THE GEOLOGY OF THE COUNTRY AROUND KUBUTA

SOUTHERN SWAZILAND

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C O N T E N T S.

VIII. Karroo System/....

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I. P R E F A C E.

This work is presented as a study in regional geology. An area of approximately 90 square miles has been mapped, and is described in some detail. The scope of the work, however, is not limited by those confines; and, in reaching my final conclusions, observations made at various points outside of the area mapped are used.

My attention was originally drawn to the area by a collection of rock specimens brought to me by Mr. I. H. Pierce of Kubuta, who, when I expressed the desire to examine them in the field, extended to me a generous offer of his hospitality. The granting of four-months' leave by the Council of the Witwatersrand Technical College, provided me with the necessary opportunity to start the work.

In all, five months were spent in the field, viz., March 27th to July 30th, 1935, and June 30th to July 28th, 1936.

At intervals, in answer to my appeals, I have received from Mr. Pierce several parcels of additional located specimens for laboratory examination. Acknowledgment of my indebtedness to him, and others, is recorded elsewhere.

The work has been carried out entirely by myself, both in the field and in the laboratory.

References are collected together in an appendix under "Bibliography". In the text they are recorded thus:- (1).

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II. INTRODUCTION.

(a) The Area.

The area is situated in central Southern Swaziland and is co-ordinated by Long. 31° 30' E., Lat. 26° 53' S. It, therefore, lies just north of the extreme north-east corner of the area mapped in Sheet Map No. 68 of the Union of South Africa Geological Survey's publications.

It is 300 miles from Johannesburg by road through Piet Retief and Hlatikulu. It is accessible also by the train and bus services of the South African Railways by the same route. Kubuta lies 20 miles by road N.N.E. of Hlatikulu which is the magisterial centre of the district, and is a small village of some 100 odd inhabitants comprising mainly civil servants and store-keepers.

The area is very sparsely populated. It is divided up into farms and Native reserves. The farms stand to-day, with but few exceptions, uncultivated and untenanted.

The native population is small. Their picturesque hemispherical thatched huts, grouped and screened by reed stockades, make neat and compact homes.

(b) Methods of Working.

Headquarters was made at the Kubuta homestead.

A small field-laboratory was set up there for the purpose of systematically storing specimens collected in the field. It was also equipped as a mapping office so that field notes could be plotted on a complete map without delay. In addition, chemical reagents, and simple apparatus for the determination of minerals, rock-slide preparation equipment, with petrological microscope, were kept there. This ensured that no time would be lost when conditions were unfavourable for field-work.

The map used as a basis was a recently completed land-survey one with hachured topography, surveyed early in 1935, for the particular purpose of water-rights' preservation. In this, I was particularly fortunate, as streams and, in particular, stream confluences, by being accurately located were of the greatest assistance in my mapping work. Several copies of this map to a scale of 1" = 200 Cape roods. (0·4694 Mile = 1 inch or, approximately, 825 yards = 1 inch) were available for my use.

A table for field use in terms of average pace was compiled. This table took into account ground slope, and up-, down- and across-slope pacings, averaged over 100 paces, made in such conditions as were encountered. The distances traversed by trial pacings were measured by steel tape and the usual corrections for inclination applied.

In addition to the main beacons shown on the map, many subsidiary farm and line beacons were available. These, to avoid confusion, have been omitted.

Thus, it was considered that, in view of the many factors governing the work, in particular, that I was working alone, a satisfactory degree of accuracy was attainable by prismatic compass traversing (1). Where, owing to the interference of magnetic rocks, the prismatic compass was rendered unreliable, resort was made to theodolite and the fixing of subsidiary beacons by the three-line-intersection method. This was seldom necessary.

In the traversing of stream beds, the accuracy of stream confluence points was assumed and distances by pacing taken for plotting.

A map was cut into suitably sized sections for convenience in carrying in the field.

The ground was covered on foot, by horse, and by car, according to accessibility and convenience. When surveying those areas

so far/....

so far distant from Kubuta as to entail waste of time in reaching, camping was adopted. As supplies had to be carried, in addition to equipment, an ox-wagon was employed. This proved exceedingly convenient as camp could be pitched and struck in the minimum of time. Also because by sleeping under the wagon one could get protection from malarial mosquitoes.

The first week was spent on a reconnaisance survey so as to gain a broad perspective of the area as a unit and to enable me to block out a system of working.

This was ultimately carried out by a series of main traverses as follows:-

(i) From Mhlope S.E. along the quartzite ridge - the most prominent topographical feature of the area as well as being composed of the basal beds of the principal group of sediments.

(ii) From Mhlope S along the same quartzite to the dolerite contact.

(iii) From Lokolwane to Ngcongcwane.

(iv) From the vicinity of Maasingobe by way of the waggon-track towards Mooihoek.

(v) From m beacon to Sutugaans.

(vi) From the Sebowe eastward to Ngcongcwane.

(vii) From A beacon to Mtambama.

(viii) Stream beds and secondary traverses.

Opportunity was taken to visit areas to the South, (the northern limit of Sheet Map No. 68), and West, (Mahamba Mountains), for correlation purposes. Although unmapped, the formation of the Upper Pongola Series was followed to the neighbourhood of Hlati Kop (Some $3\frac{1}{8}$ miles on the extension of the Ngcongcwane - E beacon line) where the topmost bed is considered to be. This was done so that an approximate estimate of the maximum total thickness of the Upper Pongola Series as developed in this area could be given. Many spot-height altitudes were determined by compensated altimeter fitted with vernier and lens for reading. Rock, mineral and sand/....

sand specimens were taken back to Johannesburg for laboratory investigation. In addition to a large number of rock-slides prepared by myself, and with the aid of some students, many selected specimens were sent overseas for like treatment. Numerous field photographs were taken. These have proved invaluable in refreshing my memory in this write-up. Some are included to illustrate the text.

Photomicrographs have been prepared and several of these selected for inclusion.

The map has been photographically reduced to accord as nearly as possible with the foolscap text sheets. This has reduced the scale to very approximately one mile to the inch.

(c) Previous Work.

At the time of starting, I was unaware that the area had been given any official geological attention. I have since learned, however, that, during 1931, Dr. L. J. Krige, of the Union Geological Survey, visited the area in order to complete Sheet Map No. 65 of the Geological Survey. This map and the accompanying description have not yet been published.

III. PHYSICAL FEATURES.

(a) Topography.

The area is situated entirely in the Low Veld region.

The Western boundary approaches the Middle Veld belt, and, about eight miles beyond the Eastern boundary lies the low-lying Bushveld. In general, therefore, there is an eastward ground slope which determines the flow of the major streams.

The maximum elevation is 3,825 feet (Mtambama peak) and the minimum 1,380 feet (Hlatusane River bed on eastern boundary).

The main topographic feature is the north-west to south-east trending quartzite ridge. (Plate I: Figure 1). This attains its maximum heights on the crest of the north-east face of Mhlope (2,950 feet), and at a point approximately one mile south-east of the Lokolwane beacon (3,166 feet). From this latter point a mean elevation of 2,850 feet is maintained for a further two miles. Thereafter, there is a steady lowering to 2,550 feet at the boundary in this direction.

Throughout the greater part of its length the N.E. face of this ridge is a vertical escarpment, from 100 feet to 300 feet in height, with a narrow shelf splitting it into two tiers towards the summit. The wall-like continuity of this escarpment suffers two main interruptions; the one in the form of a semi-circular embayment at the headwaters of the Sihala spruit in the vicinity of Lokolwane; the other in the form of a slight depression where the transverse dolerite sheet cuts through it in the vicinity of Maasingobe.

The lower slopes of this escarpment are steep and covered with talus boulders, and soil supporting abundant vegetation in the form of large trees, thorn-bush, and tall, coarse grass. The north-west face consists of steep dip-slopes of bare rock, almost completely barren of vegetation and negotiable only on foot. Both slopes are highly dissected into deep dongas with vertical sides. These invariably harbour an almost impenetrable vegetation.

The quartzite ridge in the Sebowe region is much less prominent. The next most prominent feature is the nose escarpment of Ngcongcwane with its north- and west-facing walls and terraced structure. (Plate I. Figure 3). This feature in conjunction with the Sutugaans-Mooihoek granite massif forms the principal watershed of the area.

Other watersheds, which form less prominent and severe ridges, are two parallel and northerly trending ones in the western area. The less-marked of the two forms a divide between the

Sebowe/...

Sebowe and Lubuya streams. The other roughly follows the western boundary and is terminated at its southern end by the conical peak of Mtambama. Mavugute (3,405 feet) stands out as a twin peak at the southern end of the former watershed. The granite hills of Singceni to the north, with their high degree of dissection into steep sided valleys and ravines, resplendent with bush and trees, complete a scenic picture of no mean beauty.

Viewed as a whole the area is a small portion of the typically maturely eroded mountainous Low Veld, the more prominent features being the natural consequents of differential weathering, and mature erosion. The highly resistant quartzites, and the tough dolerite intrusions contribute largely to the positive features.

The whole area at the beginning of the Karroo Period (Dwyka = Upper Carboniferous) suffered extensive glaciation. No physical features reminiscent of that remain. This is not surprising when it is borne in mind that there has been uninterrupted erosion since the close of that Period (= Jurassic). (2).

(b) Drainage.

The area is situated in a region of Summer rainfall. From the meteorological records, kept officially at Kubuta for the past several years, the average annual rainfall is computed at 24 inches. By far the greater part of this, about 22 inches, is precipitated in the three months from December to February. In the current year, 1937, over 14 inches were recorded in the first 17 days of February, one single fall of short duration claiming over 4 inches. Thus, as is general throughout the eastern portion of South Africa, the area is visited by intermittent thunderstorm deluges in the mid-summer period, and, throughout the remainder of the year, receives only very sparse moisture in the form of misty rains. During my four-month stay, in 1935, a total of less than one inch was

measured/...

measured. Nonetheless, all the streams, with the exception of some minor tributary off-shoots, which are to be classed more as dongas (very new, deep and steep sided excavations in soil), are perennial.

In Summer, following rainfall, each stream even to the smallest, is a raging torrent capable of trundling large boulders along its bed, and of transporting a considerable load. In Winter, a consistent flow of crystal clear water is maintained only the larger streams carrying small quantities of the finest clay in suspension. The maintenance of flow is due to the immense storing capacity of the well-jointed quartzite and dolerite formations. The granite formations are less well-jointed but must also provide good reservoir facilities. Permanent cold water springs are fairly abundant.

With the exception of the area underlain by the slate formations, where the streams have excavated steep sided ravines up to 100 feet in depth below the surrounding country, and have deep sand -and gravel-covered beds, the stream beds are rocky and cleanly scoured. In the bed of the Hlatusane, within the area of the map, are many large-sized boulders (many must weigh well over a ton) that must have been transported for two or three miles. All streams are fastly eroding their beds, there being only a few isolated cases of temporary graded conditions. In all cases this is due to the presence of waterfalls.

The bed of the Hlatusane also provides examples of meanders and deserted courses. (Plate I. Figure 1). The meanders are due in largest measure to the variable resistance of bed- and bank-rock. It will be seen from the map that these meanders are roughly square-shaped with a parallelism of their arms. These directions conform with the foliation and the "dip" joints of the bed-rock. In 1922 this stream flooded in its lower reaches (of map section) with the deposition of much sediment both in and around its banks. This resulted in a change of course in two localities so that the river now excavates its channel/...

channel in material (boulders and gravel) deposited at that time. The resultant locally developed terraces, some 3 to 10 feet above the normal water level, pay tribute to the transporting power of this stream.

The main stream draining the area is the Hlatusane to the North. It rises in the Singceni hills and flows through a narrow gorge for the greater part of its length, ultimately joining up with the Great Usutu River in the Bushveld. Three-quarters of the area mapped is drained by north-easterly flowing tributaries of this main stream, and in particular by the Lubuya and Sebowe streams in the west and west-centre, and the Mpopota in the east. On the western boundary the ground slopes steeply down into the deep gorge of the Assegai River and its tributaries. At the head of the Mantshiyane stream, only a matter of some fifty yards separates the eastward and westward drainages. Stream capture in this locality is imminent, and the ultimate drainage of the Mtambama valley appears destined to proceed Assagaiwards.

The Sebowe in its upper reaches is a quiet-flowing small stream. It suffers a sudden eastward change of course, and cuts its way by a deep gorge through the quartzite ridge, following, in doing so, a joint-plane. As a result of this it now receives all the waters of that portion of the shale and slate basin west of the wagon-track between Maasingobe and Mooihoek. From its junction with the Lubuya to the Hlatusane its bed lies in a steep-sided narrow valley and gorge, and the flow consists of alternating rapids and pools.

The Mpopota drains the major part of the eastern area. It leaves the shale and slate dissected plateau region by precipitating itself over a waterfall nearly 100 feet in height. The lip of this fall is the basement quartzite. (Plate I. Figure 2). Thereafter, for the succeeding two miles, this stream has developed a precipitous gorge not easily explored.

The/...

The country all around this region provides hard going.

The only southerly drainage is provided by the small tributaries of the Hlatuse. In its course through the granite massif, this stream is a typical mountain torrent, now flowing smoothly on a rocky bed, again crashing down rapids, and yet again cascading over waterfalls. In the vicinity of D beacon it flows in a deep gorge. After leaving the mountainous country, which continues for some two or three miles eastward, the Hlatuse meanders northwards through the Bushveld and ultimately also joins the Usutu.

The area is, thus, a well-drained one in the most southerly part of the immense basin of the Usutu, which, although little known, is reputed to be the largest easterly flowing river in South Africa, south of the Zambesi. The Usutu cuts through the high Lebombo escarpment in a magnificent "poort", and ultimately debouches in the Indian Ocean.

IV. GENERAL GEOLOGY.

(a) Formations.

The most widespread formation is that usually referred to in South African geological literature as the "Older Granite", but described here, although such a correlation is recognised, as the "pre-Pongola Granite". This body, along with a few patches of schists and gneisses (Primitive Series), which it has invaded intricately, and sheets and dykes of dolerite ("Karroo Dolerites"), by which both in turn have been invaded, occupies about two-thirds of the area. With the exception of short distance in the South-east corner, where the sediments continue eastwards and the "post-Pongola granite" intrudes into them ("Sutugaans-Mooihoek massif"), this formation surrounds the sediments on all sides.

The next most abundant rocks are a portion of the sediments of the Upper Pongola System occupying the South-central area.

They/...

They are fully described in Chapter VI, and their probable correlation discussed.

No trace of Lower Pongola Beds has been found. There is an elliptic-shaped outlier of Dwyka Series in the neighbourhood of Sutugaans, consisting of boulder-conglomerate and fine-grained, thin-bedded laminated sandstone. Lying with angular unconformity on dark, red-weathering shales and slates, this formation is conspicuous in the stream beds which cut through it. So far as I am aware, this is the most northerly representative of this widespread glacial formation in this part of South Africa. Its nearest known neighbour of Dwyka is a similar small patch some 11 miles to the south-west near the Moweni river. Intrusives are abundant and widespread throughout the area. They take the forms of transverse sheets of considerable thickness, small nearly flat-lying outlying remnants, and large and small dykes. The smallest dykes are acidic -- pegmatites, granodiorites, granophyric quartz porphyries and quartz veins. The larger dykes, which vary from 50 to 500 feet in width, are basic -- epidiorites and dolerites. A glance at the map reveals the abundant dolerite sheets. These, and the dykes of similar composition, are undoubtedly of "Karroo dolerite" affinities. Around Ngcongcwane is a thick, apparently conformable, but in reality slightly transverse, sheet of granophyric quartz-porphyry. The largest of all the intrusives is that referred to as the "Sutugaans-Mooihoek massif".

To sum up, in tabular form, the following are the formations represented in the area:-

Sediments/...

Sediments	Recent - Alluvium, talus, etc.	
	Karroo System - Dwyka Series (Upper Carboniferous)	- Tillite, etc. approx. 150 feet.
	Upper Pongola System (Pre-Cambrian)	- Quartzites, shales, slates, etc. approx. 14,600 feet.
Intrusives	Post-Pongola	"Karroo Dolerite".
		"Post-Pongola Granite" and associates.
	Pre-Pongola	"Pre-Pongola Granite" and associates.

Primitive Series - Hornblende - schist, talc-schist, pyroxene-gneiss, etc.

(b) Structure.

Viewed as a whole, the area comprises an outlying remnant of ancient folded and fractured sediments largely surrounded by granite.

In the area covered by the map, the beds of the Upper Pongola System take the form of a portion, so far as I have been able to ascertain, the most northerly, of a pitching syncline with its axis trending in a direction approximately 15° West of North. The rim of this basin remnant is composed of a thick quartzite formation.

Followed south and south-west beyond the limits of the map, the general structural conception persists for several miles, ultimately to suffer complete disruption and to link up with the main development of the same beds in the Pongola area through a series of discontinuous and disorderly outcrops separated by extensive areas of "Granite" and "Karroo Dolerite". These latter features are clearly depicted in the N.E. corner of Sheet Map No. 68.

Within/...

Within the limits of the map, the rim suffers several breaks as the result of thrusts from a westerly direction. The breaks are clearly seen on the map and consist of a series of N - S striking thrusts connected by E - W trending dip faults. Thus, the western edge of the rim suffers a progressive eastward thrusting until, between Mavugute and Ngcongcwane, a considerable thickness has been eliminated completely. It may be that neither thrusting nor faulting alone could explain this and that it becomes necessary to assume that foundering into and assimilation by a sea of molten acid magma have taken place. Evidence of this is not wanting, but becomes somewhat equivocal in view of the presence of vast dolerite intrusives. The complete elucidation of the structure of this area is rendered the more difficult, by the attendant difficulties of correlation of contiguous and adjacent beds. The alternating thick bands of shales and slates and banded ironstones, with intercalated discontinuous thin cherty and quartzitic seams, and the quartzites, display no special features to render correlation other than tentative, wherever the general sequence is interrupted, or represented only in small part.

In short, the principal structure is that of a thick group of alternating arenaceous and argillaceous sediments which have been subjected to earth movements and igneous intrusions at a period subsequent to their consolidation. This has resulted in their folding and fracturing,

V. ANCIENT GNEISSES AND SCHISTS.

(Referred to in Map Index as "Unclassified Schists, etc.")

Within the area are several small patches of granulose, gneissose and schistose rocks of variable composition. Their original composition and character is obscured by their complete recrystallization and, frequently, high alteration. Detailed examination is rendered somewhat difficult by the general lack of good outcrops, and the intensely weathered character of the few limited exposures. The intrusive nature of the granite into/....

into them is beyond all doubt, as also their dynamo-thermal metamorphism. They are structurally inseparable from the pre-Pongola granite intrusion, and are to be regarded as isolated remnants of the oldest formations. Dr. A. L. Hall has drawn attention to similar occurrences in the vicinity of the Komati River in the Barberton district. Of these he says:-

> " .... the exact relationship to the surrounding granite cannot be made out very satisfactorily; they appear, on the whole, more closely analogous to the Jamestown Series than to any other group and may represent isolated remnants of that formation. " (3)

Dr. L. J. Krige likewise draws attention to occurrences of massive and schistose, basic and ultrabasic crystalline rocks, surrounded by granite, in the country south of Piet Retief. These he has mapped as belonging to the Swaziland System, and the convention on the map is the same as that adopted for the Jamestown Series on the Barberton map. One concludes, therefore, that such a tacit assumption has been tentatively made although no such implication is specified in the text. (4).

The occurrences within the area under consideration will now be described. As already mentioned, those patches, which are intimately associated with the intrusive pre-Pongola granite, have been recorded on the map by stippling among the conventions employed to indicate this granite.

(a) The Basic Schists.

In the vicinity of the orchard of Kubuta Estate, and about 300 yards to the west of the stone building, an outcrop of black, glistening, foliated rock occurs. The outcrop is not prominent and forms a part of the general westward slope without any surface irregularity to indicate it. It can be seen in the bed of a small deep spruit to dip at an indeterminable though apparently steep, angle towards the south-east/...

south-east. In another smaller spruit 900 - 1,000 yards towards the north-east it is again exposed, but less clearly, and in a more weathered condition. The weathering is characteristic, yielding a deep-reddish soil with abundant shed fragments, angular and rounded, of white, and black glassy quartz. This feature has been employed for the tracing and delimiting of those unexposed occurrences. The dark glassy quartz occurs as small veins cutting the rock in all directions and becomes particularly abundant in the vicinity of the dolerite dyke intrusions. No exposures were found in the beds of either the Hlatusane or Mpopota in this vicinity. Towards the south-west, and close to the spruit in which it is best exposed, it is cut through by a dolerite dyke with prominent boulder outcrop. Beyond this, in the same direction along the strike, any evidence of its continuance becomes obscured by a thick covering of lightish sandy soil.

A slide (D.8) was prepared for microscopic examination. This revealed the rock as an amphibolite with pronounced and typical granoblastic texture, and no sign of schistosity (Plate IV, Figure 1). The apparent schistosity in some hand specimens may be due to local alignment of the hornblende crystals. A detailed petrographic description is given in Appendix I. The rock recalls the plagioclase-amphibolites found in the epidiorite group of Pitlochry, Perthshire, Scotland. (5)

Immediately underlying the above black, glistening amphibolite and showing a pale-brown, nodular and pitted, weathered surface, is a talc-rock. This is depicted on the map and marked Tc. Exposures are limited and difficult of detailed examination. In hand specimen the rock is pale yellowish to greenish in colour, fibrous in character, and very soft with a somewhat soapy feeling. In general, the fibres form a felted plexus, rather than a parallel arrangement, of elongated blades and acicular crystals. Under the microscope, the fibrous/...

fibrous crystals are seen to have an interlacing and plumulose arrangement. The crystals are predominantly colourless tremolite with marginal alteration to talc, and, what appears to be scaly antigorite. Grains of magnetite, some well-shaped, are fairly abundant and are mostly confined to the margins of the tremolite crystals. The rock is a typical tremolite-talc-schist with weak schistosity.

