jet of distilled water. Whatever was retained on the sieve was washed into a Petri dish to be examined later; any significant mineral component was removed by treatment with cold (usually) or hot 40% HF and hot 10% HCl. The pollen and other plant material was then acetolysed for c. 3 minutes. After washing in glacial acetic acid, and transferring the preparation in distilled water to 15 ml centrifuge tubes and centrifugation, a few drops of 10% NaOH and c. 10 ml of distilled water were added to try to neutralize the preparation (not always achieved) prior to staining with aqueous safranin. The preparation was washed in distilled water and then treated with c. 10ml tertiary-butyl alcohol. Following centrifugation, the alcohol was decanted and the residue stirred before adding a further amount of alcohol so that the preparation could be transferred by pipette to a small vial. This was gently centrifuged and the supernatant drawn off by pipette. The residue was stirred and then an approximately equal volume of silicone oil (viscosity 70% 500 c/s and 30% 12500 c/s v/v) was added. The preparation was mixed and left in an oven at 50° C, at least overnight, to drive off the remaining alcohol. The slides were ideally made up by spreading a suitable amount of the preparation over an area slightly less than that of the coverslip (22 x 22 mm, No. 0 or 1) before it was put in place. Occasionally small air bubbles were trapped in the preparation but this is not thought to introduce error due to movement of grains because of the larger spacing of the counting traverses.

Absolute method - When absolute counts were required tablets of either *Lycopodium* or *Eucalyptus* were added to a measured volume of sediment. The measurement was made by the displacement of distilled water in a measuring cylinder. Two cylinders were used at various times. The volumes of sediment from Torrs Warren were obtained from a 12mm diameter cylinder, graduated in 0.2 ml divisions (for a temperature of 20°C, BS 604). It was possible to read the level at the bottom of the meniscus to a precision of $\leqslant\pm$ 0.1 ml. The other cylinder, used for the Sheshader samples, was graduated in 0.1 ml divisions, but having a smaller diameter (11 mm), it was slightly less convenient. The precision in reading the volume was estimated to be $\leqslant\pm$ 0.1 ml.

The volume of sediment was flushed out of the measuring cylinder into a centrifuge tube so that after centrifugation, most of the distilled water could be poured off without loss of sediment. A number of tablets were then added to the sediment. When the order of magnitude of the pollen concentration was known, the number of tablets added was that expected to give a preparation having about twice as many fossil grains as exotic grains or spores. This is the ratio making the pollen analysis most efficient for a reasonable precision in the counting statistics (Maher 1981). The tablets were dissolved in the centrifuge tube by 10% HCl; they were added two at a time to keep the rate of effervescence under control. Occasionally a squirt of acetone was needed to prevent the mixture rising above the top of the tube. A 250 ml beaker was used for some of the Torrs Warren samples when a large number of tablets produced much effervescence. In the preparation of two of these samples (levels 24 and 185cm), a small amount of the mixture was lost. The mixture was frequently stirred and so how great an error was introduced would depend on the extent to which the tablets had dissolved (and thus on the number of exotics present in the spilt mixture, compared to the fossil pollen); however, it is unlikely to be greater than a few percent. The mixture was then washed and thereafter the procedure followed the standard preparation.

The main practical sources of error in the method are in the measurement of the volume and the possible deformation of the sediment altering its volume or density, as it is removed from the core. It is assumed that the fossil and exotic pollen or spores are completely mixed so that any losses during the preparation are not significant.

There are, however, the statistical uncertainties inherent in the method. These are dealt with in some detail by Bonny (1972) and Maher (1981), both of whom indicate the magnitude of the errors associated with the technique, in which only a small sample of the total fossil grains are counted (usually a minimum of 500) and of these, certain taxa appear relatively infrequently. Also, the number of exotics is known only within the limits as specified by the supplier; and the overall ratio of fossil grains to exotics significantly affects the limits within which the final figure of grains/ml may be set. Here the figures plotted (see Appendix 2) use the mean number of exotics quoted by the supplier and no calculation of possible error is attempted, this being considered much less than the magnitude of the overall range of values for each site.

Surface samples - Three surface samples from Torrs Warren were analyzed for their pollen content. Moss from a 5 x 5m quadrat was collected in polythene bags. The collections were made from a number of places so as to minimize the chance of collecting a disproportionate quantity of one type by the inclusion of any anthers (cf. Birks 1973, 283). The vegetation cover of the quadrat and some nearby plants were recorded (see Appendix 1).

In the laboratory the moss was first treated with 10% NaOH in a large (1l) beaker placed in a boiling water bath for 5 minutes. The mixture was stirred well and next sieved before treatment with cold HF. The standard preparation was then followed.

Sediment Description

The method of Troels-Smith (1955) was used to describe the sediments from the two sites. It was intended as a method for describing sediments in the field, but was used here with the knowledge obtained from examining the sieve washings and after the cores or monolith samples had been stored for a considerable period (3 and 5 years respectively).

The amount of sediment recovered by a Russian corer is small (the diameter of the approximately semi-circular cross-section is

c. 5cm) and it was conceiveable that further work might be carried out on the core, which came from a deposit that is now destroyed. Thus, having cleaned the surface of the peat and judged its colour by reference to the Munsell soil colour chart, the physical properties were assessed after removing a slice of peat from the edge of the core along its length so that at least a small amount of the peat could be handled. The composition of the peat was described after visual examination, but also by breaking up some of the removed peat in water in order to identify its components under low magnification.

Since there was more sediment available from Sheshader, larger amounts could be removed. Most of the levels contained burnt plant remains but no detailed study was made of their concentration throughout the peat, which might have been made, perhaps after taking contiguous samples.

Loss on Ignition

Samples taken from the peat from Sheshader were oven dried (at c. 70°C) for a minimum of 24 hours and then the sediment ground in a mortar pestle. The samples were returned to the oven (c. 70°C) for a minimum of 12 hours. They were removed to a desiccator and when cool the crucible and dried samples were weighed.

The samples were then combusted in an oven at c. 550°C for 9 hours. The residues were placed in a desiccator and after cooling these and the crucibles were weighed. The loss on ignition was calculated after the weights of the crucibles had been ascertained:

$$\frac{(Is + C) - (Fs + C)}{(Is + C) - C} \times 100\% ;$$

where Is = Initial weight of sample,
Fs = Final weight of sample,
C = Weight of crucible.

Pollen and Macrofossil Analyses

The routine pollen analysis was carried out at a magnification of 500 (Reichert microscope) or x 520 (Vickers Patholux). The oil immersion lenses, giving a magnification of x 1250 and x 1300 respectively, were used for more critical identifications. Whole traverses were counted and latterly these were spaced to cover the slide approximately evenly. A pollen sum (TLP) of over 500 grains was obtained at most levels; at some, counting was stopped at less than this if the trend of the pollen spectra seemed clear from the levels analysed above and below the one being counted; or if the preservation was very poor.

The key in Faegri and Iversen (1975) was followed for the initial identifications, as well as the key in Moore and Webb (1978) and Andrew's (1980) pollen file. Reference was also made to slides of modern pollen.

The diagrams below show the indeterminable grains ('indeterminable (deteriorated)') without specifying the nature of the poor preservation. During the analyses a record of this was kept for the indeterminable grains under the headings of: 'crumpled', 'broken', 'crumpled and broken', 'corroded'; in addition, further categories prefixed by 'corroded and' added to those above, gave more detail about the state of the grains. A record was made of obscured grains and of those too heavily stained, which are shown on the diagram under the heading 'indeterminable (concealed)'. States defined by Cushing (1967) as corroded, thinned or degraded were all encompassed in the term 'corroded'.

The most convenient method of estimating the relative abundances of the macrofossils was found to be by scanning a square transparent plastic dish with a grid of sixteen squares drawn on the base so that one grid square was approximately covered by the field of view at a magnification of x 6 (the maximum magnification used was x25). The abundances were estimated on the five point scale: absent, rare, occasional, frequent, abundant.

Some macrofossils (e.g. *Juncus* seeds, *Glyceria fluitans* fruits, moss fragments) were mounted in gum chloral on microscope slides so that a higher magnification could be used to examine them.

Presentation of Results

The pollen types of Faegri and Iversen's (1975) key generally describe those identified and form the headings on the pollen diagrams. Exceptions to this are the Campanulaceae type, which is subdivided into *Campanula* and *Jasione* by Faegri and Iversen, though not by Moore and Webb (1978), who have a *Campanula* type only; and *Rumex crispus*-type which is defined by Birks (1973). Cerealia-type is a Gramineae grain large enough to be considered a possible cereal pollen (see Table 2 and above pp. 17-18).

The thickness of the lines at each level is proportional to the 1 cm thickness of the slice of peat usually taken. At the 31cm level on the Torrs Warren diagram, the slice was only 0.5 cm thick, but is drawn as being 1 cm thick. The same procedure is followed for the diagrams showing the macrofossil abundances.

The diagrams have been divided into zones solely on the basis of changes in the pollen stratigraphy (cf. West 1970). Following

Aaby (1979), a simplified notation for the sediment description (Troels-Smith 1955) has been used.

Radiocarbon Dating

Radiocarbon dates were obtained from the peat from both sites. The small amount of peat from Torrs Warren representing a given time-span meant that in order to have an adequate weight of peat after pretreatment, c. 11cm of peat, which may have accumulated over 190 calendar years, had to be submitted. The larger samples of peat from Sheshader meant that a thickness of between 1 and 2.5 cm, representing perhaps up to 100 calendar years, was pretreated. The thickness of the peat submitted is shown to scale on the pollen diagrams.

The pretreatment method used by the Glasgow University Radiocarbon Dating Laboratory has been devised to minimize the amount of carbon derived from plants of a later date than the peat at the level being assayed. In the first place, the peat is examined under a low power microscope and extraneous roots or plant material picked out. A chemical pretreatment follows, in which fulvic acids and the more soluble acids are removed (Stenhouse 1981). At each stage the solution is passed through a fine mesh sieve.

In calculating a time-scale for the sequences at both sites, the radiocarbon dates have been converted to calendar dates after the method of Clark (1975); and the graduations on the scale evenly divide the number of calendar years between the calibrated mean dates, assuming a constant deposition rate. Due to the error attached to the mean calibrated date, which for the uncalibrated date is probably an underestimate (Clark 1975, 253; cf. International Study Group 1982), the deposition rate per calendar year is uncertain. Also the compression of the peat towards the base is likely to give an apparently slower rate of accumulation through this part of the profile. The radiocarbon dates have been converted to calendar dates, partly because the sequences are to a large extent within historical time (although the difference in any age as judged from the time-scale compared to the radiocarbon age is not significant for this period); and partly because a deposition rate per radiocarbon year means 'per radiocarbon year within two dates' (in any given period). Strictly, there is no constant radiocarbon year, as the attempt at calibration demonstrates.

CHAPTER 2

POLLEN STRATIGRAPHY OF A DUNE-SLACK DEPOSIT AT TORRS WARREN, LUCE BAY, WIGTOWNSHIRE, IN RELATION TO THE FORMER LAND USE OF THE DUNES.

I Background

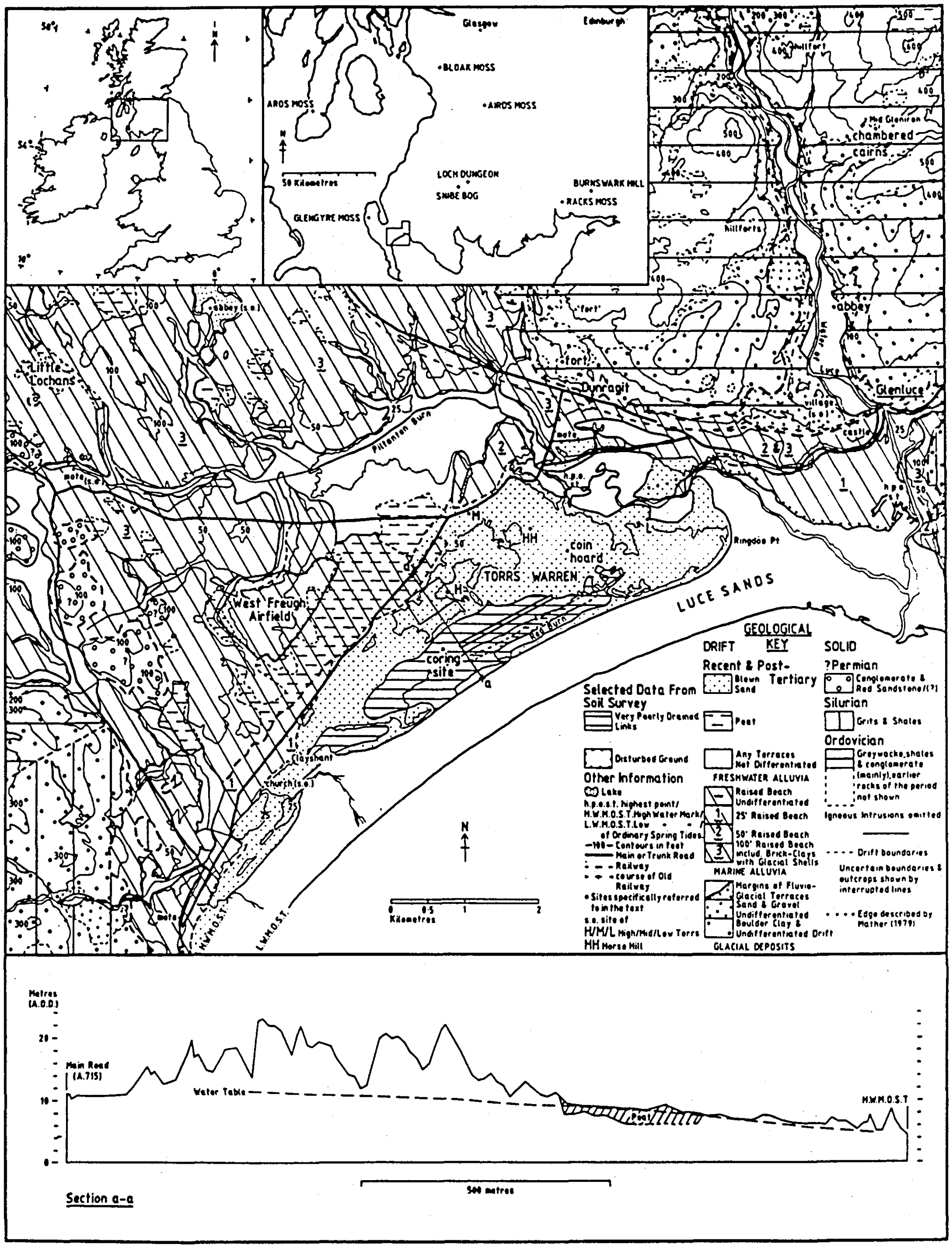
The work to be described below arose as a result of the archaeological excavations undertaken by T G Cowie. In view of the proposed damage to the semi-natural habitat in that area and more extensively within the strip of the dunes to be developed, it was decided to extract a peat core from the large slack deposit nearby for pollen analysis (Cowie, in preparation). This was carried out by D E Robinson and T G Cowie in August 1979, while levelling of the dunes by contractors was in progress (see Photo.1). The archaeological record from Torrs Warren is well-known, but the finds are largely unstratified. It was hoped that the vegetational history of the area to be inferred from the analysis would provide an environmental setting in which the archaeological evidence for the former activity of man might be better understood.

II The Site

i) Position, Stratigraphical Context, Consideration of Chronology

The position of the sampling site (NX 132541) within the dune system of Torrs Warren is shown on the accompanying map (Map 1). The stratigraphy and chronology of the Luce Bay coastal deposits are not well understood to date, but may be summarized as follows.

The transect (section a-a on the map) illustrates the topography of the older dunes, slack and foredunes. The older dunes have been built on arcuate ridges of beach gravel and this



Map 1. Simplified solid and drift geology of Torrs Warren and its environs; the coring site and archaeological sites are also shown. Insert map shows sites of previous pollen analytical investigations in SW Scotland (Little Lochans is on the larger map) and a transect illustrates the topography of the dunes of the Warren. (Sources: O.S.1:2500. 1st.Series. Sheets NX05, NX15, N X16. I.G.S.1:63,360. Scotland. Sheets 3 and 4 (solid and drift editions). Soil Survey Scotland. 1:63,360. Sheets 1,2,3,4 and part 7. Transect from DOE (1975)). The area of recent archaeological excavations is indicated by a rectangle on the transect line a-a.

process may have begun after the sea receded froms its Post-glacial maximum level, when the raised-beach gravels were probably deposited. Marine regression eventually exposed the area on which the foredunes subsequently became stabilized (see Mather 1979, 325-329). The slack may owe its position to a trough in earlier foredunes and this perhaps reflects an undulating surface of gravels beneath.

The edge of the 25' raised beach is recorded at the SW of Luce Bay, and also between Piltanton Burn and the Water of Luce to the NE of the Bay (Geological Survey, Scotland, Sheet 3, Solid and Drift edition, 1966; see Map 1).

Raised beaches at about this height are associated with the main Post-glacial marine transgression. In the eastern part of the Solway Firth, this has been approximately dated to 5630 ± 116 b.p. (Birm-220) in a recent summary and synthesis of the evidence (Jardine 1980, 52). At the head of Wigtown Bay, peat accumulation began at c. 4700 b.p., from which it was concluded that the main marine transgression ended there at c. 5000 b.p., a temporary halt to the ensuing regression occurring at 2150 b.p. (Jardine and Morrison 1976, 184; 186). This interruption in marine regression is suggested by the break in slope at between 5-6m A.O.D. in open bay sediments and shell ridges at Wigtown Bay, and by a 'low discontinuous terrace' in the eastern Solway Firth area (Jardine 1975, 186; 187; 195).

Mather (1979, 326-327) has described a 2m cliff, the top of which is at c. 4m A.O.D. cut into beach gravels between Piltanton Burn and the Water of Luce at Luce Bay. It has not been investigated whether this feature relates to the temporary halt referred to above.

The position of the 'few flints .... which appear to be of

Mesolithic type' from Luce Sands is not accurately recorded (Coles 1964, 67-68). Even if it was, however, the instability of the dunes would not allow such finds to be used to date any early activity on the dunes themselves, or as a terminus ante quem for the infilling of the bay by sand, unless they belonged to an exceptionally well stratified assemblage. The usual location of Mesolithic sites in this region is on the terrace above the '25' beach' deposits (e.g. Jardine and Morrison 1976, 188).

In conclusion, it seems likely from what is known of the coastal deposits at Luce Bay and in the Solway to the east, that the raised-beach gravels were laid down during the maximum Post-glacial marine transgression, about 5000 radiocarbon years ago. The regression from this time may have been interrupted, with a temporary halt occurring at c. 2000 years b.p., although there is no clear evidence for this in the Bay.

The greatest depth of peat found during engineers' investigations at the slack from which the cores were later taken, was approximately 3.5m. A hand auger was used to obtain this depth and the peat was thought to be overlying sand (DOE 1975).

The results of the pollen and macrofossil analyses, described below, do not indicate any plant community typical of a saline habitat. On the basis of the radiocarbon date from the basal sample, and given that peat had begun to accumulate, it may be inferred that some time before 2850 b.p. the dune system was relatively stable at the sampling site and separated from any direct influence of the sea.

ii) Climate

Torrs Warren lies in the region typified as being 'warm rather dry lowland', 'exposed with extremely mild winters'. The winds are predominantly (c. 60%) from the west, though winds from all directions are well represented in spring and frequently from the east in winter. The data from West Freugh (1960-71) show a range of mean monthly temperatures from 3.9°C (January) to 14.3°C (July) and air frost occurred on average 54 days/year from 1960-68. The coast is particularly sunny in an area where the average daily duration of bright sunshine is 3.5-4 hours. For the period 1916-1950 the mean annual rainfall recorded at West Freugh was 1015mm (Bown and Heslop 1979, 13-30).

iii) Present-Day Vegetation

The dominant vegetation of the slack deposit in the area sampled is a *Molinia*-*Myrica* (purple moor grass - bog myrtle) association, with sallows (*Salix cinerea* /*S. aurita*) growing on the seaward side where drainage is very poor, and, inland, a bracken (*Pterdium aquilinum*) invaded heath which extends into the high dunes (see Photo.1). There are drier, bracken-covered ridges within the marshy area. The interest of the vegetation cover today for the interpretation of the pollen analysis, lies in its distribution of types roughly parallel to the seaboard. Taking a transect from the road to the sea, including the position of sampling, there is firstly the variety of dunes and sandhills mainly covered by heather (*Calluna vulgaris*) and bracken, then the large slack deposit, and finally the foredunes. The coastal fringe of foredunes has been stabilised by marram (*Ammophila arenaria*) and sand couch-grass (*Elymus farctus*). Between it and the slack, heath has developed in places, and elsewhere there has been colonisation by creeping willow (*Salix repens*).

The broad distribution of vegetation types locally and the position of the coring site mean that the composition of the pollen and spore rain will have varied depending on the direction of the prevailing winds. If these were from the south of an approximate SW to NE line drawn through the coring site, catchment of the rain from plants on the foredunes would have been favoured, but when from the other half of the compass, the bias would then be toward the high dune and inland vegetation. The slack vegetation would always have made a comparatively high contribution.

The pattern of vegetation found on dunes may be largely dependent on their age, since dune formation tends to proceed towards the sea, with progressive stabilisation of the older dunes. Thus there may be a variety of vegetation types of differing maturity represented in the pollen and spore rain and the area of suitable ground available for plant colonisation may increase (cf. Salisbury 1952, 297). In addition, the local level of the water table may be most significant in determining the vegetation established.

The Torrs Warren dune system is mainly acid in reaction, though there is an area of calcareous shell-sand to the east of the bay near Ringdoo Point. Much fuller descriptions of the vegetation may be found in Idle and Martin (1975), Ratcliffe (1977,30) and a map showing the distribution of broad types is given in Mather (1979, 324; 326).

III Methods

i) Sample Collection and Sediment Description (Troels-Smith 1955)

A single complete set of cores was extracted from the deepest part of the deposit that could be found, using a Russian peat sampler. The individual cores were sealed in polythene and latterly stored at c. 4°C. The top 20cm of loose litter was not sampled.

Simply described, the sediment is a highly decomposed peat or mud, with varying amounts of macroscopic plant remains and fine sand.

Depth (cm)	
0.0- 2.0	Nig 2, strf 0, elas 0, sicc 2, colour 10YR 3/1; Sh 4, Dh * +, Ga + .
2.0- 8.0	Nig 1, strf 0, elas 0, sicc 2, colour 10YR 3/1; Sh 3, Dh +, Ga 1; lim sup 2 .
8.0- 16.0	Nig 2, strf 0, elas 0, sicc 2, colour 10YR 3/1; Sh 3, Dh +, Ga 1; lim sup 2 .
16.0- 30.0	Nig 3, strf 0, elas 1, sicc 2, colour 10R 3/1; Sh 4, Dh +, Dg +, Ga +; lim sup 1 .
30.0- 30.8	Nig 0, strf 0, elas 0, sicc 2, colour 10YR 7/4; Sh 2, Ga 2; lim sup 3 .
30.8- 34.0	Nig 3, strf 0, elas 0, sicc 2, colour 10R 3/1; Sh 4, Dl +, Dh +, Ga +; lim sup 3 .
34.0- 52.0	Nig 3/4, strf 0, elas 1, sicc 2, colour 7.5YR 2.5/0; Sh 4, Dl +, Dh +, Ga +; lim sup 2. Fragment of *Betula* (sp.) wood found between 35-37cm**.
52.0- 97.0	Nig 3, strf 0, elas 1, sicc 2, colour 10YR 3/1-3/2 (from 71 cm).
52.0- 71.0	Sh 3, Dl 1, Dh +, Ga +; lim sup 0 . *Betula* (sp.) anthers found between 52-71cm;
71.0- 81.0	Sh 4, Dl +, Dh +, Ga +; lim sup 0 .
81.0- 97.0	Sh 3, Dl 1, Dh +, Ga +; lim sup 0 .
97.0-123.0	Nig 3, strf 0, elas 0, sicc 2, colour 10YR 3/1-3/2; Tb +*** ; Sh 3, Dl +, Dh +, Ga 1; lim sup 1 . 99.3-110cm submitted for radiocarbon dating.
123.0-143.0	Nig 3, strf 0, elas 1, sicc 2, colour 10YR 3/1-3/2; Sh 3, Dl 1, Dh +, Ga + ; lim sup 0 .
143.0-150.0	Nig 3, strf 0, elas 1, sicc 2, colour 10YR 2.5/1; Sh 4, Dl +, Dh +, Ga +; lim sup 0 .
150.0-202.0	Nig 3, strf 0, elas 1, sicc 2, colour 10YR 2.5/1; Sh 3, Dl 1, Dh +, Ga +; lim sup 0 .
202.0-215.0	Nig 3, strf 0, elas 0, sicc 2, colour 10YR 2.5/1; Sh 4, Dh +, Ga +; lim sup 1 .
215.0-221.5	Nig 3, strf 0, elas 0, sicc 2, colour 10YR 2.5/1; Sh 3, Dh +, Ga 1; lim sup 2 .
221.5-230.0	Submitted for radiocarbon dating.

* In this description Dh may contain remains that should be designated Th, by strict definition, being from underground parts of a plant, or connected to the root system.

** The wood was identified by means of transverse, tangential, and radial sections.

*** This moss component (Turfa bryophytica) was only observed in the sieve washings.

ii) Radiocarbon Dates

Two radiocarbon dates were obtained:

Lab Ref No.	Depth (cm)	Years (b.p.)	Mean B.P.	Range B.P. (@ 2 s.d.)
GU-1399	99.3-110	1480 ±110	1450	1220-1690
GU-1355	221.5-230	2780 ±130	2960	2700-3370

From these, assuming the surface of the sediment to be undisturbed and assigned a date of 1980 A.D., the following deposition rates (calendar years/cm) were calculated:

	Mean Rate	Range (from errors @ 2 s.d.)
1450 B.P. - 1980 A.D.	14.2	11.9 - 16.4
2960 B.P. - 1450 B.P.	12.4	8.3 - 17.8

IV Zonation of the Pollen Diagram

Zone TW-1 (230-198.5 cm; 2800-2500 b.p./1100-700 B.C.)

The zone is characterized by an increase in *Betula* from <5% to ⩽50% (TLP, unless otherwise specified the percentages quoted hereafter have been calculated on this basis). *Quercus* remains approximately constant at >10%, rising very slightly at the top of the zone. As *Calluna* declines there is a rise then fall in the Gramineae, and similarly, *Salix*. The herbs reach a maximum value of c. 40% (TPS), with the Gramineae being the principal contributor. Comparatively high values of *Rumex* (5%), and *Pteridium* (10%) are noteworthy, as is the presence of *Anthoceros punctatus*. By the end of the zone, AP has reached a value of >70%

(TPS).

Zone TW-2 (198.5-144.25cm; 2500-1900 b.p./700-0 B.C.)

The high percentage of AP is maintained at roughly the same level throughout the zone. It is mainly of *Quercus*, though there is a slight increase in *Alnus* pollen from the previous zone. *Betula*, by contrast, almost disappears from the record after two samples, as does *Salix* and *Calluna*. The Gramineae values fluctuate a little around 10% and form most of the herb pollen count. The presence of *Potamogeton* continues at low values comparable to the previous zone, apart from the maximum (7%) at 196cm.