The area occupied by these rocks is estimated at approximately 70 acres. The line of demarcation between the two appears to be sharp.

Crossing the road in a south-westerly direction towards Maasingobe one comes to the Sihala spruit. In the bed of this spruit, at about 300 yards from its junction with the Mpopota, dark schistose rock with lighter bands is again encountered, intimately associated with banded and gneissose granite . The exposure is poor. From this point in the same direction the ground rises to a prominent kopje. The top and upper slopes of this kopje are composed of massive dolerite. On the western slopes, immediately underlying this flat-lying dolerite, are a few exposures of the dark schist again. This rock has a superficial resemblance to that described above, in its dark colour and glistening appearance. Its coarser grain and massive character are, however, obvious even in hand specimen. Under the microscope, it is seen to consist essentially of a coarse mosaic of plates (showing the characteristic amphibole cleavages) and fibrous aggregates of greenish-brown, pleochroic, uralitic hornblende, and long bladed prisms, frequently in platy aggregates, of tremolite. Grains of epidote, interstitially in trains and small blebs, as well as enclosed within the colourless amphibole, are fairly abundant. Magnetite, in secondary grains bounding the colourless amphibole, and also in well-shaped primary crystals, is present in fair amount. The rock is best described as an amphibolite. (Slide D.6.A. Plate IV, Figure 2).

The strike/...

The strike and dip conform to the other occurrence just described, and this is probably a continuation of the same formation. Exposures were sought in the lower slopes but could not be found on account of the tall, dense grass and abundant soil. It was, thus, quite impossible to make even an approximate estimate of the thickness or extent of the formation.

The general strike direction was then followed farther towards Maasingobe down steep slopes, littered with dolerite boulder talus, into the deep, dongalike, dry-bed of another tributary branch of the Mpopota. In this locality, the search for further outcrops was carried out in the somewhat difficult conditions of very dense vegetation and advanced weathering. Indications in the form of a few talcose pebbles and boulders were observed. In the neighbourhood of a Kaffir kraal on the uprising slopes towards the dolerite, a further small outcrop of schistose rock is found. This is continuous below the thick dolerite sill which rises as precipitous kranztes to the summit of Maasingobe. An exposure at a short distance below the dolerite permitted of examination. The outcrop is identical with that of the tremolite-talc-schist described above and would lead to a similar description. Specimens taken after excavation to a depth of a few feet show differences in the lighter colour and more granular character of the rock and in the the presence of asbestiform bands up to 2½ inches in width. The rock itself is composed almost entirely of plates of fibrous tremolite aggregates with marginal scales of talc. Epidote grains are abundant and the rock is cut by small veins of that mineral. Magnetite grains occur in fair quantity. The asbestiform bands consist essentially of tremolite and actinolite with some talc, in typical cross-fibre arrangement. The fibres are brittle and compact and cannot be separated in the manner usually associated with the name asbestos, but may become more typical when followed deeper. The rock is a tremolite-talc-schist, with asbestiform seams.

The general/...

The general strike and dip again conform with those just described. This occurrence is, therefore, regarded also as being continuous with the others and forming part of the same body.

The homestead and store of Kubuta Estate are situated on the southern end of a small ridge, terminated at its northern end by the Hlatusuane river and sloping steeply on the western side to the ravine-like channel of the Mimiti spruit. The road follows the lower contours of the more gentle eastern slopes. Outside the store, small outcrops of greenish weathered schists occur striking N.E. - S.W. On the eastern slopes other small, isolated outcrops occur, the characteristic of this region, and well seen in an old cotton land extending towards the Hlatusane, being prominent red soil admixed with much white and glassy quartz pebbles. A deep furrow cut along the roadside yields a good exposure of the somewhat weathered rock. The schistosity is well marked, and the reason for the abundance of shed quartz, seen in the ramifying quartz and pegmatitic veins. Small excavations here, and further up the slope, yielded fresh specimens. In the neighbourhood of the confluence of the Mimiti and the Hlatusane, and north of the road, a water-furrow had been blasted through the solid rock, and much material was here available for the securing of fresh specimens. A coarse white pegmatite vein about 5 feet wide cuts through the formation vertically and stands out in sharp contrast with its black and glistening host. A further prominent pegmatite vein is exposed about 600 yards north of the store. The final feature of this area is an elliptical shaped outcrop of a small boss, 250 yards by 80 yards, cut through by the road, just after the Mimiti crossing going towards Kubuta, and forming two small but prominent kopjes in its outcrop. This is composed of granophyre. It cuts through the schist formation with a well defined boundary. In the bed of the Hlatusane the dark schist is also exposed much cut by pegmatitic and granitic veins in lenticular bands.

Identical/...

Identical exposures, highly weathered, are also seen in the neighbouring Mimiti and Sihala spruits.

The schist itself is a typical hornblende- schist, typified in Slide D.7. (Plate IV. Figure 3), the schistosity being due to the linear arrangement of the hornblende. The hornblende is in excess over the light-coloured constituents and occurs as bands of green and highly pleochroic blades. The light coloured constituents are a plagioclase, of andesine affinities, and quartz, in small quantity, forming an interstitial mosaic. Epidote occurs both as a turbid alteration of the plagioclase and in small veins cutting the rock. Magnetite occurs as a fine secondary dust and also in small grains of original igneous origin.

A low level bridge carries the main road over the Sebowe. The descent to this bridge is steep and winding by both approaches. In this vicinity yet another small patch of basic schist occurs. An exposure, in the form of greenish coloured, slaty-cleaving rock is to be seen on the road-side banks about 500 yards up the hill on the westward side of the bridge. Its relationship to the adjacent sheared rocks and granite is a highly confused one. Granite and pegmatitic veins intersect it in great quantities. It was found impossible to obtain a specimen from which a slide could be cut, on account of the deeply-weathered character of the few small exposures, and its diagnosis as a basic-schist (probably hornblendic) is based on its general characters and by comparison with the more highly weathered outcrops of the other occurrences.

All of the above occurrences of basic schists are interpreted as regionally (Harker) (6) or dynamothermally (Tyrrell) (7) metamorphosed, basic igneous rocks representing the oldest formations in the area.

The marked uniformity of the strike of the several occurrences within the area in an average direction approximately due North is noteworthy. The strike of the foliation of the gneissoid-granite and associated pyroxene-gneisses, etc., seldom departs from a general direction N.10° E. And, in the Sebowe stream, shearing along a strike of N.5° E has been observed. It is not improbable, therefore, that the orogenic stresses of the metamorphism were set up by the intrusion of the granite.

The main evidence of stress as a major factor in the metamorphism is afforded by the dominance of green, pleochroic hornblende, tremolite and talc, in the compositions of the schists.

The final conclusion reached, therefore, with regard to the basic schists, is that they represent original basic igneous rocks that have been subjected to the highest grades of regional metamorphism in which the stress (i.e. dynamic) factor, due to orogenic movements, has been dominant over the temperature (i.e. thermal) agent.

It remains to consider the probable composition of these original rocks. The absence of such minerals as sillimanite, cyanite, staurolite, garnet and biotite, from all specimens examined and, therefore, assumed as being general, is taken as sufficient to preclude the possibility of their consideration as original argillaceous or impure calcareous sediments. Moreover, any hypothesis presupposing an original sedimentary character of any sort, would seem somewhat gratuitous in the complete absence of any other associated rock of sedimentary affinities. Hence, the original rock was most probably a basic igneous rock, such as dolerite. The presence in comparatively small quantity of magnetite would further suggest the abundance of original pyroxene rather than olivine, the conversion of which latter to talc, etc., would imply the setting-free of iron. That the original rocks had suffered a certain amount of weathering prior to recrystallization, is evidenced by the presence of veins of epidote.

(b) <u>The Pyroxene-gneisses</u>.

The head-waters of the Mantshiyane and Ngudwane tributary streams of the/...

of the Lubuya, arise as springs emanating from joints in the rock-formations forming the prominent watershed in this western area. All of the streams have eroded steep, ravine-like channels both on the eastern and western slopes. The western slopes are particularly steep and the stream beds follow their downward path by a series of small waterfalls. The ravines are overgrown with large trees, thorn-bushes and a maze of pendant "monkey ropes". There is permanent water in their beds, although in some this is a mere trickle between pools. Nonetheless, several good exposures of the formations are available for examination in these localities, although fresh specimens require a certain amount of labour before being procured. Fairly good, fresh outcrops are available on the topmost parts of the slopes particularly in the vicinity of the source of the northernmost of the trident tributaries of the Mantshiyane.

The map shows the distribution of the main rocks of the area. The pre-Pongola granite formation right along the ridge is represented mainly by a banded granulite, pale-pinkish to pale-green in colour, intersected by sheared and coarse pegmatites varying up to many feet in width. There is also abundant olivine-bearing dolerite in the form of almost flat-lying, thick sheets and sinuous, dyke apophyses.

The southernmost patch as mapped will be dealt with firstly.

The dominant feature of this area is the very prominant white outcrop of rock, forming a steep-sided ridge, around the northern point of which the stream bends sharply. (Plate II, Figure 1). This rock is well-jointed, and has a well-marked, banded structure, so that, superficially, it resembles a quartzite body. This deception is furthered by the apparent bedded character of the rock and its possession of a measurable dip. In hand specimen, the rock is pale-cream coloured, and the banding can be seen as being due to the segregation of quartz into bands and irregular streaks. Under

the/...

the microscope (Slide Q.3), the rock is seen to consist of a coarse aggregate of large plates of microcline, with well-marked cross-hatched twinning, subordinate microperthite and clear quartz arranged in the typical, pegmatitic habit of long streaks. The abundance of microcline and the apparent complete absence of mafic constituents, are the characteristic features. The rock must be described, therefore, as a slightly sheared pegmatite, (See Plate VI. Figure 6), and, any possibility of its sedimentary origin dismissed.

Lying contiguous with this, apparently with a clearly defined boundary, is a somewhat darkish coloured, heavy rock, forming the topmost slopes and high summit in this region. The area occupied by its outcrop is shown on the map. The outcrop is characterized by its light brownish to greyish colour and well-jointedness, so that, in places, for example on the flattish top of a spur about 200 yards north of the stream bend, it forms a sort of paved arrangement of foot-square blocks. The abundance of shed, rose-pink quartz, and the sandy soil are further noteworthy features, particularly of the lower slopes. The several outcrops permitted of the measurement of dips and these are recorded on the map. It will be seen that those are variable, although the strike direction is fairly uniform, and in remarkably close agreement with that of the foliation of the gneissose-granite.

The rock occurs in large, elongated, lenticular masses and in well-defined bands from about 2 to 5 feet in width, separated by lighter bands of granulitic rock, pegmatite and veins of rose quartz.

In hand specimen the rock is dark grey in colour, and speckled with rounded crystals of black augite and red garnet. It is tough and dense and tends to break with a rectangular cleavage, parallel and at right-angles to the banding.

Under the microscope (Slide Q. 2), it shows a typical gneissose, though somewhat granulose, structure. Greenish to pinkish pleochroic/...

pleochroic hypersthene is the dominant mafic constituent, and forms subhedral to euhedral crystals which frequently show uralitic striation and form radial fringes to the garnet (Plate IV, Figures 4 and 5). Highly refringent, rounded crystals of pink garnet are abundant, the larger ones showing cataclastic effects. Some small grains of brownish augite, and green to brown hornblende occur in small quantity, not uncommonly in well-shaped crystals. All these mafic constituents occur in a coarse groundmass of clear and fresh crystals of quartz and untwinned orthoclase. There are also minute grains of magnetite scattered through the rock. The rock is, therefore, a garnetiferous-pyroxene-gneiss.

About two miles to the north, and separated from the above by granulite and dolerite (as shewn on the map), is a further smaller but similar occurrence. This is depicted as a small elliptic-shaped area and is encountered on the steep, western slopes. The absence of pegmatite, other than in very thin veins, and of rose quartz, are conspicuous differences. Its relations with the granite are, however, identical, but it occurs in rather thinner bands, some being as narrow as an inch. The strike direction conforms with the other but the dip is uniformly towards the east at high angles.

In hand specimen, this rock is lighter grey in colour, and featured by recognizable black, glistening plates of mica. Under the microscope (Slide Q.5, Plate IV, Figure 6) the gneissose structure is somewhat obscure.

The rock consists of large, platy crystals of clear and colourless quartz and even-grained mosaics of quartz and oligoclase, making up about two-thirds of the rock. The quartz is in slight excess over the lamellar-twinned acid-plagioclase. Augite, as well-cleaved, light-brownish, rounded to irregular crystals, along with biotite, in small, reddish-brown plates make up the rest of the rock in about equal quantities. Sphene is an important accessory. The rock is, therefore, a biotite-

pyroxene/...

pyroxene-gneiss.

These rocks, associated as they are with typical granulites and much injected into by granitic material must be regarded as being a normal feature of the Archaean basement. The associated pegmatite and veins of rose quartz are the usual late phase consequents of regional intrusion of granite which forms such a dominant feature of this area. Thus, the features, as exhibited here, are attributable to plutonic metamorphism.

In fact, the various petrological descriptions of the classical Saxon granulites bear a singularly close analogy to some in this area. And, the Lewisian gneiss of North-West Scotland contains almost identical occurrences. As stated by Tyrrell (8), "they are believed to be all of plutonic igneous origin".

Thus, the above pyroxene-gneisses are taken as representing original basic igneous rocks which have suffered structural and constitutional changes under the influence of those agencies summed up in the concepts of plutonic metamorphism and regional intrusion of granite. The shearing of the pegmatite is due to subsequent orogenic stresses. The structural relations with the granite intrusion bear, as with the "Basic Schists", what may be interpreted as a completely enveloped, infolded arrangement accompanied by "lit-par-lit" injection.

VI. THE UPPER PONGOLA SYSTEM.

(i) General Remarks.

On evidences to be stated later, the conclusion has been reached that the "Granite" of the area is not of one age. pre-Pongola and post-Pongola bodies are postulated. It would seem logical, therefore, to deal with the pre-Pongola (post-ancient Schists, etc) granite at this stage in order to maintain a time-order. But, it has been decided to keep the two

together/...

together in the next chapter, so that their differences may be the more easily discussed, and also to maintain a single chapter devoted to the Acid Igneous Rocks of the area.

(ii) Detailed Description.

(a) Succession and Characters of the Rocks.

The areal distribution of the rocks and the physiography due to them, has been dealt with in some detail above. It now remains to describe their more intimate characters.

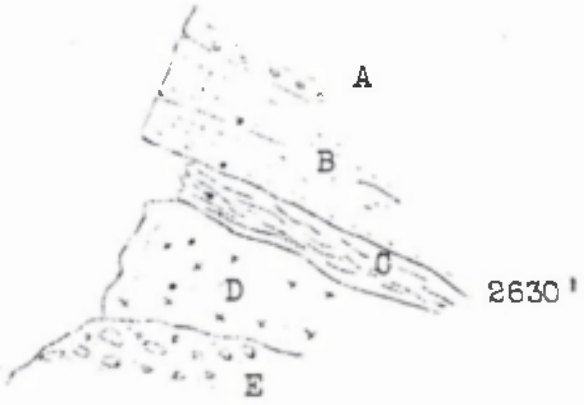
The Pongola beds are represented by a thick and conformable succession of quartzites, quartzitic conglomerates, slates, sandy shales, glossy slates, brecciated siliceous rocks, gritty quartzites, contorted ferruginous chert rocks and highly ferruginous quartzites. Broadly, there are two distinct facies, the one distinctly arenaceous and the other dominantly argillaceous, and, the associated topographic features are dominated by this conception. Thus, the basal arenaceous formation forms a girding escarpment or ridge around a succeeding inner area of lower-lying, highly dissected ground; this, in turn rises to a second dominantly arenaceous, stepped escarpment, which, in turn fringes another belt of lower-lying ground.

The Basement Quartzite.

The stratigraphical base of the series in the area is the thick, quartzite body forming the Mhlope-Lokolwane, south-easterly trending, prominent ridge. The steep, north-easterly slopes of this ridge were subjected to a minute examination in the search for a granite contact. Only in one locality was this found. This was on the South-easterly face of the arch-like excavation of Adit No. II, referred to in my paper on the ancient workings developed into this formation, and shewn in Figure 2 of that paper (9). This gives the altitude of the base as 2,630 feet, which at the known amount and direction of the general dip,

conforms/...

conforms with the altitudes of all the other adits and the assumption that they all (the lower ones) go in on a horizon close to the contact. Adit No. II almost keeps to the contact for its first few feet. And the base as exposed here conforms to the conception of a sedimentary, and not an intrusive, one. This exposure will now be dealt with in some detail. The diagram below (not drawn to exact scale) shows the dispositions of the rock bodies in section as exposed at this point.



Specimens were taken from the various rock bodies at approximate intervals of 18 inches across the face as indicated by the dots and examined in slices under the microscope.

A is a prominent band of quartzitic conglomerate about 3 feet in thickness and forming the roof of the inner portion of the adit entrance. The pebbles average about 1 inch in diameter, with larger ones up to 2½ inches. They are densely packed and cemented together by fine quartzitic material containing much pyrite and some sericite. The pyrite appears to replace some of the quartz grains, both in part and completely, and is quite irregular in form.

The pebbles are composed dominantly of white vein quartz, with fewer of black glassy and cherty quartz. No pebbles of any other rock were found in spite of a close search. They are rounded to ovular in shape and display no marked sorting, there/...

there being a heterogeneous arrangement of both large and small. There appears to be a tendency towards a rude alignment of their major axes parallel to the dip. The band is somewhat composite in character, being broken by thin lenticular quartzite seams, and is discontinuous along the strike. Several samples assayed for gold, all showed a trace. This conglomerate resembles, in general, many of the bodies of the Main Reef Series of the Witwatersrand System and, in particular the South Reef of the Central Rand, but, is conspicuously different from them in the absence of carbon. (10).

B is a fine-grained, greyish rock with a slightly soapy feeling. It is well-bedded and jointed in the manner typical of the quartzites of the area. Its overlap of C provided an exposure for a dip measurement. The parting between B and C is sharp. Under the microscope (Slide K.J. 1, Plate VII, Figure 3) it is seen to be composed of small rounded and irregular grains of clear quartz, with crenulate margins, separated by thin films of flaky sericite. In places, an indistinct schistosity, or fine banding, is developed due to the presence of fine-grained quartz mosaic containing abundant sericite arranged in rough bands. The quartz grains show strain shadows. The rock is describable rather as an altered quartzite, than as a true quartz-schist and is regarded as representing a quartzite which has suffered crushing and partial recrystallization as the result of differential movement along the contact with the granite.

C is a band, 17 inches in width, of greenish-white rock with a soapy appearance and well-developed schistosity. Under the microscope (Slide K.J. 2), it is seen to consist entirely of quartz, and fine, flaky sericite in about equal proportions with a small amount of magnetite dust. The quartz forms irregular grains and aggregates and shows marked undulose extinction. The elongation of the quartz grains and the linear arrangement of the sericite flakes determine the schistosity. The rock is a quartz-sericite schist.

D, which/...

D, which underlies C with an irregular junction, is a light greenish, somewhat coarse-grained, massive rock without any trace of schistosity and with a general granite appearance. Under the microscope it is seen to consist of large irregular grains and aggregates of colourless quartz, showing marked strain shadows, set in an abundant matrix of fine sericite, which exceeds the quartz in amount (Slide K.J. 3A, Plate VII, Figure 2). There are also present, in small amount, ragged flakes of green chlorite and some grains of brownish sphene and black magnetite. The name given to this is quartz-sericite rock or sericitized-granite. C and D appear to represent granite which has suffered intense dynamo-thermal metamorphism, under physico-chemical conditions involving pneumatolytic action, resulting in the complete sericitization of the felspars. The pronounced schistosity of the mass on the contact as represented by C is due to differential movement subsequent to the general metamorphism. Many cases of the development of quartz-sericite schist on a granite contact are described in the case of the contact surface (sedimentary) between the Older Granite and the Witwatersrand System beds. Dr. L. T. Nel, for example, cites several cases as occurring along the base of the Dominion Reef Series in the south-western Transvaal (11). All such occurrences have been generally interpreted as suggestive, if not proof, of a sedimentary contact. Interpreting this occurrence in a similar manner, with due regard to the added fact of the hard and fast surface of demarcation between B and C, the intrusive character of the granite in this region must not only be regarded with doubt, but, apparently, dismissed, and a sedimentary relationship postulated.

In further support of this contention, is the absence of any contact aureole as demarcated by typical contact minerals in this sedimentary base, and the general presence of metamorphic phenomena which are compatible rather with the conception of orogenic forces than with intrusion. Neither is there any

conclusive/..

conclusive evidence of a tendency of the contiguous granite body to develop a more acidic character, nor to become finer grained, in the immediate vicinity of the sedimentary contact. It seems, therefore, justifiable to refer to this quartzite body as the basement quartzite. It is represented in its maximum development in the vicinity of Lokolwane, and is well exposed on the north-easterly facing escarpment, dipping at 25° in a direction W.20° S. This dip is maintained over the whole exposure in this vicinity and on Mhlope. The estimated thickness is approximately 1,800 feet. The formation consists essentially of fine grained, well-bedded white quartzite. Towards the base, pebble bands are locally developed. As already mentioned above some of these are definite, quartzitic-conglomerate bodies. On a prominent high/ krantz, formed by landslipping of large masses of rock, on joint planes, to the west of and just below the Lokolwane beacon, seventeen thin bands are exposed within a vertical range of 50 - 60 feet. In width these vary from a mere single pebble layer up to 12 inches. They are separated by thin bands of whitish sugar-grained quartzite, without a definite parting, so that they are more in the nature of "pebble washes" than definite conglomerates. In composition they are identical to the occurrence described above, but differ in the less dense packing of the pebbles, and the consequent greater abundance of quartzitic cement. The topmost band observed is not more than 80 feet above the assumed base. The surface of this krantz is stained a bright red by the deposition of ferruginous matter from waters percolating down from the overlying doleritic sheet, and stands out in sharp contrast with the general whiteness of the other outcrops, and abundant talus littering the steep, girding slopes. The quartzites are well-bedded and jointed. There are two sets of joint planes, the one parallel with the dip and the other forming steep angles with the bedding-planes.

So well/...

So well is this latter developed that there is frequently a certain confusion in deciding on a dip measurement. This was so found, particularly in the vicinity of the Sebowe on Mhlope. The consequences of this well-jointedness are the regression of the escarpments by rock-slips, and the accumulation of much talus, in the form of very large, rectangular blocks, on the adjacent slopes. They also give rise to small intermittent springs. In colour, the rocks are white and greyish. The lower layers tend to be very fine-grained to glassy. They are splintery and break with a conchoidal fracture. Towards the top, they are more saccharoidal in character and show a development of larger, sporadic, irregularly shaped quartz grains, up to about 3 m.m. in size. These larger grains are of bluish-coloured, transparent quartz. False-bedding, as determined by well-developed bedding-planes, was not observed; but, in several places, phenomena related to this were observed in the analogous arrangement of trains of coarser and finer bands. Near the base, the quartzites are much cut by abundant thin veins of white and pale-pink quartz. These seldom exceed one-quarter of an inch in width and are usually much less. They have a sort of fibrous appearance, the "fibres" lying across the veins. They grade by undefined boundaries into the normal rock and are evidently associated with diffusive processes during the general crystallization of the original sandstone. They show no signs of deposition by infilling or metasomatic processes. Under the microscope, the quartzites show normal features, consisting essentially of a fairly uniform mosaic of subangular grains of quartz displaying strain shadows. Small interstitial flakes of sericite are present in variable, but usually small, amounts.

In the neighbourhood of Maasingobe, (located by the word "ridge" on the map) the quartzite becomes locally denser and somewhat glassy, The dip is steep, 65°, to 70° at the lip of the/...

of the waterfall (Plate I, Figure 2). In this locality also there are thin, intercalated seams of friable sandstone. These are most clearly seen on the top of the ridge behind the farm-house, the position of which is determined by the meeting and terminal point of the two tracks shown on the map. On Mhlope, highly ferruginous bands up to 25 feet in thickness are found. These are discontinuous on the strike. The iron-rich bands are describable as siliceous ironstones, and recall those identical occurrences in the "Water Tower Slates" zone of the Hospital Hill Series (Lower Witwatersrand System). (12).

When followed down to the Sebowe, the formation forms a high escarpment on the east bank. In the bed of the river, which in and around this region follows a belt of intense crushing, the quartzite has suffered considerable change in character and shows a banded structure. It is also cut by thin dykes (1 - 3 feet in width) of granophyric quartz-porphyry. On the west bank, there are a few outcrops until one reaches the upper slopes (near the point indicated by the letter q). Here the continuation of the thrust as mapped is indicated by the coincidence of the abruptly cut off quartzite against the slates. The outcrop of the quartzite from here south-westwards is again prominent, and, for a distance of about two miles in this direction, maintains a westerly dip of 40° - 45°. Where the Sebowe cuts through by a steep-sided poort, it is well exposed, and, from its characteristics, appears to merit correlation with the basement quartzite, although no conspicuous pebble bands were observed. A granite contact was sought for in vain. The reason for this lies in the abundance of talus on the western slopes and of thick sa sands, gravel and boulder accumulations in the river bed. The assumed base of the quartzite is defined by a somewhat banded quartz-schist which grades upwards within a few feet

to normal/...

to normal quartzite. This quartz-schist displays cataclastic effects in the larger recrystallized quartz-grains but, in contrast with the example quoted above, is poor in sericitic matter.

The continuity of the quartzite suffers another break by a dip fault. This is well exposed on the waggon track about 1,000 yards up from the drift through the Sebowe. The throw of this fault, calculated on the assumption of correlation of the two quartzites on either side of it, is about 750 feet on the south side. Finally, the quartzite disappears under a dolerite sheet.

The dip fault, just mentioned, trends in an almost due east direction (E.10° N) in a straight line, as marked by the abrupt discontinuity of prominent quartzites. The directly opposed dips of the strata on its opposite sides are clearly seen. It appears to terminate on the approximately north-south trending thrust which forms an important structural feature of this region, and is, therefore, probably older. The faulting, in general, by the dip faults in this region appears to have a pivotal tendency.

The sequence of the succeeding beds is best followed on a south-westerly traverse from the basement quartzite in the neighbourhood of Maasingobe towards Mooihoek. In this locality the succession is conformable and very slightly disturbed, in addition to being well exposed, so that it has been possible to regard it as typical. Furthermore, the first mile lies along a comparatively flat stretch of ground on a ridge, so that an estimate of the thickness of the first shale and slate group is possible.

The 1st Shale and Slate Formation.

This is a thick (2,800 feet, approximately), dominantly argillaceous formation, consisting of pinkish weathering shales, ferruginous slates, with locally developed highly magnetic bands of iron ore, contorted "banded ironstone", and discontinuous, white cherty rocks.

The base/...

The base of the formation is a bluish-black shale or slate. It weathers to give a pinkish to reddish, somewhat sandy soil, and forms no outcrops. The soil is deep and fertile. Fresh specimens for microscopic examination were obtained in the Sebowe and in a deep ravine south of Lokolwane. Under the microscope (Slide S. 2), it is seen to be a normal shale or slate, composed of quartz and white mica together with some obscure felspathic matter and showing the characteristic lamination.

It displays well-marked cleavage, these planes making steep angles with the bedding-planes. On cleavage surfaces, it displays a distinct glossiness due to the development of white mica. It is, therefore, to be described rather as a slate.

Towards the top of this body in the neighbourhood of the dolerite in particular, the rocks take on a distinctly ferruginous character and become highly magnetic, with marked effect on a compass needle. The ore mineral is magnetite containing more or less manganese, and to be named mangan-magnetite. It yields haematite, limonite and pyrolusite on alteration. Many old workings are to be seen in the neighbourhood of the native school and chief's kraal at Sutugaans. In this locality it is exposed as well defined interbedded bands up to 3½ - 4 feet in thickness.

Then follows a thick highly contorted, "banded ironstone". This rock is identical in character to the well-known "Contorted Bed" of the Hospital Hill Series and consists of fine alternating bands (from $\frac{1}{8}$ to $\frac{1}{2}$ inch in width) of crypto-crystalline quartz (chert) containing little ferruginous matter, and, iron-rich bands. The rock forms some good outcrops, and frequently displays a handsome appearance with its rapid alternations of white, deep-red and brown to black bands. It is flung into largish to smallish sharp and flattish small

folds/...

folds, the axes of which form steep angles with the bedding planes. Numerous small normal and reversed faults intersect it. Its maximum thickness is about 1,200 feet. In the neighbourhood of t beacon (between the Lokolwane and Ngcongcwane trigonometrical beacons) its shows its highest degree of contortion and passes upwards imperceptibly into a well-developed brecciated rock. This peculiar rock was picked up at intervals along a strike distance of about 1½ miles. It forms a compact body, of about 200 feet in thickness, and is conformable with the general stratification. It is composed of rectangular and irregular fragments of light and darkish banded chert, arranged in rough bands, cemented together by glassy quartzite containing abundant pyrite often in well shaped crystals. The pyrite, in the vicinity of the dolerite intrusion, exceeds the quartzitic material of the groundmass in amount. The quartz grains of the groundmass are frequently well-rounded. This breccia appears to represent an extreme phase of the effects of the contorting forces of compression, which has resulted in the shattering of the contorted rock and the recrystallization of the finer powdery products. The abundance of pyrite is due to the conversion of the magnetite liberated as grains during the crushing through the influence of the intrusive dolerite. It ought to be mentioned that the larger fragments of the breccia are generally akin to the iron-poor bands of the contorted rock. As a general rule, throughout the area, pyrite is a mineral characteristic of zones near intrusive dolerite.

The "Ridge" Quartzite.

The contorted rock forms uprising slopes which are topped by a small escarpment giving rise to a scalloped ridge. The headwaters of deep, ravine-bed streams arise here, and provide good exposures. For these reasons the quartzite formation is termed the "ridge quartzite".

The elevation of the ridge just west of the waggon track is

2,890 feet/...

2,890 feet. The thickness of the quartzite is estimated at about 350 feet. It is light-coloured and, like all the others, gives rise to a prominent white to creamish outcrop. Toward the base it is distinctly gritty, with sporadic development of small pebbles. At and near the top, there is also a gritty band. The main body is a typical, sugar-grained quartzite. Its dip suffers a gradual steepening from west to east; in its extreme west exposure the dip is 20°. Here it yields a wide outcrop on dip slopes, and there are evidences of the locally developed (rather, pebble bands) conglomerate at the base having been prospected on and "washed". This is seen between the waggon track and the deep-ravine, where the quartzite is cut-off by the fault and lies against oppositely dipping slates, at the foot of a krantz which forms the north-easterly face of the outcrop. The abrupt change in dip (20° to 35°), and the change of strike, on opposite sides of the dolerite dyke seems to indicate faulting, and the probability that the igneous matter of the dyke has been insinuated into and along a fault plane.

Proceeding eastwards, the outcrop bends in gentle curves around the steep, rounded, talus-strewn slopes, and plunges, in cusp-like forms, into deep ravines (with dense vegetation) difficult of descent and exploration. Near the waggon track, of original mention, the dip is 45°, increasing within short distance to 50° and maintaining this for the remainder of its course. It is again faulted (400 yards west of the track) by a small dip fault, with a downthrow of about 60 feet on the eastward side.

In the neighbourhood of the Sutugaans-Mooihoek granite massif which cuts it off abruptly, it begins to assume a more glassy character, and close to the contact suffers complete recrystallization so that, under the microscope, it has all the characteristics of vein-quartz. Several specimens were selected for microscopic examination and all revealed this feature. No contact or pneumatolytic minerals were observed;

nor/...

nor any development of felspar. Flakes of sericitic mica suffered no noticeable increase in development.

The 2nd Shale and Slate Formation.

This formation shows no peculiar nor characteristic features. It is 350 - 400 feet in thickness and consists of dark weathering, somewhat splintery, sandy shales or slates which, locally, become ferruginous, without developing any noticeable magnetic properties.

The "Lone Tree" Quartzite.

This prominent quartzite body is so named because the Mooihoek waggon track sweeps westwards round a prominent hill formed mainly by its outcrop and marked at its summit by a solitary tree.

It also forms the first step (arising above the dolerite) of the "staircase" slopes around Ngcongcwane (Plate I; Figure 3). The scenic beauty of this stepped escarpment with its markedly white, quartzite outcrops, forming the uprising "step" edges, alternating with the dark brown to reddish, weathered argillaceous outcrops, forming intermediate depressions, has to be viewed to be appreciated.

It is 400 - 450 feet in thickness and consists essentially of a light-coloured, fine-grained to glassy, quartzite. The elevation of its topmost exposure was measured, north of Ngcongcwane and is given by 2,695 feet. In this vicinity the dip is 35° in a direction S. 15° E. It is well-jointed, both on strike and dip and breaks into roughly rectangular blocks.

The 3rd Shale and Slate Formation.

Following conformably on the above is this dominantly argillaceous body of about 450 - 500 feet in thickness. At its base is a 100 - 120 foot thick band of distinctly ferruginous, non-magnetic, dark slate. This is followed by an unlaminated, sandy mudstone, greyish in colour and about

25 feet/...

25 feet thick; and this, in turn (only in the Ngcongcwane vicinity), by a thin, (2 - 3 feet), discontinuous bluish, glassy quartzite. Above, and continuing throughout the remaining thickness, the rock is more in the nature of a pinkish-weathering, sandy shale, well laminated and having a distinctly glossy appearance in the finer-grained bands.

The "Poort" Quartzite.

This name is given because it is this quartzite which, on the Mooihoek waggon track, forms, with the dolerite, a sort of gateway entrance to the narrow valley gradually ascending to the heights overlooking Mooihoek's scattered dwellings. In the vicinity of Ngcongcwane it is well exposed as the second "step" with an elevation of 2,825 feet. At the "poort" its maximum elevation is 2,940 feet, on the crest of a prominent whale-backed hill, where it is cut through and comes to be both over- and under-lain by a dolerite sill to the complete exclusion of a thin, slate band. The section, dolerite-quartzite-dolerite-quartzite, is to be seen on the eastern side of the "poort" just before the track descends sharply into the rocky (quartzite), stream bed.

This quartzite is a thinner body, 120 - 150 feet in thickness. It is a dark greyish compact and glassy quartzite, becoming distinctly gritty in places. The large fragments in the gritty bands attain sizes up to 6 mm. and are composed of light- and dark-grey. banded chert. Locally it also contains pyrite.

The Fourth Shale and Slate Formation.

In the type locality around Ngcongcwane, this is a thinner (150 feet) body composed essentially of thin-bedded, compact, ferruginous slates. Followed eastward it becomes, for a distance of 800 yards on the strike, cut out by a dolerite sill, to come in again in a deep ravine between the dolerite and granite by which latter it is completely eliminated. In

this/...

this ravine it is highly weathered, as the result of permanently trickling, abundant springs and fresh specimens were sought in vain. The only observable effect of the dolerite intrusive sill is that of slight induration and development of a more ferruginous character. Specimens, from near the granite contact, examined under the microscope, revealed no contact minerals, and only a slightly increased development of fine flakes of white mica.

This intrusive sill, since for a considerable distance it forms a part of the general stratification, may conveniently be considered here. It forms a sheet from 450 - 500 feet in thickness. It is a typical dark, bluish-grey, fine-grained and jointed rock. It gives rise to abundant, rounded boulders and forms bold and smooth outcrops. Around Ngcongcwane the depression occupied by the Fourth Shale and Slate, is littered by its abundant talus. Under the microscope it is seen to be a normal olivine-bearing dolerite identical in character with that of the main neighbouring body and typical of the type developed in this south-western area. Its intrusive character is revealed both by its finer-grained (basaltic), chilled top and bottom selvages, and by the manner in which it splits and cuts across the formations at the "poort", ultimately to pass into a dyke body and disappear underground.

The "Contact" Quartzite.

On the western face of the nose of the Sutugaans-Mooihoek granite, this quartzite forms a local fringe, as if frozen to the granite. Hence the name. Its whitish, angular, outcrops are in sharp contrast with the rounded and smooth, greyish granite. In this locality it assumes a highly, glassy character, typical of all the quartzites at or near the contact of this intrusion.

It forms the third and last marked "step" of the Ngcongcwane escarpment. Here it is about 250 - 300 feet in thickness and is a distinct quartzitic- grit formation, with subordinate, intercalated bands of coarser, round-grained quartzite closely resembling/...

resembling the "Sago"-quartzite of the Hospital Hill Series. Cross-bedding is observable on a small scale. The larger grains in the gritty facies measure up to 8 m.m. They are sub-angular to angular in form and are composed of fine-grained quartzite and banded chert.

The Fifth Shale and Slate Formation.

This is an approximately 500 foot-thick formation consisting of fine-grained sediments of a dominantly argillaceous character. These vary from pinkish-weathering, fine glossy shales or slates (in very thin bands), to thicker bands of pinkish to brownish, friable sandstones. The main body is describable as a laminated, sandy-mudstone. The complete absence of ferruginous slates demarcates this body from the others. It weathers in general to yield a pinkish fine sandy soil.

The "Escarpment" Quartzite.

This formation, (approximate thickness 250 feet), in conjunction with the overlying, sill-like quartz-porphyry, forms the topmost cliff slopes. It extends as a continuous body in a loop-like outcrop from the south-east corner of the area, as delimited by the junction of the Hlatuse and Little Hlatuse streams, to the south centre. It is continuous beyond the south-east corner for a considerable distance (observed for 4 - 5 miles), but is cut off by a granite body at a distance of about 1½ miles beyond the south centre.

In its south-eastern exposure it forms a prominent feature from the river junction to the waggon track, being separated from the main granite range by a deep and narrow ravine. From there onwards around Ngcongcwane it is somewhat overshadowed by the more prominent quartz-porphyry, and was, in fact, not observed at the waggon track neck on my first reconnaisance visit to this part for that reason. In this region it is represented by an inconspicuous ledge for a distance of 200 - 300 yards and closely resembles the igneous body in its superficial characters.

The dip/...

The dip varies in amount from 40° to 30°, and in direction from S 20° W to E 25° S.

It is essentially a fine-grained light coloured rock cut by numerous small quartz veins. In contact with the quartz-porphyry it becomes glassy with a greenish-grey colour and a development of pyrite. It is well-jointed and weathers to form creamish, sandy outcrops. Where the pyrite is well-developed, the outcrops become brownish stained. Springs arise as small trickles from many of its joints.

<u>The Sixth Shale and Slate Formation.</u>

This is a typical shale or slate body about 450 feet in thickness with an average dip of 25° in the same variable directions just mentioned. It displays well marked cleavage apparently parallel to its bedding planes and is generally more apt in description as a shale. It weathers with characteristic pinkness to form a clay which is locally employed as a base for "wash paints". Ferruginous developments were not observed. About 1,200 yards south of the Ngcongcwane beacon, the contact of this formation and the quartz-porphyry is fairly well exposed on a steepish slope. The shale is indurated into a bluish, tough rock much cut by sinuous glassy quartz-veins up to 3 inches in width. It may be described as a hornfels, but such is admittedly inaccurate. The rock has a counterpart in the Sebowe region (in the 1st Shale formation) and the two are given more detailed consideration in the section on general metamorphism.

A small elongated, moon-shaped outcrop of dolerite, taken as indicative of a continuity of the sill between the "Poort" and "Contact" quartzites, cuts through this formation, in the neighbourhood of the second small tributary stream of the Little Hlatuse and approximately 400 yards north of that stream.

The "Mooihoek"/...

The "Mooihoek" Quartzite.

This arenaceous phase shows no particular features. It is a fine-grained, light-coloured rock body 250 - 300 feet in thickness, forming krantzes and steep slopes along the northern bank of the Little Hlatuse from its source near E_1 beacon for a distance of about 3½ miles, where the river takes a sharp bend to cut through. It thus determines the course of the river for this distance. The average dip is 25°.

The Seventh Shale and Slate Formation.

It is along the base of this formation that the Little Hlatuse cuts its bed. And it is on the fertile, reddish, loamy soils derived from it, that the small farms support their crops. From excavations for a well 20 feet deep beside the School-house at Mooihoek, specimens were obtained for examination in hand. The rock here is a soft, pinkish, glossy shale, somewhat phyllitic in character. The glossiness appears to be due to a development in thin films along the laminae planes, of white micaceous matter. Towards the Little Hlatuse (below the school) it becomes somewhat sandy in character as is evidenced both by soil characteristics, and by a poor exposure on a track, leading riverwards, in this vicinity. Followed southwards up the slopes, it becomes distinctly sandy and greyish in colour. Thereafter, up to the succeeding quartzite, it is a pinkish, sandy, shale. The thickness is estimated at 600 feet.

The Remaining Beds.

As already mentioned, a rapid traverse to Hlati Kop vicinity was undertaken, in order to establish, approximately, the stratigraphical top of the sequence in the area and, also, to gain an estimate of the total thickness.

Hlati Kop trigonometrical beacon lies on a summit composed of dark coloured, amygdaloidal lava. This formation, whose approximate thickness may be 400 - 500 feet, is taken as the

topmost/...

topmost bed, because, to the south, granite cuts the beds off and interrupts the continuity of all but some of the lower beds, thus rendering any correlation with detached groups farther to the south somewhat gratuitous. In the several exposures examined, this lava appears perfectly conformable with the underlying sediments, and, it does not seem unnatural to regard it as a contemporary volcanic phase terminating the prolonged period of sedimentation.

Between this amygdaloidal lava and the "Seventh Shale and Slate" formation, the succession of shale and slate and quartzite continues. Immediately south of Mooihoek, the shales and slates predominate and obly two further quartzite formations were observed. The dip continues in the same general directions, namely, from south-easterly to south-westerly when followed from west to east. In amount it shows a progressive decrease, and averages from 10° to 20°, being 10° below the lava on the Mooihoek side.

The total estimated thickness is taken as very approximately 6,000 feet, including the lava.

The stratigraphical succession of the Upper Pongola Beds, as represented in the area, may be summed up as follows:-

Name of Formation.	Characteristics.	Estimated thickness in feet.
Lava	Amygdaloidal basic.	500
Upper Shales and Slates, and Quartzites.	Not separated. Two dominant quartzites. Shales, sandy shales and darkish slates.	5,500
Seventh Shale and Slate.	Pinkish glossy slates, sandy shales and siltstone.	600
"Mooihoek" Quartzite.	Light coloured, fine-grained quartzite.	300
Sixth Shale and Slate.	Bluish-grey, pink-weathering shale.	450

Quartz-porphyry/...