Zone TW-3 (144.25-125cm; 1900-1700 b.p./0-200 A.D.)

The first spectrum of the zone shows a sharp drop in *Quercus* pollen, but with more *Alnus* and Gramineae than in TW-2. Initially, these three types have roughly equal values. Of the herbs, Campanulaceae has its maximum value (9%) and *Plantago lanceolata* is at 4%. This marked change is seen in the summary diagram where for two samples total herb pollen is 46% and 28% (TPS). Subsequently,the Gramineae values are lower, then slightly higher, following the trend of the *Quercus* values. The main feature of the zone is the predominance of *Alnus* (75% max) after the first sample. Latterly, as it declines, *Quercus* and Gramineae show a small increase in their values. *Salix* is more prominent than in the previous zone, as is Coryloid pollen, though neither reach the amounts recorded in Zone TW-1. The group of greater values of Filicales spores coincides with the high *Alnus* values. *Hydrocotyle* takes its maximum value (9%) at the level of the last sample in the zone.

Zone TW-4 (125-99.5cm; 1700-1400 b.p./200-600 A.D.)

The fall in AP pollen continues as the Gramineae rise. The high values of Gramineae and low values of trees characterize the zone, in which compared to TW-3 and TW-5, there are greater values of *Calluna*, Cyperaceae, and *Sphagnum*. The tree pollen is almost uniformly low: *Betula*, *Quercus* and *Alnus* are all at c. 5%, with *Betula* increasing just before the next zone. The highest record of *Melampyrum* (5%) is at 101cm, and of *Sphagnum* (18%) at 105cm.

Zone TW-5 (99.5-44cm; 1400-600 b.p./600-1400 A.D.)

Tree pollen regains dominance at the start of the zone, but although the percentage (TPS) is higher here than in Zone TW-2, there are markedly reduced percentages at 69cm and 53.5cm, and the trend is for tree pollen to diminish during this zone. Most of the tree pollen is *Betula*. *Quercus* is always present (rising to 34% at 77cm) and so, to a lesser extent, is *Alnus*. The Gramineae values increase towards the end of the zone, with Coryloid contributing 25% at its maximum value, when *Betula* has its lowest percentage in the zone. It later recovers, as Coryloid becomes reduced. *Sphagnum* has a conspicuously high value (17%) at the last level of the zone.

Zone TW-6 (44-0cm; 600 b.p.-Present/1400-1980 A.D.)

The beginning of the zone is drawn before the rise in *Calluna*, Cyperaceae, *Plantago lanceolata*, *Potentilla*, and the decrease of all tree types. In general there are comparatively high values of *Calluna*, Gramineae, Cyperaceeae and the tree pollen values are <15% (TPS) after the first sample. The records of *Plantago lanceolata* (36%), *Lycopodium clavatum* (13%), *Lotus* (5%), are maximum values. Considering the zone as a whole, *Pteridium* is more noticeable in this than in any previous one, although remaining fairly low.

V Inferred Vegetational History and Discussion

i) Previous Work

a) SW Scotland

The sequence from Torrs Warren spans nearly the last 3000 radiocarbon years. It has not been possible to correlate this directly with the activity represented by the finds of the recent excavations (which include Late Neolithic assemblages of pottery and associated flints (Cowie, in preparation). However, by briefly reviewing some of the published work from SW Scotland (omitting the work from NE Ireland and NW England), it will be possible to combine earlier conclusions with the results presented here and in this way provide some insight into the environmental conditions that may have prevailed on the dunes during the period 5000-3000 years b.p. It was probably from about 5000 radiocarbon years ago that the supply of sand for dune formation became available, following marine regression (see Section II i above). The Elm Decline, documented in many pollen diagrams in the British Isles, also occurred at approximately this time.

Unfortunately, the nearest sites have been investigated with the aim of understanding the vegetation of Late-glacial times. Little Lochans is about 11km away (see Map 1, where an inset map shows most of the sites referred to in this section). It produced a sequence starting in the Late Devensian continuing to the local zone, equivalent to the Atlantic period (zone VIIa, of Godwin 1975). The Elm Decline (Atlantic/Sub-boreal, VIIa/b boundary of Godwin) was not thought to be represented, although as AP pollen decreases, the values of Gramineae, Ericaceae, *Calluna* and *Plantago* show increases towards the top of the sequence, which might have been due to the beginning of limited clearance. The nearby site of Culhorn Mains also has a record beginning in the Late-glacial, the short Flandrian (Post-glacial) sequence may well belong to the later of the two zones of the Boreal period (Godwin's zones V and VI), the earliest Flandrian being absent or recorded in highly compressed sediment, since it was not detected over the interval sampled (Moar 1969a).

Indirectly, the most relevant radiocarbon dated pollen diagram is that published by Turner (1965, also 1970, 1975) for Bloak Moss (250ft, 76m), Ayrshire. The earliest levels are before the Elm Decline, but the interest lies in the evidence for later, Bronze Age, clearances between c. 1400-c. 1000 b.c. These were the first to be noted in the diagram and were estimated to have lasted c. 50 years, during which time, clearance, occupation, and regeneration of the forest took place, corresponding to the stages in the 'landnam' of Iversen (1949). The site is c. 150km from Torrs Warren and while direct cultural correlation with such local changes in the vegetation would not be possible without good archaeological evidence, it shows the manner in which the vegetation was being altered. Since such changes have been noted in subsequent work in this region of Scotland and compared to those at Bloak Moss (see below), it may have been that at Torrs Warren and its environs local clearances were being made. The archaeological evidence indicates human activity in the area in the late 2nd millennium b.c. (Cowie, in preparation). Overlapping in time with the Torrs Warren sequence, 'extensive clearance' was inferred from the values of Gramineae c. 100% AP between 415±90 and 580±90 a.d. (1535-1370 b.p.); this succeeded an apparent regeneration of trees which began at c. 425 b.c. (2375 b.p.), and will be referred to in Section Vii.

Two sites have been investigated by Nichols (1967) at Aros Moss (34ft, 11m A.O.D.), Kintyre and Racks Moss (49ft, 14m A.O.D.), near Dumfries, both between 130-150km from Luce Sands. At Aros Moss there is evidence for an early opening of the tree canopy, partly shown by the birch pollen curve, which may have been caused by Mesolithic man (between c. 8000 and 7500 b.p.). Both sites have evidence for more open ground after the Elm Decline. The Decline often occurs with changes in other values of the spectra, which point to some degree of human interference.

The two diagrams were seen to have many parallel changes in their pollen assemblages from the time of the Elm Decline and the principal divisions into the zones followed below, are usually common to both sites, although they only reflect changes within the catchment area of the individual sites.

After the disturbance of elm growth at first, regeneration took place, to be followed by at least two further decreases associated with increases in Plantago lanceolata, Gramineae, and Pteridium, suggesting pastoral activity (Zone A). These phases of pastoral activity were not succeeded by similar clearance, apart from a brief one in the middle of the zone(B); rather this was a time of re-afforestation.

It is the start of the next zone (C) that clearance was resumed at Aros Moss. In the absence of radiocarbon dates, the chronological framework was given with reference to the known presence of Bronze Age farmers in S Kintyre during most of the period 2000-1000 B.C. (after Piggot 1962, although this span has not been radically revised since), and the clearances at Bloak Moss, from c. 1400-1000 b.c., mentioned above. At Racks Moss, the pollen record and archaeological evidence argue against clearance and settlement at the beginning of the zone (C1).

The end of a subsequent phase of more forest clearance (subzone C2), allowing mainly pastoral farming, but also agriculture, is marked by a change in the degree of peat humification at both sites. This is correlated with the Grenzhorizont (RY III) and thought to reflect the onset of wetter climatic conditions. Similar changes in peat growth have been dated at many sites, indicating a deterioration in the climate that may be dated within the period 900-500 b.c. However, a return to drier conditions has been suggested for the slower rate of peat formation calculated at Bloak Moss between c. 425 b.c. and 415 a.d. (see Turner 1981, 251-261;261).

Forest regeneration followed the Grenzhorizont (during subzone C3), but hereafter it was not possible to tie any of the zones into the context of the 'imperfectly-known archaeology of Scottish settlement in Roman and Dark Age times' (p. 182). It looks as if at least 'extensive clearance' by Turner's (1965) definition, was carried out during periods from this time at both sites.

At Burnswark Hill (600ft, 183m) c. 17km from Racks Moss, deforestation may have begun at 2400 b.c. This continued until an apparent regeneration, as herb pollen declines, which was assumed to have taken some centuries beginning at c. 460 a.d. It reaches a climax represented by a tree pollen count of c. 50% TPS (less obligate aquatics). Charcoal was found in the sediment very close to both points at which trees decrease. The charcoal was probably blown onto the bog surface, whereas the mineral stripes described were more likely the result of inwashing from the steep slopes surrounding the basin and were found in greater number during the period of deforestation. The chronology is based on calculating the rate of peat formation between two radiocarbon dates, which though c. 3860 radiocarbon years apart are separated by only c. 16cm of a sediment of very variable composition (Squires 1977-8).

Another upland site to have been investigated is Airds Moss, Ayrshire (750ft, 230m), a much larger bog than the small basin bog at Burnswark Hill. The diagram has no clear signs of human interference in terms of its grass curve, until recent times. There is an overall gradual reduction in tree pollen from the start of the Sub-atlantic (Zone VIII of Godwin 1975), as heath pollen shows a general trend to increased values (Durno 1956).

Birks (1972a) acknowledges the difficulty of comparing the regional vegetational changes as inferred from the pollen and macrofossil analyses of a raised bog (Snibe Bog 825ft, 251m) and a lake sediment (Loch Dungeon 1000ft, 305m) in the Galloway Hills. However, such division of the pollen diagram into 'zonules' (within the regional zone <u>Alnus</u>-<u>Quercus</u>-<u>Plantago</u>-<u>lanceolata</u> as defined from both these sites) has been possible from c. 5000 b.p. at Snibe Bog and some attempt made to relate these to cultural phases, although there are no radiocarbon dates. Individual clearances could not be distinguished following the Elm Decline and the combination of several small temporary clearances was offered as an explanation for the pollen spectra observed for this period. The subsequent drop in tree pollen, with increases in that of weeds and of bracken spores argue for further deforestation. As at sites previously discussed this is thought to have been due to Bronze Age activity. Occupation seems to have continued until later 'extensive clearance' tentatively correlated with that at Bloak Moss (i.e. in the period c. 415±90 to 980±90 a.d.) and evidence for increased erosion at Loch Dungeon lends support to this.

There is evidence of early fire (charcoal at c. 7000 b.p. at Cooran Lane (900ft, 274m), in the Galloway Hills, one of three sites analysed as part of the investigation of pine stumps in Scottish blanket peats (Birks 1975). The burning was not necessarily started by Mesolithic man, but there are archaeological finds of this period in the area (Edwards *et al.*, in press). At each of the sites the same regional pollen assemblage zone after c. 5000 b.p. was distinguished as that at the two other sites in the same vicinity (see above).

The mire between Torrs Warren and West Freugh Airfield, now largely ploughed over, was examined by Hulme (in Bown and Heslop 1979). The peat stratigraphy and macrofossil content were recorded, but there was no pollen analysis carried out. The diagram from the nearest site analysed in the same survey, at Glengyre Moss (250ft, 76m), is not sufficiently detailed for close comparison with the smaller divisions made at some of the sites already discussed. Nevertheless, it does show the general trend of reduced trees and increasing heaths during the Sub-atlantic, seen at Airds Moss for the same period.

The West Freugh mire began accumulating on clay and is now at a maximum depth of approximately 2.5m from the undisturbed surface, which is similar to the maximum depths so far recorded in the main peat deposit of the Warren (DOE 1975). The bottom of the mire basin at West Freugh is at a level of 8m (26ft) A.O.D. A general sequence has been deduced from seven sites on the mire and is given as follows.

The pioneer vegetation seems to have been a birch-rush carr, on the basis of the wood and seeds found. The peat is highly decomposed and amorphous (2.8-2.0m). Remains of *Molinia caerulea* and sedge then become dominant, associated with a large number of taxa including *Potentilla erecta* and *Juncus* seeds, ericaceous twigs and frequent *Sphagnum* sect. Acutifolia leaves (2.0-1.6m). Subsequently, abundant *Sphagna* spp. remains were recorded, with those of *Phragmites australis* (reed) occurring between 1.5-1.2m, up to the present-day surface, which is dominated by *Calluna*, *Erica tetralix* (cross-leaved heath), *Eriophorum vaginatum* (common cotton-grass, hare's tail), *Myrica gale* and locally *Molinia*. Where the latter two species grow together in abundance, the surface vegetation is comparable to that of the Torrs Warren sampling site.

b) At Torrs Warren

A pollen count has been made from each of three soil layers within the dunes at Torrs Warren. One, was made by Durno (in preparation), from a humus layer in a profile described by Bown. The profile was taken independently of the recent excavations, but close by. By analogy with the archaeological stratification, the humus layer is at least post-Late Neolithic in date and represents a heath vegetation (the Ericoid pollen is approximately 75% TLP).

Two pollen counts were obtained from humus separated by blown sand in connection with the excavation of a hoard of 15th-century coins and other remains (Dimbleby, in Jope and Jope 1959, 278-9). The lower layer yielded a result of *Calluna* 33% , with Gramineae c. 44% (TLP); the upper, *Calluna* c. 45% and Gramineae c. 28% (TLP). It was inferred from the context of the coin hoard that the upper heath vegetation had formed prior to c. 1495 A.D.; and that the building remains and other associated finds dated from the later-13th or earlier-14th century. The structure may have continued to be used into the earlier part of the 15th century (*Ibid*., 262). It was thought that the weak iron-pan formation within the sand separating the humus layers and the lowest humus layer could have taken [illegible] years or less, given the moist climate and permeable sand. The strongest iron pan was found at the base of the lowest humus layer.

In both reports the comment is made that the soil profiles were developed on terrain that was of a different topography than that seen in many parts of the dunes today. Exposures suggesting an undulating surface for the earlier profiles, were noted; and the humus layers which developed before the beginning of the 16th century were seen to extend horizontally several hundred feet from the site to the north, east and west.

Finally, there is a record of 'peat, brown, fibrous and tree roots', for a depth of 0-1.8m, within the slack area, about 320m NE of the sample site (DOE 1975).

ii) Inferred History of Vegetation

The chief difficulty in making any inference about the past vegetation lies in deciding on the position of the sources of the pollen rain. Some consideration has already been given to this in Section II iii). The regional catchment from the SE is probably small because of the coastal situation of the dunes. If, as seems likely, trees were growing near the site, the regional component from the NW would be reduced in the record, partly by filtering, assuming that they would have spread from inland. If the trees were actually growing on the slack then the representation of local plants would be even higher. In the account below it is assumed that most of the pollen has come from the vegetation of the dune system (i.e. it is the local and extralocal components of the pollen rain (sensu Janssen 1966) that are mostly represented).

Zone TW-1 (230-198.5cm; 2800-2500 b.p./1100-700 B.C.)

It was not possible to sample the very bottom of the peat deposit, although it is unlikely that more than 10cm is missing. For there to have been stability for such peat infilling, the water table must have been relatively high and thus allowed colonisation by plants characteristic of such habitats. Here *Salix repens* may have helped to stabilise the area of peaty sand, at first. *Salix* pollen is likely to be under-represented (cf. Bradshaw 1981 and its value from the surface sample from Site 2, see Appendix 1), so that perhaps willow trees and bushes were growing at the site in addition to the creeping willow. In any case, the dunes may not have been entirely without trees at the start of the sequence, since there may have been oaks present. The open nature of the vegetation at the beginning of the peat formation is not only suggested by low tree pollen values, but also by the comparatively high values for heather at the start of the zone (cf. the surface sample results from Site 3, Fig. 7), and the amounts of grass and ribwort (*Plantago lanceolata*) pollen, together with the peak of *Pteridium* spores. Of the Campanulaceae, *Campanula rotundifolia* (harebell) or *Jasione montana* (sheep's-bit) are characteristic of drier, open ground and would perhaps have been growing on a higher ridge of sand and gravel.[1]

Potentilla (*P. erecta*, tormentil; or *P. palustris*, marsh cinquefoil), *Lythrum* (*L. salicaria*, purple loosestrife), *Filipendula* (*F. ulmaria*, meadowsweet), *Hydrocotyle* (*H. vulgaris*, marsh pennywort) and *Potamogeton* (pondweed) pollen; a fruit of *Lycopus europaeus* (gipsywort); and *Juncus* sp. (rush) seeds represent plants typically of a damp habitat, most likely to have

[1] The most or only likely species represented are given in this section.

been growing on the surface of the incipient bog. Shallow pools of water may be indicated by the generally small values of pondweed pollen.

By the end of the zone, the high percentage of birch pollen suggests that birch trees had reached the slack area and were probably growing on the shallow peat, where they would compete with any willow trees or bushes. The high representation of birch pollen may be in part due to better dispersal, and production, when the trees became more numerous, but it would appear that they grew so as to shade out the willows of whatever form. Their proximity to, or presence on, the site is also indicated by the wood, budscales, *Betula* sp. fruits, and dicot. leaf fragments recorded latterly in the zone.

It may have been that as today in most areas, the fringe of the dunes towards the sea was always treeless and a suitable habitat for *Plantago lanceolata* and *Anthoceros punctatus* (hornwort). In this zone, however, the records for the liverwort occur when *Plantago lanceolata* takes higher values, before the temporary dominance of birch. From the three lowest samples the *Juncus* seeds that were identified are referable to *J. effusus* (soft rush) or *J. conglomeratus* (conglomerate rush). No seeds of rushes characteristic to a specifically maritime habitat were observed.

The peat at West Freugh, as recorded in a single transect, has a maximum depth comparable to that of the Torrs Warren slack deposit. In contrast, it is predominately a *Sphagnum* (bog moss) peat, perhaps a consequence of the peat forming in a depression whose base may be mainly of clay (see Section V ia). Drainage may then have been difficult or slow, depending on the number and nature of the outlets. Nevertheless, its change from a birch-rush carr to an often acid peat vegetation may have been related to a regional rise in the water table at the start of the Sub-atlantic period (see discussion of the Grenzhorizont in Section V ia above), which, by the same argument, was a contributory factor in the establishment of the slack vegetation.

Zone TW-2 (198.5-144.25cm; 2500-1900 b.p./700-0 B.C.)

For the next c. 700 years, oak became the dominant tree succeeding birch, the pollen values of which fall to <5% for the whole of this and the following zone. The macrofossil assemblage recorded and the results of the surface sample analysis at Site 1 (see Fig. 7) provide good evidence that the trees were growing on, or at least very close to, the coring site. Grass pollen is low, having fallen as the tree cover became more complete at the end of the previous zone. It is interesting to note how a high percentage of tree pollen is accompanied by a lower number of taxa in the pollen sum, a feature that may be seen at each occurrence of tree dominance in the pollen record. This might suggest partial exclusion of the regional pollen component; or this factor combined with a reduction in the number of species able to live in the more shaded local habitat. However, it could simply be a statistical effect, resulting from the much greater amounts of tree pollen arriving at the site.

Alder trees were probably growing with the oaks in places, or perhaps with willows in wetter situations nearby. The presence of *Potamogeton* pollen is maintained from the previous zone, indicating poorly drained areas near the site, a conclusion supported by the records of *Glyceria fluitans* (flote-grass) fruits.

The absolute counts (see Table 4, Appendix 2) show the increased tree pollen production as the oaks became dominant. The pollen records may be mainly representing a persistent local oak scrub (which can produce very high oak pollen counts, see results from Site 1, Fig. 7), but if not, it is reasonable to suppose that larger areas may have been covered with oak woodland. During this time, considerable soil development and fixing of dune sand could have taken place. The foredunes seaward of the slack may have remained an open landscape.

There is no obvious indication of renewed interference of the vegetation during approximately the first 1000 years of the sequence, which perhaps reflects the fact of there being few archaeological finds from Luce Bay during this period. That the heath represented at the beginning of the zone TW-1 may have been a result of earlier clearance and subsequent grazing is discussed in the Conclusion (Section VI).

Zone TW-3 (144.25-125cm; 1900-1700 b.p./0-200 A.D.)

The greater values of alder pollen and the decline of those of oak suggest a replacement of values, the one by the other. The absolute counts show this to be the case. An absolute increase in Gramineae, *Plantago lanceolata* and Campanulaceae pollen accompanies the replacement. These last indicate areas of drier, unshaded ground; the former, at least a more open canopy. There was thus still a component of the pollen rain coming from plants preferring a drier soil, such as may have covered any ridges of sand and gravel as was suggested in discussing Zone TW-1 above, or from areas of open dunes. Using the calculated sediment deposition rate, a time of about 30 years separates the highest oak value and the beginning of the rise in alder.

There is no good evidence for a gradually rising water table during the previous zone (TW-2), although it has been seen that there may have been pools of water in places. The instability of a dune system, however, particularly perhaps towards the sea, allows the possibility of sudden flooding due to a change in a local water course. This could have been sufficient to kill off a number of oaks and temporarily open the tree canopy, which may then have permitted a larger alder pollen rain from an established stand nearby, formerly screened by oaks.

Alternatively, a rapid spread of alder because of the wetter ground, thereby screening the oaks, if they continued to flourish, would cause its contribution to the pollen rain to be increased. The orientation of a small stream or flush through the slack might be expected to have run parallel to the axis of the slack (cf. the course of Red Burn, Map 1). This may have carried alder seed from a more distant locality and deposited it on soil now suitable for successful germination and seedling growth (see Appendix 3). The outer trees of any oak stands may then have died and their new limits bordered by alder trees. In any event, it would seem that the water table was now higher and the increase of willow and probably bog myrtle pollen favours this interpretation.

If the oaks were cleared by man, it was not a complete clearance and there is no evidence for burning, nor of occupation that can be definitely dated to this time.

Zone TW-4 (125-99.5cm; 1700-1400 b.p./200-600 A.D.)

The inference from the values of *Sphagnum* spores and *Hydrocotyle* pollen, together with the macrofossil assemblage, is that there was perhaps increased surface water on the slack compared to the previous zone; also that the water may have been poor in nutrients, more acid in reaction, possibly stagnant and thus anaerobic. The increased sedge pollen values are probably related to a wetter regime on the slack. This change would appear to have begun by the time of the last level in the preceding zone, when movement of sand within the dune system may have caused any flow of water through the slack to become impeded in some way.

The decline in tree pollen is not recorded in detail on the diagram, but during this zone neither the pollen , nor the macrofossil evidence point to there having been sizeable stands of any tree species by the slack. Lacking a flow of water and adequate supply of nutrients it is unlikely that alder would have continued to grow on the slack or at its edge. With the effects of filtering, or over-representation due to nearby trees, removed, the pollen component from the dunes was almost certainly higher during this zone.

Heather prefers a drier soil than could have developed on the slack, unless there were raised areas, proud of the surface water. The heather pollen values may then represent its presence on the dunes, which seem to have been subject to some erosion, given the increased quantity of sand in the slack sediment. A proportion of the grass pollen was probably coming from the dunes too, and not all from Molinia, for instance, on the slack. These percentages for grass and heather may mean that there was grazing on the dunes preventing the establishment of birch.

Both the oak and alder pollen percentages are reduced from TW-3 to TW-4, so it is possible that trees were cleared during the time between these zones. During the period (TW-4) when it is suggested that a part of the Warren could have been in use as pasture land, the only evidence of fire is the very small fragments of burnt plant remains at one level, which were probably blown onto the slack.

Roman finds from approximately 200m west of Horse Hill (see map 4) point to a date of perhaps the late 2nd to 3rd centuries A.D. for the cremation associated with them, and for this a quantity of wood was required. Mrs C.A. Dickson identified charcoal of alder, birch, oak, willow and elm from the site. There are few other Roman artefacts from the area (Breeze and Ritchie 1980).

Additional indications of activity on the dunes during the zone are the rim sherd of 'E' ware from near Mid Torrs (Thomas 1981, 22) and two bronze ring brooches. The first of the brooches was found some 800m to the north of the coring site, the second approximately 200m NW of this (Rynne 1965, 1968). The class of pottery has been given a date range of 525/50 A.D. to c. 700 A.D. or slightly later (Laing 1975, 273). The brooches are thought to belong to the periods of the 5th to 8th, and 5th to 7th centuries respectively; the author preferring the earlier half of the longer span for the first of the brooches to have been discovered.

The picture that emerges after considering the archaeology of the Rhinns is a complicated one, involving several lines of enquiry. Gaelic settlement may be implied in certain place-names, and the name 'Dunragit' has invited speculation as to whether its fort was of importance in the native kingdom of Rheged. There are early Christian monuments in this area of Galloway (see Thomas 1971, 1968; also Rynne 1965, 111-113).

The 'extensive clearances' seen in the regional pollen diagrams are believed to date to a time which partly coincides with the period of Zone TW-4.

Zone TW-5 (99.5-44cm; 1400-600 b.p./600-1400 A.D.)

At the start of TW-5, as during the first zone of the sequence, there is invasion by birch of dwarf-shrub and herbaceous communities. The time-scale for sediment deposition indicates that it took less than 50 years for this transition, which had taken a much longer time in TW-1. This may be attributable to filtering by willow trees or bushes, if any there were, or a damper soil, in the earlier case. The first three levels of this zone have the highest records of tree pollen of any zone and the number of taxa (TLP) at these levels is correspondingly low. From the small amount of sand in the sediment, wood and dicot. leaf fragments, budscales, and especially birch fruits and catkin scales, it is clear that the site was covered by a canopy of birch trees.

These shaded out heather and grasses whether growing on the peat or the sand dunes. The slack may have been drier now, and birches able to spread onto parts of it. There was no competition from alder in occupying open areas. The record of oak is more pronounced than that of alder and it may have grown more extensively than is at first apparent, being under-represented on account of the very local cover of birches. Certainly at 77cm it has a value that suggests that it could have provided competition. The now relatively deep and acidic peat of the slack would have favoured birch locally and if the soil had been impoverished during the time of possible grazing in Zone TW-4, birch would have tended to grow better than oak elsewhere. At the present day, the oak scrub at High Torrs is growing much less strongly than the birch that is spreading in other places (see Photos. 2 and 3).

For something like 500 years birch was dominant close to the site, nevertheless at 69cm there is a hint of some disturbance to the tree cover, where it looks as if succession to oak may have been deflected, and a much clearer sign at 52 and 53.5cm. At the second occurrence, more open ground allowed expansion of grasses and bog myrtle. A significant reduction in birch pollen takes place, perhaps partly due to the proportional representation of the diagram. Further absolute counts would aid the interpretation here, although it is unlikely that bog myrtle, grasses, dock and also bracken would show increases simultaneously, unless areas nearby had become less shaded. A higher water table might have favoured bog myrtle over birch on the slack. Most of the grains of Coryloid type at 52cm were identified as being probably those of bog myrtle on the criterion of pore morphology (see Moore and Webb 1978, 53).

It is interesting to note that the beginning of higher grass values from between 66cm and 52cm belongs to a period between c. 1050-1250 A.D., using the estimated time-scale, since the Warren is believed to have become part of the Glenluce Abbey holdings, being founded in 1129 A.D. (Idle and Martin 1975, 10) and settled in 1190 A.D. (Rusk 1930, 69-70). Part of the dunes may have been used for grazing then, though there is still a fairly high represenation of birch, and some oak. The building, found whilst excavating the coin hoard, may have been in use throughout the period 1200-1400 A.D. and was interpreted as possibly a hunting lodge built on a surface that was originally supporting a grassy heath (Jope and Jope 1959, and see above,Section V ib).

Zone TW-6 (44-0cm; 600 b.p.-Present / 1400-1980 A.D.)

It has been supposed throughout the discussion of the above zones that the land surface of the dunes may well have been relatively regular, if undulating, and during times of an apparently stable vegetation cover, appreciable soil development took place. This is based on field observations of some, not all, fossil soils having approximately horizontal strike or dip (see Photo. 4). They may have a large depth of overburden on top of them and as far as can be seen, formed on several metres of sand. Similar observations have been made by others, as mentioned above (Section V ib), and there is sometimes more than one fossil soil in a section (cf. Smith (1908, 37-38), who recorded four). The coin hoard of c. 1495 (referred to above, Section V ib) was found cut into an approximately horizontal humus layer, and the depth of the sand overlying the hoard must post-date it. The excavators' proposition that the high dune area had been built up relatively recently is accepted here. If the stripe of sand recorded in the core at 30.0-30.8cm is a result of a catastrophic sand blow (or a series of such) on the Warren, then this occurred, as could be expected, when the landscape was essentially treeless.

There is no obvious reason why birch trees, at least, should not have continued to grow with oaks from the end of Zone TW-5, unless the dunes were being grazed. Following clearance perhaps, grass and heath covered the dunes and the overall landscape was probably like that of TW-4, only it appears that heather was now more important. The diagram indicates an association of *Potentilla* (presumably *P. erecta*) with the heather. Different intensities of grazing are possibly shown in the absolute concentrations of herb and dwarf-shrub pollen grains during Zones TW-4 to TW-6 (see Table 4, Appendix 2), or its absence during the former. If the pollen record is mainly showing local changes, heavy grazing or burning would result in much reduced flowering of grass and heather. Their concentrations shortly before 30.0-30.8cm are very low.

There is evidence of burning recorded in the macrofossil diagram in this zone (TW-6) and if frequent it would prevent mature *Calluna* bushes being established. This would encourage the spread of *Potentilla* because of the reduced dwarf-shrub canopy, and at 16cm, a correspondingly low value of *Potentilla* (<1%) is associated with a high one for *Calluna*. This coincides with the maximum percentage of *Lycopodium clavatum* (stag's horn clubmoss), a plant of heathy habitat. These assemblages may imply a resistance to fire by tormentil and would support the idea of a succession with no human interference in Zone TW-1, where *Potentilla* is also <1%. The peak of *Plantago lanceolata* must be partly due to local over-representation, but it still indicates open ground, probably maintained by grazing. This could also explain the smaller peak of *Lotus* (probably therefore *L. corniculatus*, birdsfoot trefoil; or *L. uliginosus*, large birdsfoot trefoil) recorded at the same level.

Idle and Martin (1975, 5-6) cite two documentary sources of 1560 and 1572, which both include references to the two farms "Hiddir" (High) and "Over" (Low) Torrs, and they therefore infer that the high dunes were built after the second date. There was clearly some form of land management prior to 1560 A.D. The thin sandy layer in the sediment occurs at a date close to the middle of the 16th century on the estimated time-scale: it is probable that over-grazing and wind storms combined to cause sand blows of sufficient severity and frequency to form the irregular dunes that are the most conspicuous feature of the landscape now. That blow-outs and widespread dispersion of sand happened earlier is shown by the obervations of sand separating layers of soil development. An example on a small scale is the sand between the humus layers described in Jope and Jope (1959, 261).

Of the recently catalogued "Mediaeval" objects from Luce Sands, generally belonging to the 13th to the 16th centuries, there are many whose precise location is unknown. The nearest location to the coring site is Knockdoon, some 660m north of High Torrs Farm, a find of pottery fragments. Slightly further away are the locations at "Mid Torrs", and Horse Hill or thereabouts (Williams

1976-7).

A brief account of the land-use history from the 16th to the 19th century by Idle and Martin (1975, 6-7) includes a reference to a violent sandstorm in 1756, and the complaint that good pasture was lost because of sand deposition. The earliest mention of a rabbit warren given is that in the Statistical Account of 1791. Rabbits would likely have been a significant influence in grazing grassland and heath. The same Account tells of land being drained, manured and enclosed.

The vegetation in Zone TW-6 was probably very similar to that at present, with erosion and blow-outs continually changing the topography. There is slightly more grass and less heather pollen in the last two levels than earlier in the zone, but this may only be a variation in the vegetation near the coring site. Most of the sedge pollen was perhaps from common cotton-grass (*Eriophorum angustifolium*) which fruits prolifically in parts of the dunes, where there is a wet peaty soil, rather than *Carex arenaria* (sand sedge).

VI Conclusion

The depth of peat that was cored for the pollen analysis is the most that could be found in the area of the slack, which has now almost certainly been so disturbed that any similar investigation in the future will be impossible. The analysis offered the only hope of providing an environmental background to the activity represented by the finds of the recent excavations, from a site near to them. Of equal importance perhaps, this would inevitably provide some insight into the vegetational history of Torrs Warren for as long a period as possible. The results make the first contribution towards understanding how the dunes may have been vegetated from later prehistoric times to the present, in a continuous sequence. This understanding is also thought to bear some extension to the earlier prehistory of the dunes.

The pollen analyis has shown that the vegetational change at Torrs Warren has been marked. The difficulty of assessing how widespread these changes might have been on the the dunes has already been referred to. However, at least locally, fluctuations from heath to woodland, a reversion to some heath perhaps, then woodland to heath can be inferred from the pollen assemblages. The possible activity of man in effecting these changes has also been considered in the discussion of each zone; although this was deferred until now, in the case of Zone TW-1.

There are no indications that the sea was close to the slack at the beginning of the sequence and since stands of trees could develop later, there may have been some form of woods before the period of TW-1. The initial presence of heath may therefore have been due to earlier clearance, and when the area was abandoned or the pressure of grazing relieved, it was eventually colonised by birches. The suggestion that there were trees on the dunes before the beginning of the sequence is supported by the conclusion of Romans and Robertson (in preparation), that a stable soil could have supported oak trees and perhaps other species, the charcoal of which was not identified. By analogy with the stratigraphy of the nearby excavations, this tree cover would have been present before Late Neolithic times (i.e. before c. 2000 b.c.). The pollen analysis of the humus layer of the podsolised soil, that was probably the result of clearance, shows that it supported a heath vegetation (Durno, in preparation; see Section V ib above). It would appear that the sea had regressed beyond the site sufficiently far for the trees to grow, some time before c. 2000 b.c. This is confirmed by the location of the sites, at a similar distance from the sea, which produced pottery belonging to the 3rd to 2nd millennia B.C. (McInnes 1963-4).

Having reviewed some of the conclusions reached from the regional diagrams, it can be said that there is good evidence for human disturbance of the forest in existence at 5000 b.p., but that clearance on a large scale was probably not widespread until within the last 2000 years. It may have been that at Torrs Warren clearances were made between c. 5000 b.p. and c. 3000 b.p. and it has been demonstrated by this work that parts of the dunes could have been wooded and that trees were able to regenerate after periods of open landscape. The composition of such woods or scrub could have been dominated by birch, oak, or locally, alder. Hazel or elm would not be expected to grow on an acidic sand-dune system. The alluvial lowlands between Luce Bay and Loch Ryan now have mainly 'brown forest soils', reclaimed from podsolised soils. These, in turn, were probably derived from better, ancient soils which developed under comparatively undisturbed forests, but with clearance, they became more prone to leaching. The wetter climatic conditions thought to have prevailed from around 2500 b.p., discussed previously, would have contributed to soil impoverishment. The increase in Ericoid pollen at Glengyre Moss and other sites is seen as evidence of this (Bown and Heslop 1979, 53). The natural forest at about 5000 b.p. in the area of Glengyre Moss (250ft, 76m) was of alder, birch, oak and elm, with hazel being important, but little, if any, pine (Durno 1979, 190-194). The Atlantic (zone VIIa) forest at Little Lochans was probably composed similarly (Moar 1969a; cf. Birks 1977, 125-126).

The use to which the cleared ground was put is largely a matter for speculation, without adequate evidence for the prehistoric economy, though some stability of society may be indicated by the chambered cairns at Mid-Gleniron, perhaps an upland relict of a larger distribution (Corcoran 1969, and see Map 1).

The grain impressions in pottery and carbonised cereal fragments and weeds, found at Luce Bay (Jessen and Helbaek 1944) do not necessarily imply that cereals were grown on the dunes themselves, and the infertility and instability of the dunes would suggest that if they were, it would not have been for any length of time (cf. Romans and Robertson, in preparation). The problems associated with identifying one or two pollen grains as being those of cereal grasses has been outlined above (p. 18; also see Appendix 4 i).

In whatever way the dunes at Torrs Warren were to be utilised, it is likely that if the Bay was first approached from the sea or along the shore by Mesolithic man, a wooded coastline was before him. Later arrivals may also have been partly attracted by trees on the dunes, which were formed as a supply of sand became available with marine regression. The combination of potential fishing, land for grazing, initially trees for providing a means of shelter or source of fuel, and perhaps fresh water flowing along a course not traceable today, or from a well, may acount for the abundance of archaeological finds for certain periods in the prehistory of Torrs Warren.

The landscape as seen today is no doubt partly due to the overall climatic conditions characteristic of the Little Ice Age, whose main phase dates to c. 1550-1700 A.D. (Lamb 1977, 449-473). By way of comparison, in 1413 A.D., according to local legend (Gimingham 1964, 106-112) and documentary evidence suggests by 1600 A.D. (Walton 1966, 42), a large movement of sand overwhelmed a village on the Forvie Sands on the north east coast of Scotland. However, Torrs Warren was perhaps more inviting to earlier peoples; the possibility of there having been a relatively stable dune system, that may have been to some extent wooded, offers an explanation for this.

CHAPTER 3

POLLEN STRATIGRAPHY OF A BLANKET PEAT AT SHESHADER, ISLE OF LEWIS, IN RELATION TO THE CONSTRUCTION OF A PREHISTORIC FIELD WALL BURIED IN THE PEAT.

I Background

A survey of archaeological sites principally on the coast of Harris and Lewis was conducted under the direction of T G Cowie in the summer of 1978. During the course of this, the occurrence of a collapsed stone wall buried under peat was reported to him. Since the peat was being cut at the point where the wall disappeared into the face, to a depth that threatened to disturb the stones, it was decided to take a peat column from the face close to the wall for future study by pollen analysis. The exact stratigraphical position of the wall was unknown at that stage. The peat cutting is continuing at the bank and a further section of the wall has been uncovered.

There were two main problems to be tackled in the subsequent study: to try to date the period of construction and use of the wall; and to infer the pattern of local vegetation during that time, as well as before and after it. To do this it was necessary to carry out a limited amount of excavation to ascertain the stratigraphical position of the wall, which also gave an opportunity to take further small samples of peat directly beneath the wall and of the peat that had completely covered it.

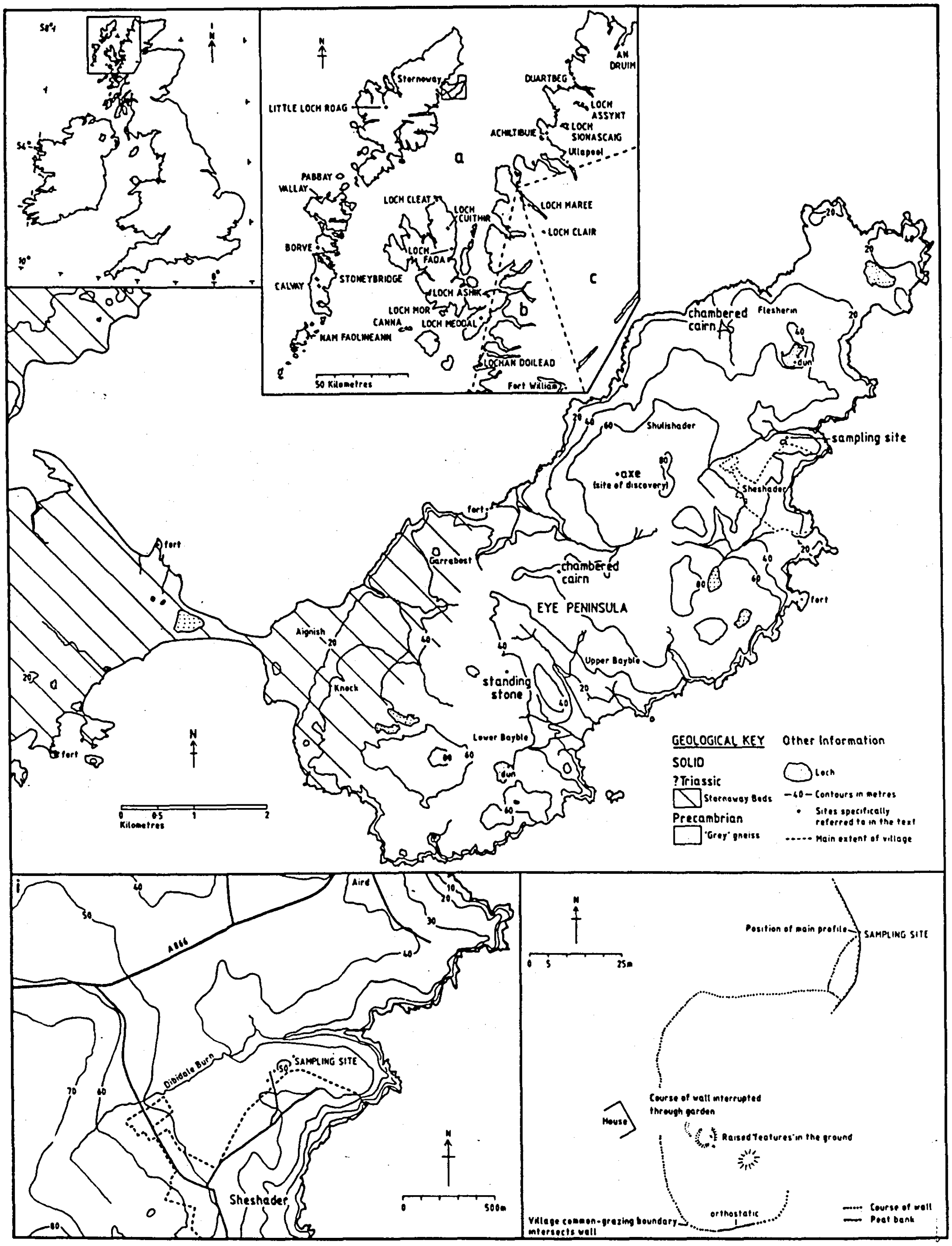
II The Site

i) Position, Stratigraphical Context, Consideration of Chronology

The buried stone wall is situated within an area of moorland to the north of Sheshader village (NB 555348), which is c. 13 km east of Stornoway, on the Eye Peninsula, Isle of Lewis. The ground at the site slopes convexly towards the Dibidale Burn, which eventually flows approximately west to east to the sea, where its mouth is less than 1 km from the site (see Map 2 and Photo. 5).

The solid rock of the eastern end of the Eye Peninsula is grey gneiss, as it is for the majority of Lewis, apart from the most western seaboard, which is predominantly granite or gneiss and small outcrops of 'dominantly metasediments and associated basic rocks', with mylonite elsewhere. There is, however, a small region of sandstones and conglomerates known as the 'Stornoway Beds' which separates the eastern end of the Peninsula, geologically, from the rest of the grey gneiss (see Map 2). The Beds extend some 10km further north than is shown on the map to form a strip, c. 3.5km at its widest, which runs roughly parallel to the coast (Smith and Fettes 1979).

Most, if not all, of Lewis was covered by ice during the last glaciation. According to von Weymarn's theory, the Eye Peninsula would have been transgressed by ice coming from a local ice cap on Lewis and Harris, rather than from the direction of the mainland as previously proposed;



Map. 2. Simplified solid geology of the Eye Peninsula; the sampling site at Sheshader and archaeological sites are also shown. Inset maps show the topography of the site in more detail (i), the course of the field wall and the sites of previous palaeoecological investigations (the zones a, b and c are those of McVean and Ratcliffe (1962), see Fig. 2). (Sources: O.S. 1:2500, 2nd Series. Sheets NB 33/43 NW, NE, SW, SE. Geology from Smith and Fettes (1979). Field wall survey provided by T.G. Cowie).

mainland ice may have reached Tolsta Head and the north end of Lewis (von Weymarn 1979). Glentworth (1979) considered that mainland ice may also have reached the eastern end of the Peninsula. The mainland ice front would have caused the flow of ice from the interior of the island to have been deflected towards the north and west. It is accepted by Flinn (1978) that ice may have come from east of Lewis during a previous glaciation to the last one, but he independently arrived at similar conclusions to von Weymarn that there had been a local ice shed during the final glaciation and the directions of ice flow radiated from this. The northern part of the island, including the Eye Peninsula, was probably covered by a 'relatively inactive outer part of the local ice cap'. However, for the same period, Synge (1977) considered that much of this northern part of Lewis and the eastern end of the Eye Peninsula were ice-free.

At the site, the parent material for subsequent soil development is one made up of stones of fragmented rock within a matrix of sand. The soil that formed has been buried by blanket peat. It is likely that the buried soil is comparable to the type described as a 'peaty podzol with iron pan' (Glentworth 1979, 132-3); the leached layer has been stained with humus, but the mineral grains above the iron pan are white when washed, in contrast to the orange-yellow of the grains beneath the pan. A recently exposed profile near to the site is shown on a photograph (Photo.6).

The chronology of the deglaciation is not understood in any detail (von Weymarn 1979, 102), neither is there a concensus view as to the probable extent of the ice on this part of the Eye Peninsula during the last glaciation. Nevertheless, it may be assumed that the fragmented rock and sand as seen today has been available for the development of a mineral soil at least since the beginning of the Post-glacial until the onset of blanket peat formation. The date obtained from the lowest peat collected in the 1978 suggests that this was some 3700 radiocarbon years ago.

The stratigraphical context of the stone wall was ascertained by a series of small excavations, which are not described in detail here. The essential results are shown in Figs. 4 and 5, and Photo. 7. The base of the wall was found to be resting on c. 20cm of peat, which contained darker layers.

ii) Climate

The climate of the Outer Hebrides is 'in essence ...... decidedly windy, often cloudy, and with frequent though not exceptional amounts of rainfall on the low ground'. The winter temperatures are high for the latitude and severe frost is relatively uncommon. The maximum and minimum mean daily temperatures as recorded at Stornoway airport (at approx. sea level) from 1941-1970 are 12.9° C (for July), 4.1° C (for January). The average number of days of frost per year (1956-75) was 47, at the same station; the number of 'days with gale' (1931-60) was 50 (Manley 1979).

The climate of the interior of the Eye Peninsula is characterized as 'fairly warm and wet', and as 'fairly warm and moist' for the very low-lying ground and coast. Most of the Peninsula lies between the contours of 1000 and 1200mm of annual rainfall (Hudson *et al*. 1982).

iii) Present-Day Vegetation

The vegetation around the excavated site is growing on disturbed peat. To the west of the peat bank where the wall has been exposed, the peat has been cut away to a level close to the mineral soil and in the past, turves thrown down from the top of the bank then being cut has formed an irregular surface, which has caused the drainage to be locally impeded (see Photo. 8). There are some peat hags upstanding from this surface. A general description of the vegetation here is one of a 'moorland' type, having *Calluna vulgaris* (heather), *Eriophorum angustifolium* (common cotton-grass), *Tricophorum cespitosum* (deer-grass) and *Molinia caerulea* (purple moor-grass) as the dominant species; with *Erica tetralix* (cross-leaved heath), *E. vaginatum* (cotton-grass, hare's-tail), *Potentilla erecta* (common tormentil), *Narthecium ossifragum* (bog asphodel), *Dactylorchis maculata* (spotted orchid) and *Pedicularis sylvatica* (lousewort) occurring commonly. The last four species may be locally abundant. There are frequent patches of moss including *Sphagnum* (bog moss) spp. and *Racomitrium lanuginosum* within the mosaic. Lichen (*Cladonia* cf. *impexa*) is also frequent.

To the east of the peat bank the vegetation is broadly comparable and in places is clearly growing on peat that has been previously cut over. Hummocks of Calluna are often capped by Racomitrium lanuginosum and there are gullies caused by erosion. Continuing further east to the cliff edge, the moorland is fringed by a grassy sward in which there is abundant Succia pratensis (devil's-bit scabious), with Potentilla erecta and Leontodon autumnalis (autumnal hawkbit). Plantago lanceolata (ribwort) and P. maritima (sea plantain) are present along sheepwalks.

The banks of Dibidale Burn and part of the sloping ground on either side are predominantly covered by grass; Ranunculus acris (meadow buttercup), Trifolium repens (white clover, Dutch clover), Cardamine pratensis (cuckoo flower, lady's smock), Euphrasia officinalis s.l. (eyebright), Plantago lanceolata, Prunella vulgaris (self-heal), Galium saxatile (heath bedstraw), rushes (Juncus spp.) and Blechnum spicant (hard-fern) were observed in this habitat. Calluna occurs in discrete patches. On the north side of the burn, the moorland has been re-seeded to make grass pasture. At the mouth of the burn where it is flanked by steep creviced rock, Plantago maritima is common, with Sedum anglicium (English stonecrop) and Armeria maritima (thrift, sea-pink) present. On a south-facing slope of the cliff edge having mainly a cover of short grass, Plantago coronopus (buck's-horn plantain) is common.

III Methods

i) Sample Collection and Sediment Description (Troels-Smith 1955)

The main profile was collected in metal boxes measuring 50 x 15 x 10cm. The peat samples were then wrapped in polythene.

The field-wall profile was collected after excavating a part of the wall to leave a section in the extant peat bank (see Fig. 4). The samples were taken by cutting the peat vertically at the required width and then removing the peat from the section using a large knife and a plasterer's leaf trowel. They were wrapped in polythene for storage.

The main profile comprises fragmented rock at the base with a fossil podsol with iron pan above, which is overlain by blanket peat.

Main profile

Depth (cm)	
0.00 - 2.50	Nig 3, strf 0, elas 1, sicc 3, colour 10R 2.5/1; Sh 4, Tl^{0}+, Th^{0}+.
2.50 - 32.00	Nig 2, strf 0, elas 0, sicc 3, colour 2.5YR 2.5/2; Sh 3, Tb +*, Th^{0}+, Th^{3}1; lim sup 1.
32.00 - 119.50	Nig 3, strf 0, elas 1, sicc 3, colour 2.5YR 2.5/0; Sh 2, Th^{2}2**; lim sup 1.
119.50 - 178.00	Nig 3, strf 1, elas 1, sicc 3, colour 2.5YR 2.5/0-2; Sh 3, Th^{3}1; lim sup 1.
178.00 - 186.25	Nig 3, strf 0, elas 1, sicc 3, colour 5YR 3/2; Sh 2, Th^{2}1, Ga 1, Gs +; lim sup 2.
186.25 - 194.00	Nig 1, strf 1, elas 0, sicc 3, colour 10YR 5/8; Ga 1.5, Gs 0.5, Gg 2; lim sup:iron pan (c. 0.5cm thick).

* This moss component was only observed in the sieve washings.
** Including cf. *Eriophorum* sp. remains.

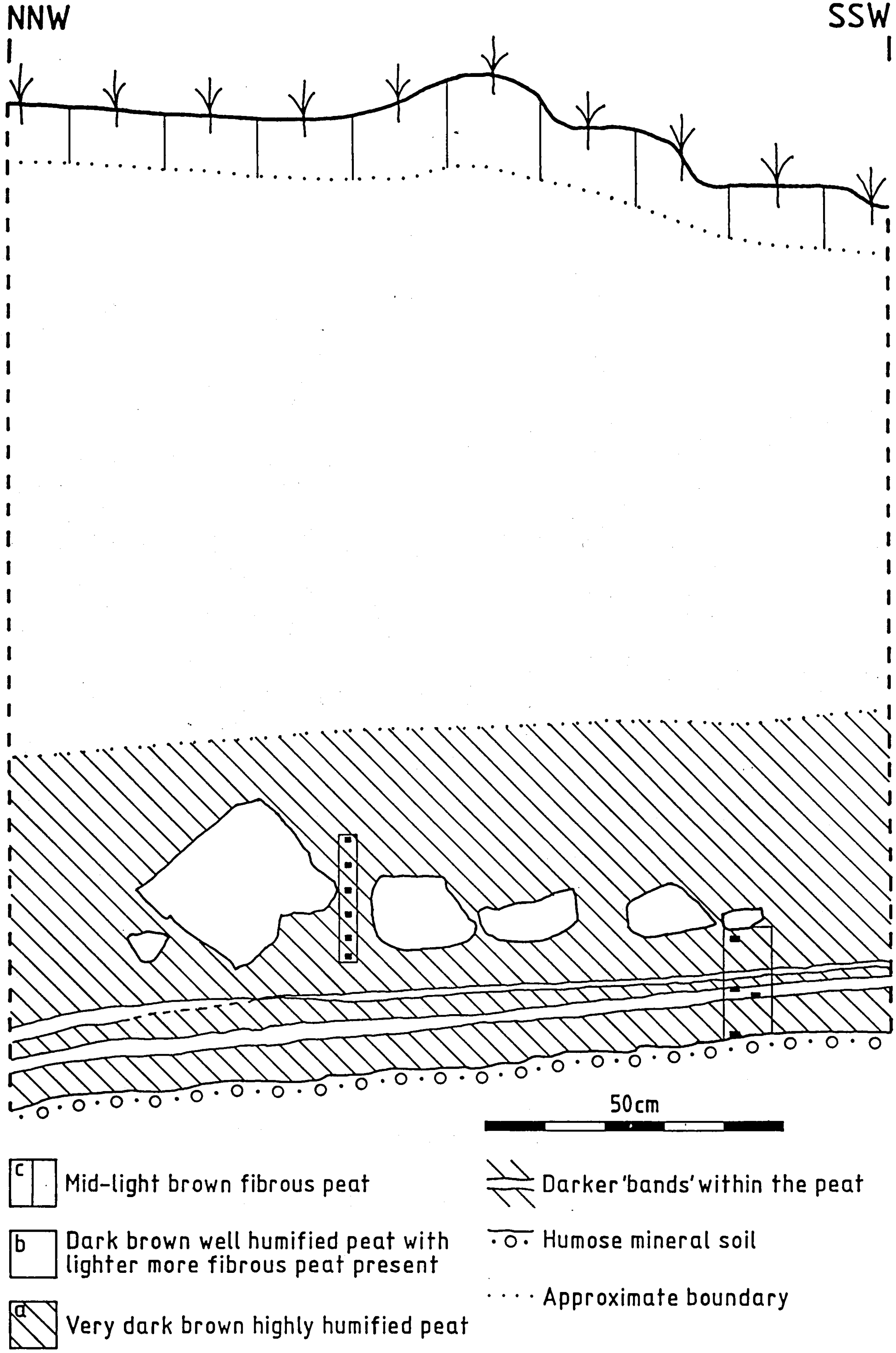


Fig. 4. Elevation of the peat bank at Sheshader (in 1981) showing the stones of the field wall in section and the positions of the samples taken for pollen analysis. The principal units of peat stratigraphy (a, b, c) noted in the field are drawn schematically and broadly correspond to the three largest units identified in the main profile.