Name of Formation.	Characteristics.	Estimated thickness in feet.
	Quartz-porphyry.	
"Escarpment" Quartzite.	Light-coloured, fine-grained; cut by small quartz veins.	350
Fifth Shale and Slate.	Sandy mudstone, with thin bands of "glossy" slates and brownish friable sandstones.	500
"Contact" Quartzite.	Gritty quartzite with bands of "Sago" quartzite.	300
	Dolerite	
Fourth Shale and Slate.	Ferruginous slates.	150
"Poort" Quartzite.	Greyish glassy to gritty quartzite.	150
Third Shale and Slate.	Ferruginous slates, sandy mudstones, pinkish shales, thin quartzite band.	500
"Lone Tree" Quartzite.	Light-coloured, fine-grained to glassy quartzite.	450
Second Shale and Slate.	Dark splintery ferruginous slates and sandy shales.	400
"Ridge" Quartzite.	Light-coloured, gritty to sugar-grained quartzite with some pebble bands.	350
First Shale and Slate.	Dark bluish slates, ferruginous and magnetite bands, "chert" seams and lenses: contorted banded "calico rock": brecciated rock.	2,800
"Basement" Quartzite.	Light-coloured fine-grained to glassy quartzite: quartzitic conglomerate: sandstone, iron ore.	1,800
	Total Estimated Thickness:	14,600

In arriving at this estimate, the maximum thickness of each formation has been taken.

Expressed in rough percentages of argillaceous and arenaceous facies, on the basis of the above figures, we have:-

argillaceous/....

Argillaceous sediments - 61 per cent.

Arenaceous sediments - 39 per cent.

The complete absence of calcareous sediments is a feature of this thick sedimentary formation. The preponderance of fine sediment over coarse is also noteworthy, and, in general, the passage from arenaceous to argillaceous beds is gradual, so that the lower layers of the argillaceous formations tend to be composed of silty materials, with a progressive change to muddy and clayey facies towards their middle layers, and a reversion to a silty character towards their tops. Also, the finest grained arenaceous seams are disposed towards the topmost layers of the arenaceous bodies and, in all but the "basement quartzite", towards their bases. These facts lead one to the conclusion that deposition has been rhythmic on an oscillating littoral of a coastal embayment, with wave and ocean current action. The materials have been brought down from granitic highlands, probably lying towards the north and east, by large rivers debouching through broad mouths. The monogenetic character of the conglomerates is due to the destruction of the less resistant original pebbles by decomposition and attrition. Since altered calcareous sediments are known to exist in what are regarded as older rocks (e.g. in the Jamestown Series rocks in the Murchison Range (13)), the absence of calcareous sediments is probably to be explained by their representing an entire terrigenous deposit of the "Belt of Variables" (14).

(b) Structural Features.

The principal structural features have been described broadly in the foregoing section. It is proposed here merely to recapitulate and extend that treatment.

The broad structure is that of the "nose" of a modified pitching syncline, with its major axis trending in a direction N. 10° E.

Within/...

Within the limits of the area, and for a considerable distance towards the south and south-east, on the eastern limb, and towards the south-west on the western limb, outside of the area, this general conception is maintained. In fact, the synclinal basin (or basins) structure would appear to be applicable to the entire development of Upper Pongola Beds throughout their distribution in this part of the country, extending southwards across the Pongola River. (See Sheet Maps 102 and 68 of the Union Geological Survey).

The modifications are due to earth-movements and intrusions. In the first place, there is the system of thrusts and faults on the western limb. The main thrust (Plate III, Figure 1), in the low lying ground about 1½ miles west of Lokolwane, is traceable in the sediments in a north-south direction, for a distance of about 3 miles, and, in the granite, as a belt of crushing and shearing, for a further two miles down the Sebowe. The maximum throw is estimated at 750 feet, on the assumption that the Mhlope and Sebowe quartzites are correlatable. No trace of any disruption of the strata beyond the southern limit of this thrust as mapped, was observed. The ravine-like bed of the tributary stream just west of t beacon afforded no evidences of its further continuation in this direction. The second thrust follows a direction parallel to the main thrust and is observed in the slates approximately 1½ miles west of t beacon. It is cut off at its northern end by a dip fault, trending west-east and connecting the two. In this neighbourhood, the granite to the immediate west also displays shearing, which is particularly well-marked in the exposures offered by the two circular inliers in the dolerite. This is taken as evidence of a probable further thrust (Plate III, Figure 2), also parallel, and effecting a further elimination of outcrops. In addition, it seems beyond all doubt that the tongue-like dolerite apophyse, shooting out in a westerly direction from the sill, has been injected along the plane of a further east-west trending dip fault.

The dip faults are regarded as being pivotal in character, with an increase of throw in a southward direction, and an eastward rotational movement. Their effect, therefore, has been that of the eastward displacement of the lower beds, accompanied by an anti-clockwise rotation of the strike, so that an original north-east to south-west strike has become one of north to south.

On the eastern limb, that is the lee-side of the thrusts, no faulting was observed, but, at a distance of approximately 3 miles beyond the eastern boundary, the continuation of the basement quartzite suffers a break, with change of strike to a south-south-east direction, as a result of the in-butting of a granite massif (Bokweni Hill), the western extreme of which is shown as a large tongue-like body in the south-east corner of the map (Sutugaans-Mooihoek massif).

The only other faults observed were:-

(a) a locally developed small dip fault on the "Ridge Quartzite" just west of the Mooihoek waggon track. The effect of this fault is to cause an eastward downthrow of about 60 feet, and

(b) a strike fault of small extent, on the "Contact Quartzite" about a mile east of Ngcongcwane. This fault has had the effect of locally changing the general strike direction and of duplicating a part of the outcrop, thereby narrowing the slate outcrop in this area.

The development of the highly contorted bed, and its extensive brecciation in its uppermost layers, is attributed to the thrust movements and their compressional effects.

It would appear that the stresses were set up by orogenic movements acting in an easterly direction. In view of the fact that the Sutugaans-Mooihoek granite shows no effects of

such/...

such stresses, the major movements must have preceded its emplacement and, perhaps, even have been causal of such. On the other hand, being on the lee-side, this body may have escaped modification, the forces becoming dissipated by the yielding of the rock-formations to its west.

(c) Intrusives into the Pongola Beds.

Bearing an indubitable intrusive relationship to the Pongola Beds are two major phases of igneous activity of widely different composition and age.

The older is of acidic character, and the younger, basic.

The older ones are the "post-Pongola" granite and its associates. These comprise:-

(a) the biotite-granite massif of the south-east corner;
(b) the granophyric-quartz-porphyry sheet around Ngcongcwane;
(c) small dykes and stock of granophyre and granophyric-quartz-porphyry exposed in several localities indicated by q.p. on map;
(d) quartz-veins in the biotite-granite.

The younger consists of dykes, and sheets of a widespread olivine-dolerite, correlated with the "Karroo Dolerites", of post Karroo age.

(d) Metamorphism.

The entire lack of development of contact minerals, even such low-grade metamorphic ones as cordierite, andalusite and chiastolite, is stressed. These were expected, but were sought in vain, in spite of close search, even with the aid of small excavations, in appropriate localities.

That the quartzites, or rather, arenaceous sediments should have resisted metamorphism to a high degree, is comprehensible; but it is much less simple to try to reconcile the almost complete lack of metamorphism of the argillaceous sediments

with/...

with large scale normal granitic intrustion. Probable explanations are given in the next chapter.

The arenaceous sediments show all features from sandstones to completely recrystallized quartzites. Specific cases have already been described in detail of the alteration of the basal quartzite on the granite contact in the Lokolwane vicinity, and also of the complete recrystallization of the several quartzites in the close vicinity of and in contact with the red granite of the "Sutugaans-Mooihoek massif". The close resemblance of these latter under the microscope, to "vein-quartz" and their almost complete lack of sericite, indicate their alteration by dominantly thermal agency due to the intrusion of this granite.

South of the "poort", through which the Sebowe cuts into the slates, the base is represented by more pronounced shearing of the quartzite in its lowest exposed three to five feet. Sericite, interstitially in small flakes, is not abundant, but the definite banding of the rock compels one to describe it at least, as a highly sheared quartzite. This is characteristic of all this vicinity.

In the neighbourhood of Maasingobe, the quartzites shows considerable recrystallization, and are compact and glassy. Under the microscope, they consist of a medium-grained mosaic of quartz plates, showing "strain shadows" with slightly crenulate margins, and subordinate interstitial sericite.

A granite contact was searched for, but was not found. Field relationships and the general character of the rocks are again in favour of the assumption of a sedimentary contact, and of the dominance of the dynamic factor in their metamorphism.

The effect of the various dolerite intrusions on the quartzites with which they come in contact, is restricted to a limited amount of recrystallization, so that, for example, in the neighbourhood of Lokolwane, the coarser and sugar-grained

quartzites/...

quartzites become altered to more glassy types, not infrequently with the introduction of a little pyrite.

As detailed already, the argillaceous sediments are represented by shales and slates. In the Sebowe bed fresh slate outcrops are well exposed in the scoured bed and banks for a distance of about two miles. It was, accordingly, in this area that the main search for metamorphic effects was made, and, in particular for contact minerals. The main exposures consist of bluish, normal slate, with its cleavages at steepish angles to the bedding planes. At a distance of a few yards from the confluence of the main tributary at the elbow bend of the Sebowe, and conformable with the slates, there is exposed in the river bed, a dark greenish, banded, and slightly contorted, rock, much cut by glassy quartz veins. Its thickness is about 25 feet. It forms a small krantz on the eastern bank and a small waterfall in the river bed. At a distance of 600 yards to the north-west, at the next bend, it is again well exposed for some yards, forming another krantz, and giving rise to large talus boulders at the base. Under the microscope, it is seen to be a fine-grained, feathery aggregate of quartz, felspar and chlorite. The structure is most peculiar, and the description as a hornfels is considered the nearest approach in nomenclature (Slide S.1., Plate IX, Figure 6).

This rock is a slate contact altered by an obscured intrusion. Small dykes of quartz-porphyry and granophyre which cut through the sediments at two points from 600 to 1,000 yards distant, might indicate the presence of the necessary intrusion.

An almost identical occurrence of "mild hornfels", with absence of contortion, is exposed on the contact of the slates and the quartz-porphyry sill south of Ngcongcwane. The quartz veins are more abundant in this locality and are up to 3 inches in width.

(e) Correlation./...

(e) Correlation.

The field relationships of the beds demand their correlation with the Upper Pongola beds of Krige and Humphrey (15).

It is not, however, considered by any means sufficient to let the matter rest there. It is proposed to examine into the broader questions of correlation, and to make some suggestions as to the more probable stratigraphical relationships of the Upper Pongola Beds.

Present opinions may be summarized firstly.

Dr. Krige has suggested the correlation of the Upper Pongola beds with those of the Moodie's Series of the Swaziland System mainly on the basis of lithological similarity (16).

He points out, however, that, in general, metamorphism even of the basal bed (the Warmbad quartzite) of the Lower Pongola Beds is frequently completely absent:- "the basal portion of the Warmbad Quartzite through a thickness of 400 feet consists of argillaceous sandstone." His conclusion, in this area, is that the field evidence is in favour of a sedimentary contact. In general, in this area, one comes to the general conclusion that any definite contact metamorphism, even of the lowest grade, is conspicuous by its absence.

At the same time, Dr. Humphrey, in dealing with the metamorphism of the same beds in the country around Vryheid, mentions the very local development of contact metamorphic phenomena in the Pongola Beds (17).

Finally, with regard to the granite, both authors have come to the tentative conclusion that it "apparently belongs to the "Older Granite" of the eastern and northern Transvaal". Only one "granite" is recognized. (18).

Dr. A. L. du Toit (19), in the face of correlation uncertainties, adopts the use of the term "Primitive Series" in preference to "Swaziland System", in describing the ancient rocks of the

Nkandhla/...

Nkandhla area. His Insuzi series is correlated with the Lower Pongola Series, and he points out how this series not only rests with a sedimentary contact on an older granite-gneiss, but has also been invaded by a younger. Thus two "granites" are recognised in the field, but their compositions are not specified.

Dr. A. L. Hall (20), in summarizing his conclusions on the formations of the Barberton district, has no doubts whatever about the intrusive nature of the granite into the Moodie's Series, which group of rocks (quartzites, sandstones, shales and slates) he regards as the oldest in the area, namely, the base of the Swaziland System. He points out how metamorphism of the base of the Moodie's Series rocks is both widespread and, in places, considerable. The possibility of the "de Kaap" granite's being a younger one is not denied.

Two or three facts appear to come in for emphasis in surveying the above literature:-

(i) The Upper Pongola Series is composed almost entirely of arenaceous and argillaceous sediments showing, with almost negligible local exceptions, a remarkably low degree of metamorphism.

(ii) That over wide areas in both the Pongola centrocline area and the Vryheid district, particularly on the western contact of the Pongola beds and the granite, the bulk of evidence tends to point to a sedimentary rather than to an intrusive contact.

(iii) Much of the metamorphism observed bears interpretation as being of a dominantly dynamic character.

(iv) There is a certain amount of doubt in regard to the "Granite" itself, and the evidence from Nkandhla tends to suggest the existence of two such bodies of widely different age, both intimately associated with Pongola Beds.

(v) The accent placed on the Granite when the question of correlation is raised.

(vi) The/...

(vi) The attribution of the earth stresses, resulting in the present structures, to the "granite" intrusion.

(vii) The poverty of late phase intrusives, for example, pegmatites and quartz-veins, in the Pongola beds.

(viii) The general uniformity in composition of the main granite body, and its lack of an intimate penetrative relationship to the Pongola Beds.

(ix) The highly folded nature of the Moodie's beds in the Barberton area; the comparatively gentle, synclinal basin structure of the Pongola beds.

Before proceeding to the expression of a considered opinion, it is proposed to examine very briefly some of the more salient features of the beds of the Witwatersrand System.

The beds consist of sediments, averaging 25,000 feet in thickness, and comprising alternations of fine- and coarse-grained quartzites, grits, conglomerates and argillaceous rocks which at and near the surface are to be described as shales, but which tend to be slaty at depth. Bands of highly ferruginous shales and quartzites are not of infrequent occurrence, particularly towards the base of the system. A "Contorted Bed" (highly folded and minutely faulted "banded" or "calico" rock) is a feature of the Hospital Hill Slates.

The structure is always that of a modified (by faulting and thrusting) synclinal basin, it being possible that there are several such, certainly two, major basins.

The metamorphism of the beds is of low degree, except locally in the Vredefort area, in the Northern Free State, where an intrusive granite has effected considerable metamorphism.

Everywhere the beds are established as having a sedimentary relationship to the "Older Granite", although many contrary opinions have been expressed, both in the Centre Rand and Vredefort areas. It is in particular regard to the latter area, that diversity of opinion has abounded in the past (21)

and only/...

and only after much detailed work by many prominent geologists, can it be stated that present day authoritative opinions make the contact a sedimentary one.

As pointed out by Dr. A. L. Hall, "the question remained undecided for many years down to the time when Molengraff and the writer began its special study .... to remove the uncertainty .." And the paper referred to above is a record of one result of this joint investigation. This paper deals with the varieties of the altered sediments, and their detailed petrography. The possibility of a definite progressive metamorphism is examined on a zonal basis, and found to give complete asymmetry. There is no annular aureole around the periphery. Both exomorphic and endomorphic phenomena compatible with the intrusive character of the "Older Granite" are absent. There is a conspicuous absence of apophyses from the Older Granite into the sediments. In short, the intrusive character of the "Older Granite" is dismissed, and the general and, frequently, intense, metamorphism of the Lower Witwatérsrand Sediments attributed to two factor polymetamorphism, namely, a "regional component" giving static pressure, and, a "local component", mainly heat yielding, and due to a younger, and mainly concealed, igneous body composed of alkali-granite and, probably of the same age as the Bushveld or Younger Granite.

The above view is regarded to-day as the official one, and has been confirmed by Dr. L. T. Nel (22), who undertook the official survey of the area in 1923. Nel, however, suggests that the metamorphism is essentially thermal, any pressure factor being incidental to intrusion. North-east of Parys, the "Older Granite" trangresses the sediments, thus, apparently, breaking through the "ring" outcrop. This is explained by Nel as being due to thrusting. The more pertinent points, with regard to the discussion in hand, which arise from a study of the abundant literature (23) on the Witwatersrand System, may be summed up briefly thus:-

(1) The beds of the Witwatersrand System consist of quartzites, shales and slates along with some well-defined

bands/...

bands of quartzitic conglomerates. A conspicuous bed is the "Contorted Bed" in the Hospital Hill Series. The shales and fine-grained quartzites of the Hospital Hill and Government Reef Series (Lower Witwatersrand System) tend to be generally ferruginous, and, fréquently, highly so. The alternations of arencaeous and argillaceous sediments in the same series are rapid.

(ii) Diastrophism has resulted in their assuming a general synclinal structure.

(iii) They have a sedimentary relationship with the "Older Granite".

(iv) The rocks show a remarkably low degree of metamorphism, except in the Vredefort Mountain Land where the beds of the Lower System have been locally metamorphosed by a younger intrusive alkali-granite.

With the above summary of the more relevant facts contributory towards the correlation of the Upper Pongola Rocks, in the area under consideration in particular, may I turn to a summary of my own observations and enquiries:-

(i) The Upper Pongola Rocks in the area consist of quartzites, shales, slates, etc., bearing an astounding similarity in "individuality", to those of the Lower Witwatersrand System. This similarity is not only one of lithological character, but, in part, also, of sequence and general structure.

(ii) The rocks display a remarkably low degree of metamorphism. The question of the existence of any suggestion of a contact aureole does not arise.

(iii) Intrusive apophyses, related to the Older Granite, even in the form of quartz veins were not found among the sediments.

(iv) The granite, namely, that one regarded as being the

"Older",/...

"Older", displays no endomorphic phenomena compatible with an intrusive disposition, and, certainly, there is no evidence to warrant the conception of a more acidic character in the vicinity of the sedimentary contact.

(v) The "Older granite" is gneissose and granulitic in structure, and in places has been crushed and sheared. The banded, lenticular and "augen" structures, which it frequently displays, must be interpreted as normal consequents of Regional Metamorphism, almost certainly, recurrent, in which the sediments have also participated.

(vi) The absence of extreme subdivision in the "Older granite", as evidenced by an extreme diversity of rock types, due to fractional crystallization and filtration, and also of any intimate penetration of the Pongola Beds, largely precludes the hypothesis of its intrusion under orogenic stresses, and, therefore, of its being the cause of the displacements of the sediments.

(vii) Drilling operations in the country around Bethal, within recent years, have revealed the continuation, in general synclinal basin form, of the Witwatersrand System Beds in the area and, geophysical prospecting results, suggest the continuation of these same beds as far east as Ermelo, with the hypothesis of a southerly strike of the rim of the basin in this vicinity. Thus, the beds of the Witwatersrand System are believed to exist, below a later Karroo covering, to within a few miles of the outcrops of the Pongola Beds in the Amsterdam and Piet Retief districts.

To conclude, therefore, I am of opinion that the bulk of the evidence is in favour of a correlation between the Pongola (Upper, at any rate) Beds and the Witwatersrand System Beds. The conditions of lithological character, general metamorphism, structure and contiguity appear to be fully satisfied.

It is generally agreed among geologists to-day that, in the absence of fossils, those four features must be the main ones

employed/...

employed in any endeavour to effect a correlation. With regard to the use of lithological characters, Professor J. E. Marr (24) points out that this is by no means a negligible factor and "that experience determines the relative value of different lithological features for purposes of correlation". Eleven years as a teacher of geology on the Witwatersrand, is my claim to familiarity with the rocks of that area. And, the similarity of lithological character between those of the Upper Pongola and Witwatersrand Systems, is to my mind, an identity. The ultimate test might lie along the lines of an investigation into their respective content of heavy detrital minerals, but no such criteria are available for either group. Experience among rocks impresses upon them a frequently indescribable "individuality". I see in the Upper Pongola rocks, that "Witwatersrand individuality" to a marked degree.

Diastrophism imposes on rock groups over wide areas certain major structural features. And this fact, has to a very large extent been the ultimate basis of correlation of the larger rock groups of the world. The basin-like structure assumed by both the Witwatersrand and Upper Pongola groups, would appear therefore to be a further justification for the suggested correlation.

The relationship to the "Older Granite" is satisfied in so far as any such can be. The difficulties of using an intrusive rock for correlation purposes over any extensive area, must always be considerable, if not, insuperable. And especially when that same instrusion is by no means established as being of one phase, let alone of one geological age. Finally, all geologists are familiar with the oft-time difficulties in explaining vast variations in grade of metamorphism of the same group of sediments by the (apparently) same intrusion, within comparatively short distances.

VII. **THE "GRANITES"**/...

VII. THE "GRANITES" AND ASSOCIATES.

(i) The Pre-Pongola Granite ("Older Granite").

(a) Distribution and General Notes.

The widespread nature of this formation has been Noted in Chapter IV.

In its normal facies, it is mainly exposed within the area of the low-lying ground in and around the beds of the Lubuya and Hlatusane streams, and also in the dongas and tributary streams around Kubuta kop, as a bluish, banded and gneissose, coarse-grained rock, traversed by lighter-coloured sinuous veins and bands of granitic material. It maintains these features beyond the south-western area into the higher ground towards Hlatikulu, and also into the Singceni hills towards the north. In the latter area it is characterized further by the abundance of coarse pegmatites in large bodies.

As a consequence of dynamo-thermal metamorphism subsequent to consolidation, and, perhaps, associated in part with the intrusion of dolerite, it has suffered considerable granulitization and assumed a granulose structure over a larger area. This area is of horse-shoe shape, the two forks extending along the ridges of the western area, namely, in north-north-easterly directions from both Mtambama and Mavugute and separated by the valley of the Lubuya, and uniting in the area around those peaks. The northern limit of the western "fork" extends for a few hundred yards beyond the map boundary, while that of the eastern "fork" (Lubuya-Sebowe ridge) ends in the neighbourhood of the junction of the Lubuya and the Sebowe.

Along a line approximately delineated by the Sebowe, there is evidence of large-scale shearing so that, in places the rock has been reduced to what is most nearly described as a mylonite.