Field-wall profile

Depth of peat above mineral soil (cm)

40 - 19	Nig 3, strf 0, elas 0, sicc 3, colour 2.5YR 2.5/0-2; Sh 3, Th^{3}1, Gs +.
18 - 0	Nig 3, strf 0, elas 0, sicc 3, colour 2.5YR 2.5/0-2; Sh 4, Th^{4}+, Gs +.

ii) Radiocarbon Dates

Three samples from the main profile were submitted for radiocarbon dating and one from directly beneath the field wall (GU-1665, see Fig. 5).

Lab Ref No.	Depth (cm)	Years (b.p.)	Mean Date B.P.	Range B.P. (@2s.d.)
GU - 1454	38.5- 40.0	685 ± 65	620	540 - 780
GU - 1455	119.0-120.0	1840 ± 60	1760	1650 - 1950
GU - 1456	175.5-178.0	3671 ± 65	4070	3780 - 4400
GU - 1665	20.0- 22.0 (above mineral soil)	2900 ±100	3130	2850 - 3430

Deposition rates (calendar years/cm)

	Mean	Range (@2 s.d.)
620 B.P. - ?1980 A.D.	?16.7	14.9 - 20.6
1760 B.P. - 620 B.P.	14.1	10.8 - 17.5
4070 B.P. - 1760 B.P.	40.4	32.1 - 48.0
4070 B.P. - 3130 B.P.	?47.9	17.9 - 78.7

The top of the main profile may have been disturbed and so the assumed date of 1980 A.D. may be erroneous. The last rate has been calculated assuming the same date for the base of the blanket peat under the field wall at the position of sampling (for GU-1665) as at the base of the main profile.

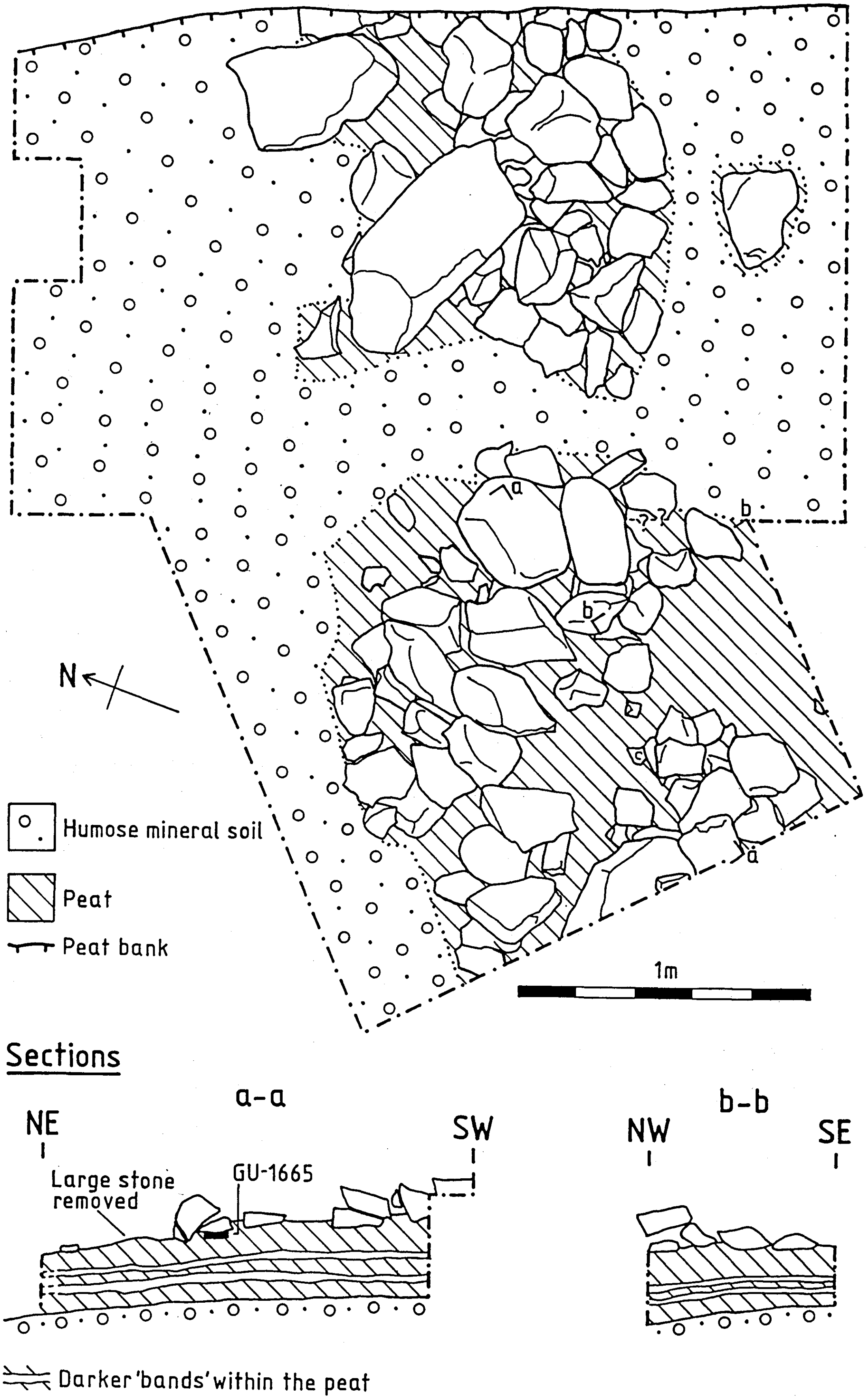


Fig. 5. Plan and sections of the field wall at Sheshader as revealed by excavations (in 1981, eastern part; and 1982, western part) with the position of the sample submitted for radiocarbon dating also shown. The course of the wall is interrupted due to the removal of a large stone during peat cutting in 1978.

IV Zonation of the Pollen Diagram

Zone S-1 (194-182.75cm; before 3700 b.p./2200 B.C.)

The values for Coryloid, *Betula* and *Betula*/Coryloid are comparatively high (50, 18 and 28% respectively), as are those for *Polypodium* and Filicales. These five types together characterize the zone. By contrast, the values for *Calluna*, Gramineae and Cyperaceae (where present) at levels 187.5 and 185cm are $\leqslant$ 5%, although the lowest spectrum (190.5cm) has higher percentages of *Calluna* (19%) and Gramineae (14%). *Potentilla* is also recorded (5%).

Zone S-2 (182.75 - 178cm; before 3700 b.p./2200 B.C.)

There are marked increases in the percentages of Gramineae and *Plantago lanceolata* from the previous zone (34 and 40% are the respective maxima in the zone); whilst the percentages of *Betula*, Coryloid, *Betula*/Coryloid, *Polypodium* and Filicales are considerably reduced. There are significant percentages of Compositae pollen (6 and 3%) and a rise in *Calluna* values has begun at the top level of the zone, to be continued in the next.

Zone S-3 (178-0cm; 3700-?Present/2200 B.C.- ?1980 A.D.)

In this zone either *Calluna*, Gramineae (including Cerealia - type), Cyperaceae, or *Potentilla* has the highest percentage at any level. The zone is divided into six subzones.

Subzone S-3a (178-150.25cm; 3700-2800 b.p./2200-1100 B.C.)

Calluna rises to 35% at the first level of the subzone and thereafter its values are greater than those of Gramineae, reaching 65% at the top level of the subzone. *Potentilla* percentages are high (19, 27 and 36%) when *Calluna* percentages are comparatively low (38, 41 and 31%); but they are reduced to < 5% when *Calluna* is >60%. *Ranunculus* grains are commonly present; Cerealia - type, *Trifolium* and Liguliflorae grains also appear. Overall, the amount of tree and shrub pollen (≤ 7%) is much less than in the previous zone, as is the number of fern spores.

Subzone S-3b (150.25-144.25cm; 2800-2600 b.p./1100-800 B.C.)

The three highest Gramineae values dominate this subzone. *Calluna* pollen is <8% with *Potentilla* 14-19% and there are two high values (6 and 7%) of *Plantago lanceolata*. Other possible indicators of agriculture (Cerealia - type, *Rumex acetosa*/*acetosella*, *Ranunculus*, Caryophyllaceae and *Trifolium*) are represented. Tree and shrub pollen is ≤ 5%.

Subzone S-3c (144.25-127.5cm; 2600-2100 b.p./800-0 B.C.)

This is dominated by the three maxima of *Calluna* pollen (68-74%). Gramineae pollen is <18%, Cyperaceae <4% and *Potentilla* <6%. *Plantago lanceolata* is >2%. Possible indicators of agriculture: Cerealia-type, *Rumex acetosa*/*acetosella*, Caryophyllaceae, *Lotus* and Liguliflorae are present. Tree and shrub pollen continues to be low (≤3%).

Subzone S-3d (127.5-43.5cm; 2100-700 b.p./0-1400 A.D.)

The percentages of *Calluna* range from 35-43%, those of Gramineae are consistently higher than previously, apart from the single earlier high value (19%) at 150cm, and *Sphagnum* is more abundant. *Potentilla* varies from 4 to 33%. *Plantago lanceolata* percentages decline towards the end of the subzone, whilst *Betula* and Coryloid increase slightly after the first two levels of the subzone to total between 3 and 7%. The highest total for tree and shrub pollen in the zone (S-3) is 11%, at level 84cm.

Subzone S-3e (43.5-12.75cm; 700-?200 b.p./1400-?1800 A.D.)

This subzone is defined on the basis of the two highest values for Cyperaceae pollen (58 and 54%) with a corresponding reduction in *Calluna* (now 23 and 24%), Gramineae (7 and 12%) and *Potentilla* (2%) compared to subzone S-3d. *Plantago lanceolata* is <1%. Tree and shrub pollen (mainly *Betula* and Coryloid) declines from 8 to 3%.

Subzone S-3f (12.75-0cm;?200 b.p.-?Present/?1800-?1980 A.D.)

The values of Cerealia - type are very high (11 and 30%). These are associated with relatively high percentages of *Rumex acetosa*/*acetosella* and *Artemisia* pollen and smaller amounts of *Plantago lanceolata*. The presence of *Polygonum persicaria*, cf. *Rumex-crispus* type, and Caryophyllaceae pollen are recorded at the top level of the subzone. The percentages of Cyperaceae pollen are much lower than previously (subzone S-3e), but Gramineae has increased, as has *Calluna* at the lowest of the two levels (6.5cm). Tree and shrub pollen is ≤1%.

V Inferred Vegetational History and Discussion

i) Previous Work

a) NW Scotland

Following Birks (1977), it is convenient to discuss the Post-glacial history of the vegetation of NW Scotland within the context of the potentially dominant vegetation types as distinguished by McVean and Ratcliffe (1962) for the present climatic regime and without the influence of man (see Map 2). More attention will be given to mainland sites at comparable latitude to Lewis and to the investigations carried out on the Inner and Outer Hebrides.

Within the zone of predominantly oak forest, oak with birch was the main woodland type at least as far north as Argyll and Perthshire (Birks 1977, 126); but at no time was oak important in southern Skye (Birks and Williams 1983, 284), where the sites of Loch Meodal and Loch Ashik lie close to the hypothetical boundary between the predominantly oak and predominantly birch forest zones.

The pollen evidence from Loch Clair (300ft, 92m; Pennington *et al.* 1972) and Loch Maree (sea level;Birks 1972b) within the predominantly pine forest zone, shows that the birch and hazel woodland established in the first part of the Post-glacial was replaced by pine from c. 7900 b.p.

and 8250 b.p. respectively. This woodland was fern-rich and latterly an open canopy is suggested by the presence of Pteridium (bracken) spores and at Loch Maree, by Sorbus aucuparia (rowan, mountain ash) pollen. Alder became established after 6500 b.p. The pine pollen percentages begin to decrease from c. 7000 b.p. at Loch Maree and c.6000 b.p. at Loch Clair, but there is a more pronounced decrease, particularly at Loch Maree, at 4000 b.p., when the increases in Calluna values point to the growth of blanket peat in the region. There are carbonised plant fragments recorded from the Loch Maree sediment before the rise in pine pollen and subsequently there is an almost continuous record to the present day. Charcoal is recorded at Loch Clair at c.5500 b.p. and shortly before 5000 b.p.

Pollen analysis at three sites lying within the predominantly birch forest zone has shown the course of vegetational development during the Post-glacial. The sequence from the most southerly, Loch Sionascaig (240ft, 74m; Pennington et al. 1972), indicates that from c.8000 b.p., birch and pine forests largely replaced the birch-hazel woods previously established, but that the birch and hazel woods seen today are ultimately from the earlier distribution. The amounts of iron and manganese ions accumulated in the sediment suggest increased erosion in the catchment area and the start of blanket peat formation from c.5000 b.p. Although pine and birch continued to grow on the peat, the percentage of pine pollen declines suddenly at c.4000 b.p.,when peat growth was rapid. There was probably clearance of pine and birch at c. 3500 b.p., after which there has been no regeneration of trees to the present.

Further north, by Loch Assynt (390ft, 120m), birch-hazel wood developed from 8950 b.p., with alder pollen becoming abundant at 6500 b.p. (at the same time as at Loch Sionscaig) and pine migrating into the area to be present from c.5300 b.p. until c. 4000 b.p. Its decline at this time is associated with the spread of blanket peat. There is a significant reduction in birch pollen from c. 1500 b.p., probably due to clearance (Birks 1980; pollen analysis by Birks H.H. 1973-4).

At An Druim, Eriboll (70ft, 20m) birch-hazel woods or scrub were forming from c. 10 000 b.p. and locally elm was present between c. 7250 b.p. and 5500 b.p. The 'alder rise' (to c. 40 - >50% TLP) occurred soon after c. 6000 b.p.; the pine and oak pollen was probably transported from some distance away. Clearance of the woods proceeded from c. 5000 b.p. The presence of Plantago lanceolata, Ranunculus acris and Urtica (nettle) pollen and Pteridium spores in the record is associated with the clearance (Birks 1980; pollen analysis by Birks H.H. 1974-5). The birch-hazel woods at both these last sites were rich in ferns and herbs (Birks 1977, 129) and as noted above, with respect to the sites in the predominantly pine forest zone, the occurrence of Sorbus aucuparia pollen and Pteridium spores implies a relatively open canopy.

By Loch Meodal (360ft, 110m), southern Skye, birch-hazel woodland, also rich in ferns, was established from about 9700 b.p. and associated with this were communities of tall herbs, including Filipendula ulmaria (meadowsweet), Angelica sylvestris (wild angelica) and Rumex acetosa (sorrel). The presence of oak is recorded from c. 9000 b.p. but its percentages never increased to those at the mainland sites (Birks and Williams 1983). At Lochan Doilead (130ft, 40m), for instance, the percentages of oak pollen were highest between c. 5500 b.p. and 3600 b.p., reaching a maximum of c. 15% TLP (Birks 1980; pollen analysis by Williams 1974-5). But at both sites pine was never a significant tree in the woodlands; alder pollen became frequent at c. 6500 b.p. in the two sequences. The earliest clearance at the first site occurred at c. 5200 b.p., which allowed grasssland and heath to expand during the next millennium.

There was no appreciable change in the vegetation pattern of a still largely wooded catchment area (but with the open communities of grassland and heath and the growth of bog) until c. 2700 b.p., when the Coryloid and alder pollen percentages begin to decline further and those of grasses rise to a value of c. 25% TLP, which is sustained until c. 300 b.p. (i.e. c. 1650 A.D.). This date marks the final major vegetational change when the percentage of grasses increases to >35% at the expense of heather and almost all remaining birch, alder and hazel were cleared.

Some 12km to the north and about 3.5km to the east of Loch Meodal, Loch Ashik (130ft, 40m) has provided a pollen record for the Post-glacial showing that birch-hazel woods, again rich in tall herbs and ferns, developed from c. 9000 b.p. Oak and elm were probably a minor component of the woods from 9000 b.p., as was the case at Loch Meodal. Alder expanded at c. 6300 b.p. Differences with the more southerly site are the probable presence of blanket bog, heath and grassland from 9000 b.p.; there is no sign of human interference at 5000 b.p.; and there is an increase in pine pollen between 4600 and 3900 b.p., when at this last date its abundance rapidly decreases, a feature noted in the discussion of the mainland diagrams. Heath and grass expanded following this development of pine, which was perhaps only local; although the pollen values of birch (5-10% TLP), hazel (c. 10-20%) and alder (c. 10%) and possibly oak (<5%) suggest that there was still some woodland remaining in the area. From c. 2750 b.p., after a brief increase of Coryloid pollen, the reduced amount of tree pollen and higher percentages of heather pollen imply only scattered occurrences of birch, alder and perhaps oak in the region, now dominated by bog. An essentially treeless landscape has prevailed during the last c. 250 radiocarbon years (i.e. from c. 1700 A.D.).

The most northerly site investigated on Skye is Loch Cleat (100ft, 30m). Here the Post-glacial record shows that birch, hazel and willow scrub had formed by 8900 b.p. The rise in alder is dated at 6300 b.p., the same date as at Loch Ashik. Alder was never as important as it was at the other two sites. However, at Loch Fada (490ft, 150m), there is apparently more alder represented than at Loch Ashik

(Vasari and Vasari 1968). The amounts of pine, elm and oak pollen also indicated that these trees were not significant in the vegetation. Their low pollen percentages are corroborated by the pollen analysis at Loch Cuithir (590ft, 170m) and Loch Fada in northern Skye, although there may be perhaps twice as much oak and elm being represented at Loch Cuithir and less alder and hazel compared to Loch Fada, the more southerly of the two sites (Vasari and Vasari 1968; see Map 2). From all three analyses, it is suggested that the woodland was never closed in north Skye during the Post-glacial and that exposure to wind was an important reason for this (Birks and Williams 1983, 284; 286). The westerly position of Loch Cleat and a prevailing wind from that direction may mean that the regional pollen rain from the east is under-represented at that site (cf. below, p. 85). As by Loch Meodal, human clearance of birch and hazel began at c. 5000 b.p. at Loch Cleat. The herb pollen assemblages point to there having been both pastoral and arable agriculture practised from this time until 700 b.p. The landscape remained largely cleared throughout this period, with birch and hazel being somewhat further reduced, on average, from 2600 b.p. (650 B.C.). The relict birch and hazel were finally destroyed during the last 700 radiocarbon years.

With one exception (Little Loch Roag, Isle of Lewis; Birks and Madsen 1979), the other pollen analytical work carried out on sites of the Inner and Outer Hebrides is without a series of radiocarbon dates. In addition to this work there are records of fossil tree remains or their fruits from the Islands. In only one instance (Borve, Benbecula; Ritchie 1966) has a radiocarbon date been obtained. Also, historical reports of formerly wooded areas, place names, inference from the present fauna and fossil faunal assemblages, molluscan assemblages, archaeological discoveries of charcoal and artefacts contribute to the body of evidence by means of which the earlier pattern of vegetation, particularly the extent of any woodland or scrub, may be reconstructed.

The work of Blackburn (in Heslop Harrison 1948, 89-90; Godwin 1943, 229) on sediments from near Loch Mor (sea level), Isle of Soay, demonstrated the Post-glacial date of the marine transgression represented by clay and mud, about a metre thick, that overlay Sphagnum peat. Near the top of this peat, dated by reference to Godwin's (1940) zones to the end of the Boreal (zone VI), the amount of hazel pollen is apparently >65% TLP (>4000% AP), with birch pollen at c. 6.5% TLP and that of pine at 10%. Such a value of hazel pollen would seem to imply its presence near the site. Later, at the level above the zone VII/VIII boundary, arboreal pollen is c. 40% TLP, birch pollen contributing 32% TLP. Generally, however, the non-arboreal pollen counts indicate the predominance of heath or grassland. Total arboreal pollen has been used as the basis for expressing the relative percentages of the pollen taxa. This common feature of the early work means that individual values have to be read off the diagram and the percentage calculated with total land pollen as the sum for comparison with more recent diagrams and to assess the importance of trees in the vegetation more easily.

It was found impossible to divide the two diagrams prepared from investigations on Canna (300ft, 90m; Flenley and Pearson 1967) into zones, with any certainty and therefore the sequences can only be very tentatively dated, in the absence of radiocarbon determinations. It is suggested that the sequences together may be a complete record from before the Boreal/Atlantic (zones VI/VIIa) transition to the present day; during which period, there must have been an almost, if not entirely, treeless landscape, though willow scrub is likely to have been present on the site at times; local hazel may also be represented.

As for the calculations of the pollen analysis from Loch Mor, Soay, Blackburn (1946) has used the sum of arboreal pollen to calculate the relative percentages of the taxa recorded from a 4ft deep peat profile at Lochan nam Faoileann (100ft, 30m), Barra. The profile may be truncated, the most recent peat having been cut away. Within the humose mineral soil, which is approximately 5cm thick, at the base of the profile, the values for hazel pollen are c. 30% TLP at two levels. That birch was locally present is indicated by the remains of birch twigs within the next approximately 30cm of overlying peat. Generally, however, throughout the record, thought to begin in the Boreal (zone VI), the relatively high Ericoid and grass pollen values suggest that any birch and hazel woodland was not extensive but co-existed with open heath and grassland. It is not stated how many tree pollen grains were counted at each level, but it is implied that it was sufficient to allow zonation, partly on the basis of the tree pollen profiles.

Results from two profiles from South Uist (on the Isle of Calvay, at sea level; and near Stoneybridge, 50ft, 15m) were fully published by Blackburn (Heslop Harrison and Blackburn 1946) following the discovery of a nut of Trapa natans (water chestnut). The 2m sequence from Calvay was judged to have begun in the Boreal (zone VI). The highly humified ('buttery') peat of this zone contained birch twigs, with birch pollen at the lowest level amounting to a maximum of nearly 90% AP (c. 16% TLP). Here hazel pollen is 133% AP (c. 24% TLP). Apart from one level, where there appears to have been a local growth of willow scrub, the Ericoid values are >100% AP throughout the profile, which extends into the Sub-atlantic (zone VIII). It seems that the landscape was open, with local stands of trees or shrubs accounting for the instances of comparatively high values of birch, hazel, or alder pollen. The evidence from near Stoneybridge perhaps supports this. The 'alder rise' is not as pronounced on the published diagram from one site in the area, where birch twigs occur in the sediment at that level, as it is recorded from another site nearby. In this instance, no birch twigs were found. The peat stratigraphy at the first site is comparable to that at Calvay, although there are Phragmites (reed) remains associated with the birchwood peat, common to both sites, which occurs from a depth of c.45cm. The profile is, however, only 75cm deep in total. The lowest sample taken from humose mineral soil within zone VI gave a spectrum with birch pollen c. 35% TLP, hazel pollen c. 45%, Ericoid and grass pollen each c. 10%. Non-arboreal pollen is more than arboreal pollen throughout the sequence and may reach very high amounts compared to those of the latter.

Branches and twigs were found in organic deposits within coastal sand at Borve on Benbecula (Ritchie 1966). The wood was not identified. Pollen analysis from an organic layer (c. 4cm thick) separated by c. 7cm of sand from an organic deposit containing wood within the top 5cm, dated to 5700 ± 170 b.p., showed that tree pollen was c. 30% TLP. At two other levels the percentages of tree pollen were less (5-8% TLP), although wood remains were present. It is suggested that the debris had either dropped into marsh or open water, or had been washed in. The pollen evidence would perhaps favour the last suggestion.

'Pabbay was not always treeless' (Elton 1938). The submerged trees off the west coast of this island in the sound of Harris were noted at the turn of the 17th century by Martin Martin (1703) and by Sinclair (1794). Elton found traces of these remains in the intertidal zone and fragments of birch bark (Betula pendula). A trunk and small branches of the same species were also retrieved. 'Abundant' birch pollen was recorded from the associated peat, among other pollen and spores, but not hazel pollen, and the only other tree to be represented was oak (one grain). He cites other reports of submerged peat and tree remains from south Harris, in particular, Killegray (Jehu and Craig 1927) and from North Uist, on the Isle of Vallay; also the record of submerged peat at Kilphedir (Beveridge 1911; and MacRae 1845, writing of Vallay). An investigation in 1937 showed that the tree remains in the Vallay deposits had either been washed away or inundated by sand. It is not clear from the reference to the Vallay deposits observed in 1924, whether any tree remains were then extant Jehu and Craig (1926). They give other instances of submerged peat off Benbecula, North Uist and Berneray (Sound of Harris).

Inland on Pabbay, Elton recorded rhizomes of _Equisetum fluviatile_ (water horsetail) and hazel bark at the junction of the present-day grassy turf and thick fibrous peat that became more humified towards the mineral substratum. Pollen analysis through this lower peat revealed that 'tree pollen was scarce' with birch, pine and hazel present. Ericaceous pollen was 'very abundant'. The author provides additional records of hazel bark and birch wood from Achmore, Lewis; earlier identifications of wood species in the Statistical Accounts (viz. those instanced by Niven 1902), may not be reliable.

The place-name evidence for the existence of former woods assembled by Elton and his observation that the present fauna of the Outer Hebrides 'has a pronounced woodland character, especially in the birds and mammals' support the idea that Lewis and Harris may have had at least scrub woodland in places. Some of the skeletal remains from the 'Iron Age' midden at Galson (Baden-Powell and Elton 1936-7) similarly suggested an interpretation of there having been woodland on Lewis. That red deer, an animal naturally of woodland habitat, was also represented, is interesting in this respect. Henshall (1972, 155) cites Dean Munro's mentions, in the 16th century, of the orchard of Macloed of Lewis on an island in Loch Erisort and the forests on the 'eist wist' of Uist; also of there being some forest on Lewis and North Harris.

Lewis (1906) reported fossil birch remains from the lowest level of peat sections in southern and central Skye and these were sometimes associated with hazel and alder remains. Small birch stems and compressed bark were found in basal layers of a section on the west side of North Uist. The same author (1907) also noted birch remains from early layers in peat at four sections in north Lewis and again hazel remains came from the same levels at two sites and those of alder from one. The findings of Samuelsson (1910) confirmed that birch and hazel grew in this part of Lewis early on in the period of peat formation; and after the peat had become about a metre deep, in one instance, there was a further growth of birch. The number of records of fossil tree remains is likely to increase if it is known that such information is of interest to palaeoecologists and recently more have been reported. Pine stumps were reported by Peacock in Birks and Madsen (1979); and 40 sites of fossil wood (of willow, birch or pine) were recorded by Wilkins (1984), mainly from the central part of the island. The ranges of dates from a total of 11 radiocarbon determinations were Salix, 9140-8550 b.p.; Betula, 7980-5030 b.p.; and Pinus, 4870-3910 b.p. (see Fig. 6). Pine stumps were abundant at two sites and resembled the remains of former woods.

The pollen analysis by Erdtman (1924) was restricted to recording the relative proportions of tree and shrub pollen and thus cannot be used to evaluate the former tree cover in Lewis. Birch pollen was generally the most abundant tree type, often having several times the percentage of any other tree pollen. The 3m sequence from the valley mire at Little Loch Roag, however, provides a record with radiocarbon dates from early Post-glacial times until the present day (Birks and Madsen 1979). Since it is the only such record to be published, it is worth summarizing the authors' conclusions in a table for easier comparison with the sequence to be described below (see Fig. 6).

The predominantly treeless character of the landscape inferred from the Little Loch Roag sequence apparently contradicts the conclusions from the analysis of molluscs found at Northton, Harris (Evans 1971). It was suggested that at times the site had been wooded during a period from before 2461 ± 79 b.c. (4411 b.p.; Burleigh et al. 1973) to the Iron Age. Even if it is simply a local stand of trees that is being represented, it is still questioned whether the ecological requirements of the molluscan species

Local pollen assemblage zone	Years b.p.	Features of the relative pollen and spore frequencies (% TLP)	Ranges of dates of tree remains from Lewis, with no. of dates (Wilkins 1984)	Interpretation of the pollen and spore record	Features of the sediment composition & inferred local sedimentary environment
LLR-3 5200	0 1000 2000 3000 4000 5000	c.1100 Cerealia-type grains (<0.5%) c.1700 *Plantago lanceolata* consistently present (≤2%) throughout zone LLR-3, with *Pteridium* 3700 Slight rise in *Plantago lanceolata* 3900 Rise in *Calluna* to >10% hereafter 4100 Beginning of sequence of lower values for *Pinus*	3910 *Pinus*, 5 4870 5030	Landscape predominantly treeless; ?scattered birch copses locally in favourable situations; ?hazel or bog myrtle and willow locally. Surrounding vegetation a mosaic of grassland, *Calluna* heath and bog communities. Tall-herb communities less common than during zone LLR-2 3900 4100 Expansion of heather moor, grass land & pasture (anthropogenic?) ?Reflection of regional decline in pine	500 – 900 mineral inwash 3500 mineral inwash 3900 -Beginning of record of carbonised plant remains 4450 – 4800 mineral inwash
LLR-2 6400	6000	5300 Beginning of continuous curve for *Plantago lanceolata*; *Pinus* maximum (c.5%) 6100 Beginning of *Alnus* percentages having larger values on average; but still ≤3%		Scattered birch and hazel scrub with some rowan very locally. Tall-herb communities including ferns	Soligenous mire
LLR-1c 7700	7000	Highest values of *Betula* and *Corylus/Myrica* (12% & 10% respectively) in this subzone	*Betula*, 4	Small areas of scrub in sheltered situations only. Species-rich grasslands and tall-herb communities locally on more fertile soils	Pool largely overgrown by *Sphagnum*
LLR-1b 9140	8000 9000	7700 *Ulmus* & *Quercus* present from this date; rise in *Calluna* 7900 Small rise in *Corylus/Myrica* Highest values for *Salix* & *Juniperus* (c.2-3%) in these subzones	7980 8550 *Salix*, 2 9140	Expansion of *Calluna* heath ?Small areas of birch and hazel scrub locally in sheltered situations only. Species-rich grasslands and tall-herb communities	Shallow acidic pool; no further accumulation of minerogenic sediment; deposition of humified organic debris
LLR-1a		Base of sequence		Predominantly species-rich grassland ?Tall-herb and willow communities	Shallow base-poor pond; accumulation of sand and silt

Fig. 6 Correlation table showing selected results from the investigation of the mire near Little Loch Roag, Isle of Lewis, and the main environmental reconstructions made (Birks and Madsen 1979); the ranges of dates from tree remains discovered on the island (Wilkins 1984) are also shown.

are sufficiently well understood to make valid reconstructions of the former tree cover (Birks and Madsen 1979). The dates of the small maxima of *Salix*, *Betula* and *Pinus* pollen at Little Loch Roag broadly correlate with the ranges of dates for the wood remains of those genera recorded by Wilkins (Fig. 6). The impression gained of pine woodland overwhelmed by peat growth at two of the sites, makes it probable that the pollen sequence is mainly representing the relatively local vegetation around the site, particularly to the west, since the wind was no doubt always predominantly from that direction.

Charcoal of tree species has been found on various sites in the Outer Hebrides, eg. hazel, birch, willow, oak and pine (Henshall 1972, 115), but the dangers of interpreting these finds as deriving from local trees has been pointed out by Godwin and Tansley (1941) and reiterated by Pilcher (1974) and Birks and Madsen (1979), for instance.

A number of stone axes have been found on Lewis, of a type belonging to a period dated as beginning in the late 4th millennium b.c., with perhaps the industry at its height in the 3rd millennium b.c. (Smith 1974, 105-106). They include two porcellanite axes of group IX (Ritchie 1968, 123-126). Their use for ritual may be likely if several are found together (as at Balallan; Cowie 1982) and are in an unworn condition, but their origin must lie in the manufacture of a tool suitable for cutting wood. A recent find at Shulishader is notable for the well preserved wooden haft. The site is c. 2km from Sheshader (see Map 2).

b) Pollen Analysis related to Prehistoric 'Field-Boundaries' in Scotland

Pollen analysis of deposits relating to prehistoric field walls has given an indication of the contemporaneous surrounding vegetation at two sites in west Scotland, at Achnacree, Argyllshire (Ritchie *et al.* 1974; Barrett *et al.* 1976) and at Callanish, Isle of Lewis (Bohncke, in preparation). A comparable investigation was made of a site on Shurton Hill, Shetland by Whittington (1977-8).

The radiocarbon date obtained from the uppermost horizon (O_1) of the fossil soil directly under the bank at Achnacree (70ft, 20m) is 1359 ± 50 b.c. (3309 b.p.). At another part of the Moss the basal peat was dated to 980 ± 80 b.c. (2930 b.p.). The pollen spectrum from the O_1 horizon was one of 7% tree pollen, with Ericoid, mainly *Calluna*, being 66% (Total Pollen). There was no evidence for cultivation in the spectrum.[1]

Three profiles in the Callanish area have provided a sequence for the inferred vegetational history in the vicinity seaward of Callanish, at Leobag (approx. sea level). Excavations of the field walls buried by peat in this locality have given the opportunity of sampling the peat for pollen analysis in order to try and establish the period in the vegetational sequence in which the walls were constructed and in use.The main sequence so far deduced begins in the 8th millennium b.p.

Pollen analyses of two short profiles on Shurton Hill (560ft, 170m) have been carried out. One, of 8.5cm depth,

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1. See footnote on page 88.

came from beneath the side stones built up adjacent to the larger upright stones of the wall. The top is therefore dated to the time of the wall's construction. The results show that a treeless environment pertained during the history of the profile, with _Calluna_ and Gramineae pollen as the most abundant types (fluctuating between c. 40-55% and c. 10-40% TLP respectively). The soil may have been subject to some disturbance when the wall was constructed and also the pollen may not be in its original stratigraphical position due to later movement through the soil. The radiocarbon date from the soil under the dyke is 2800 b.c. (4750 b.p., UB 2122). The second profile, taken from a point away from the wall, includes the mineral soil (c. 8.5cm) and the lowest peat (c. 16.5cm). A similar spectrum for the mineral soil was obtained, but after the peat began to form a rise in the amount of _Calluna_ (from c. 50 to c. 75%) and Cyperaceae pollen (from <1% to c. 15%) is simultaneous with a marked decline in Gramineae pollen (from a maximum of c. 35% to a minimum of c. 2%). The concentration of charcoal covering the period from the top 5.5cm of the mineral soil to the first 9cm of peat suggested that perhaps the heath may have been deliberately burnt, and that ultimately the burning almost eliminated the grass as heather and sedges became dominant.

In all three cases, as far as information is available, the vegetation of the landscape that was being divided by field walls was moorland, with communities of heather, grasses or sedges in varying proportions as the dominant elements of the vegetation.[1] The walling at Leobag was always found to lie on some depth of peat (up to c. 45cm). In one case the wall had a core of peat, which was different from that which had buried it. The sections at the other two sites showed that the walls were constructed on weathered bedrock or mineral soil, later to be covered by peat. The form of construction at Shurton Hill was one of large (70cm) uprights set into the weathered bedrock and between small stones stacked at each side on the mineral soil. There was perhaps a large capping stone resting on the uprights. The longer face of the uprights appear to be set at right angles to the direction of the course of the dyke. The three Achnacree sections showed that two walls were built having a core with overlying stones, one of which had a single quarry ditch for some distance along one side; the other had a ditch on both sides for some of its length, but elsewhere was apparently without ditches. The third wall seemed to have neither of these features. As indicated above, for one example, all the walls were found to be resting on a fossil podsol developed within the glacial outwash gravels (Soulsby 1976).

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[1] It has recently been suggested, from more detailed absolute analyses of a nearby profile under the bank at Achnacree, that the Ericoid pollen may have been derived from later vegetation; and that a spectrum having more Gramineae and especially <u>Plantago lanceolata</u> pollen was contemporaneous with the building of the bank (Whittington 1983).

ii) Inferred History of Vegetation

a) Main Profile

Zone S-1 (194-182.75cm; before 3700 b.p./2200 B.C.)

In spite of the possible misrepresentation of the contemporaneous pollen rain due to differential preservation or mixing of the surviving pollen grains, it seems clear that during the time of this zone, there must have been a hazel with birch scrub, rich in ferns, growing on the slope of the small valley down which the Dibidale Burn flows. That the Coryloid pollen is almost certainly of hazel may be argued from the type of vegetation to be inferred from two of the pollen spectra of the zone, indicating a low percentage of pollen from heathland or bog plants; from the likelihood that the topography of the site promoted good drainage; and perhaps from the observation that bog myrtle (*Myrica gale*) is rare on Lewis today (Birks and Madsen 1979, 828), in spite of there being widespread bog and heaths. The records of *Calluna* and *Plantago lanceolata* pollen throughout the zone suggest that the canopy was either not closed, or that there were discrete stands of trees.

Two of the three spectra of the zone are from soil that is beneath the iron pan. The lowest has significantly larger amounts of *Calluna*, *Gramineae* and *Potentilla* pollen and the percentage of *Betula* is about a quarter that at the two levels above it. The predominance of fern spores made the counting of a greater pollen sum prohibitive.

Nevertheless, the sum of 95 probably means that the differences noted are to be accounted for in other ways than as a result of it being too small. The survival of such a high proportion of fern spores is presumably a reflection of differential preservation (see Table 1). It was observed that the almost entirely mineral soil (loss on ignition 2.6%) at this depth did contain small pockets of humic soil and these may have separated from later humus development or be remnants of humic soil forming at the time corresponding to the spectrum at this level. The sieve residues contained occasional Sphagnum sp. leaves, which might imply that there was a component from the more organic constituent of the soil, or possibly even some more recent contaminant introduced when sampling in the field, although the poor preservation and high Coryloid value perhaps discounts this as being an important factor. After scanning part of the slide it was impossible to say whether, in general, Calluna was significantly better preserved than relatively uncorroded Coryloid grains. Gramineae and Potentilla grains appeared to be well preserved; but equally, often thinned and broken Filicales spores could also be relatively uncorroded.

From the evidence reviewed in the preceding section it would appear quite likely that both birch and hazel could have grown on Lewis. The over-representation of Betula or Coryloid pollen compared to Alnus or Pinus seems unlikely (see Table 1). The inference made here is in agreement with the reconstruction of McVean and Ratcliffe (1962, Map B), but the exposed situation of the peat cutting from which the peat column was taken raises the question of how 'sheltered' (Birks and Madsen 1979) a suitable location for the growth of birch and hazel needed to have been. The valley on its southern side slopes relatively steeply down to the burn and this probably afforded sufficient shelter for the trees to become established. Once this had occurred the trees would then offer shelter to later saplings and by this process a general cover of at least scrub resulted. The presence of burnt plant remains at each level in the zone implies that already any natural scrub may have been affected by man's activities, but there is no time-scale by which to date the spectra here. The local stands of hazel and birch inferred from the pollen record at Little Loch Roag were formed by c. 7700 b.p. (5750 b.c.); the first occurrence of carbonised plant material was at c. 3900 b.p. (1950 b.c., Birks and Madsen 1979 and see Fig. 6 above). The early beginning for the consistent record of such remains at Loch Maree (just prior to c. 8250 b.p., 6300 b.c.; Birks 1972b) has been referred to above (pp. 72-73).

The sum of the Betula, Coryloid and Betula/Coryloid percentages at the lowest level is 59%; at the two above, both are 91%. These, together with the high amounts of fern spores, make it most likely that the woodland or scrub was growing at least close to the sampling site, certainly in the case of the upper two levels. The Calluna pollen probably originated either from cleared areas supporting heath vegetation or from ground too exposed for tree growth.

The Plantago lanceolata that is represented may have been growing along the cliff edge, but since there is no other pollen type in the record which may have derived from that habitat specifically, it may indicate pastoral farming. The pollen percentages are relatively small (2.1, TLP=95; 1.4; and 1.0%), but comparable to those of the continuous record interpreted by Johansen (1978) as anthropogenic and local to Shetland, that is, not the result of long-distance transport.

The landscape around the site during the time of zone S-1 may be envisaged as mainly of scrub or woodland, perhaps with heath and grassland in the vicinity. It would have differed from the vegetation surrounding Little Loch Roag before c. 4000 b.p. (c. 2000 b.c.) in that at Sheshader it would appear that the sampling site is closer to, or possibly covered by, hazel and birch scrub rather than at some distance from such vegetation. The beginning of the continuous Plantago lanceolata curve at Little Loch Roag was dated at 5300 b.p. (3350 b.c.). There had been an expansion of Calluna heath at 7700 b.p. (5750 b.c.) and although the percentages of Calluna pollen fluctuate thereafter, being more and less than 10%, until 3900 b.p. (1950 b.c.) after which date it is generally never less than this value, it could clearly have been an important component of the vegetation before the 4th millennium b.p.

Zone S-2 (182.75-178cm; before 3700 b.p./2200 B.C.)

The vegetational change inferred from the two spectra of this zone marks a transition between the scrub or woodland thought to have existed during the period of the first zone and the start of blanket peat formation with its characteristic communities at the beginning of zone S-3. By the end of zone S-2 the amount of scrub or woodland had been very much reduced, the extent of heath was increasing and grassland used for grazing was apparently the most common vegetation type around the site.

As during the time of the previous zone, the record of carbonised plant remains hints at human activity in the area and because the very high percentages of *Plantago lanceolata* pollen and also the small peaks of Compositae pollen suggest that animals were grazing at the site, believed to have been formerly wooded, the case for deliberate clearance has good supporting evidence. The chambered cairns north and east of Stornoway and on the Eye Peninsula (see Map 2 for the latter) perhaps indicate settled occupation in this part of Lewis in the 5th millennium b.p. (3rd millennium b.c., Henshall 1974, 162). The porcellanite axe head found at Shulishader (see p. 85 and Map 2) probably belongs to approximately the same period (cf. Smith 1979, 19-20), and it is possible that the standing stone at Bayble is of similar age. Other finds that may be approximately dated to this time are the Cushion mace head from Knock (Smith 1979, 14-16) and the sherd (probably Neolithic, Cowie, pers.comm.)from Aignish. The chambered cairn at Flesherin may be, in some way, associated with a recently discovered field wall system (Cowie, pers. comm.). Whether the scrub was deliberately cleared or diminished due to factors of grazing and adverse climate, the soil conditions would have been altered so as to favour the process of podsolisation.

Without a time-scale for the deposition of pollen during zones S-1 and S-2 it is not possible to deduce the rate of vegetational change. Nor is it possible to deduce the status of the soil at the time a pollen assemblage was being deposited. However, accepting the argument of Dimbleby (1961a, see above, p.15), that where there are different pollen spectra clearly stratified, there is a consistent record of changing vegetation patterns (cf. Keatinge 1983, by implication), then the reconstruction offered seems a plausible one. Even if the soil was at some stage sufficiently basic to support an earthworm fauna, the process of pollen burial has resulted in there being distinctive pollen assemblages, comparing those of zone S-1 to those of S-2. The assemblages immediately above the iron pan (185cm) and below it (187.5cm) are almost identical, with the spectrum representing more open vegetation occurring at only 3.5cm above the upper one, at 181.5cm. The total thickness of the humose mineral soil above the iron pan is on average only about 7.5cm thick. Since there is a similar assemblage below the iron pan in a matrix of unbleached mineral grains, podsolisation must have begun after the scrub was established. Unless most of the predominantly mineral soil above 185cm within the leached part of the profile has accumulated after the reduction in scrub, which is most unlikely, the assemblage of 185cm has reached its present depth by perhaps a combination of processes resulting in downward movement. The assemblages of zone S-2 have subsequently been buried and are also now found in a matrix of bleached mineral grains. It cannot be stated with certainty either that the podsolisation began after the change to a grassland environment, or during the period of hazel and birch scrub. It may not have begun until the moorland with heather as an important plant in the community, started to develop at the end of this zone. The process would have been accelerated significantly by the spread of heather.

Zone S-3 (178-0cm; 3700 b.p.-?Present/2200 B.C.-?1980 A.D.)

In contrast to the assemblages of the preceding two zones, all the analyses of zone S-3 are from samples taken from blanket peat. The term 'blanket peat' is not used as a precise description (see Chambers 1982, 37-38); here it describes the peat that has acumulated above the mineral soil. There are difficulties in dating the initiation of blanket peat growth in a given region. Firstly, there is the possibility that highly humified and compressed peat at the base of a deposit may make the dating of a thickness of peat imprecise; and secondly, that the basal peat may not be representative of the earliest blanket peat in the region (see Edwards and Hirons 1982, Chambers 1982).

For the present discussion it is interesting to note that the date obtained from the base of the blanket peat (3671 ± 65 b.p.) is relatively shortly after the date for the decline of pine (c. 4000 b.p.) at Loch Maree, Loch Clair, Loch Sionascaig and Loch Assynt on the mainland and at Loch Ashik in SE Skye, which was associated with the growth of blanket peat, or an increase in the rate of its formation (see above Section V ia). The pine remains at Achiltibuie (50ft, 15m; Lamb 1964) and on Lewis (Wilkins 1984); and the decline of pine pollen values at Duartbeg (50ft, 15m; Moar 1969b) are of broadly similar date. Also, the first carbonised plant remains to be recorded from Little Loch Roag on the west of the island occur at about this time (c. 3900 b.p.) and from then, the percentage (TLP) of _Calluna_ pollen is typically more than 10% (Birks and Madsen 1979, see Fig. 6 above). If there had been deliberate clearance which promoted podsolisation and the development of a hard iron pan in the soil between the time of the spectra of zones S-1 and S-2, then part of the reason for the start of blanket peat growth is probably accountable to man.

Since all the samples for the pollen analyses of zone S-3 were taken from a blanket peat it is not surprising to find that throughout the zone various types of moorland (as loosely defined by Pearsall 1971, 140) are represented. The growth of pine, birch or willow could possibly have occurred if the peat was sufficiently dry and the moorland neither grazed nor burnt, but all the indications are that both these processes may have been important factors in producing the different assemblages grouped as subzones S-3a-f. Where heather was growing as the dominant species a 'swamping effect' (Tinsley and Smith 1974, 555) may have caused its over-representation, but it is thought that most of the pollen arriving at the site during the period of zone S-3 would have been derived from at least the area represented in Map 2i. The pollen rain falling onto the site would therefore consist of the local, extralocal and regional components (after Janssen 1966), with the first two components being relatively more represented than the last.

Subzone S-3a (178-150.25cm; 3700-2800 b.p./2200-1100 B.C.)

The transition to moorland with heather, grasses and tormentil (presumably represented by the *Potentilla* pollen) is reflected in the first assemblage of the subzone. The abundance of tormentil appears to be inversely proportional to that of heather during the zone (S-3) as a whole, probably indicating a reduced canopy of the heather plants due to grazing or burning. Generally the carbonised plant remains are very small and could well have blown onto the peat surface from the surrounding moorland, rather than necessarily being the result of burning at the sampling site. Occasionally small pieces of wood charcoal were noted in the sieve residues (see Diag.2), but at only one level of the main profile (169.5cm) during this subzone was there evidence that burning had occurred very locally. At this level a darker band about 2cm thick was discernible in the peat. By the time of the end of the subzone, heather had established dominance over grass, but a mosaic of areas having heather or grass dominance may be a truer description of the moorland vegetaion in the vicinity at any one time. In this respect, the reciprocal behaviour of the percentages of grass and heather pollen in samples collected at random from moorland of which areas had been burnt the year before, may be partly analogous (Tinsley and Smith 1974). The presence of Cerealia-type grains (see Appendix 4 iia), the records of *Plantago lanceolata*, *Rumex acetosa/acetosella* (sorrel/sheep's sorrel), *Ranunculus* (buttercup), *Trifolium* (clover) and Compositae (daisy family) could all be the result of farming having been practised near to the moorland, which itself would probably have been used for grazing.

The total pollen concentration is at its maximum value at the end of the subzone, the majority is *Calluna* pollen, but as also indicated by the relative percentages, the amount of grass pollen (per ml of sediment) has increased by this time.

Subzone S-3b (150.25-144.25cm; 2800-2600 b.p./1100-800 B.C.)

The marked increase in the percentages of Gramineae pollen on the relative diagram is accompanied by a decrease in the absolute concentration of *Calluna*; whereas the highest concentration of Gramineae in this subzone is not much greater than the last values of the previous one, when the concentration of *Calluna* was about twice that value. The change to moorland dominated by grasses, represented here, was completed within 40 years on the basis of the estimated time-scale. The data are slight, but they suggest that the spectra are reflecting management that favoured grasses by causing the growth of heather to decline within a comparatively short time. Perhaps an explanation for this, if the grass then present was the second choice (after heather) of the sheep or cattle, is that the heather was selectively reduced by over-grazing (cf. Gimingham 1972, 184). At two of the three levels in the subzone (147 and 151cm, the levels of the two peaks of Plantago lanceolata), no carbonised plant remains were recorded, so that the reduced burning, or its absence, may have made the heather effectively less competitive. The modal size of the Gramineae grains at the level of the highest Gramineae percentage (level 148cm) was c. 30µm (maximum diameter, M+), having an annulus of c. 6µm. However, this is insufficient information to distinguish whether the species of grass in question was of relatively good grazing quality or of poor (e.g. perhaps Festuca ovina (sheep's fescue); or Molinia caerulea, Nardus stricta (mat grass) or Deschampsia flexuosa (wavy-hair grass); see Table 2). The single high value of Cyperaceae pollen may point to wetter soil conditions at the site. The buried field wall was possibly in use during this period (c. 300 years) of dominant grass and so associated with the prehistoric heath management inferred above (see also pp. 110-113). The spectrum of herbs, including Cerealia-type grains, is similar to the previous subzone, implying the same sort of land use nearby. The two peaks of

Plantago lanceolata pollen could be due to grazing more locally to the site, now that the shade of many heather plants had been reduced.

Subzone S-3c (144.25-127.5cm; 2600-2100 b.p./800-0 B.C.)

By the time of the first assemblage of the subzone the moorland vegetation has reverted to one dominated by heather. The estimated time-scale indicates that this occurred within 200 years (compare the marked change to grass domination at the opening of the previous subzone). The relative percentages of Calluna pollen are the highest of any zone and the two absolute values are slightly less than the maximum of subzone S-3a, but higher than the rest of that subzone. As noted above, when the Calluna percentages are very high, the percentages of Potentilla are correspondingly lower. The growth of sedges was limited and no Sphagnum spores were recorded. Taken together, the evidence suggests drier soil conditions with heather growing well, to the partial exclusion of tormentil. The heather dominance could have been deliberately sought by burning and, once again, the presence of carbonised plant remains in the peat probably reflects this. There are two records of Cerealia-type pollen (found by scanning the slide and not included in the pollen sum, see Appendix 4 iia). Plantago lanceolata continued to grow in the grazed areas of the vicinity.

Considering subzones S-3a-c as a whole, the pollen record may perhaps be regarded as showing that whilst some sort of heath management contributed to the fluctuations between *Calluna*, Gramineae, perhaps Cyperaceae and *Potentilla* pollen; the comparatively high percentages of *Plantago lanceolata*, the record for *Rumex acetosa/acetosella* and a number of other herbs (*Ranunculus*, Caryophyllaceae ('pink' family), *Trifolium*, *Lotus* (trefoil) and Compositae) most likely reflect agricultural activity elsewhere (cf. Behre 1981). This may have included some cereal cultivation (see Appendix 4 iia).

It is almost certain that the construction of the field wall belongs to this period (subzones S-3a-c), on account of its stratigraphical position, the pollen record from the peat beneath and above it, and from the radiocarbon date of peat taken from directly under a basal stone (see sub-section iib, below).

Subzone S-3d (127.5-43.5cm; 2100-700 b.p./0-1400 A.D.)

There are few herb pollen types for the period represented by this subzone, apart from Gramineae, Cyperaceae, *Plantago lanceolata* and *Potentilla*. Overall, Cyperaceae pollen has increased in comparison with the previous three subzones, at the expense of *Calluna*, which may imply that the peat was wetter than before. The abundance of *Sphagnum* spores is on average greater than previously. By interpolation between the mean calibrated dates at 119.5cm and 39.25cm, the rate of peat growth during most of this subzone is more than 2.5 times the earlier rate (i.e. 14.1 years/cm, as opposed to 40.4 years/cm). The percentage of *Plantago lanceolata*, declines from 3.8%, at the first level of the subzone, to 0.5% at its last. There is a small increase in tree and shrub pollen, mainly *Betula* and Coryloid respectively.

The lack of herb pollen types indicating possible agricultural activity, except for *Plantago lanceolata*, perhaps signifies that the degree of grazing in the region nearby was less than before; but that, nevertheless, the *Plantago lanceolata*, was growing on land that was progressively less utilised for grazing towards the end of the subzone. Being a species whose pollen seems to disperse widely (cf. Tinsley and Smith 1974, 564), its representation may reflect grazing in a wider area than the other indicator herbs. A similar argument may apply to the small increase in *Betula* and Coryloid pollen and therefore that birch and hazel were able to establish themselves in other areas where perhaps grazing was now less intensive.

A wetter climate may have prevailed so that the rate of peat formation was more rapid and sedges more common. The record of burnt plant remains persists and so even if less productive for feeding than at the highest values for *Calluna* pollen in subzones S-3a and S-3c, intentional burning of the moorland was probably still practised.

It is not known for which period, or periods, the duns of the area (see Map 2) provide evidence of occupation, but they probably date to within the time represented by the later part of the subzone S-3c, and S-3d (cf. Feachem 1977, 175; 177).

Subzone S-3e (43.5-12.75cm; 700-200 b.p./1400-1800 A.D.)

The time-span of this subzone, if correctly deduced, approximately corresponds to the Little Ice Age (Lamb 1977, 449-473), of which an increased rainfall, compared to earlier centuries, was characteristic. The dominance of Cyperaceae pollen is pronounced and the growth of heather is apparently somewhat reduced. Tormentil, however, does not seem to have benefitted from this reduction, perhaps because sedges now occupied some the herb canopy space formerly dominated by heather. The record of *Erica tetralix* seeds indicates the actual presence of the species at the site and coincides with ericaceous pollen (other than that of heather) found at that level (20cm). It is likely that this species was present where ericaceous pollen is recorded at previous levels in subzone S-3d and is a sign that the peat was comparatively wet at these times.

The peat during the greater part of this subzone is lighter in colour and thus perhaps less humified (in spite of the 'humo' value of the sediment description) with the probable remains of *Eriophorum* sp. (cotton-grass) more abundant than previously. The qualification with regard to the rate of peat growth must be included because it may be that the top of the sequence has been cut away or disturbed (see Photo.8). The rate between the uppermost radiocarbon date and the surface (assuming it to be the natural one at c. 1980 A.D.) is 16.7 calendar years/cm, which is close to the earlier rate of 14.1 calendar years/cm.