(b) <u>Petrography.</u>

Within the area mapped, this granite forms no prominent outcrops, and is mainly confined to the low-lying ground. Towards the north it gives rise to the grass- and bush-covered, highly dissected Singceni hills with isolated, bare, whale-backed, exfoliated outcrops, which form so characteristic a feature of the "Older Granite" in other parts of the country. These features are also characteristic of the country beyond the western boundary in the neighbourhood of the canon-like basin of the Assegai River. Towards the south-west (in the direction of Hlatikulu) it is much invaded by large dolerite sheets, and occupies the higher ground forming many smooth and rounded, exfoliated outcrops. In the south, it is again mainly confined to the valley floors, with here and there, prominent, immense boulder and pillar-like outcrops, some of which have been used as the burial places of Swazi "kings" (Makosini).

Weathering yields a pale, sandy soil. For descriptic purposes, the excellent exposures in the bed of the Hlatusane may be taken as typical.

The rock is generally pale bluish in colour, banded and much intersected by light-coloured veins, which traverse the rock in a sinuous and anastomosing manner, in a general direction parallel to the banding. (Plate II, Figure 3).

In the neighbourhood of the weir, large bodies of pegmatite, cut through the granite, leaving "islands" of the blue rock, in the form of varying sized lenticles.

A lighter-coloured variety becomes, in places the main body. Its lower resistance to weathering, results in the darker variety standing out as prominent bars across the river bed.

Jointing is well developed in two directions, one set parallel to the banding, and giving a sort of stratified appearance to the mass as a result of its "dip" towards the east;

the other, at right angles to this and giving rise to frequent deep and narrow rocky channels. The two largely determine the river-meanders.

The dark variety, which predominates, displays a variable grain, but is usually coarse-grained. The open foliation is an almost general feature, recognizable even in hand specimens; but, with finer grain, the structure tends to become granulose, and, in places, granoblastic.

Several specimens, regarded as representative, were selected for examination in thin slices under the microscope.

Slides, G.4., G.5., and G.2., (Plate V, Figures 2, 3 and 1 respectively), are typical of the darker variety. The gneissose structure is shown by the parallel alignment of the ferro-magnesian minerals. Quartz and felspars (the latter in excess over the former,) predominate and form a coarse, irregular mosaic, the individual crystals interlocking along crenulate margins. Oligoclase appears to be present in slight excess over the alkali-felspars, consisting of microcline and microperthite. The dark constituents are shreds of green biotite and small irregular plates of greenish hornblende. The accessories are magnetite, brownish sphene (frequently euhedral) and needles and small rectangular plates of colourless apatite.

In Slide G.5., no hornblende was found.

In Slide G.2., the structure tends to be granoblastic and the grain variable. Hornblende becomes an important constituent (green, pleochroic) and is in excess over biotite (brown).

Slides G.3., and G.1., (the former from the bed of the Hlatusane, the latter typical of the Maasingobe area) are representative of the leucocratic, variety. In both the grain is fairly coarse and the structure granitic.

In Slide G.3., the rock is seen to be composed of large anhedral crystals of quartz, somewhat turbid oligoclase and orthoclase, the felspars in excess over the quartz, and the

oligoclase/...

oliglase and orthoclase in approximately equal proportions. A few shreds of green chlorite and grains and veins of epidote are secondary altération products of an original ferro magnesian mineral (?biotite). The only other constituent is a little greenish uralitic hornblende. Slide G.1., contains microcline in place of orthclase, biotite as the only ferromagnesian mineral and apatite as an additional accessory. The felspars also show a high degree of saussuritization. Both, however, are granodioritic in composition.

The distribution of the granulose varieties has been detailed. All are to be described in general as quartz-felspar-granulites. It will be enough to select a few for detailed consideration, each being representative of types.

In the area around Mavugute and Mtambama, these rocks form the higher ground and compose both of those prominent peaks. Good exposures are abundant. In the topmost parts of both peaks, the rock weathers to form extensive, smooth, curved, surfaces by exfoliation, and pillar-like masses as a result of their well-jointedness. Caves have been developed by the slipping of large blocks along joint-planes. The weathered surface is greyish-brown. In all of these respects, the rock might well be normal granite. In hand specimen, the rock is reddish coloured, and distinctly banded. The banding is due to the alternations of fine and coarser textures. Under the microscope (Slide G.6: Plate VI, Figure 2), it is seen to consist of an even grained, fine-mosaic of quartz and microcline, along with subordinate oligoclase. Myrmekite intergrowths are not uncommon. Small plates and shreds of greenish-brown biotite, with a sub-parallel alignment, are fairly plentiful. This particular slide recalls the potash leptites, and certain of the Moine "gneisses".

Slide G.7. (Plate VI, Figure 1) is of a coarser band. The constituents are quartz, in the form of sub-parallel rod-like crystals, in a mosaic of microcline, and very subordinate

oligoclase/...

oligoclase. There are a few shreds of biotite and secondary chlorite. The structure is somewhat pegmatitic.

Slides G.9, G.11, and G.12 show no sufficiently distinctive features to require description here. (See Appendix and Plate Vi, Figures 3 and 4). In G.11, the structure is distinctly gneissose.

In the Sebowe region, as defined by the area of a belt of narrow, but indefinite and variable width, extending from the southern boundary along the Sebowe to the confluence of the Lubuya, the rocks retain similar general characters, but become more compact. The first noticeable difference is in their tougher nature, so that they are not easily broken by a hammer. Many specimens were examined under the microscope, but, only two need be described.

Slide Q.4., (Plate 6, Figure 5) is typical of the rocks exposed in the bed of the Sebowe over a distance of 1½ miles, both below and above the Lubuya junction. The slide is selected because it demonstrates pronounced effects of shearing. The structure is schistose, in part, flaser. The texture is irregular consisting of abundant augen, composed of granular aggregates of quartz and felspar (orthoclase and oligoclase), set in a fine-grained mosaic of the same minerals, and some sericite developed at the expense of felspar. The larger grains of both quartz and felspar show cataclastic structure. The rock is evidently a sheared quartz-felspar-granulite.

Slide G.15, (Plate VII, Figure 1) is selécted as illustrating the maximum effects of shearing in this area. In hand specimen it is creamish-white in colour, with pronounced schistosity The rock is found in somewhat inconspicuous outcrops, in the region between the Lubuya junction and the road. Near the river it is exposed on a small krantz in association with rock typified in slide Q.4. It is again exposed on the road cutting through the basic schists. It is

a very/....

a very fine-grained schistose rock composed dominantly of quartz-mosaic with a small amount of alkali-felspar, (orthoclase). It may be described as a quartz-schist, but appears to be better described as a mylonite. Its field relations seem to demand its interpretation as a completely crushed pegmatite or quartz-vein.

Attention is drawn to the fact that these quartz-felspar-granulites are confined to the higher ground in this western area, with the normal gneissoid-granite (granodiorite) exposed in the lower parts. The transition from the one to the other is gradual. In the extreme western area, in the vicinity of the Mantshiyane stream, the sequence of transition appears to be granulite - pegmatitic granite - gneissoid-granite. This is not suggested as being general, as in other localities examined no such traceable series was found. Taken in conjunction with the pyroxene-granulites (or, gneisses), already described, the analogy of the "Saxon granulites" becomes more pronounced. The exception lies, of course, in the complete absence from this area of any intercalated sediments.

The general problem of the origin of granulites is a vexed one. In this area there seems to be no doubt that they have arisen from the plutonic metamorphism of such quartzo-felspathic igneous rock types as aplite and pegmatite. Their distribution on the upper surface and, possibly, margins, of the gneissoid-granitic rock of more basic composition, is indicative of their having been a late phase product of that parent magma. The cataclastic structures have been induced by subsequent stresses.

Summing up, the pre-Pongola granite represents a body of general granodioritic composition, with more acid late phase associates. It forms, in its many and divers characters, the main body of an Archaean basement.

(c) Associated Aplites, Pegmatites and Quartz-Veins.

About 400 yards east of n beacon, and striking in a

north-easterly/...

north-easterly direction a small outcrop of whitish rock can be seen among the litter of dolerite boulders. This is a small dyke of aplite, about 5 feet in width. It disappears below the dolerite towards the west, and below a thick soil covering towards the east.

It is a fine-grained, granitic rock with typical aplitic structure, and consisting of an even-grained mosaic of anhedral quartz, oligoclase, and subordinate orthoclase, together with rather abundant small plates and shreds of brown biotite and secondary green chlorite. Zircon is a conspicuous accessory. The mineralogical characteristic of this rock is the abundant oligoclase, and the composition is decidedly granodioritic. (Slide G.8).

This was the only aplite found within the area of the map, but in the neighbourhood of Hlatikulu several small aplite bodies were observed in the form of smallish, elongated lenticles among the blue-gneissoid rock. Slide G.13, is typical. The structure is aplitic (Plate V, Figure VI). The rock consists of quartz, potash felspars (orthoclase, microcline and microperthite) and oligoclase, the felspars in excess over the quartz, and the acid plagioclase slightly subordinate to the potash felspars. Biotite is present as scattered brown plates.

Pegmatites are largely confined to the north-central area, delimited approximately by the Sebowe in the west and Kubuta in the east. In the Singceni hills to the north they become abundant, and the bodies within the area appear to be the smaller apophyses from the northward large bodies. Their trend and distribution are erratic. They are of small size, the largest observed being about 5 feet wide, while the smaller range down to a mere inch or two. Among the basic schists near the Sebowe, they occur as a plexus of small veins. They are from white to pale-cream in colour. They consist of an irregular, coarse quartz-felspar aggregate, microcline

dominating/...

dominating over common orthoclase, and frequently excluding it. Both hornblende and muscovite occur in segregated nests and clusters, the former invariably in the central parts, and the latter along the margins.

Pneumato-hydatogenic replacements were not observed, nor were any of the commoner economic and rarer minerals.

These pegmatites, therefore, appear to belong to the group referred to in the Regional classification of Professor T. W. Gevers as "Interior" or "Core" pegmatites. (25).

Quartz veins, except among the basic schists where, as already mentioned, numerous small ramifying ones occur, are not numerous. Only two occurrences of any note need be mentioned, and those because of the light that they throw on the mineralizing action of this granite.

The one occurs, prominently outcropping (as shewn on the map) on the crest of the ridge between the Sebowe and Lubuya streams. It is intersected by a large dolerite dyke. It is composed entirely of white vein-quartz and is about 5 feet in average width. It was found to carry a small quantity of copper ores, malachite at the surface, and minute well-shaped crystals of chalcopyrite deeper.

The other is poorly exposed in the neighbourhood of the granite contact north of Lokolwane. It forms two or three small, discontinuous, outcrops, among the abundant white quartzite talus, striking in a north-south direction. It was not traceable into the sediments, and must be presumed to be of prior age, and continous beneath them. In view of the fact that it cuts through the granite, and is probably a last phase granite magma product, this occurrence is a further evidence in support of the view, that the contact between the granite and the sediments is a sedimentary one. This vein, of uncertain width, also carries copper ores, malachite and bornite, along with galena, cerussite, and incrustations of

a deep/...

a deep azure blue mineral, which answered to tests for Cu, Pb, SO_4 and H_2O, and is probably linarite.

It is observed that those veins occur in the outer fringes of the region of pegmatites. That there are others, which have not been observed, is probable. Their hydrothermal origin is apparent, and their characteristics suggest their belonging to deposition under conditions of temperature and pressure connoted by the term "Mesothermal" (26). It is not unreasonable to assume that they are genetically related to the pegmatites.

While, as already observed, no economic minerals were found in the pegmatites, cassiterite is found in fair abundance, in small grains as an alluvial deposit in and around the bed of the Hlatusane, and, in larger grains (up to one-inch in length), as an eluvial deposit, on the slopes of the Singceni hills. The occurrence of tin in association with the "Older Granite" is a feature of this body over a wide area, and much profitable recovery work is carried on on various scales.

A further example of the tin-, copper-, lead paragenesis appears to be suggested.

(ii) The Post-Pongola Granite.

(a) Distribution and General Notes.

This body composes the large V-shaped mass cutting into, and wedging apart, the sediments in the south-east corner. It has been referred to as the "Sutugaans-Mooihoek massif" above, and its physiographical features and structural relationship to the sediments discussed.

It forms a rounded, whale-backed feature rising from 500 to 600 feet above the surrounding country. Examined in the light of tectonics, its intrusive disposition is beyond reasonable doubt. Its metamorphism of the quartzites by recrystallization has already been described. But I have been unable to detect any development of contact minerals in the shales

and slates/...

and slates. These were expected, looked for, but not found. Also, there is no surface evidence of any apophyses from the granite into the sediments.

I suggest that those apparent anomalies may find an explanation along the following lines:-

(1) that the granite body was of very shallow origin, and was forced in slowly as a plastic mass at low temperature, and already in greater part consolidated;

(2) that the composition of the shales and slates, namely their general ferruginous character retarded the chemical actions necessary to bring about the molecular movements for the formation of new minerals.

(3) that the heat conducting power of the slates, due to the presence of abundant iron, has been sufficient to cause a wide dissipation of the heat received from the intrusion, and so prevented that local elevation of temperature necessary to produce their fusion.

The contact with the sediments, in the few localities available for such observations, is fairly sharp, having been narrowed down to distances of 3 feet and less.

(b) Petrography.

At its western end, in its highest parts, there are prominent and extensive, fresh outcrops. Here weathering has resulted in the production of immense detached, rounded blocks and rectangular slabs with abundant smaller boulders. Followed to the south-east, fresh outcrops are not available until the scoured parts of the bed of the Hlatuse are reached. The many deep ravines eroded out by the streams which arise from this region, support a majestic growth of ferns, bushes, and large trees, and their beds consist of highly decomposed rock, thus providing poor facilities for the making of observations. Most of these streams are perennial and originate from joint springs. The soil tends to be pale and clayey. In fresh specimens, the rock is pinkish-grey in colour; when slightly weathered it has a handsome appearance owing to the brick-red colour assumed by the abundant felspars. The rock is massive, and coarse grained with a tendency towards becoming slightly finer grained around its margins.

Examined in thin sections (typified in Slide G.10; Plate V, Figure 5), it is seen to consist of a coarse mosaic of allotriomorphic crystals of quartz, microperthitic orthoclase (with albite intergrowths), twinned oligoclase and a few small flakes of altered biotite. A little magnetite is accessory, and chlorite and epidote are secondary constituents. Quartz makes up slightly more than one-third of the rock, microperthite is in excess over the quartz; and oligoclase represents about one-seventh of the whole. Mineralogically, therefore, the features of the rock are the abundance of quartz and microperthite, and the comparative poverty of mafic constituents. The rock would appear to be a typical soda-granite.

In the nomenclature of Johannsen (27), the name sodaclase-granite seems appropriate on its estimated mode. The name I have employed, from reasons of familiarity by usage, is leucocratic biotite-granite.

Both in hand-specimen and under the microscope, this granite bears a singularly close resemblance to the "Younger" or "Bushveld" Granite, with several specimens of which it has been closely compared. In his classical Memoir on the Bushveld Igneous Complex (28), with its invaluable Bibliography

of/...

of Chapter I, Dr. A. L. Hall presents an exhaustive survey of the characteristics of the "Bushveld" or "Younger Granite".

The lithological and petrographical characters of the "Bushveld Granite" have been summed up, and may be quoted in brief here:-

> "The common fresh Red Granite has a prevalent pale to dark reddish colour, owing to the large proportion of red felspar .... There is evidence to show that the rock at depth tends to be very pale reddish ....
>
> "The Texture is coarse, equigranular, and without directional properties .... In approximate order of abundance the mineral content is as follows: Felspar, quartz, hornblende, biotite, apatite, and zircon, associated in a hypidiomorphic granular texture; micropegmatite elements are also common. The prevailing felspar is microperthite made up of an intimate intergrowth of cloudy soda-orthoclase and clear oligoclase albite."

Attention is also drawn to the prevalence of associated granophyric varieties, and to the absence of pegmatites.

Quartz/...

(c) Quartz Veins.

The complete absence of pegmatites from this granite is recorded.

The quartz-veins present no unusual features. They tend to be small and consist of pinkish-white quartz. Prospecting on them has failed to reveal the presence of any economic minerals.

(iii) Granophyre and Granophyric-Quartz-Porphyry.

(a) Distribution.

Attention has already been drawn to the large transgressive sheet of granophyric-quartz-porphyry around Ngcongcwane, and reasons given for regarding it as intrusive.

Other sporadic occurrences, in the form of small outcrops of dykes and a small stock of granophyric rock have also been mentioned, and are located on the map by q.p.

(b) Petrography.

The Ngcongcwane sheet, throughout its occurrence in the west and north faces of the escarpment, appears to lie conformably on the "Ridge" quartzite, which has suffered considerable recrystallization thereby. Towards the east it partly overlaps this body. Its general dip direction conforms with that of the sediments, but the amount varies from 5° to 10° less, so that by nearly conforming to the ground slope, it forms an extensive outcrop. Its average thickness is estimated at 500 feet.

The rock is well-jointed, in directions parallel to the dip and strike. Many springs emanate from them, and the Little Hlatuse, and many of its tributaries, arise therefrom. Weathering produces a pale-brownish to pinkish, rough surface.

The fresh rock has a greyish, glassy appearance, with distinct porphyritic structure due to well-developed, euhedral to subhedral, quartz phenocrysts up to 4 m.m. in size. Under

the/...

the microscope (Slide G.14; Plate VII, Figure 6), the quartz phenocrysts, usually fringed with micropegmatite, are seen embedded in a compact groundmass composed of micropegmatite and a fine mosaic of quartz and orthoclase with a little oligoclase. Some chloritized biotite, a little sericite and magnetite are the only other constituents. Thus, the rock is granophyric quartz-porphyry.

The only other occurrence of note and requiring any description is that of a small oval-shaped outcrop, of greyish, granitic rock. This occurs on either side of the road north of Kubuta. The light-colour, and the boulder-like formation, of the outcrop, is prominent among the long grass and bush and the dark-red, quartz-littered surrounding soil. It cuts through the basic-schists, apparently in the form of a small stock.

The rock (Slide D.2; Plate VII, Figures 4 and 5), is a holocrystalline and porphyritic igneous rock with granophyric texture. Rounded to euhedral crystals of quartz, tabular plates of perthitic orthoclase, and subordinate stout crystals of twinned oligoclase, are embedded in a groundmass of micropegmatite. This granophyric intergrowth of quartz and orthoclase also forms fringes around the larger crystals. Uralitic hornblende occurs sparingly in fibrous prisms, and secondary chlorite in small radiating clusters. Well shaped zoned and twinned orthite (allanite) is a conspicuous accessory. There is also a little secondary epidote and white mica (sericite). The rock is a typical granophyre.

The smaller dykes are also composed of granophyre.

All of these occurrences are regarded as being genetically related to the post-Pongola granite.

VIII. KARROO SYSTEM - DWYKA SERIES.

(a) General Remarks.

This small remnant of that widespread glacial formation, which forms the base of the Karroo System (29) occurs as an unconformable outlier on the "1st Shale and Slate" formation at Sutugaans.

It forms a rounded hill, the pale, sandy soil of which, in contrast with the reddish, clayey soil of the slate area, drew my attention to it primarily.

The dip is uniformly 10° towards the south.

The maximum thickness is estimated at 150 feet.

So far as I am aware, this is the most northerly occurrence of this formation, as yet discovered, outside of the High Veld regions of South Africa.

(b) Characters of the Rocks.

The basal 5 to 15 feet consists of typical tillite (compact, glacial conglomerate). The boulders comprise all of the more resistant rock types of the area, with the exception of the post-Pongola coarse, red, granite. The larger blocks, up to 4' by 3' by 2½' in size, are composed of quartzite, derived almost entirely from the "basement" formation. Boulders of quartzitic-conglomerate and of the "contorted" rock are also abundant, while those of the gneissoid granite are relatively scarce. The pebbles are dominantly of quartzite and white vein-quartz.

The largest blocks are sub-angular in form, and there is a marked tendency towards more perfect rounding with decrease in size. All are characteristically smoothed, but striations were not observed. There is also the typical random arrangement.

These boulders and pebbles are embedded in an abundant, pale greyish-brown, unlaminated, compact material, whose average

grain-size/...

grain-size is to be described as of silt grade (30).

This is followed by a variable thickness (1 foot to 4 feet approximately) of a finely-laminated, fine-grained to gritty, brown coloured, friable sandstone, devoid of pebbles. Above this a thinner layer of tillite comes in, similar in character to the lower layer. Additional exposures of higher layers are poor, but tend to indicate a dominance of the laminated sandstone. On the topmost parts of the hill, a few scattered random boulders and fairly abundant pebbles, among the thick sandy soil, indicate a continuation of the same general character throughout. No evidences of the existence of intercalated shales were found. This occurrence of Dwyka Tillite resembles that described by Dr. L. J. Krige as occurring over large areas in the Vryheid district (31), and, in more isolated patches, in the northern adjoining area (32).

The nature of the glaciation, which led to the deposition of the Tillite in this eastern part of South Africa, has been effectively disposed of by Dr. du Toit (33). This small patch would appear to represent a remnant of an old valley infilling. A northerly source of the materials is indicated only by the absence of red granite boulders, and the abundance of materials belonging to rocks only known to lie towards the north.

IX. THE KARROO DOLERITES.

(a) General Remarks.

The immensely wide-spread character of this "imperial invasion of the earth's crust" (34) by basic magma during the Jurassic Period, is outlined by Dr. A. L. du Toit (35).

Its extraordinary penetration of the Karroo System beds, in the form of sills, low-angle sheets and dykes, particularly depicted in the Pondoland, Maclear-Umtata and Matatiele sheet

maps/...

maps of the Union Geological Survey, has justly earned it its name.

That it is not by any means confined to these sediments, but is also present, in like majesty, among the oldest formations, is illustrated in the Nkandhla, Vryheid and Piet Retief sheet maps.

Its mode of origin, and, in particular, its relationship to the "Stormberg" basaltic lavas, examined in the light of the crystal-fractionation of basaltic liquid theories of N. L. Bowen (36), have been examined by R. A. Daly (34).

The effects of its differentiation in its thicker masses of Tabankulu and Tonti, in Pondoland have been described by Dr. A. L. du Toit (37), and of Insizwa, East Griqualand, by Dr. D. L. Scholtz (38).

The mechanism of the probable mode of injection of the Dolerite sheets into the Granite has been examined by Dr. L. J. Krige (39), and Dr. du Toit's views on uplift of overlying masses revised.

All authors stress the remarkably uniform composition of the rocks throughout their wide distribution.

(b) Petrography.

Within the area under survey, the Karroo Dolerite intrusives take the form mainly of low-angle, transverse sheets, up to 200 feet in thickness, and numerous large and small dykes. The sheets are best developed in the western area, attaining their maximum thickness around Mtambama and Mavugute. There is no doubt that the occurrence of the similarly disposed body, eastward from Lokolwane, was originally continuous with the other, all forming part of one immense sheet now in large part eroded away. Small, ramifying dykes are particularly abundant in the low-lying ground to the north-east. These appear to be branches and sub-branches from the

large/...

large dyke cutting across the north-east corner of the map. The numerous dykes in the high-ground of the north-west corner are definite apophyses from the main sheet.

Beyond the eastern boundary, the dolerite continues, forming the tops of numerous "island" kopjes, and giving rise to a conspicuous "range" (the Sitobela Kopjes) 8 miles to the east. Numerous dykes are found in the low-lying Bushveld as far as the Lebombo Escarpment. Towards the south and south-west, thick sheets and their remnants are abundant, notably around Hlatikulu.

Weathering is characteristically spheroidal, resulting in the formation of boulder strewn outcrops. In places, the well-jointed character of the rock has resulted in the development of "mural" features.

The rocks are variously gabbroic, doleritic and epidioritic. The normal dolerites are olivine-bearing with a tendency towards quartz-dolerites, and with a considerable variation in structure, porphyritic and ophitic varieties predominating.

Numerous petrographic descriptions of selected slides are contained in the Appendix. It will be enough to discuss the more distinct varieties here, with particular regard to their areal distribution.

The Mtambama sill is typified in slide D. 13. The rock is composed essentially of plagioclase and augite, in about equal quantities, and arranged in a typical ophitic manner. The plagioclase is a basic labradorite. It forms stout laths and irregular plates, and is twinned on the albite law. It is only slightly turbid in places, being generally clear and fresh. The augite is pale-brownish in colour, non-pleochroic, characteristically cleaved, and the smaller euhedral crystals frequently simply twinned. Its extinction angle is constant at 36°. It may be the pigeonite variety.

Olivine is present in fair quantity as small rounded to euhedral crystals, showing alteration to green serpentine, around margins and along sinuous cracks. Accessories are small flakes of partially chloritized biotite, and magnetite. The rock is an olivine-bearing dolerite, and is characteristic of the whole mass around the Mtambama and Mavugute peaks and along the vicinity of the western boundary. Olivine is always present in small quantity. Quartz was not found in any of the specimens from this area.

Slide D.5 (Plate IX, Figure 1) is representative of the transverse sheet extending south-eastwards from the Lokolwane trigonometrical beacon. This sheet, in its western limit forms a vertical cliff about 80 feet in height, at which exposure it can be seen cutting transversely through and overlapping the "basement quartzite". Large-scale mural jointing is a feature in its several cliff exposures. Distinct basaltic (that is, very fine grained) facies are developed on top and bottom surfaces.

The slide (D.5) shows the rock to be a quartz-bearing olivine-dolerite. The grain is coarser than that of D.13, and the ophitic texture not so pronounced. The plagioclase is a labradorite with extinction angle on c/b varying from −20° 6' to − 28° 12', so that it tends towards bytownite in composition. It forms generally turbid stout laths and plates and is in slight excess over the augite. The augite is the usual brownish, non-pleochroic variety, and forms irregular plates a and smaller euhedral, simple-twinned crystals. In places it displays alteration in the form of small marginal fringes of secondary greenish chlorite. The olivine is present in numerous small rounded grains and is highly serpentinized. Much of it has been converted into secondary, reddish-brown, pleochroic iddingsite. A feature of the slide is the comparative abundance of quartz-orthoclase (micropegmatite) mesostasis between the felspar laths. These general features are also

typical/...

typical of the same sheet in its exposures around Maasingobe (Slide D.4, Plate IX, Figures 2 and 3), and of the Sitobela kopjes rock (Slide D.3., Plate IX, Figure 4), except that in both these latter the micropegmatite mesostasis, and olivine are not so abundant, and the ophitic texture more pronounced.

A specimen taken from a large dyke cutting the pre-Pongola Granite about 5 miles beyond the northern boundary of the map was examined. I was attracted to this on hearing of blasting operations in the course of the making of a cutting. The full width of the dyke was not exposed but is estimated at from 400 to 500 feet. In contrast with the usual dull appearance and fine grain of the dolerites, in hand specimen this rock is bluish-black, bright and coarse grained. Under the microscope (Slide D.14), the rock is decidedly coarse grained with granitic texture. Augite and olivine make up about three-fourths of the rock, the former only in slight excess over the latter. The plagioclase forms small laths and groups of laths occupying interstices between the mafic constituents. It displays fine lamellar twinning and has been the last mineral to crystallize. The augite is pale-brown in colour, non-pleochroic and well-cleaved. It occurs in large rectangular plates and smaller subhedral to euhedral crystals. It is simply twinned and also zoned, with an extinction angle of 35°. The olivine occurs as large subhedral to euhedral plates with characteristic alteration, and has been the first of the minerals to crystallize. Magnetite occurs in well-shaped and skeletal crystals. This is an Olivine-Gabbro.

In the low-lying ground of the north-east corner, numerous small and larger dykes (from 5 to 300 feet in width) and sheet outlying remnants occur. All of these are composed of epidiorite (meta-dolerite).

Some of these will now be described in detail; the bulk of the petrographic descriptions have been referred to the appendix.

In the/...

In the extreme north-east corner (the southern limit is more or less bounded by the road), the several dykes trend in an approximate south-easterly direction, with off-shoots at right-angles. These appear to form a sort of parallel and linked system, the main body being the large one (up to 750 in width) to the north of the river. They follow the joint and foliation planes of the gneissoid-granite. Their outcrops are generally prominent and boulder-strewn. In the river-bed they contribute towards small waterfalls and cataracts.

Slide D.1., is typical of the dykes in the vicinity of the orchard. Labradorite and greenish uralitic hornblende in approximately equal proportions make up the essential rock. Magnetite, and a little sericite and epidote are accessories. The labradorite forms stout laths and smaller rounded plates. The larger laths show a tendency towards glomeroporphyritic grouping so that in hand specimen the rock has an indistinct porphyritic appearance. This is seen under the microscope as a variation in grain. In the coarser-grained areas the felspar is related to the uralitic hornblende in an ophitic manner (Plate VIII, Figure 1), while in the finer-grained portions they occur as scattered rounded blebs (Plate VIII, Figure 2). The labradorite is lamellar twinned and zoned, with more basic cores. It is turbid, the alteration products consisting of aggregates and trains of granular epidote and flaky sericite around the margins and along the cleavage planes of the crystals. The base is composed of greenish-brown pleochroic uralitic hornblende, in the form of irregular plates and fibrous aggregates. The abundance of associated magnetite dust is a by-product of the conversion of the original augite. This rock is an epidiorite with obscure porphyritic structure.

Slides D.12., and D.9., are of the rock forming the north-south trending dyke to the west of the above. Slide D.12 (Plate VIII, Figure 6) represénts a marginal facies of this 300 foot wide body, and is generally similar to all the normal epidio-

rites/...

epidiorites. Its original doleritic nature is retained in the lath-shaped form of the labradorite and the recognizable ophitic texture.

Slide D.9. is representative of the rock forming the more central portions of this and other larger similar bodies. The grain is coarser (Plate VIII, Figure V), and the structure somewhat granitic. The felspar plates are highly saussuritized to a fine-grained aggregate of epidote and sericite mainly. A small amount of quartz and alkali-felspar form a micropegmatitic mesostasis particularly between the saussurite plates. Greenish uralitic hornblende forms large plates of fibrous aggregates. Magnetite occurs both as skeletal crystals and fine secondary dust. This rock appears to be more aptly described as an altered quartz-dolerite, although obviously a general epidiorite.

Some interesting variations from the above normal dolerites and epidiorites will now be described.

On the map, about a mile east of the Lokolwane beacon, two dykes are depicted forming a "wish-bone" pattern. These give rise to a prominent kopje locally known as "Prospect". In hand specimen the rock has a somewhat porphyritic structure. Slide D.17 is typical. The grain is fine and the texture obscurely ophitic. The noteworthy feature is the presence of both augite and uralitic hornblende, the former occurring both as platy individuals and as transitional fringes around augite cores. These fringes are sometimes very narrow so that the augite individual predominates; again, the bluish-green pleochroic, fibrous and granular uralitic hornblende almost completely replaces the augite which is then represented by a small core. In addition there are euhedral to irregular plates of unaltered augite, and also irregular, stout rectangular and elongated crystals composed entirely of rather pale, yellowish brown to faint bluish green pleochroic, uralitic hornblende. Those latter usually contain many small crystal

inclusions/...

inclusions of felspar in sufficient quantity to merit description as "schiller". The labradorite occurs both as elongated laths and small plates, with local glomeroporphyritic grouping into felted plexuses and radiating arrangements with small smounts of interstitial, uralitic hornblende. This gives the rock its obscure porphyritic structure. The small rounded felspar plates by their clearness from alteration products and absence of zoning and twinning would appear to indicate a certain amount of recrystallization. Magnetite is accessory in the usual manner.

Slide D.16, prepared from a specimen taken from a small dyke, forming the lip of a waterfall on the Hlatusane just outside the north-east boundary, displays the same features with regard to the augite and uralitic hornblende. There is no trace of porphyritic structure; and the texture is granular; the felspar is highly saussuritized and olivine is present in subordinate quantities. These rocks represent an intermediate type between normal dolerite and epidiorite, and are instructive in this regard. I have not encountered such transitional types before.

In the course of an examination of the dolerite bodies in the neighbourhood of the Sitobela kopjes, my attention was attracted to the basal portion of a sill remnant forming am outlier on the pre-Pongola granite. Superficially, in its dark colour and general features, the rock résembles the porphyritic varieties of the epidiorites. The abundance of glassy phenocrysts, apparently quartz, prompted me to a closer examination. A sharp contact with the underlying granite could not be found. The rock grades upwards into the normal dolerite by imperceptible transition. The normal dolerite has already been described (Slide D.3).

This rock, under the microscope (Slide D.10; Plate IX, Figure 5) consists of quartz, orthoclase and hornblende, with marked porphyritic/...

porphyritic structure. The quartz occurs as phenocrysts consisting of rounded crystals and granular aggregates of clear quartz. These are embedded in a groundmass of fibrous micropegmatite (quartz, orthoclase) containing abundant acicular crystals of brownish hornblende. The peculiar and characteristic mineralogical feature is the abundance and fibrous nature of the micropegmatite. Without knowledge of the field relationships the rock would be described broadly as granophyre. It is obvious, however, that such a name masks its reality, namely its syntectic origin. It appears, beyond doubt, to represent contact altered granite enveloped in and to a large extent assimilated by the dolerite magma.

The general composition of the dolerite appears to be that connoted by the name olivine-bearing quartz-dolerite. Admittedly quartz is not a prominent constituent, but the occasional presence in variable quantity of quartz in quartz-orthoclase micropegmatite is taken as justification for this generalization.

The epidiorites represent low-grade dynamically metamorphosed facies of the dolerite. The fact that such rock type composes the smaller dykes of the north-eastern area, suggests that these dykes represent the feeder channels, of original deeper seatedness, exposed in the lower ground by erosion over a long period.

The sheets, in general, adopt a sill-like character both in the granite and in the sediments. The magma would appear to have insinuated itself along original planes of weakness in both the sediments and the pre-Pongola granite. In the case of the granite body, the planes of weakness are those of foliation and jointing, in the sediments, bedding- and joint planes. Thus, the superincumbent layers have suffered uplift in order to provide the necessary accommodation for the intruded mass. This is well evidenced in the case of the "basement quartzite" in the vicinity of Lokolwane, and in the Mtambama and Mavugute peaks.

Further/...

Further evidence of this is afforded by the fact that the post-Pongola granite, which is massive, has no dolerite bodies intrusive into it. In fact, the sill-like body of dolerite, below the "contact quartzite", has every appearance of having suffered a northerly deflection on approaching this granite: and this bears interpretation of the magma's having chosen the line of least resistance on encountering the great resistance of the massive granite body, as also of its apparent inability to create the necessary planes of weakness in that body.

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X. ECONOMIC NOTES.

(a) Gold and Ancient Workings.

Mention has already been made of the occurrence of gold in minute traces in several of the quartzitic-conglomerate bands near the base of the "basement quartzite" formation.

In all fifteen chip samples were taken from various bodies in the vicinity of Lokolwane and Mhlope, and assayed for gold. Ten of these samples showed a trace of free-milling gold.

The occurrence of sporadic gold in the Pongola System, at the same horizon, is well known in many localities, particularly in the neighbourhood of the Pongola River south-east of Piet Retief, e.g. on the farm Wonderfontein.

The ancient workings around Lokolwane, indicative of extensive mining operations in the dim past, are unique in their adit approaches to the old working places.

Their ramifications are immense and thoroughly unsystematic, so that here it would appear that a bedded deposit had been exploited, while there the development follows a maze of tunnels and chambers in barren country. In the absence of indications of any other metal, it has been assumed that gold was sought.

Much/...

Much of the abundant talus on the neighbouring slopes represents the waste from these workings.

In the absence of any artifacts it becomes impossible even to hazard an opinion regarding the workers or the period of their activity.

The term ancient, as applied to the old workings found in Rhodesia and the Northern Transvaal, is applied here because of the development of considerable stalactitic quartz incrustations on the rock faces and because they have become legendary among the native population.

(b) Iron and Native Industry.

The occurrence of seams of iron-rich rock at several horizons, particularly in the "basement quartzite" and "1st Shale and Slate" formations has been referred to.

In the vicinity of the native school at Sutugaans, extensive exploitation of siliceous iron-stone bands in the "contorted" body, has been effected for, at least, according to hearsay, the past one hundred years. The bodies are to be described as fine-grained highly ferruginous quartzites. An analysis of several specimens gave an average of 27·7 per cent iron and 4·6 per cent manganese. The remainder being dominantly silica and not estimated.

There is still resident in the area a native family whose predecessors for two or three generations have worked and smelted this ore for the manufacture of weapons (assegais and axes).

In several localities in the Pongola River area, the weathering and leaching out of iron from the outcrops of similar bodies has led to the concentration of residual deposits of manganese ores. Attention has been drawn to these by Dr. Hatch (40).

(c) Copper and Lead.

The occurrence of chalcopyrite, malachite, galena, cerussite and linarite in small quantities in quartz-veins of

hydrothermal/...

hydrothermal origin has been described in Chapter VII, para. (i)c.

(d) Tin and Associated Rare Earth Minerals.

Within the limits of the area mapped, cassiterite occurs in both alluvial and eluvial deposits.

The alluvial deposits are confined to the bed, deserted channels, "ox-bows", and surrounding flood-plain areas of the Hlatusane below the weir.

The cassiterite occurs in small crystals, many displaying the characteristic "knee bend" twinning habit, and irregular grains from mere specks up to 6 mm., concentrated in pebble layers.

Several specimens of washed sands were taken and separated into their constituents by elutriation, magnetic and heavy liquid processes.

Quartz predominates, making up approximately 70 per cent by weight. The other mineral constituents in approximate order of abundance are, magnetite, ilmenite, haematite, cassiterite, topaz, zircon, monazite, euxenite and apatite.

An analysis of one specimen for tin, gave 0·17 per cent metallic tin.

Large crystals and grains of cassiterite, up to about one inch in length were found eluvially on the higher slopes to the north.

The source of these deposits is the mineralized and pegmatite invaded pre-Pongola granite forming the Singceni hills to the north. The deposits would appear to be worthy of close investigation.

(e) Talc.

Although occurring in fair quantity as a slightly schistose body, as already described in Chapter V, the presence of grains of iron scattered through the mass render it somewhat impure, and hardly comparable in quality with other occurrences e.g. the body in association with a quartz-schist exposed near the dam constructed on the Pongola River in connection with the irrigation scheme of that area.

XI. SUMMARY.

(i) The work is a study of the regional geology of an area of approximately 90 square miles situated in Southern Swaziland, commenced in March 1935 and completed in December 1937.

(ii) The area is a maturely eroded, mountainous one, typical of much of the Low Veld region of South Africa.

(iii) The drainage is towards the north and east by the southernmost, perennial tributary streams of the Great Usutu River.

(iv) The geological formations represented in the area are:-

- (a) Some small patches of basic schists and granulites.
- (b) A large area of gneissoid-granodioritic rock, the "Older Granite" of the eastern portions of the Union of South Africa, described here as the pre-Pongola granite.
- (c) A considerable area of Upper Pongola System beds.
- (d) A large body of red granite intrusive into the Upper Pongola System beds, and described as the post-Pongola granite.
- (e) Granophyric intrusives related to the post-Pongola granite.
- (f) A small patch of the Dwyka Series (Karroo System).
- (g) Abundant sheets and dykes of "Karroo Dolerite".

(v) The basic schists comprise hornblende schists, amphibolites, talc-schists and talc-tremolite-schists. The basic granulites or gneisses are represented by pyroxene-garnet-gneiss and biotite-pyroxene gneiss.

They are interpreted as high-grade regionally (i.e. dynamothermally) metamorphosed basic igneous rocks, and as plutonically metamorphosed basic igneous rocks respectively. They are regarded as forming with the pre-Pongola granite an "Archaean basement".

(vi) The pre-Pongola granite is associated in an intimately intrusive manner with the basic schists and granulites.

It is almost invariably banded and gneissose. In colour it is usually light bluish-grey with light cream to white coloured variations. Aplites and pegmatites in association are locally abundant, while in the higher ground in the western area, quartz-felspar-granulites appear to represent plutonically metamorphosed more acid varieties. Shearing along a thrust plane has resulted in the production of bodies of mylonitized granulite and pegmatite.

The average composition of the rock suggests a granodioritic composition tending towards the granite end of the series.

This body is correlated with the "Older Granite and Gneiss" formation of the eastern part of the Union of South Africa, and it is postulated as non-insrusive into the sediments of the Upper Pongola System.

(vii) The Upper Pongola System is represented by a thick (14,600 feet approximately), conformable group of quartzites, slates and shales, with a topmost bed of amygdaloidal basic lava

(diabase)/...

(diabase), resting on the pre-Pongola granite with a sedimentary contact, and intruded into by the post-Pongola granite and associates, and "Karroo Dolerites".

The metamorphism of these beds is only slight; in the vicinity of the post-Pongola granite massive the quartzites have suffered complete recrystallization, while the slates show no development of contact minerals. In two localities the slates have been contact metamorphosed to "mild" hornfelses. Probable explanations of the very low-grade metamorphism of the slates are offered.

The structure is that of an outlying remnant of a modified, pitching syncline or centrocline.

These beds have been correlated by Dr. L. J. Krige and Dr. W. A. Humphrey with the Moodie's Series (Swaziland System) of Barberton. A case is made out suggesting a more suitable correlation with the Witwatersrand System of the Transvaal.

(viii) A massif of red granite, intrusive into the above sediments, is recognized as a body distinct and much postdating the pre-Pongola granite. It is named the post-Pongola granite.

This granite is massive and coarse-grained. It is red in colour, becoming pinkish-grey in deeper regions, and is remarkably uniform throughout. There are no associated pegmatites.

It is characterized mineralogically by the abundance of quartz and microperthitic-orthoclase and poverty of ferromagnesian minerals. It is regarded as a typical sodagranite and, following Johannsen, has been named sodaclase-granite, or, otherwise, leucocratic biotite-granite, resembling in mode that of Benguella, described by Dr. G. W. Tyrrell.

Attention is drawn to the remarkably close resemblance of this granite to the "Younger" or "Bushveld" granite of the Bushveld Igneous Complex of the Transvaal as described by Dr. A. L. Hall.

Such a granite has previously not been recognized in this part of South Africa nor farther south, and is now described for the first time.

(ix) A sheet, a small stock and some small dykes of granophyric-quartz-porphyry and granophyre are described.

These are regarded as consanguinous with the post-Pongola granite.

(x) A small patch of Dwyka Series, represented by tillite and fine laminated sandstone is described.

It is believed to be the most northerly occurrence of this formation outside of the High Veld regions as yet described.

(xi) Occurrences of sheets and dykes of "Karroo Dolerite" are described. These are represented by all varieties from olivine-gabbro, through normal ophitic and obscurely porphyritic dolerites and transitional types to epidiorites (metadolerites).

The general composition is described as olivine-bearing quartz-dolerite.

The probable mode of emplacement is briefly suggested.

(xii) A geological map is included, also nine Plates.

The plates comprise two geological sections to illustrate the main structural features, six scenic photographs and thirty-six photomicrographs to illustrate the petrographical descriptions.

(xiii) Brief petrographical descriptions of forty four selected rock slides are contained in an appendix, as also a brief bibliography of references made in the text.

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XII. ACKNOWLEDGMENTS.

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The draughting work of the map and of the Sections on Plate III was done by Mr. John Biggar, one of my students. I have pleasure in acknowledging with sincere thanks my indebtedness for this help.