As before, the presence of carbonised plant remains suggests that some form of moorland management may have been practised, but the percentage of Plantago lanceolata pollen has become minimal at the level of the last assemblage of subzone S-3e.

Subzone S-3f (12.75-0cm;?200 b.p.-?Present/?1800-?1980 A.D.)

The comment concerning the possibility of the peat having been disturbed applies equally to this subzone as to the previous one. The two assemblages of subzone S-3f are separated by only half a centimetre and the term 'subzone' is really used as a way of describing the division, mainly made for convenience of discussion. If the time-scale is valid, then it may be said that the assemblages belong to a time within the last three, possibly even one, hundred years.

Ecologically, two components are combined in both spectra. There are still the spectra from the moorland, as throughout the zone; but there are again several pollen types characteristic of flora associated with agricultural activity (cf. subzones S-3a-c). In addition, the pollen rain from trees and shrubs, perhaps coming from a wider area, is almost negligible.

Of the moorland component, sedges are no longer important; heather seems to be dominant with a high relative pollen percentage at 6.5cm and a percentage that is depressed by the peak of Cerealia-type pollen. Of the 'agricultural' component, the percentage of Cerealia-type pollen is very high and with it are relatively high values for *Rumex acetosa/acetosella*, *Artemisia* (mugwort); cf. *Rumex crispus* (presumably dock), Caryophyllaceae, *Polygonum persicaria* (persicaria) and Compositae (both Liguliflorae and Tubuliflorae) pollen are present. The percentage of *Plantago lanceolata* is more than for a considerable time previously (since approximately the first half of subzone S-3d) at 5cm, but not as great as the highest percentages in subzones S-3a-d.

The virtual absence of tree pollen makes it reasonable to compare the cereal percentages with those obtained by Vuorela on the basis of NAP at a site chosen in order to study the behaviour of the agricultural pollen record in relation to the history of cultivation on the Island of Retula, Finland (Nunez and Vuorela 1979). The *Sphagnum* peat bog there is almost encircled by fields whose edge is from between 100 and 320m from the sampling site. The vegetation of the bog surface today is dominated by *Sphagnum* with heath (*Calluna vulgaris*, *Vaccinium uliginosum* (bog whortleberry), and *V. oxycoccus* (cranberry)) of increasing importance towards the edge. At the sampling site the bog is without trees, whereas the growth of stunted pine trees surrounding the clearance gradually becomes dominated by birch and pine towards the fringes of the bog. The fields are then around these. By considering the fluctuations of cereal pollen as the percentage of NAP, for an analogy with the treeless vegetation at Sheshader, it is seen that during the first part of the 19th century (if correctly interpreted), the maximum peak of cereal pollen is 35% NAP (7% NAP + AP). It is thought that the peak of cereal pollen may to some extent be attributable to the cultivation of rye (*Secale cereale*), 'which was still the dominant grain during the first half of the nineteenth century', and is a wind-pollinated species. The least distance between the sampling site at Sheshader and the village field boundary separating the infield from the common grazing is about 25m.

A sample of 25 cereal grains from level 5cm were measured and the results are given in Appendix 4 iib. Bere (*Hordem vulgare*), oats (*Avena sativa* and *A. strigosa*) and rye have all been cultivated on Lewis; and in the recent past artificial fertilisers may have been added to the soil (see Reports in Moisley 1961 and Caird 1959). Bere, rye and the bristle oat (*A. strigosa*) are traditional crops of the machair (Grant 1979, 530); the last was perhaps sown on more acid soils in the past (Findlay 1956, 18) and was grown on lazy-beds (Darling and Boyd 1969, 64). The pollen of rye is characteristically 'prolate' in form Faegri and Iversen (1975, 256), with the pore positioned laterally and distinguishable from other cereal types. Bere is excluded as a possibility here, having grains whose overall size and annulus are too small. The cultivated oat, or bristle oat are more probably represented than the wild oat (*Avena fatua*), which is unlikely to have grown in such profusion so as to give the very high percentage at 5cm. The measurements of annulus and pore size fit those of the cultivated oat, although the average 'pollen size' and maximum diameter (M+) are larger, which may be due to crumpling.

Perhaps the best interpretation of the spectra of subzone S-3f is that whilst the moorland remained predominantly of heather and grass the area around the village was used for arable or spade cultivation and both pollen of oats and weeds of agriculture were blown onto the moorland. The cereal pollen percentages are very high and so some other explanation may be the true one for these assemblages. The very small percentages of tree and shrub pollen compare with the recent (last c. 300 years) vegetational history inferred from sites on Skye (Birks and Williams 1983, see above pp. 74-77.

b) Field-Wall Analyses and their Correlation with those of the Main Profile

The position of the samples taken for pollen analysis from the peat under, around and above the stones of the wall, as sectioned during excavation, is shown in Fig. 4 and less clearly on the pollen diagram. The samples analysed from beneath the base of the wall are assumed to be from undisturbed peat. At higher levels, the peat may have been disturbed during the construction of the wall or during any subsidence of the stones after that time. It is not known exactly how the wall was constructed, but it appears that it was built without any core of soil. The peat surrounding the stones is therefore in its present position relative to the stones, either due to subsidence or peat growth. If peat growth was occurring before the wall collapsed then this peat may have been disturbed subsequent to such an event. However, the cover of stones most likely prevented much plant debris being lodged within the stone construction and thus there may be no peat sampled that is contemporaneous with the use of the wall, or at least whilst it was standing intact.

In attempting to correlate the short sequence obtained from the field wall section, there are four principal lines of evidence: the relative pollen percentages, the absolute pollen concentrations, the radiocarbon dates from both profiles and the loss on ignition values.

There is a peak of *Calluna* at the 23cm level (the levels given here are the measurements from the top of the mineral soil to the base of the pollen sample), which could correspond to either of the high *Calluna* percentages of subzones S-3a or S-3c of the main profile. Compared to the spectrum from the darker band analysed in the main profile the spectra of relative percentages from the dark band analysed this profile (levels 6 and 7.5cm) have higher percentages of Gramineae and Cyperaceae, with *Sphagnum* spores at a much greater value at one level; but less *Calluna* and *Potentilla* pollen. Whether they may be considered as being from the same layer in the peat depends on how the pollen record is affected by the pollen rain from very local plants, but since the sequences are presumed to be from sites within 3m of each other, better agreement might be expected if they were contemporaneous. The relative pollen frequencies from the basal samples of each sequence are most different in the higher percentage of Calluna and lower percentage of Gramineae pollen in the field-wall profile.

The total pollen concentrations in the peat below the base of the wall (the lowest four samples) are greater than at any level subsequently. This is most likely due, in part, to the peat being more compressed under the wall, although eventually the additional weight of the stones would become a smaller proportion of the total weight of the peat that had accumulated above that level. At the four lowest samples of the profile the total pollen concentrations are more than at any level of the main profile, but thereafter they range from 12.7-46.1 x 10^4 grains/ml, compared to the range from the main profile of 11.2-36.3 x 10^4 grains/ml. There are very high pollen concentrations, of Gramineae pollen in particular, within the darker bands analysed (levels 6 and 7.5cm). This may mean that the darker colour is an effect of a slower rate of growth and higher degree of humification, as well as a result of there being carbonised plant remains present in the peat.

The position of the peat submitted for radiocarbon dating is shown on Fig. 5. The level corresponding to that date (2900 ± 100 b.p.; calibrated mean, 1175 B.C.), obtained by interpolation between two dates on the main profile, is marked on the pollen diagram. A difference in levels would be likely as the result of the greater amount of compression of the peat under the wall compared to that between the dated levels of the main profile. It is also possible that the wall may have sunk into the peat, but if built on dry moorland, any subsidence was probably not appreciable. In this case, the position of the date on the field-wall section is 4cm lower than its equivalent calculated for the main profile (see Diag. 2). The agreement between expectation and actual results is surprisingly good, considering the few dates and assumption of constant deposition rate. The deposition rate from interpolation between the lowest two dates on the main profile is 40.4 calendar years/cm; assuming the same basal date of 3671± 65 b.p. (2122 B.C., calibrated mean) for the field wall sequence (although the discrepancy in basal pollen assemblages noted above should be recalled), the deposition rate is 47.9 calendar years/cm (see Section III ii).

Accepting the validity of correlation between the profiles based on the radiocarbon dates alone, given that some degree of compression of the peat under the wall has occurred, the peak of *Calluna* pollen in the field wall profile probably belongs to subzone S-3a of the main profile. On the basis of the pollen spectra, the percentages of Gramineae following the *Calluna* maximum are higher than those of the main profile following the *Calluna* maximum of subzone S-3c; and the discrepancy between the level of the subzone S-3c/S-3d boundary (50.5cm) and the level halfway between the *Calluna* peak and its subsequent level in this profile (24.5cm) is too great to be accounted for by the factor of compression. The correlation of assemblages above the Calluna maximum of this profile is not obvious. Here the Gramineae percentages are higher than those of S-3c but not as great as the percentages of S-3b, whose maxima of Gramineae have not been detected in the field-wall profile. This would be expected if the activity represented by S-3b belonged to the time when the wall was standing. Another difference is the higher Cyperaceae values in this profile compared to those of S-3c. The assemblages of herb pollen types which are possible indicators of agriculture, including Cerealia-type pollen, recorded in the field-wall analyses suggest that they all belong within the period of subzone S-3a-c.

Apart from the possibility of the peat being disturbed, some of the differences might be due to very local effects, which if marked would invalidate any correlation based on the representation of local plants. In the region generally, any trends in the proportions of tree and shrub pollen record might be significant if a large enough amount of pollen was arriving at the site. Absolute tree and shrub pollen concentrations would not be affected statistically by the local pollen rain fluctuations, and have been plotted at a magnified scale (x10, see Diag. 2). Ignoring the results from the lowest four samples of the field wall sequence whose high concentrations are probably partly due to peat compression, there is no common trend in the concentrations (which are low and calculated from small numbers of pollen grains) suggesting any correlation.

Lastly, the loss on ignition values give no consistent record of significantly lower percentages due to mineral input. Vuorela (1983) has found that small changes (of the order of 2% within values ranging from 0 to 7.5% for three sites) due to increased mineral erosion do reflect regional activity, and in this case, with the main profile being so close to the wall, mineral particles in the peat might have resulted from the weathering of the stones in the wall, or even deposited at its construction. Slight deflections in the curve compared to the values above level 124cm may be noted below that level down to level 169.5cm.

VI Conclusion

Three general conclusions may be drawn from the results of the investigation. Firstly, the data provide additional evidence to that already published for there having been areas of natural woodland on the Outer Hebrides; and secondly, that it is likely that the activities of man have contributed to its destruction and hence, indirectly, promoted the growth of blanket peat.

On the same theme, it also seems likely that human activity continued to be an important factor in the modification of the vegetational pattern near Sheshader for the duration of the sequence presented above. At one stage, the form of moorland use, evidently required the construction of a field wall, which could be part of a much more extensive system (see Map 2).

Without further detailed pollen analysis it is not possible to be more certain as to the type of moorland in existence during the period when the wall was intact, however, it looks as if it may have been briefly dominated by grass (subzone S-3b). Even with further analysis an accurate correlation between the field wall and main profiles would not necessarily mean that the vegetation at the time of construction of the wall could be deduced, because of the possibility of the stones having sunk into the peat. A more precise dating of this time would require such correlation, but if, as is suggested above, the amount of subsidence was small, then the basal date of 2900 ± 100 b.p. (1175 B.C.) is a good indication of the date of construction, given the error on the mean determination and the rate of peat accumulation.

APPENDIX 1

Surface Samples from Torrs Warren

The three samples were collected from: Site 1, under oak scrub growing on a dune to the north of High Torrs Farm (see Photo. 4); Site 2, about 50m from Site 1 towards the sea, an open habitat, principally grassland; Site 3, about 200m from Site 1 in the same direction, locally an area of open heath, with *Calluna vulgaris* being dominant. The plants observed in the 5 x 5m plots sampled at each site, and some nearby, are recorded in Table 3 with their estimated cover abundance. The results of the pollen analysis are given in Fig. 7.

There is a high percentage of *Quercus* pollen deriving from the small scrub of oak. The percentage is much higher than those of *Calluna* (5%) and Gramineae (13%), even though both heather and grasses are locally abundant. In spite of there being grazed grassland in the general area inland, *Plantago lanceolata* is <1%.

The results from the second site show Gramineae at 65%, *Quercus* by contrast is down to 1% and is less than the contribution of *Pinus* pollen from surrounding plantations. *Calluna* is at 9%. The highest value of *Salix* (3%) for the three sites is in keeping with the estimate made of its abundance. Although there are sallows on the main slack area growing in dense clumps, here it is *Salix repens* pollen that is giving rise to the higher value. However, the values for this sample are somewhat distorted due to the large number of crumpled grains (34%), most probably Gramineae.

Lastly, the heath site has 86% *Calluna* pollen, Gramineae takes its lowest value (6%), as does *Quercus* (<1%). There are stands of

Table 3. Cover Abundance (Domin Values) of 5x5m Plots near High Torrs Farm, Torrs Warren.

Site Description:	Oak Scrub	Grassland	Heath
Site No.	1	2	3
n,nearby;c,catkins;+,present			
Calluna vulgaris	.	.	8
Erica cinerea	n	.	.
Quercus robur	c	.	.
Rubus fruticosus s.l.	4		
Salix repens	.	5	3
Gramineae	6	.	.
Aira praecox	+	.	.
Festuca ovina	.	8	
Poa annua	.		.
Carex arenuaria	.	3	3
Juncus cf. *articulatus*	.	3	
Luzula s.p.	3	n	3
Campanula rotundifolia	n	.	+
Cirsium palustre	.	3	.
Galium saxatile	3	.	.
Hyacinthoides non-scripta	n	5	.
Oxalis acetosella	n	.	.
Potentilla erecta	.	3	.
Ranunculus sp.		3	
R. acris	n	.	.
Rumex acetosa	.	3	.
R. acetosella agg.	n	.	.
Senecio jacobaea	3	3	.
Urtica dioica	n	.	.
Veronica chamaedrys	3	.	.
V. officinalis	3	3	.
Viola sp.	3	3	
Pteridium aquilinum	5	.	4
Campylopus introflexus			.
Ceratodon purpureus		5	.
Dicranum scoparium	9		
Eurhynchium praelongum			8
Hypnum cupressiforme			
Pleurozium schreberi			
Cladonia sp.	3	3	
Bare ground	4	5	

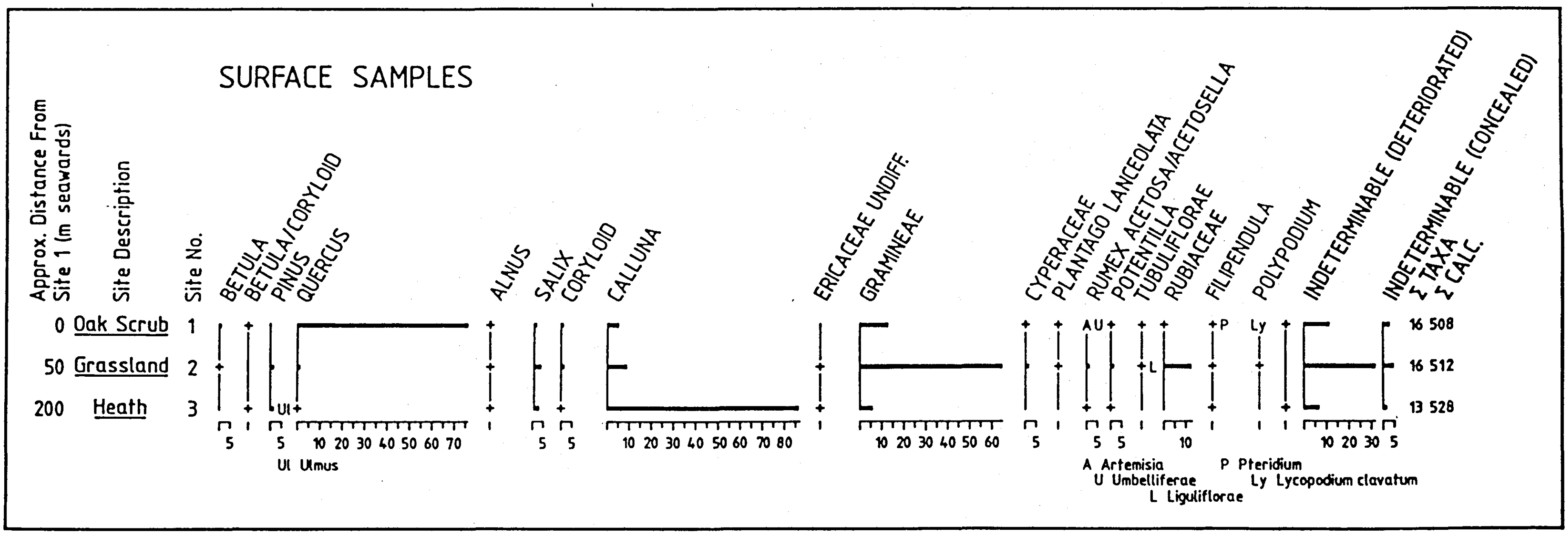

Fig. 7. Pollen diagram of the analysis of surface samples collected at Torrs Warren. The values are expressed as percentages of the calculation sum (Σ Calc.) of total land pollen, i.e. excluding spores. Values of 1% are denoted by +, or by one or two letters symbolizing the taxa represented. Σ Taxa is the number of taxa in Σ Calc.

birch trees in parts of the dunes, but in each of the surface samples *Betula* pollen is <2%.

APPENDIX 2

Absolute Pollen Counts

i) Torrs Warren

Initially tablets of exotic pollen or spores were not available for this work. Later it was possible to analyse certain levels with exotics added. The concentrations of pollen and spores are tabulated (Table 4) under the headings of the main groups of plants as they are divided on the pollen diagram, and calculated as described above (pp. 12 and 22). For levels 149.7, 145.4, 143.2 and 138.0cm, the concentrations of each pollen and spore type are shown on the diagram.

ii) Sheshader

Absolute counts were only made after a diagram of relative percentages had been drawn up for the main profile and additional samples had been obtained from peat at the position of the field-wall. Selected absolute concentrations from all the levels subsequently determined from both profiles are plotted on the diagram. The exotic used was *Lycopodium clavatum* (see specification below Table 4).

Zone	Depth (cm)	εPollen	εTrees	εShrubs	εDwarf Shrubs	εHerbs	Aquatic	εSpores	No. of Tablets	Exotic*	Volume (ml)
TW-6	24.0	1120.4	28.2	54.6	301.3	736.3	5.6	9.4	24	E	1.1
	34.5	178.2	53.0	17.4	33.3	74.6	-	12.9	24	L	1.0
TW-5	53.5	218.1	104.5	36.1	10.1	97.3	-	11.1	24	L	1.0
TW-4	101.0	299.5	69.9	20.7	8.9	200.1	-	26.3	24	E	1.1
TW-3	138.0	712.6	600.6	33.8	10.7	67.5	-	21.3	24	E	1.0
	143.2	464.2	236.1	8.0	2.7	217.4	-	9.8	24	E	1.0
TW-2	145.4	770.2	682.2	7.3	4.9	75.8	2.9	17.1	24	E	1.0
	149.7	533.8	441.8	16.4	3.3	72.3	3.3	13.1	24	E	1.0
	185.0	232.3	166.3	9.9	10.8	45.2	1.8	3.6	16	L	1.0
	190.7	189.9	132.7	11.1	13.0	33.2	5.2	8.5	16	L	1.0
	196.0	168.3	113.1	13.1	10.5	31.6	12.5	6.1	8	L	1.0

*Exotics supplied by Laboratory of Quaternary Biology, Tornavägen 13, S-22363 Lund, Sweden.

E = *Eucalyptus* (Batch No. 106720), grains/tablet = 13,550 ± 210 (1 standard deviation)

L = *Lycopodium* (Batch No. 201890), spores/tablet = 11,300 ± 400 (given as reliable working values)

Table 4. Absolute Concentrations from Torrs Warren, Expressed in Grains (or Spores)/ml $\div 10^3$.

APPENDIX 3

Pollen Stratigraphy of a 25cm 'Monolith' Sample from Torrs Warren

In June 1979, S J P Bohncke took a sample in a metal box (25 x 15 x 10cm) from the base of the same dune-slack deposit as that from which the main sequence has been obtained. The sample was 'from the bottom of a trench dug by an earthworking machine'. The exact depth is unknown 'because shortly after sampling, the profile face collapsed'. However, it was estimated that the total depth of the profile was about 2m. The location of the site was only a few metres from the later coring site (Robinson, pers. comm.), whose stratigraphy was not affected by the excavations (see Photo. 1). It was noted that the profile contained much wood and 'because of the presence of wood in the whole section, the local presence of carr vegetation right from the beginning is likely'. The bottom part of the sample is sand.

The pollen sequence (see Fig. 8) appears to show an open community of sedges, grass and heather, with other herbs, growing on the sand. It may therefore have been a pioneer community with sand sedge predominant. As the peat began to form, alder trees became established nearby, perhaps with the seed coming from a relatively local source. Gramineae pollen is at around 20%, although *Calluna* becomes reduced from its earliest two values. The Gramineae and *Calluna* percentages, with those of *Plantago lanceolata* (≤3%) and *Rumex acetosa*/*acetosella* (≤2%) and the presence of *Lotus*, *Trifolium* and Campanulaceae, amongst other types from herbs characteristically of open habitats, suggest that the alder canopy was not closed, or that the vegetation of areas

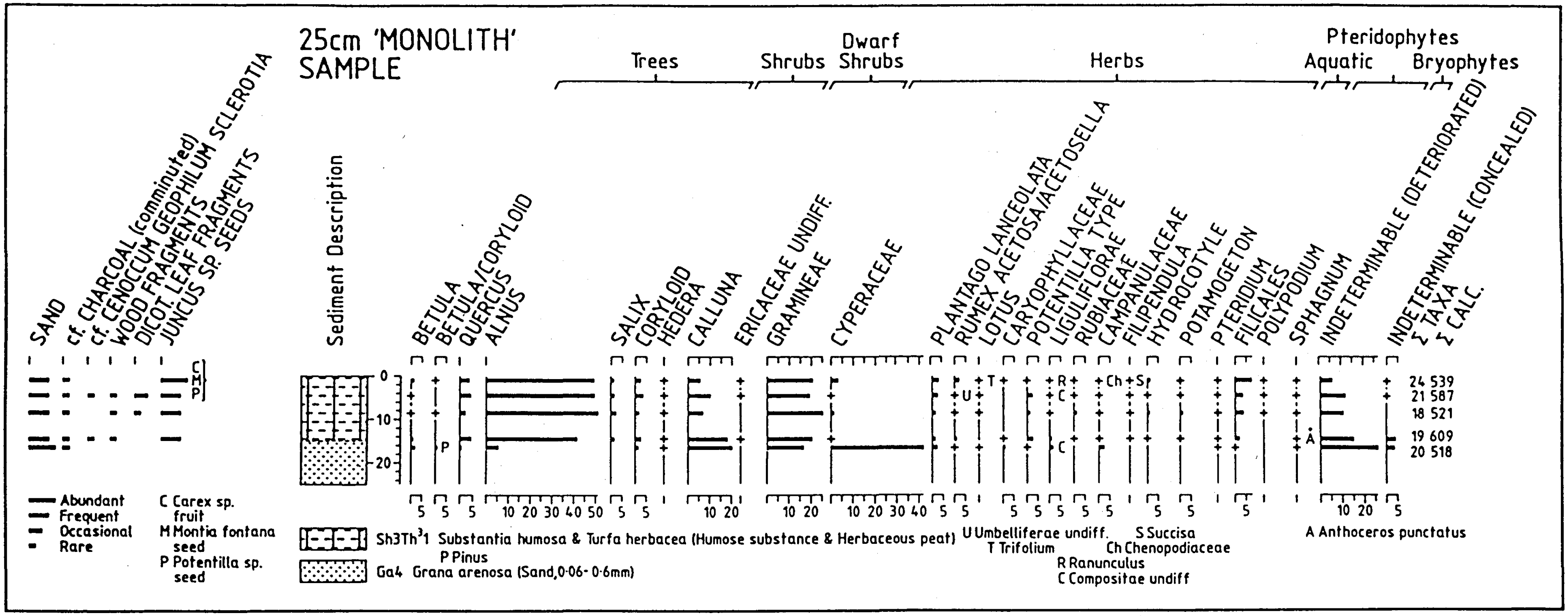

Fig. 8. Pollen (and macrofossil) diagram of the analysis of a 25 cm 'monolith' sample collected at Torrs Warren. The values are expressed as percentages of the calculation sum (Σ Calc.) of total land pollen, i.e. excluding aquatic and spores. Values of 1% are denoted by +, or by one or two letters symbolizing the taxa represented. ΣTaxa is the number of taxa in Σ Calc.; · signifies a record outside of those made whilst obtaining Σ Calc.

peripheral to the alder trees is being represented. Birch was not important locally, though oak may have grown with alder, or elsewhere in the vicinity.

The position of this sequence in relation to the main sequence is not clear. The highest values for *Alnus* pollen point to correlation with zone TW-3. Against this are the lower values for *Calluna* and Gramineae, and the higher values for *Quercus* in TW-3 than here. Also, if the spectrum from the top of the sand in the short sequence precedes a zone equivalent to TW-3, the *Quercus* value, being smaller than at any time before TW-6, makes a correlation with TW-3 less likely. Both *Quercus* and *Alnus* may be reduced due to over-representation by pollen from local sedges; nevertheless, a greater percentage of *Quercus* would be expected in view of the proximity of the sites. The remaining possibility is to place this short sequence prior to the main sequence. To do so implies another major change in the history of the vegetation around the site. The estimate of the depth of the profile would perhaps allow this and since the junction between sand and peat is c. 10cm from the bottom of the sampling box, this means that a sample has been taken which includes the peat at the base of the infilled depression.

APPENDIX 4

Cerealia-Type Grains

In the following discussion none of the measurements has been standardised with respect to *Corylus* grains (cf. Andersen 1979b). The definitions of the various dimensions measured and of 'pollen size' are given in Table 2 above.

i) Torrs Warren

The maximum measurements (M+) of the few large Gramineae grains in the Torrs Warren profile are listed in Table 5. No note was made of their state of preservation.

Inspection of the size ranges tabulated in Beug (1961, see Table 2) shows that those of three of the listed grasses commonly found on dunes: *Leymus arenarius* (lyme grass), *Elymus farctus* (named *Elymus arenarius* and *Agropyron junceum* respectively in the table) and *Ammophila arenaria* may overlap with those of cereals. This also applies to the size range of *Glyceria fluitans*. From these ranges it is perhaps most likely that the first two might be confused with *Triticum dicoccum* (emmer wheat) and *Avena sativa* (cultivated oat), rather than the last, whose average size is closer to those of *T. monococcum* (einkorn wheat) and the barleys: *Hordeum vulgare* (bere) and *H. distichon* (two-row barley). *Hordeum murinum* (wall barley), *Elymus repens* (listed as *Agropyron* cf. *repens*, couch-grass), or *Avena fatua* (wild oat) could also be represented. *Secale cereale* has a distinctive form (see the discussion of subzone S-3f in Chapter 3 above). The actual measurements are possibly exaggerated due to mounting in glycerine

Table 5. Measurements of Cerealia-Type Grains (>40μm) Recorded in the Main Profile from Torrs Warren.