In the production of the photomicrographs and in the reproduction of the map and Plate III, I had the valuable assistance of a friend, Mr. F. Groth. I gratefully acknowledge this help.

Finally, I am indebted to many friends for their reading of the manuscript, in part or in whole, and for their helpful suggestions and kindly interest.

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APPENDICES:

(a) Descriptions of Selected Rock-slides.

(b) Bibliography.

APPENDICES.

(a) Descriptions of Selected Rock-Slides.

Slide D.7.

Rock name: Hornblende-schist.

Minerals present: Hornblende, plagioclase, quartz, magnetite, epidote.

Description: In hand specimen this is a bluish-black glistening rock showing well-marked foliation.

Under the microscope this is seen to be a definitely schistose structure due to the banding and linear arrangement of the hornblende.

The hornblende is green and highly pleochroic. It occurs as elongated blades in well-defined bands. It displays the characteristic well-marked cleavages, and is present in slight excess over the light-coloured constituents.

The plagioclase occurs as a mosaic with the quartz in the form of anhedral plates. It is an andesine and is turbid with alteration products.

The quarts occurs as clear rounded to ovular blebs and is present in comparatively small quantity.

The magnetite occurs in small grains and as a fine dust.

The epidote is a secondary product occurring both as a turbid alteration of the plagioclase and in small veins cutting the rock.

(Plate IV, Figure 3.).

Slide D.8.

Rock name: Amphibolite.

Minerals present: Hornblende, plagioclase, quartz, magnetite.

Description: In hand specimen this rock resembles D.7.

Under the microscope it shows a typical granoblastic texture and no trace of schistosity.

It consists of an even-grained mosaic of hornblende and clear andesine.

The hornblende is green and highly pleochroic and shows the characteristic cleavages. It occurs in the form of rounded and irregular crystals.

The plagioclase is a twinned andesine. It is fresh and free from inclusions. It occurs as rounded and irregular crystals.

The quartz is subordinate and is seen as small, round and clear crystals.

There is also a little magnetite in well-shaped grains.

(Plate IV, Figure 1).

Slide D.6.A.

Rock name: The rock might be described as a Hornblendite. Its field relationships, however, tend to compel its description as an Amphibolite - a true metamorphic rock of original

igneous/...

igneous origin and representing a medium-grade dynamically metamorphosed basic lava.

Minerals present: Greenish hornblende, colourless hornblende (? Tremolite), magnetite, epidote.

Description: This is a phanerocrystalline, melanocratic, massive rock which is composed almost entirely of a mosaic of anhedral amphiboles.

The hornblende occurs as large platy crystals many of which display the characteristic cleavages and also as fibrous aggregates. It is greenish-brown and pleochroic and uralitic in character.

The colourless amphibole (? Tremolite) occurs as long bladed prisms commonly aggregated into plates. These plates are fringed with minute grains of secondary magnetite which serve to define the otherwise obscure mosaic character of the crystals and also to make clear the original igneous nature of the rock.

The magnetite, besides occurring as secondary minute grains, is also found in well-shaped grains of original igneous origin.

The epidote occurs as interstitial rounded grains and also as trains of minute grains in the colourless amphibole from which it has been derived. Some of the interstitial granular small aggregates may represent original laths of basic felspar.

(Plate IV, Figure 2).

Slide Q.3.

Rock name: Pegmatite (slightly sheared).

Minerals present: Microcline, microperthite, quartz.

Description: This is a cream coloured to white rudely banded rock. The structure is typically pegmatitic with the irregular segregation of quartz into elongated streaks.

The rock consists mainly of a coarse aggregate of large plates of microcline (with well-marked cross-hatched twinning), together with subordinate microperthite (with typical perthitic intergrowth of albite spindles) and quartz.

Mineralogically the rock is characterised by the abundance of microcline and the absence of mafic constituents.

(Plate VI, Figure 6).

Slide Q.2.

Rock name: Garnetiferous-pyroxene-gneiss.

Minerals present: Quartz, orthoclase, garnet, hypersthene, augite, hornblende, magnetite.

Description: In hand specimen this is a medium-grained, dense, black rock, containing abundant small red garnets and rounded crystals of black pyroxene (augite).

Under the microscope it shows a typical banded gneissose structure.

Greenish to pinkish pleochroic hypersthene is the chief mineral. It occurs as subhedral to euhedral crystals and in places displays a uralitic striation.

Highly refringent rounded crystals of pink garnet are abundant.

Some/...

Some of the larger crystals show cataclastic effects, and are fringed with radiating striated hypersthene.

Some brownish augite and greenish to brown hornblende occur in smaller quantity and frequently in well-shaped crystals.

All of these mafic constituents are set in a coarse groundmass of clear and fresh quartz and orthoclase, the latter mineral untwinned.

Minute grains of magnetite occur scattered through the slice.

(Plate IV, Figures 4 and 5).

Slide Q.5.

Rock name: Biotite-pyroxene-gneiss.

Minerals present: Quartz, plagioclase, biotite, augite, sphene.

Description: Megascopically this is a grey, dense, gneissose rock charaxterised by the numerous rounded crystals of black augite and small black, glistening plates of biotite.

Under the microscope it is seen to consist of large, platy crystals of clear and colourless quartz and even-grained mosaics of quartz and oligoclase. These two constituents make up over 60 per cent. of the rock and the quartz is present in slight excess over the felspar.

The remainder of the rock is composed of equal amounts of biotite and augite embedded in the mosaics.

The augite occurs as rounded or irregular light-brownish crystals with well-marked cleavages.

The biotite is seen as small irregular plates. It is reddish-brown in colour and strongly pleochroic.

Sphene, in well-shaped crystals and irregular grains is an important accessory and may represent original ilmenite.

(Plate IV, Figure 6).

Slide K.J.1.

Rock name: Altered quartzite or Quartz-schist.

Minerals present: Quartz, sericite.

Description: In hand specimen this is a fine-grained, greyish-coloured rock with a slightly soapy feel.

Under the microscope it is seen to be composed of small rounded and irregular grains of clear quartz, with crenulate margins, separated by thin films of flaky sericite.

In parts the rock shows an indistinct schistosity or fine-banding. This is due to the presence in rough bands of fine-grained quartz mosaic containing abundant streaks of sericite.

(Plate VII, Figure 3).

Slide K.J.2.

Rock name: Quartz-sericite schist.

Minerals present: Quartz, sericite, magnetite.

Description: In hand specimen this is a greenish-white rock of soapy appearance and displaying a well developed schistosity.

Microscopically it consists entirely of quartz and fine-flaky sericite in about equal proportions together with a small amount of fine magnetite dust.

The quartz/...

The quartz forms irregular grains and aggregates and shows well-marked strain shadows (undulose extinction).

The schistosity is visible in the arrangement of the sericite flakes and is emphasized by the elongation of the quartz-grains.

Slide K.J.3A.

Rock name: Quartz-sericite Rock (Sericitized-granite).

Minerals present: Quartz, sericite, chlorite, magnetite, sphene.

Description: In hand specimen this is a light greenish, somewhat coarse-grained, massive rock without any trace of schistosity and having the general appearance of an altered granite type.

Under the microscope it is seen to consist predominantly of large irregular grains and aggregates of colourless quartz with well-developed strain shadows set in an abundant matrix of fine-grained sericite which exceeds the quartz in amount.

The only other constituents are a small quantity of secondary green chlorite in ragged flakes, a few grains of brownish sphene and some black opaque magnetite.

(Plate VII, Figure 2).

Slide G.10.

Rock name: Sodaclase-granite (Johannsen - Petrography: Vol. II. Family 6, order 1); or, Leucocratic Biotite-Granite (c.f. Biotite-Granite of Benguella, Angola, Tyrrell).

Minerals present: Quartz, microperthite, oligoclase, biotite, chlorite, epidote, magnetite.

Description: This is a coarse-grained reddish leucocratic rock of granite texture (hypautomorphic-granular).

It consists of a coarse mosaic of allotriomorphic crystals of quartz and microperthitic orthoclase (showing albite intergrowths) together with twinned oligoclase, small plates and flakes of altered biotite, chlorite and epidote and accessory magnetite.

A survey of this and one other slide of the same rock was made in order to get an approximate measurement of the relative quantities by volume of the quafeloids present. The mean of these, which showed very close agreement, is given:-

Quartz - -	38%
Microperthite -	42%
Oligoclase -	14%

The high percentages of quartz and microperthite is a feature as also is the absence of hornblende.

(Plate V, Figure 5).

Slide G.1.

Rock name: Biotite-granodiorite.

Minerals present: Quartz, microcline, oligoclase, biotite, chlorite, apatite, epidote, saussurite, orthite (allanite).

Description: This rock is coarse-grained and of typical granitic texture, none of the component minerals showing well developed crystal boundaries.

The principal constituents are quartz, microcline and oligoclase

making/...

making up about 95% of the rock. The combined felspars are in excess over the quartz and the microcline is predominant over the oligoclase.

Biotite, undergoing alteration to chlorite and epidote, is the only mafic constituent. It occurs in small flakes and is present in slight quantity.

The oligoclase is rather turbid and in places is represented by plates of saussuritic alteration products.

Apatite is present in colourless hexagonal grains and acicular crystals.

The only other constituent is orthite (allanite) represented by two small euhedral crystals.

(Plate V, Figure 4).

Slide G.8.

Rock name: Biotite-aplite. The composition is granodioritic.

Minerals present: Quartz, orthoclase, plagioclase, biotite, chlorite, zircon.

Description: This is a fine-grained leucocratic rock with typical aplitic texture.

It consists of an even-grained mosaic of anhedral crystals of quartz, oligoclase and subordinate orthoclase. The abundance of oligoclase is a noteworthy mineralogical characteristic. Biotite is present rather abundantly in the form of small irregular plates and shreds. There is also a little secondary green chlorite.

A conspicuous accessory is zircon as brownish coloured, highly regringent grains.

Slide G.3.

Rock name: Granodiorite (altered).

Minerals present: Quartz, plagioclase, orthoclase, hornblende, chlorite, epidote.

Description: This is a coarse-grained leucocratic rock of granitic texture.

It is composed of a mosaic of large anhedral plates of quartz, oligoclase and orthoclase, the former felspar being present in apparently slight excess over the latter. The felspars are highly turbid.

Shreds of secondary chlorite and grains of epidote have been formed at the expense of the original ferromagnesian mineral.

A little greenish pleochroic hornblende is the only other constituent.

The presence of narrow veins of granular epidote are a further indication of the decomposed nature of the rock.

Slide G.2.

Rock name: Hornblende-biotite-granulite.

Minerals present: Quartz, orthoclase, plagioclase, biotite, hornblende.

Description: This is a mesocratic rock of granoblastic texture

It consists of a rather fine-grained mosaic of irregular and rounded grains of quartz, orthoclase and oligoclase, in about equal quantities together with rather abundant small plates and

shreds/...

shreds of brown pleochroic biotite and some green pleochroic hornblende. The felspar is somewhat turbid.

The grain is uneven. Locally it becomes coarser and, at the same time, green, pleochroic hornblende becomes an important constituent to the almost complete exclusion of biotite.

(Plate V, Figure 1).

Slide G.5.

Rock name: Gneissoid-biotite-granodiorite.

Minerals present: Quartz, oligoclase, orthoclase, biotite, magnetite, apatite.

Description: This is a bluish-grey mesocratic rock with a gneissose structure and of coarse grain.

It is composed of quartz, oligoclase and orthoclase in about equal proportions in an equigranular mosaic with some large crystals of felspar embedded in it. Brown pleochroic biotite is the only mafic constituent and occurs in fair quantity as plates and laths in a rude alignment.

Magnetite and apatite are accessories.

(Plate V, Figure 3).

Slide G.4.

Rock name: Gneissoid-granodiorite.

Minerals present: Quartz, microcline, microperthite, oligoclase, hornblende, biotite, magnetite, sphene, apatite.

Description: This is a mesocratic, rather coarse-grained (phanerocrystalline) rock of granitic appearance.

Under the microscope it shows a fairly well developed, linear structure (gneissic) due to the partial segregation into bands of the parallel aligned ferromagnesian minerals.

It consists of a coarse irregular mosaic of quartz and felspars, the latter in considerable excess over the former.

The felspars consist of acid plagioclase (oligoclase) and alkali-felspar in about equal proportions.

The alkali-felspar comprises both microcline (with typical cross-hatched twinning) and microperthite (with characteristic albite intergrowth structure).

The mafics consist of laths of green biotite and some greenish hornblende.

Small scattered crystals of magnetite, brownish sphene (frequently euhedral) and colourless apatite in small rectangular crystals and needles are the accessory constituents.

(Plate V, Figure 2).

Slide G.6.

Rock name: Quartz-felspar granulite. This rock recalls the potash leptites of Sweden.

Minerals present: Quartz, microcline, oligoclase, myrmekite, biotite.

Description: In hand specimen this is a pinkish coloured, leucocratic, fine grained and banded rock of aplitic appearance.

Microscopically, it is seen to consist mainly of quartz and microcline, the latter characterised by well-developed, cross-hatched twinning, in an even-grained fine mosaic together with very subordinate amounts of acid plagioclase (oligoclase).

Fine/...

Fine myrmekite intergrowths are not uncommon and show the characteristic cauliflower structure.

Imparting a rude schistosity to the rock are fairly abundant minute plates and shreds of greenish-brown biotite with a subparallel arrangement embedded in the mosaic.
(Plate VI, Figure 2).

Slide G.7.

Rock name: Quartz-felspar granulite (sheared).

Minerals present: Quartz, microcline, acid plagioclase,(albite-oligoclase) biotite, chlorite.

Description: In hand specimen this is a reddish coloured, leucocratic, fine grained rock, similar to G.6. but of slightly coarser grain.

Under the microscope it is seen to consist mainly of quartz and felspar.

The quarts occurrence is peculiar; it forms subparallel, discontinuous bands and lenticles (augen) of rod-like crystals. This structure imparts the banding to the rock.

The quartz rods are embedded in a fine mosaic of microcline crystals with a subordinate amount of acid plagioclase, a little biotite and secondary chlorite in small flakes and shreds.

The quartz shows undulose extinction and the cross-hatching of the microcline is wavy.
(Plate VI, Figure 1).

Slide G.11.

Rock name: Quartz-felspar granulite (sheared).

Minerals present: Quartz, oligoclase, orthoclase, biotite, epidote, chlorite, sericite.

Description: In hand specimen this is compact, pale pink and green, fine to medium-grained banded rock. The banding can be seen as being due to the alternation of narrow quartzose and felspathic bands so that it is more aptly described as a gneissose rather than a schistose structure.

Under the microscope the gneissose structure is in main borne out but appears to be more truly granulose.

Quartz and oligoclase are present in about equal proportions and orthoclase is a subordinate constituent.

The dark constituents are not abundant and consist of shreds of biotite (showing terminal alteration to chlorite) and secondary chlorite.

Small grains of epidote together with fine sericitic mica appear to be derived products of decomposed felspar.

The quartz and felspar form a mosaic of allotriomorphic, granular crystals. In this mosaic discontinuous bands of quartz (with undulose extinction) rods occur.

Minute broken veins of epidote cut across the banding.
(Plate VI, Figure 3).

Slide G.12.

In general structure and composition this rock so closely resembles G.11. that a detailed description is not necessary.

The texture of the rock varies so that coarser "augen" are

visible/...

visible. The undulose extinction of the quartz is more pronounced. The structure, in places, is almost flaser. The rock is, therefore, more highly sheared and recrystallised than any of those of similar character described above.
(Plate VI, Figure 4).

Slide G.15.

Rock name: Quartz-schist: practically a mylonite recrystallized under stress.

Minerals present: Quartz, alkali-felspar.

Description: This is a very fine-grained, schistose rock.

It consists almost entirely of a very fine quartz mosaic with a very subordinate amount of alkali-felspar (mainly microcline).

The quartz shows elongation and pronounced undulose extinction and appears to have suffered granulation and recrystallization under stress.

The felspar is clear and shows well-marked wavy extinction.
(Plate VII, Figure 1).

Slide Q.4.

Rock name: Highly sheared quartzo-felspathic igneous rock such as Pegmatite.

Minerals present: Quartz, orthoclase, oligoclase, sericite.

Description: In hand specimen this rock shows a schistose structure, delineated by augen or "eyes" of quartz and felspar in a fine base.

Under the microscope the structure is seen to be in large part flaser. The texture is variable. The foliation is well marked, consisting of abundant lenticular augen composed of granular aggregates of quartz and both felspars (orthoclase and oligoclase). The augen are set in fine-grained mosaic of the same minerals accompanied by subordinate flakes of sericite.

The larger quartz and felspar crystals show distinct cataclastic structures and the undulose extinction of the quartz is prominent.
(Plate VI, Figure 5).

Slide D.2.

Rock name: Granophyre.

Minerals present: Quartz, orthoclase (Micropegmatite), plagioclase (oligoclase), hornblende, chlorite, epidote, sericite (white mica), orthite (allanite).

Description: This is a holocrystalline, porphyritic rock with granophyric (or, micrographic) texture.

It is composed mainly of quartz and potash felspar (orthoclase), together with subordinate oligoclase, a little hornblende and small amounts of secondary green chorite, sericite and epidote.

The quartz occurs as rounded to euhedral crystals up to 1·5 mm. in size. It shows abundant small fluid and crystal inclusions and open curved cracks penetrated by micropegmatite, greenish chloritic matter and fine magnetite dust.

The orthoclase occurs as tabular plates of perthitic type and the plagioclase (oligoclase) as subordinate stout crystals twinned on the albite law.

These above minerals are embedded in an abundant groundmass of micropegmatite (a micrographic intergrowth of quartz and orthoclase). This granophyric intergrowth forms definite fringes around the larger crystals.

A/...

A little uralitic hornblende in fibrous prisms together with some secondary chlorite in small radiating patches, a little secondary chlorite with associated sericite and occasional euhedral grains of zoned and twinned, brownish, pleochroic orthite (allanite) are the only other constituents (Plate VII, Figure 4).

Slide G.14.

Rock name: Granophyric Quartz-porphyry.

Minerals present: Quartz, orthoclase, oligoclase, micropegmatite, chlorite, magnetite, sericite.

Description: This rock shows a typical porphyritic structure.

It consists of medium-sized (up to 4 mm.), rounded to euhedral phenocrysts pf quartz, invariably fringed with micropegmatite, embedded in a compact, fine-grained groundmass composed partly of micropegmatite and partly of a fine-grained mosaic of quartz and orthoclase together with a little oligoclase, some chloritized biotite and a very little sericite and magnetite. (Plate VII, Figure 6).

Slide G.13.

Rock name: Aplite or Biotite-microgranite.

Minerals present: Quartz, orthoclase, microcline, microperthite, oligoclase, biotite.

Description: This is a typical leucocratic igneous rock of aplitic texture.

It consists mainly of quartz and potash felspar (the latter in excess over the former) with slightly subordinate twinned acid plagioclase (oligoclase) and scattered irregular plates of brown pleochroic biotite.

The potash felspar includes three separate varieties (1) ordinary orthoclase, (2) microcline, with characteristic cross-hatched twinning, and (3) microperthite, distinguished by the typical intergrowth of spindles of albite within an orthoclase host crystal.

The individual crystals show a tendency towards the development of a tabular habit.

The brown, pleochroic biotite is altering to chlorite.

(Plate V, Figure 6).

Slide D.1.

Rock name: Meta-dolerite or Epidiorite (i.e. a low-grade dynamically metamorphosed dolerite).

Minerals present: Plagioclase, hornblende, epidote, sericite, magnetite.

Description: The rock consists mainly of basic plagioclase and greenish uralitic hornblende in approximately equal proportions together with subordinate magnetite and a little sericite and epidote.

The basic plagioclase is an original igneous constituent which has suffered no recrystallization during the process of metamorphism. It forms stout lath-shaped crystals twinned on the albite law and displays well-marked zoning with more basic cores and less basic margins. These crystals are in part altered particularly along cleavage and twin planes, to a fine-grained, turbid aggregate of granular epidote and sericite. The

extinction/...

extinction angle on edge b/c is from -21° 30' to -27° 42' so that it is to be regarded as a labradorite of composition Ab_1An_3. (A System of Mineralogy, 6th Edition - Dana: p. 327).

There is a tendency towards glomero-porphyritic grouping of the larger felspars so that in hand specimen the rock has an indistinct porphyritic texture. They are related to the uralitic hornblende in an ophitic manner.

The base in which the plagioclase is embedded consists of greenish-brown, pleochroic, uralitic hornblende which forms irregular plates and fibrous aggregates and has been produced at the expense of original augite.

The magnetite occurs both as well-formed crystals belonging to the igneous stage of crystallization of the rock, and as a fine dust in the hornblende liberated as a result of the conversion of original augite into hornblende.

The epidote occurs as trains and clusters of small rounded grains associated with the felspar and obviously an alteration product of that mineral. Its 2nd and 3rd order polarization colours tend towards diagnosis as the pistacite variety.

Associated with the epidote are small, colourless flakes possessing high birefringence. This is presumed to be sericite.

The grain of the rock is variable. On the whole it is fine-grained with medium-grained blebs giving the rock a porphyritic appearance. The transition from fine grain to medium grain is imperceptible.

(Plate VIII, Figures 1 and 2)

Slide D.6.

Rock name: Altered Basalt or Fine-grained Epidiorite.

Minerals present: Plagioclase, hornblende saussurite, epidote, sericite, magnetite.

Description: This rock is fine-grained and slightly vesicular, the texture being indistinctly porphyritic. The original igneous character is retained in the ophitic relationship of the two dominant minerals.

The saussurite occurs in large patches and appears to represent original felspar phenocrysts. It is very fine grained and consists, as far as resolution has been possible, of epidote and sericite. Other minute grains may be felspar.