Level (cm)	Size (M+), No. of Grains	Graticule division: R,3.6μm;W,2.8μm
9.5	54	R
16	42	W
24	43.2	R
53.5	54	R
61	46.8	R
113	46.8	R
135	43.2, 2	R
141	42, 2	R
143.2	43.2	R
152	43.2	R
185	43.2	R
217	43.2	R
224	44.6	R

jelly (Beug 1961).

ii) Sheshader

a) Subzones S-3a-c

During analysis of levels within subzones S-3a-c a record was made of Gramineae grains, which were larger than most. When it was realised that their occurrence might be of value as an 'indicator type' for correlating the field-wall sequence with the main profile, some of the slides already analysed were scanned by more closely spaced traverses. These records, the ones from routine pollen analysis and any other records noted when not scanning methodically, or from counts not otherwise used for the diagram have all been included on the pollen diagram and are given in Table 6.

The criteria used in attempting to distinguish cereal pollen grains from other Gramineae grains has been briefly discussed above (pp. 17-18). Here only the measurements M+, anl-D, pore-D have been made; thus the 'pollen size' of Andersen (1979b) cannot be calculated. The measurements were determined using a graticule having one division calibrated as equivalent to 1.51µm, at a magnification of x 520; and recorded to the nearest whole division in most instances. The sum of the annuli measurements may therefore be larger than was actually so, because those measuring closest to 5 divisions (=7.6µm) have been recorded as being 8.0µm.

Most of the grains are less than 45µm (M+); the three which are more than 44µm are crumpled (see Table 6). Although there is a range of sizes for any given species, lower limits of 38 and 8µm

Table 6. Measurements of Cerealia-type Grains Recorded in the Main and Field-Wall Profiles from Sheshader.

	Level (cm)	M+	Comments	anl-D	pore-D
Main profile	137.5	39	-	9	3
		39	-	9	2
	142.5	38	-	8	3
	148	38	crumpled	8	3
		38	crumpled	8	3
	150.5	42	broken	8	3
		41	-	9	3
	155	42	-	9	5
	158.5	42	-	9	3
		42	crumpled	9	3
	162	50	crumpled	-	-
Field-wall profile (Levels are in cm above mineral soil)	39	42	-	10	4
	34.5	45	crumpled	8	2
	30	38	-	8	3
	26	39	crumpled	8	3
		38	-	8	3
	22	42	crumpled	9	3
	19	42	-	8	3
	16	38	-	9	3
		41	broken	11	3
		51	crumpled & broken	9	3
		44		8.5	3

Table 7. Summary of Measurements of 25 Cerealia-type Grains Recorded from Level 5 cm of the Main Profile from Sheshader.

	Mean	Min - Max
M+, max.diameter	47.2	41.5-53.6
(M+ + M+)/2, pollen size	44.2	39.3-48.7
anl-D	11.8	9.1-13.6
anl-W	3.6	2.3- 5.3
pore-D	4.6	3.0- 6.0
M+/M-, pollen index	1.15	1.02- 1.35

for M+ and anl-D have been chosen for inclusion on the diagram. The mean value for M+ of 12 grains, not noted as being crumpled or broken, is 40.3μm; the mean value for anl-D is 8.7μm. For all the grains, the mean value for anl-D is 8.8μm.

From the species of Gramineae likely to have been growing at Sheshader and having large pollen grains, either Elymus repens or Hordeum vulgare is probably represented (see Table 2); but on the criteria of the mean size measurements, it is not possible to choose between them.

b) Subzone S-3f

Due to there being a large number of Cerealia-type grains at the levels of this subzone a sample of 25 grains was measured after the manner of Andersen and the pollen size calculated (but not standardised). The same graticule was used at the same magnification as previously, but the measurements were recorded as those corresponding to the nearest half division of the graticule. The mean values with their ranges are given in Table 7. All but one of the grains were crumpled to some extent.

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Photo.1. To the left (east), sand and peat are being spread to make even ground; to the right the bog is still intact. The cores were taken from a position close to the figure. The made ground now extends to the line of the fence posts approximately.

Photo.2. Birch trees colonising open heath. Beyond (to the north) is a section of the Forestry plantation.

Photo.3. Dilapidated building of High Torrs Farm. Oak scrub is growing on the dunes in the background (to the north).

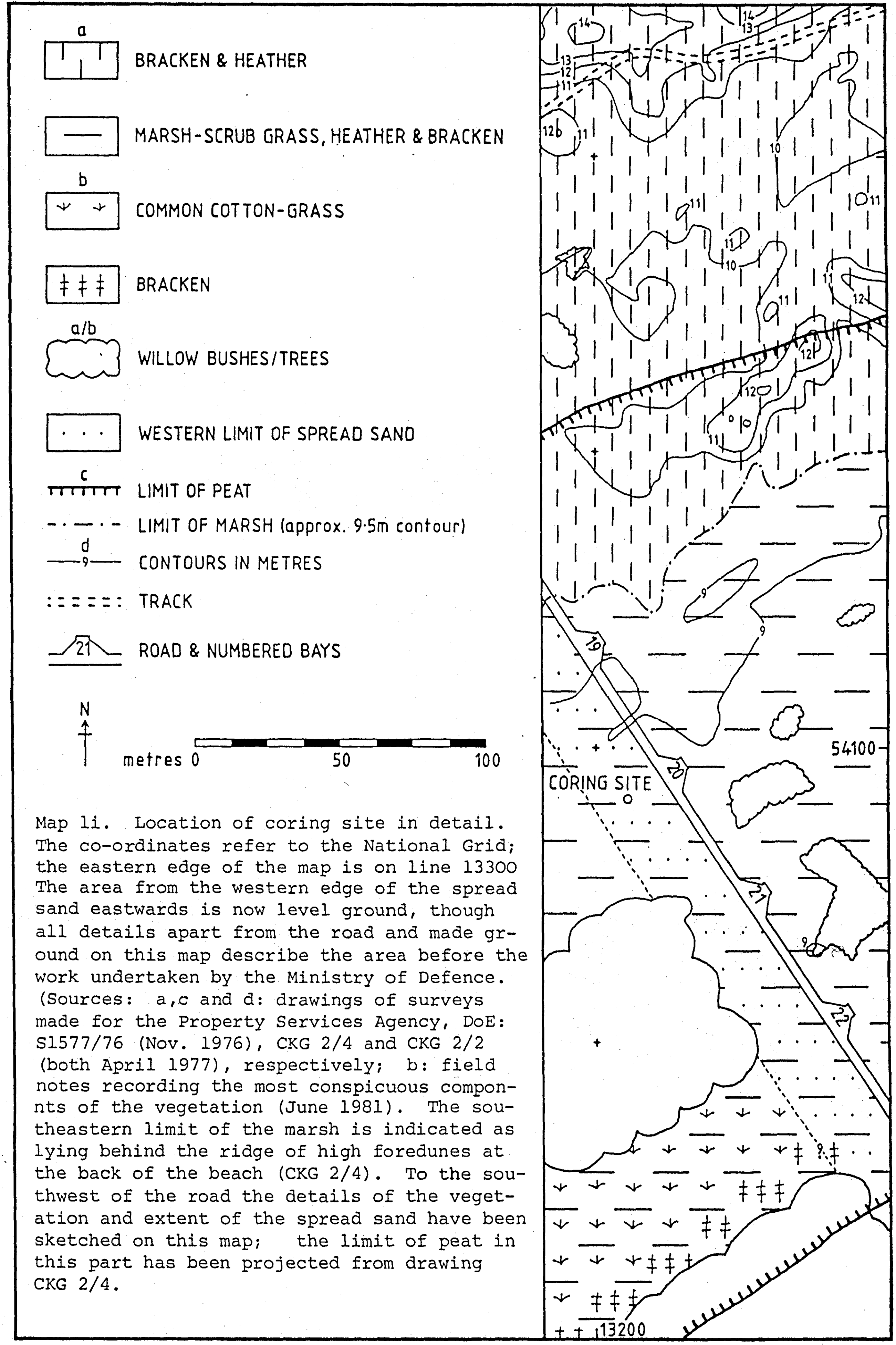
Photo.4. Eroded dune showing a fossil soil profile.

Photo.5. View of peat bank from the SW. The dried-out face has been cleaned where the wall occurs. The occasional stones in the middle ground mark the line of an unexcavated wall; those near the cleaned face have been removed from their original context during excavation. An area of re-seeded moorland can be seen in the middle background.

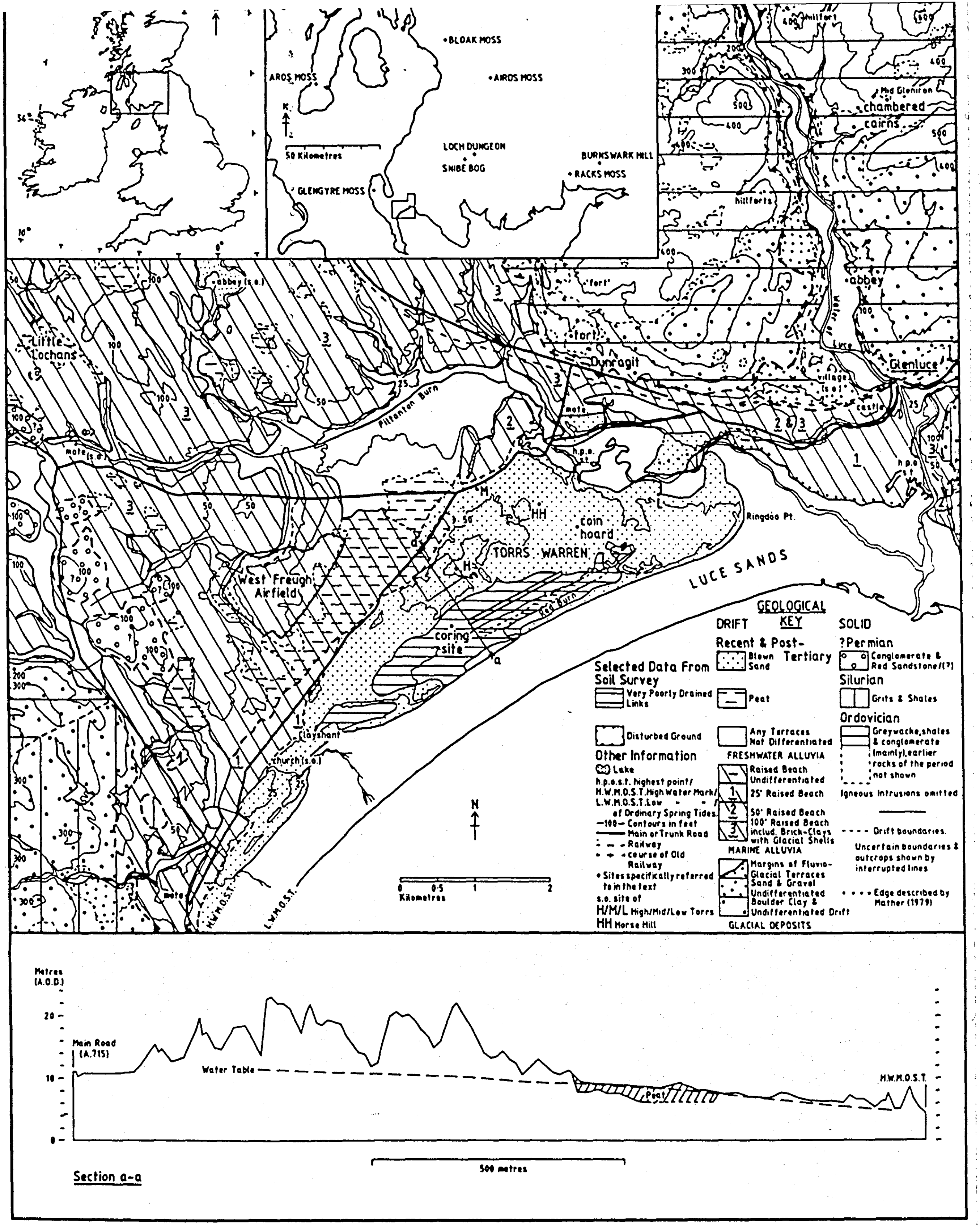
Photo.6. Soil profile showing a thin layer of peat overlying a humus-stained podsol formed in a parent matrix of fragmented rock and sand. The scale is 25 cm high.

Photo.7. Elevation of wall (as excavated in 1981) from the north. The stones are resting on a plinth of peat c.20 cm deep; elsewhere the top of the mineral soil has been exposed.

Photo.8. Closer view of the peat bank extant in 1983 and shown in Photo.5. The uneven surface of the ground at the level of the top of the bank is shown; in the foreground the upper ground is made up of turves thrown down from the top of the bank whilst it was being cut. The scale is 25 cm high.

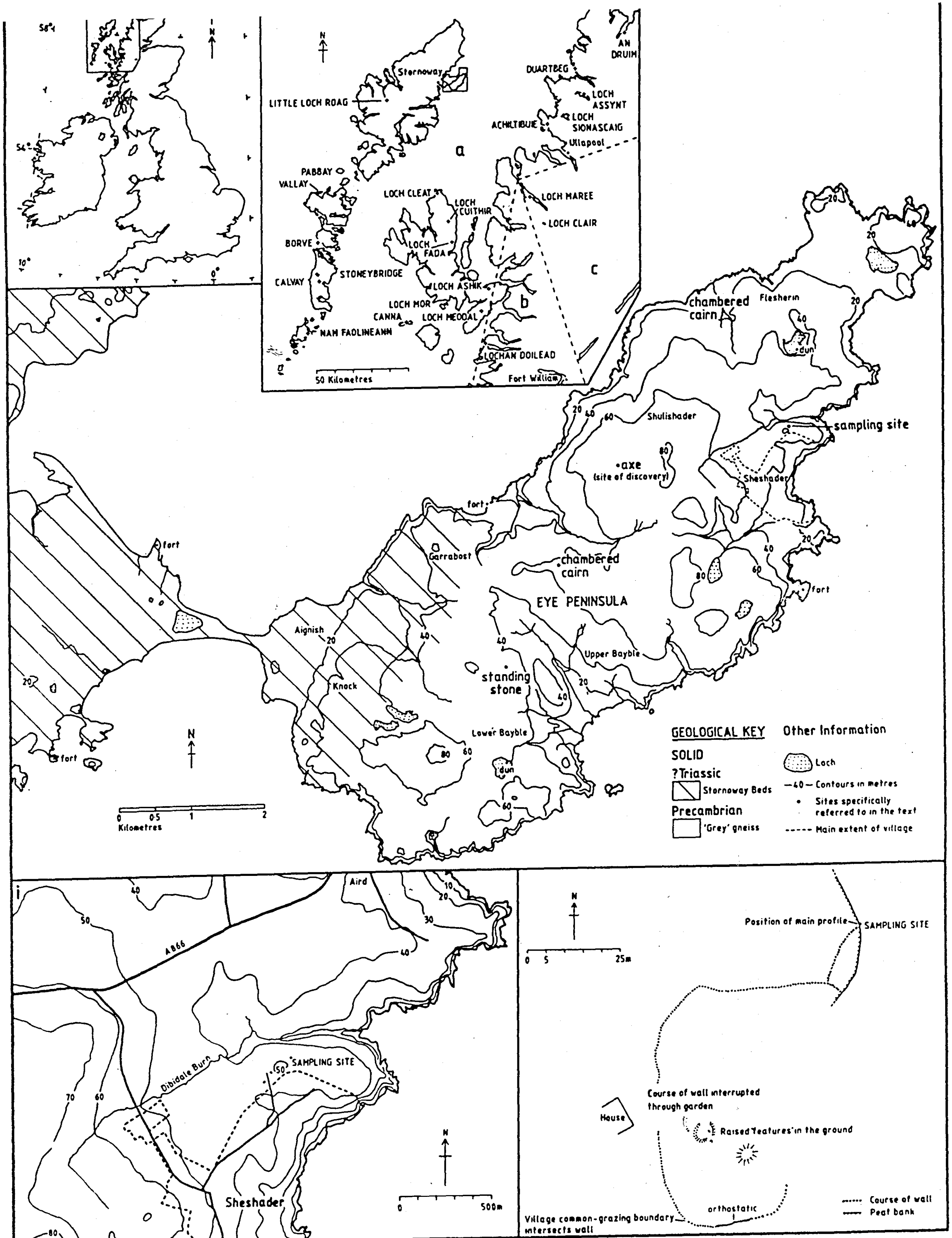


Map 1i. Location of coring site in detail. The co-ordinates refer to the National Grid; the eastern edge of the map is on line 13300 The area from the western edge of the spread sand eastwards is now level ground, though all details apart from the road and made ground on this map describe the area before the work undertaken by the Ministry of Defence. (Sources: a,c and d: drawings of surveys made for the Property Services Agency, DoE: S1577/76 (Nov. 1976), CKG 2/4 and CKG 2/2 (both April 1977), respectively; b: field notes recording the most conspicuous components of the vegetation (June 1981). The southeastern limit of the marsh is indicated as lying behind the ridge of high foredunes at the back of the beach (CKG 2/4). To the southwest of the road the details of the vegetation and extent of the spread sand have been sketched on this map; the limit of peat in this part has been projected from drawing CKG 2/4.

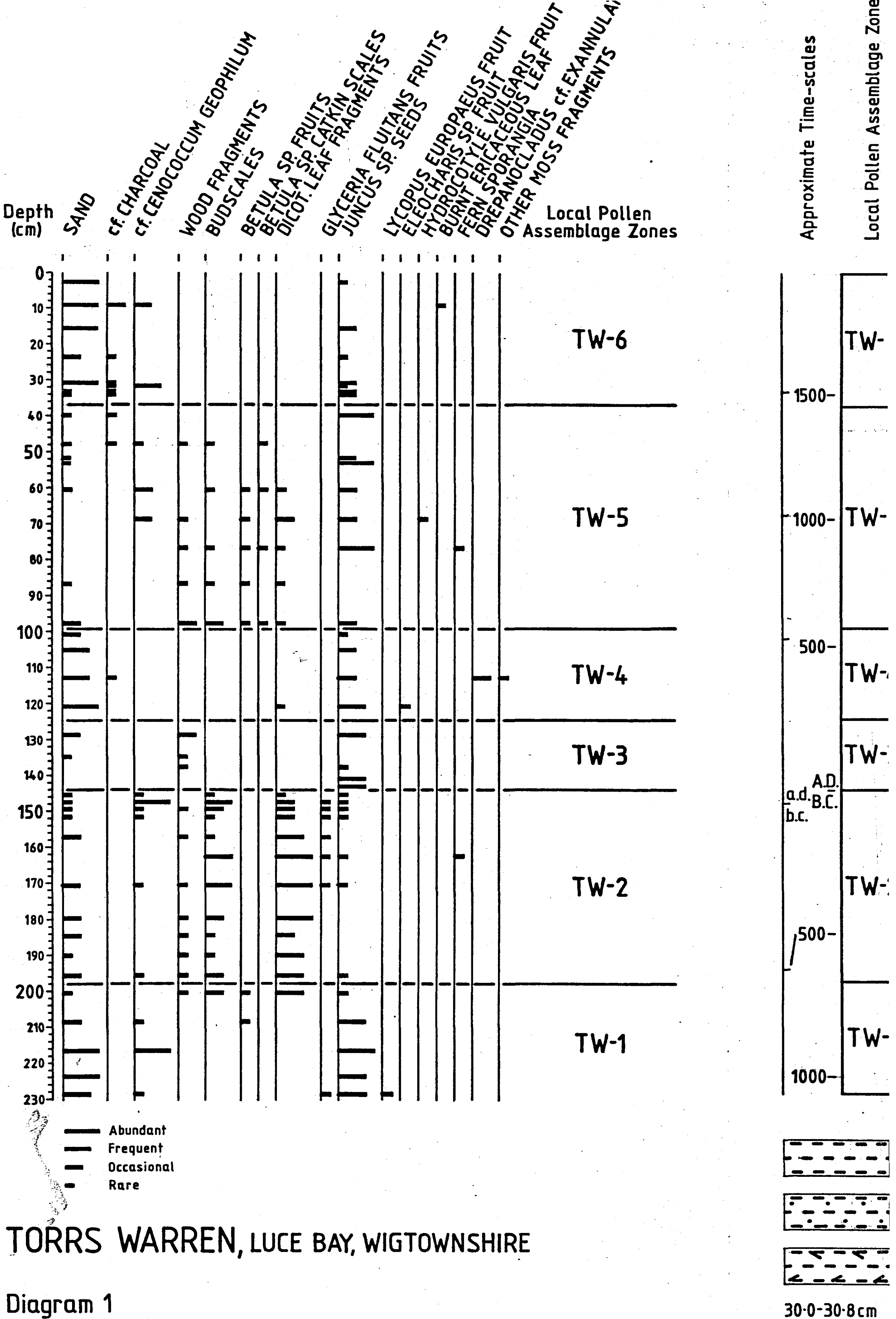


Map 1. Simplified solid and drift geology of Torrs Warren and its environs; the coring site and archaeological sites are also shown. Insert map shows sites of previous pollen analytical investigations in SW Scotland (Little Lochans is on the larger map) and a transect illustrates the topography of the dunes of the Warren. (Sources: O.S.1:2500. 1st.Series. Sheets NX05, NX15, N X16. I.G.S.1:63,360. Scotland. Sheets 3 and 4 (solid and drift editions). Soil Survey Scotland. 1:63,360. Sheets 1,2,3,4 and part 7. Transect from DOE (1975)). The area of recent archaeological excavations is indicated by a rectangle on the transect line a-a.

Map 1

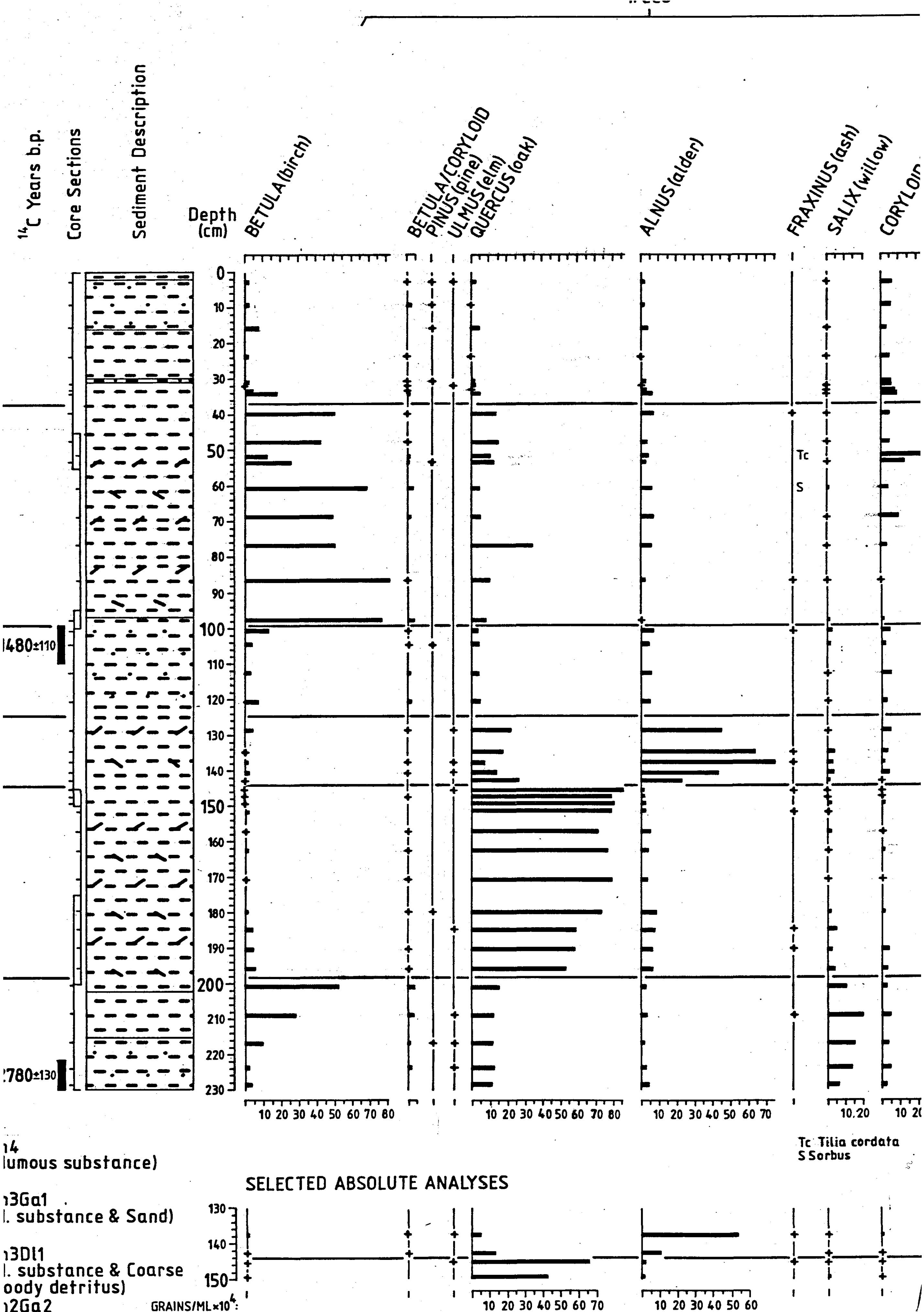


Map. 2. Simplified solid geology of the Eye Peninsula; the sampling site at Sheshader and archaeological sites are also shown. Inset maps show the topography of the site in more detail (i), the course of the field wall and the sites of previous palaeoecological investigations (the zones a, b and c are those of McVean and Ratcliffe (1962), see Fig. 2). (Sources: O.S. 1:2500, 2nd Series. Sheets NB 33/43 NW, NE, SW, SE. Geology from Smith and Fettes (1979). Field wall survey provided by T.G. Cowie).