The saussurites are embedded in a predominantly fine-grained ground-mass of basic felspar and uralitic hornblende along with magnetite.

The felspar is a labradorite and forms lath-shaped crystals belonging to the igneous stage of crystallization of the rock. These crystals show slight alteration.

The hornblende is the typical greenish pleochroic variety representing original augite. It forms prisms and felted fibrous aggregates.

The vesicular character of the rock is seen in cavities lined with blade-like prisms of pale yellowish-green amphibole (hornblende).

(Plate VIII, Figure 3).

Slide D.9.

Rock name: Taking into account the field relations of this rock, it is best named an Epidiorite although its affinities appear to lie closer to the quartz-dolerites. It may, therefore, be more accurately described as an altered quartz-dolerite.

Minerals present:/...

Minerals present: Plagioclase, hornblende, saussurite, calcite, magnetite, micropegmatite.

Description: This is a coarse-grained rock which still retains its original igneous structure.

The basic plagioclase is highly saussuritized to a fine-grained platy aggregate of epidote and sericite mainly.

The greenish uralitic hornblende occurs in large, irregular plates of fibrous aggregates and representing original augite.

A small amount of quartz and alkali-felspar occur in the form of a micropegmatitic mesostasis particularly between plates of saussurite.

Secondary calcite occurs in laths and small plates.

Magnetite occurs in skeletal crystals of original igneous origin and also as secondary dust.

Except for the presence of the felspar, in slightly smaller quantities than the hornblende, this rock resembles D.6A.

(Plate VIII, Figure 5).

Slide D.12.

Rock name: Epidiorite: similar in general to all the others.

Minerals present: Plagioclase, hornblende, quartz, albite, epidote, magnetite.

Description: The original doleritic nature of this rock is retained in the lath-shaped form of the basic plagioclase and its still recognizable although slightly obscure ophitic relationship to the hornblende.

The basic plagioclase is a labradorite. It forms laths which are rather turbid. Some recrystallization of the felspar has taken place as is evidenced by some fresh laths almost completely free from inclusions.

A little new quartz, albite and epidote has also been formed.

The hornblende occurs in long blades and aggregates of the greenish uralitic variety.

(Plate VIII, Figure 6).

Slide D.3.

Rock name: Olivine-dolerite. Although no quartz was seen on this slide, other slides from the same body have shown it in small quantities as micropegmatite, so that this rock belongs rather to the quartz-dolerite group than to the true olivine dolerites.

Minerals present: Augite, plagioclase, olivine, serpentine, magnetite, biotite, chlorite.

Description: The rock is composed essentially of basic plagioclase (labradorite) and augite, the former in slightly larger amount, and related to one another in a typically ophitic manner.

The plagioclase occurs as abundant euhedral laths of labradorite penetrating the augite plates. They are twinned on the albite law and also display zoning.

The augite is a brownish, non-pleochroic variety. It is frequently twinned and displays an "hour-glass" structure. It shows well-developed characteristic cleavages.

The olivine is not abundant and from scattered rounded crystals which not uncommonly show serpentisation around the margins and along cracks.

The magnetite occurs as scattered grains and also as small

rounded/...

rounded skeletal masses apparently representing completely altered olivine and pseudomorphous after it.

Biotite occurs in a very few isolated small platy flakes. It shows the typical strong pleochroism and is invariably altered around its margins to pale-green, pleochroic chlorite.

(Plate IX, Figure 4).

Slide D.4.

Rock name: Olivine-bearing Quartz-dolerite.

Minerals present: Plagioclase, Augite, olivine, micropegmatite (quartz, orthoclase), magnetite, serpentine.

Description: This rock shows the characteristic ophitic texture of the dolerites and is in general similar to D.3.

The plagioclase, which is in slight excess over the augite, is a labradorite. It occurs in euhedral twinned laths penetrating plates of augite and also in well-zoned plates.

The augite is the brownish non-pleochroic variety and besides occurring as large irregular plates is also found in smaller euhedral, simple-twinned crystals.

The olivine is present in small quantity as in D.3. but is more serpentinized.

There is a restricted amount of micropegmatitic mesostasis between the felspar laths. (Plate IX, Figures 2 and 3).

Slide D.5.

Rock name: Olivine-bearing Quartz-dolerite.

Minerals present: Plagioclase, augite, olivine, micropegmatite, (quartz, orthoclase), magnetite, serpentine, iddingsite, chlorite.

Description: This rock is similar in general to the other typical quartz-dolerites. The grain, however, is distinctly coarser and the ophitic texture not so pronounced.

The plagioclase is a labradorite with extinction angle on c/b from -20° 6' to -28° 12'. It therefore tends towards bytownite in composition. It forms stout laths and some plates and is generally turbid.

The augite is the brownish, non-pleochroic variety and forms irregular plates and smaller euhedral, simple-twinned crystals. In places it displays alteration in the form of small marginal fringes of secondary greenish chlorite.

The olivine is present in numerous small rounded grains and is highly serpentinized. Much of it has been converted into secondary reddish-brown pleochroic iddingsite. (Elements of Optical Mineralogy - 3rd Edition, Part II., Winchell, p. 437).

The amount of quartz-felspar mesostasis is greater than in those described above. (Plate IX, Figure 1).

Slide D.10.

Rock name: Broadly the rock may be named Granophyre. Its syntectic character is obscured by such a name.

Minerals present: Quartz, orthoclase, hornblende.

Description: In hand specimen this is a melanocratic (greyish-green), massive rock resembling the dolerites of the area but displaying well-marked porphyritic texture and not easily distinguisable in the field from D.3. with which it is intimately

associated/...

associated.

The quartz occurs as phenocrysts consisting of large rounded crystals and granular aggregates of clear quartz. The freedom from inclusions is a noteworthy character.

These are embedded in a ground mass of fibrous micropegmatite (quartz, orthoclase) containing abundant acicular crystals of brownish hornblende.

The peculiar and characteristic feature of the rock is the fibrous nature of the micropegmatite.

(Plate IX, Figure 5).

Slide D.13.

Rock name: Olivine bearing Dolerite.

Minerals present: Augite, plagioclase, olivine, magnetite, biotite, chlorite.

Description: The texture is typically ophitic: medium-grain. The light and dark constituents are present in about equal proportions.

The plagioclase is basic- labradorite. It forms mainly stout laths and some small irregular plates and is twinned on the albite law. It shows good cleavage and is only slightly turbid in places, being, in general, clear and fresh. It is related to the augite in ophitic manner.

The augite is pale-brownish in colour and shows the characteristic pyroxene cleavages. It forms irregular larger and smaller plates. It is frequently simply twinned.

Olivine is present in small quantity in rounded to euhedral and irregular crystals. It shows alteration to green serpentine around margins and along irregular cracks.

Biotite, with chloritic margins and moulded skeletal magnetite, is seen in small flakes and ragged plates.

It is strongly pleochroic from yellowish to deep reddish-brown.

Magnetite occurs as small platy and skeletal crystals moulded to the augite plates.

Slide D.14.

Rock name: Olivine-Gabbro.

Minerals present: Augite, Olivine, plagioclase, magnetite.

Description: The rock is coarse-grained with granitic texture. The mafic constituents make up about three-fourths of the rock. The main feature of the rock is the abundance of olivine which is present in quantity only slightly subordinate to the augite.

The augite occurs in large rectangular and smaller subhedral platy crystals. It is pale-brownish in colour, well-cleaved and frequently simply twinned and zoned.

The olivine occurs as subhedral to euhedral large plates and smaller rounded crystals showing the characteristic alteration.

The plagioclase is a labradorite (towards bytownite) and forms small interstitial laths and groups of laths and has been the last mineral to crystallize. It shows both coarse and very fine lamellar twinning.

The magnetite occurs in well-shaped and skeletal crystals.

Slide D.15.

Rock name: Epidiorite.

Minerals present: Hornblende, plagioclase, magnetite, epidote.

Description: This is a very fine-grained, holocrystalline rock composed essentially of greenish uralitic hornblende and basic felspar with a somewhat obscured ophitic relationship.

The hornblende occurs in blades and plates of fibrous aggregates, is faintly pleochroic and has been produced at the expense of original augite.

The plagioclase is mainly highly saussuritized to finely granular aggregates composed largely of epidote. Some clearer and fresh crystals may indicate a certain amount of recrystallization. It is a labradorite.

Magnetite occurs both as original crystals and fine secondary dust.

The rock is generally similar to the other Epidiorites.

Slide D.16.

Rock name: Epidiorite.

Minerals present: Augite, hornblende, plagioclase, olivine, magnetite, epidote.

Description: This is a medium grained holocrystalline rock of granular texture. There is no trace of ophitic texture. The rock consists essentially of rounded, subhedral to euhedral, crystals of augite, and green uralitic hornblende with interstitial basic plagioclase largely saussuritized.

The feature of the rock is that every stage, from unaltered to completely altered augite is represented. Thus, there are small crystals of pale-brownish, well cleaved augite; other crystals with narrow fringes of green uralitic hornblende around their margins; yet others with small augite cores; and finally, complete replacements of augite, by bright green, pleochroic, uralitic hornblende.

The plagioclase is present in small irregular plates and short stout laths. It is turbid with alteration products and, in places, highly saussuritized. Epidote grains occur as clusters in such crystals. It appears to be a labradorite.

Olivine is present in very subordinate amount and is represented by small, rounded, highly serpentinized grains.

Magnetite occurs both as a primary constituent in platy grains with well-defined edges and as secondary dust but is not present in any quantity.

Slide D.17.

Rock name: Fine-grained Epidiorite.

Minerals present: Augite, hornblende, plagioclase, magnetite.

Description: In hand specimen this is a typically fine-grained dolerite rock.

Under the microscope, the texture is somewhat ophitic and the grain is fine.

The augite occurs in euhedral to irregular small rounded plates. It is pale-brownish in colour and non-pleochroic, with characteristic cleavages. It is frequently simply twinned. It is commonly seen in small squares separated by greenish-uralitic hornblende, such as aggregate representing a partial alteration of an original angite individual along cleavages, and around margins. In many cases, the original augite crystal is represented by a minute core.

The/...

The hornblende is represented by irregular, stout rectangular, and elongated plates of rather pale, yellowish-brown to faint bluish-green, pl[illegible]lende. The plates are both fibrous and granular in aggregation and contain many crystal inclusions of felspar in sufficient quantity to merit the use of the term "schiller structure".

The felspar (labradorite) occurs both as elongated laths and small plates, the former predominating. The laths show a distinct tendency towards glomeroporphyritic grouping into radiating and felted arrangements with small amounts of interstitial uralitic hornblende. They are only very slightly altered and some of the more rounded plates, by their absence of inclusions and zoning, would appear to indicate a certain amount of recrystallization.

The magnetite is present both in well-shaped small crystals and as trains of dust in the amphibole.

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PLATES.

EXPLANATION OF PLATE I.

Figure 1. In background, prominent quartzite ridge trending south-eastwards from Lokolwane — knoll at right-centre on skyline. The conspicuous meander of the Hlatusane and the junction of the Mimiti occupy the foreground: the road and Kubuta Kop, with its dwellings in the left-centre.

Figure 2. Lip above waterfall on Mpopta, Maasingobe in back-ground: well-jointed quartzite in foreground. The clearly defined planes inclining from left to right in left of picture are joint planes. The dip is approximately towards the observer.

Figure 3. Ngcongcwane and surroundings from the vicinity of Mavugute. About one inch to the right of the centre-skyline is the Ngcongcwane beacon. The "terraced" character of this area is shewn.

FIG. 1.

FIG. 2.

FIG. 3.

PLATE I.

EXPLANATION OF PLATE II.

Figure 1. Headwaters of Mantshiyane: tributary bending behind ridge with prominent white outcrops of sheared pegmatite: slopes on the right are composed of pyroxene-gneiss: also the immediate foreground.

Figure 2. Mavugute from the main road near the School, showing general nature of the country in this vicinity.

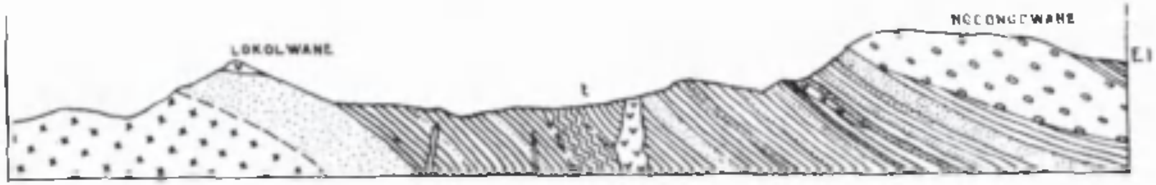
Figure 3. Gneissose-granite in the bed of the Hlatusane River, showing its high degree of banding and "veining".

FIG. 1.

FIG. 2.

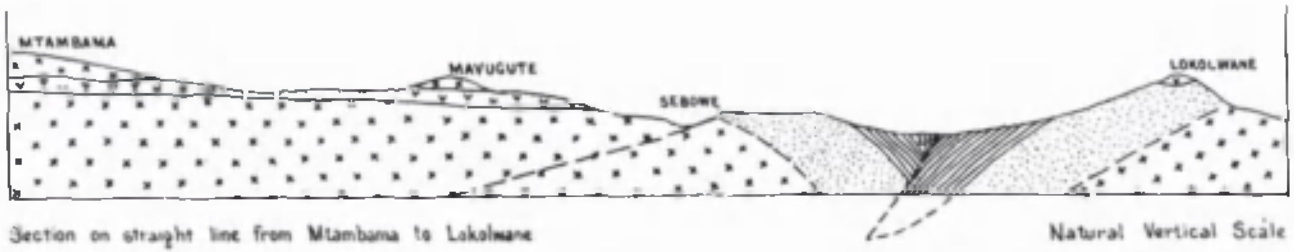
FIG. 3.

PLATE II.



Section from vicinity of Lokolwane through Ngcongcwane to beacon E1 — Natural Vertical Scale

Fig. 1



Section on straight line from Mtambama to Lokolwane — Natural Vertical Scale

Fig. 2

PLATE III

EXPLANATION OF PLATE IV.

Figure 1. Amphibolite; granoblastic texture; green hornblende with well-marked cleavages, and andesine and quartz with "sprouting" character.

Lower Nicol in. X 18. Slide D.8.

Figure 2. Amphibolite; coarse grained, and basic; plates and fibrous aggregates of greenish hornblende and colourless amphibole (? tremolite), with interstitial epidote grains.

Lower Nicol in. X 18. Slide D.6A.

Figure 34 Hornblende-schist; schistosity well-marked; interstitial bands of quartz-andesine mosaic. Portion of a small epidote vein in the bottom left.

Lower Nicol in. X 18. Slide D.7.

Figure 4. Garnetiferous-pyroxene-gneiss; in centre of the field a pink garnet, fringed and penetrated by hypersthene, displaying uralitic striations; a portion of an euhedral hypersthene crystal at the bottom.

Lower Nicol in. X 18. Slide Q.2.

Figure 5. Garnetiferous-pyroxene-gneiss. Same rock as in Figure 4, showing abundant rounded, pink garnet, hypersthene, minute augite and hornblende crystals, and clear quartz and orthoclase.

Lower Nicol in. X 18. Slide Q.2.

Figure 6. Biotite-pyroxene-gneiss. Platy quartz crystals and twinned oligoclase: dark areas mostly biotite, with some small crystals of augite and sphene.

Crossed Nicols. X 18. Slide Q.5.

FIG. 1.

FIG. 2.

FIG. 3.

FIG. 4.

FIG. 5.

FIG. 6.

PLATE IV.

EXPLANATION OF PLATE V.

Figure 1. Hornblende-biotite-granulite. Plates of biotite and hornblende embedded in even-grained mosaic of quartz and felspars: abundant minute inclusions in the quartz and felspars.

Lower Nicol in. X 18. Slide G.2.

Figure 2. Gneissoid-grandiorite. Flakes of biotite and hornblende fringing a plate of plagioclase: dark mineral towards the top left, is sphene, partly fringed with biotite.

Lower Nicol in. X 18. Slide G.4.

Figure 3. Gneissoid-biotite-granodiorite. Equigranular quartz-felspar mosaic with larger embedded crystals of the same minerals and flakes and plates of biotite.

Crossed Nicols. X 18. Slide G.5.

Figure 4. Biotite-granodiorite. Turbid oligoclase, in places saussuritized, and biotite with a crystal of apatite and some magnetite moulded to it, in a quartz-felspar groundmass.

Lower Nicol in. X.18. Slide G.1.

Figure 5. Sodaclase-granite. Quartz areas with marginal and interstitial microperthite and twinned oligoclase: dark patches are altered biotite flakes and small plates.

Crossed Nicols. X.18. Slide G.10.

Figure 6. Aplite. Quartz shows "strain shadows"

Crossed Nicols. X 18. Slide G.13.

FIG. 1.

FIG. 2.

FIG. 3.

FIG. 4.

FIG. 5.

FIG. 6.

PLATE V.

EXPLANATION OF PLATE VI.

Figure 1. Quartz-felspar-granulite (sheared). Portion of a larger quartz rod embedded in a fine mosaic composed predominantly of microcline:

Crossed Nicols. X 18. Slide G.7.

Figure 2. Quartz-felspar-granulite. In centre of the field is "myrmekite" with typical "cauliflower" structure.

Crossed Nicols. X 18. Slide G.6.

Figure 3. Quartz-felspar-granulite (sheared). Aligned quartz rods in a fine-grained quartz-felspar mosaic: the grain is finer but the structure the same as in Figure 1., the shearing effects being clearer.

Crossed Nicols. X 18. Slide G.11.

Figure 4. Quartz-felspar-granulite (sheared). Banding pronounced as also the undulose extinction of the quartz rods: the granulose texture obvious.

Crossed Nicols. X 18. Slide G.12.

Figure 5. Sheared Quartz-felspar-granulite. A cracked quartz-crystal, with undulose extinction along with a rod-like crystal of granular quartz, embedded in a fine-grained groundmass dominantly felspathic.

Crossed Nicols. X 18. Slide Q.4.

Figure 6. Pegmatite. Portion of a large characteristic rod-like, crystal of quartz with well-developed cracks and plates of microcline-microperthite.

Crossed Nicols. X 18. Slide Q.3.

FIG. 1.

FIG. 2.

FIG. 3.

FIG. 4.

FIG. 5

FIG. 6.

PLATE VI.

EXPLANATION OF PLATE VII.

Figure 1. Quartz-schist (Mylonite). The fine-grained and banded nature of the rock clearly seen.

Crossed Nicols. X 18. Slide G.15.

Figure 2. Quartz-sericite-Rock. A granular quartz aggregate enclosing a small crystal of sphene embedded in a fine sericitic groundmass.

Crossed Nicols. X 18. Slide K.J.3A.

Figure 3. Altered Quartzite. The quartz grain in the centre of the field shows characteristic undulose extinction: abundance of interstitial sericite and crenulate margins of the quartz grains.

Crossed Nicols. X 18. Slide K.J.1.

Figure 4. Granophyre. A quartz crystal with biotite flakes moulded to its edge embedded in a groundmass containing abundant micropegmatite.

Crossed Nicols. X 18. Slide D.2.

Figure 5. Granophyre. A well-shaped crystal of zoned orthite (allanite) some small hornblende and chlorite flakes, and euhedral quartz plates in a groundmass of abundant micropegmatite.

Lower Nicol in. X 18. Slide D.2.

Figure 6. Granophyric-Quartz-porphyry. Portion of a large quartz phenocryst in fine-grained groundmass composed of micropegmatite and fine mosaic mainly of quartz and felspars.

Crossed Nicols. X 18. Slide G.14.

FIG 1.

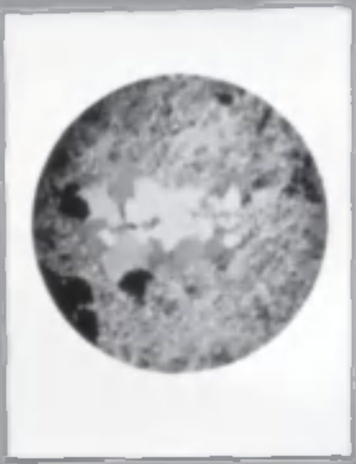


FIG. 2.

FIG. 3.

FIG. 4.

FIG 5.

FIG 6.

PLATE VII.

EXPLANATION OF PLATE VIII.

Figure 1. Epidiorite. Laths of turbid and altered plagioclase, embedded in plates of fibrous uralitic hornblende in an ophitic manner.

Lower Nicol in. X 18. Slide D.1.

Figure 2. Epidiorite. The local development of the structure shown in Figure 1., along with this gives the rock a porphyrytic appearance.

Lower Nicol in. X 18. Slide D.1.

Figure 3. Altered Basalt or Fine-grained Epidiorite. Small laths of felspar and uralitic hornblende. Embedded in this, to be seen in another part of the field are large plates of "saussurite" representing altered felspar phenocrysts so that the rock is indistinctly porphyritic. See also Figure 4.

Lower Nicol in. X 18. Slide D.6.

Figure 4. Altered Basalt. Showing portion of a vesicle with blade-like pale amphibole lining the cavity.

Lower Nicol in. X 18. Slide D.6.

Figure 5. Epidiorite. The field shows saussuritized felspars and plates of fibrous hornblende aggregates. Skeletal magnetite in centre, a and, at top, portion of a prism of calcite.

Lower Nicol in. X 18. Slide D.9.

Figure 6. Epidiorite. The ophitic texture is obscure: highly saussuritized felspars and blades and plates of fibrous and uralitic hornblende.

Lower Nicol in. X 18. Slide D.12.

FIG. 1.

FIG. 2.

FIG. 3.

FIG. 4.

FIG. 5.

FIG. 6.

PLATE VIII