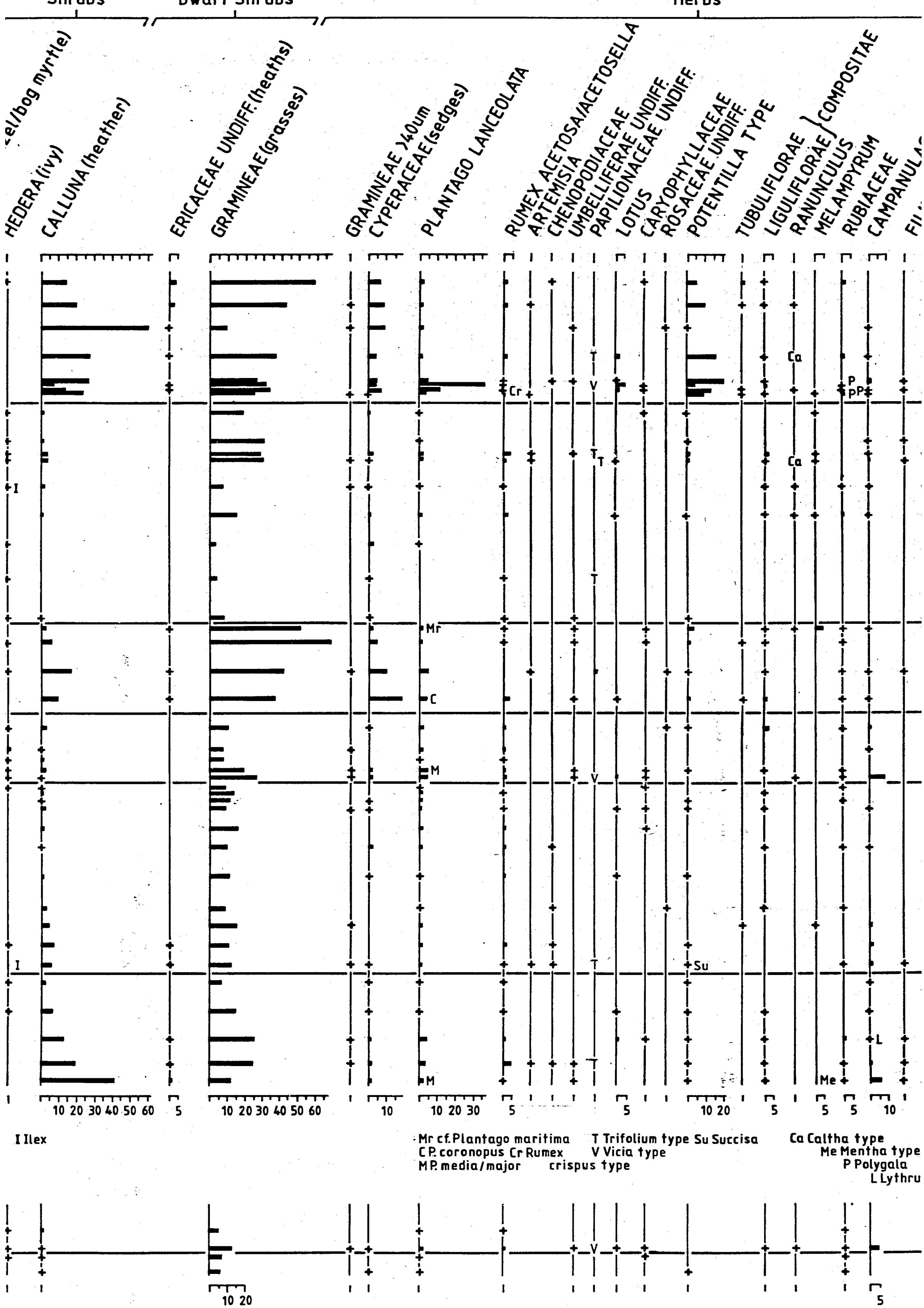


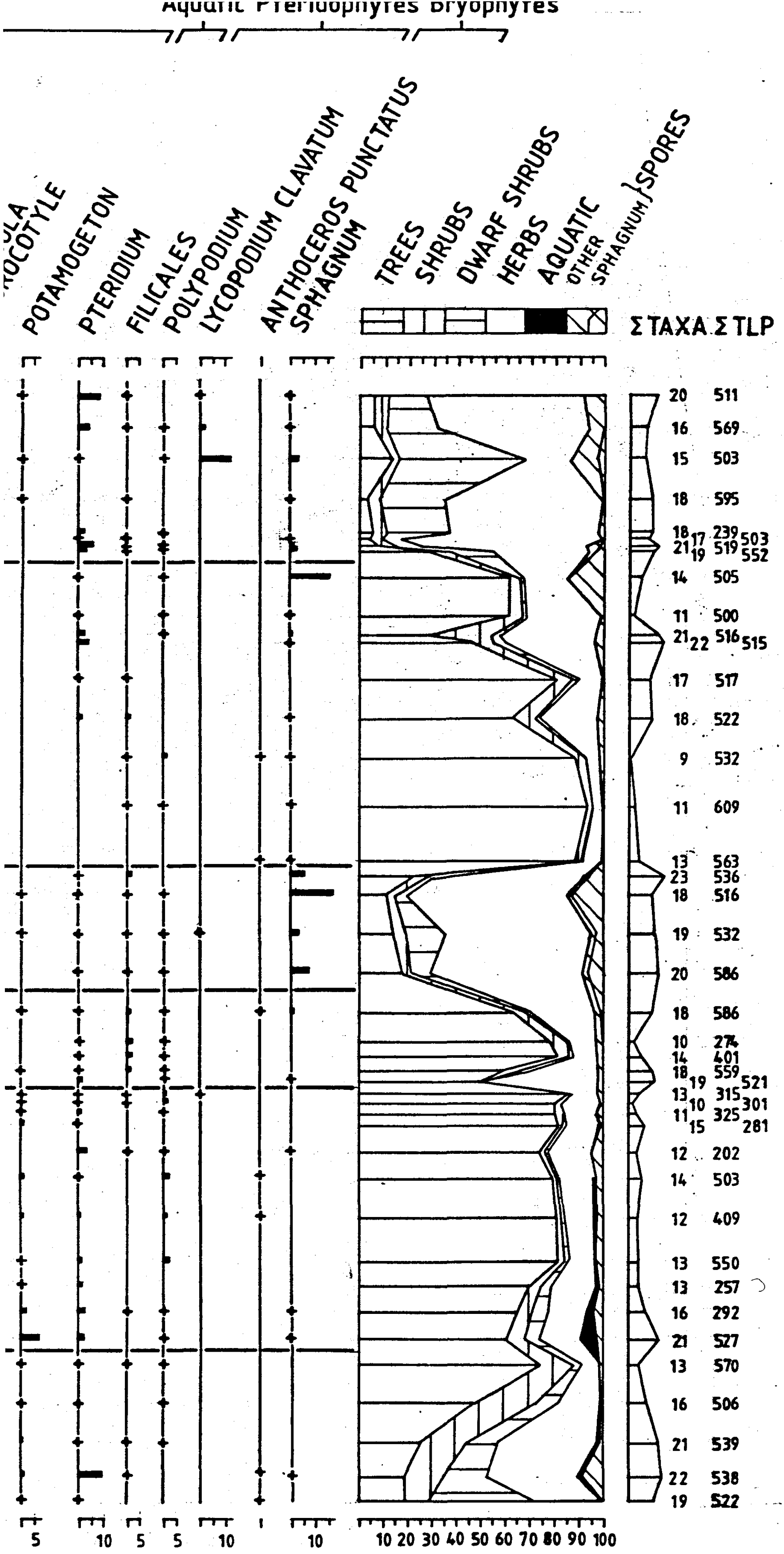
TORRS WARREN, LUCE BAY, WIGTOWNSHIRE

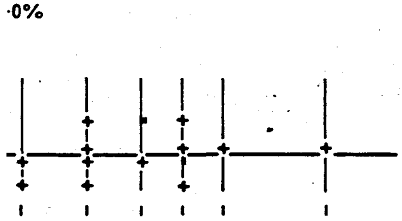
Diagram 1



¹⁴C Years b.p.
Core Sections
Sediment Description
Depth (cm)
BETULA (birch)
BETULA/CORYLOID
PINUS (pine)
ULMUS (elm)
QUERCUS (oak)
ALNUS (alder)
FRAXINUS (ash)
SALIX (willow)
CORYLOI
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
1480±110
2780±130
Tc
S
10 20 30 40 50 60 70 80
10 20 30 40 50 60 70 80
10 20 30 40 50 60 70
10 20
10 20
Tc Tilia cordata
S Sorbus
14
lumous substance)
SELECTED ABSOLUTE ANALYSES
n3Ga1
. substance & Sand)
n3Dl1
. substance & Coarse
oody detritus)
n2Ga2
130
140
150
GRAINS/ML×10⁴:
10 20 30 40 50 60 70
10 20 30 40 50 60


Shrubs
Dwarf Shrubs
Herbs
el/bog myrtle)
HEDERA (ivy)
CALLUNA (heather)
ERICACEAE UNDIFF. (heaths)
GRAMINEAE (grasses)
GRAMINEAE >40um
CYPERACEAE (sedges)
PLANTAGO LANCEOLATA
RUMEX ACETOSA/ACETOSELLA
ARTEMISIA
CHENOPODIACEAE
UMBELLIFERAE UNDIFF.
PAPILIONACEAE UNDIFF.
LOTUS
CARYOPHYLLACEAE
ROSACEAE UNDIFF.
POTENTILLA TYPE
TUBULIFLORAE
LIGULIFLORAE
COMPOSITAE
RANUNCULUS
MELAMPYRUM
RUBIACEAE
CAMPANULA
FI
10 20 30 40 50 60
5
10 20 30 40 50 60
10
10 20 30
5
5
10 20
5
5
5
10
I Ilex
Mr cf. Plantago maritima
C P. coronopus
M P. media/major
Cr Rumex crispus type
T Trifolium type
V Vicia type
Su Succisa
Ca Caltha type
Me Mentha type
P Polygala
L Lythru
I
Cr
Mr
C
M
T
V
Su
Ca
P
pP
L
Me
10 20
5

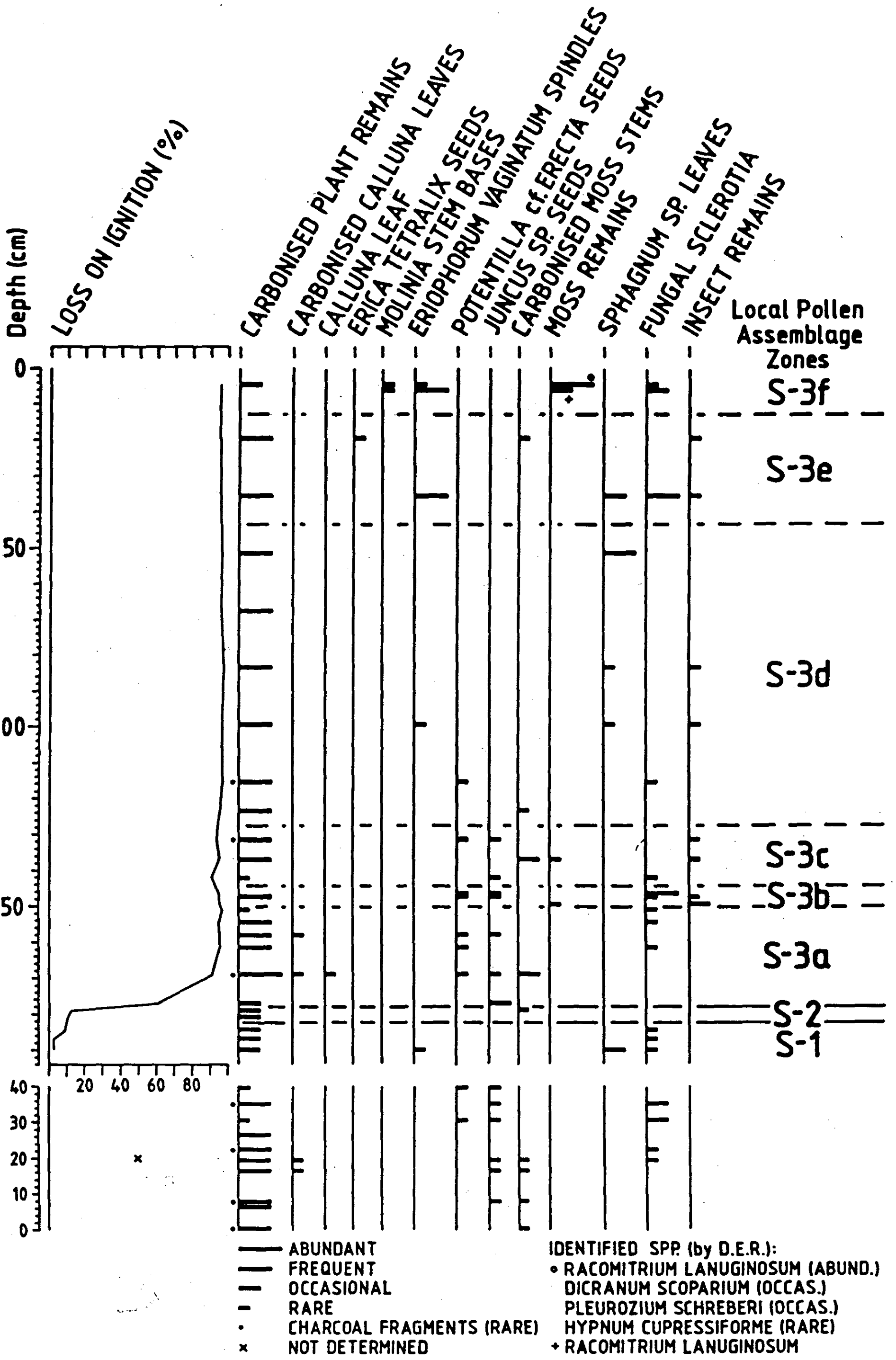




RELATIVE VALUES EXPRESSED AS %AGES OF TLP (TOTAL LAND POLLEN)

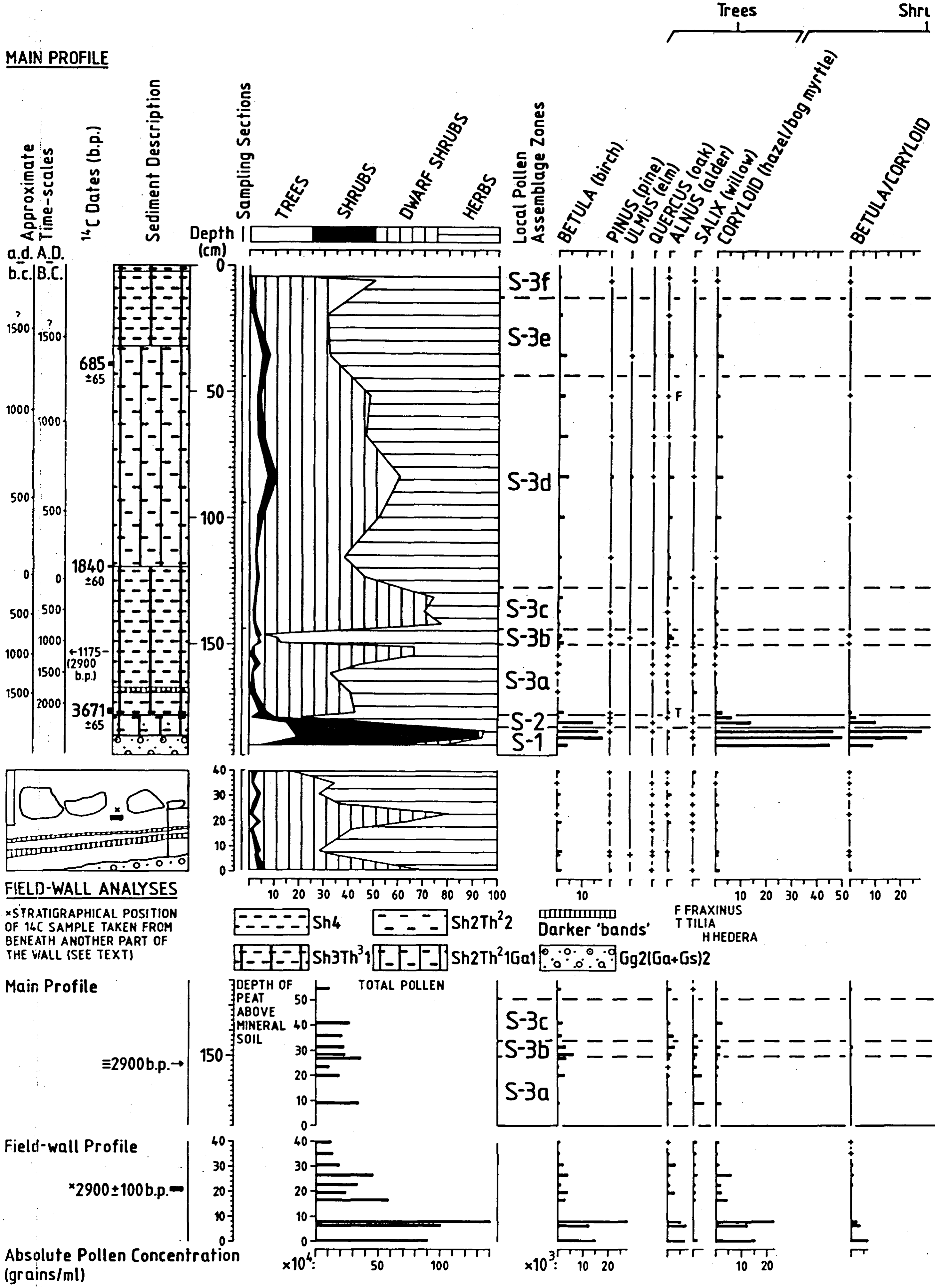
+=<1·0% (&<1·0×10⁴ GRAINS/ML)

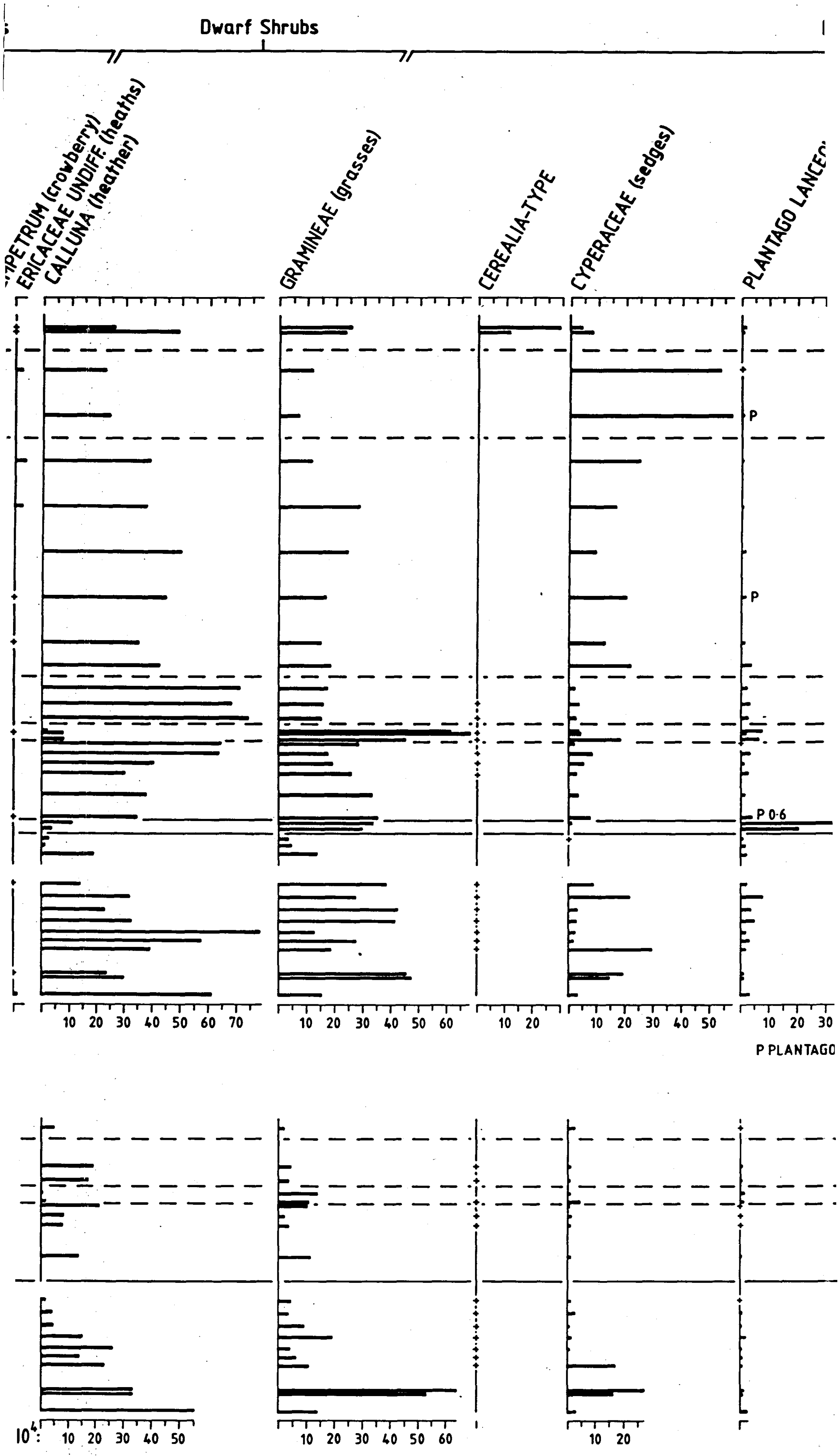
ΣTAXA=NO. OF TAXA IN ΣTLP

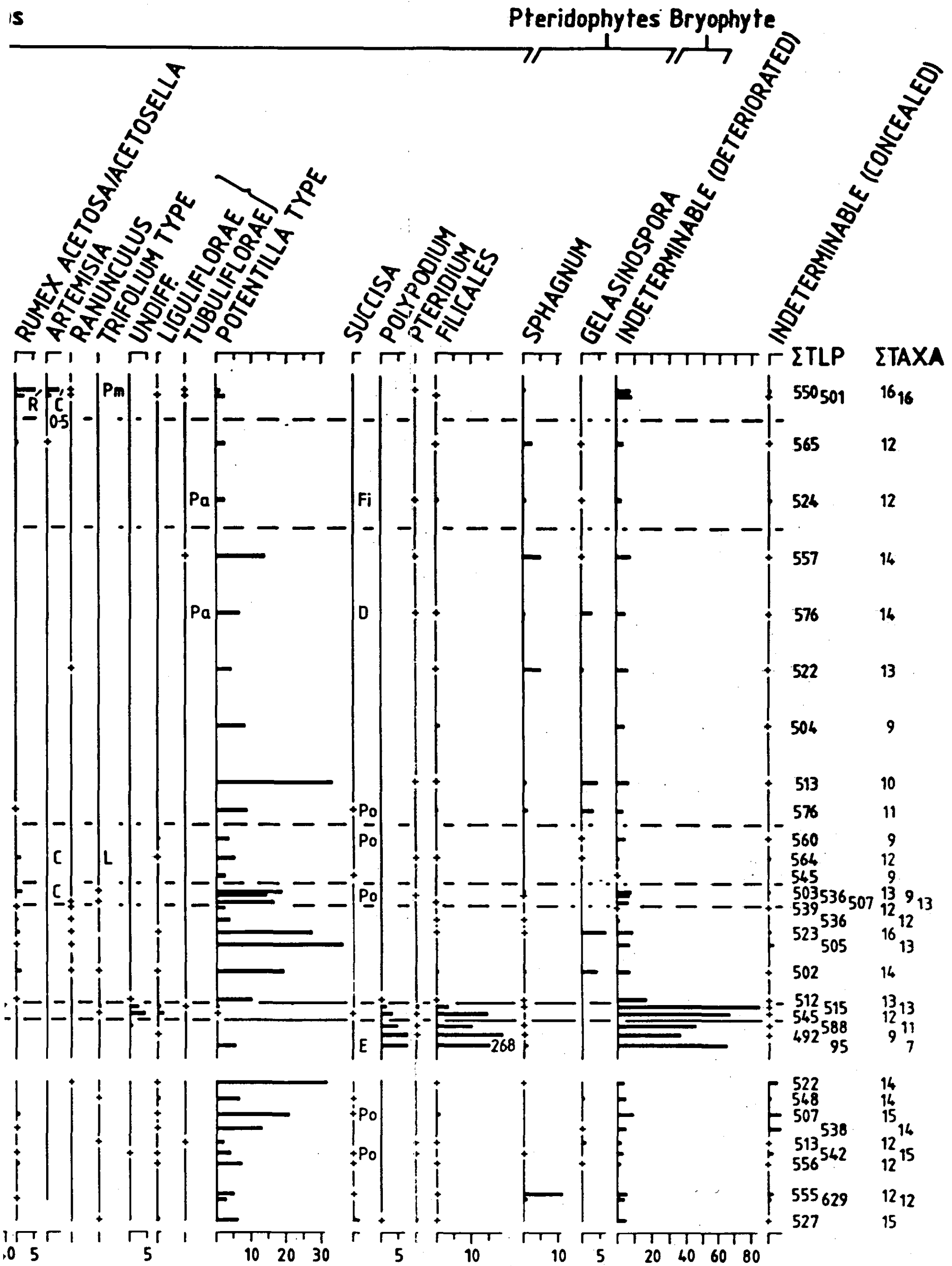


SHESHADER, EYE PENINSULA, ISLE OF LEWIS

Diagram 2


Trees
Shru
MAIN PROFILE
Approximate Time-scales
a.d. A.D.
b.c. B.C.
14C Dates (b.p.)
Sediment Description
Sampling Sections
Depth (cm)
TREES
SHRUBS
DWARF SHRUBS
HERBS
Local Pollen Assemblage Zones
BETULA (birch)
PINUS (pine)
ULMUS (elm)
QUERCUS (oak)
ALNUS (alder)
SALIX (willow)
CORYLOID (hazel/bog myrtle)
BETULA/CORYLOID
1500
1000
500
0
500
1000
1500
2000
685 ±65
1840 ±60
←1175− (2900 b.p.)
3671 ±65
0
50
100
150
S-3f
S-3e
S-3d
S-3c
S-3b
S-3a
S-2
S-1
F
T
40
30
20
10
0
10 20 30 40 50 60 70 80 90 100
10
10 20 30 40 50
10 20
FIELD-WALL ANALYSES
×STRATIGRAPHICAL POSITION OF 14C SAMPLE TAKEN FROM BENEATH ANOTHER PART OF THE WALL (SEE TEXT)
Sh4
Sh2Th²2
Darker 'bands'
F FRAXINUS
T TILIA
H HEDERA
Sh3Th³1
Sh2Th²1Ga1
Gg2(Ga+Gs)2
Main Profile
DEPTH OF PEAT ABOVE MINERAL SOIL
TOTAL POLLEN
≡2900 b.p.→
150
50
40
30
20
10
0
S-3c
S-3b
S-3a
Field-wall Profile
×2900±100 b.p.
Absolute Pollen Concentration (grains/ml)
×10⁴: 50 100
×10³: 10 20
10 20

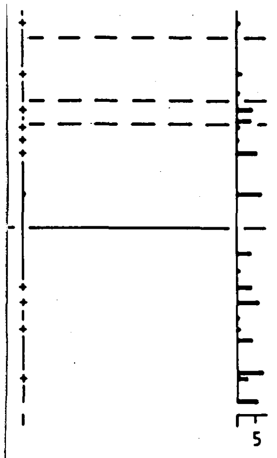

Dwarf Shrubs
PETRUM (crowberry)
ERICACEAE UNDIFF. (heaths)
CALLUNA (heather)
GRAMINEAE (grasses)
CEREALIA-TYPE
CYPERACEAE (sedges)
PLANTAGO LANCE
P
P
P 0·6
10 20 30 40 50 60 70
10 20 30 40 50 60
10 20
10 20 30 40 50
10 20 30
P PLANTAGO
10⁴:
10 20 30 40 50
10 20 30 40 50 60
10 20



NDIFF.	Pm POLYGONUM PERSICARIA
R cf. RUMEX CRISPUS TYPE
C CARYOPHYLLACEAE
L LOTUS	Pa POLYGALA

Fi FILIPENDULA
D DROSERA
Po POTAMOGETON
E EPILOBIUM

<0·5% UNLESS INDICATED OTHERWISE



RELATIVE VALUES EXPRESSED AS %AGES OF TLP (TOTAL LAND POLLEN)

+=<0·5% (& <0·5×10⁴ GRAINS/ML)

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