At the time of overturning, the beds must have been strongly confined by the pressure of the overlying sediments, and their behaviour was similar to that of a plastic substance. As discussed below, under "Joints and Cleavage" the couple formed by the pressure of folding acting against the drag of the decollement produced rotational stress. The resulting shears took the form of a system of joints, or, depending on the degree of shearing, of cleavage.

3) Major Fold Structures.

Major anticlinoria and synclinoria, with a wavelength measuring between eight and ten kilometres, were seen in the area where marble is exposed, but owing to the absence of marker horizons in the Upper Schist area to the east, these structures could not be followed as closely as in the west. In all probability the structure of the whole area follows the pattern of the folded marble bands described, except for the variation mentioned, of a northwesterly dip near the Brandberg. The line of this change of dip possibly marks the position of the axis of a major anticlinorium. This possibility is supported by the fact that synclines of quartzite make their first appearance in the area east of this axis.

If this line of change in dip-direction is the crest of an anticlinorium, then folds are incongruous with respect to the anticlinorium. If the folds are congruous however the structure must be a synclinorium, and the presence of quartzite in the southeast limb only, suggests either a change in facies towards the southeast or an infolded unconformity.

The abnormal dip may however be a result of the granite intrusion known to occur to the east.

With a few exceptions, the structures mentioned above follow a pattern normal for this part of S.W.A., i.e. folding ostensibly due to pressure from the southeast. (Gevers, 1929, p. 50).

B) The Zone of Schist and Marble Intruded by Granite.

This zone constitutes about 65 km of granite-schist contact. About 10 km of this contact is covered by younger formations.

1) The Form of the Schist-Granite Contact.

The most striking fact about this zone is that, almost without exception, the Upper Marble horizon dips beneath the Upper Schist Series a short distance, about 100 metres to 800 metres, from the granite-schist contact. In a few places tongues of granite are seen to lie along synclines of Upper Schist. Generally the folded schist and marble beds start plunging downwards the granite, at a distance between $1\frac{1}{2}$ and 3 kilometres from the granite-schist contact, or in other words, there is a line of warping of the folded beds, transverse or oblique to the strike of the schist, and roughly parallel with the present schist-granite contact. This line is shown on plan, Fig. 46.

The Upper Marble (see above) is seen in direct contact with granite at only a few places in the western part of the area, and at only one place there does granite cut across the marble, in this case across the nose of a marble anticline. (See map, Fig. 40). A further peculiarity of the contact zone is that where the granite-schist contact strikes across the general strike of the folded sediments, the fold axes have been bent towards the southwest.

The contact is rarely well-defined, as it usually lies in areas of low relief. West of the Gemsbok River, about 5 km from the Ugab River, a sharp contact of granite against schist dip at 50° to the east. At the extreme eastern end of the granite area, several outcrops of granite occur in the schist. These outcrops are possibly the upper parts of small dome-shaped granite masses.

Along the granite-schist contact between the Brak and Zebra Rivers bodies of granite are found in the schist running parallel with the contact. The width of these bodies varies from five metres to one of about 300 metres. They may be interpreted as sills separating a long xenolith of schist, one kilometre wide, from the main schist body, or as concordant bodies of granite lying within a schist anticline or syncline, the "xenolith" of schist representing either a roof pendant or a ridge of the schist floor of the granite.

2) The Probable form of the Intrusion.

The above features suggest that the granite was intruded in the form of a composite phacolith. The probable extent of the original body is shown on the plan (Fig. 46).

The edge of the phacolith did not lie in the horizontal plane, but was partly beneath and partly above the plane of the present land surface.

3) Granite beneath the exposed Schist.

Eveidence for the granite lying below schist is as follows. At the eastern end of the maim granite area, the schist forms a low scarp above the level of the granite country. The isolated outcrops of granite in schist represent windows in the schist. The elongated area of tourmalinised schist and quartz veins which lies about 3 km to the northeast probably originated in a tongue of granite lying below surface, and represents the limit of intrusion of granite in that direction. In the area between Schilfputz and the Amis River mouth numerous thin bands of marble in the schist indicated that the Upper Marble Series is not far below surface. The Blue Marble actually outcrops in one place to the east of the Karroo outlier. (See map, Fig. 27). Thus, an eastward extension of the phacolith would be confined to a small, possibly elongated area in between the two eastern-most outcrops of Upper marble. The indications are that this is the case.

West of the Gemsbok River, the evidence is not so clear. A scarp of schist lying above the level of the granite surface follows the contact northwards to a point about 5 km south-east of the place where the Gemsbok River crosses the granite. North and west of this point, granite forms high ground relative to the schist. The granite-schist contact shows a well defined dip, towards the northeast, at only one point. The presence of acid pegmatite dykes in the upper schist, near the southwestern corner of the schist country, is an indication of underlying granite in this area, and would be strong evidence if it were not for the fact that pegmatites occur near by in horizons stratigraphically as far down as the Lower Schist Series. The probable original position of the phacolith in this area is shown on the map.

4) Granite above the exposed Schist.

Evidence that the granite in the remainder of the contact area once lay above part of the exposed Damara beds, is as follows.

From the southwestern corner of the schist of the schist and marble country, to a point 16 km to the east, the folded Damara sediments show a sudden chance in strike from north-south in the main area of sediments to northeast-southwest near the granite contact. A similar structure exists over a distance of about 8 km at the head streams of the Zebra River.

In the western area, the change in strike starts along an east-west line that lies about 4 km north of the granite contact, and runs parallel with the contact.

In the eastern area, near the Zebra River, the change in strike starts along a line that lies lostly less than 1½ km from the granite contact.

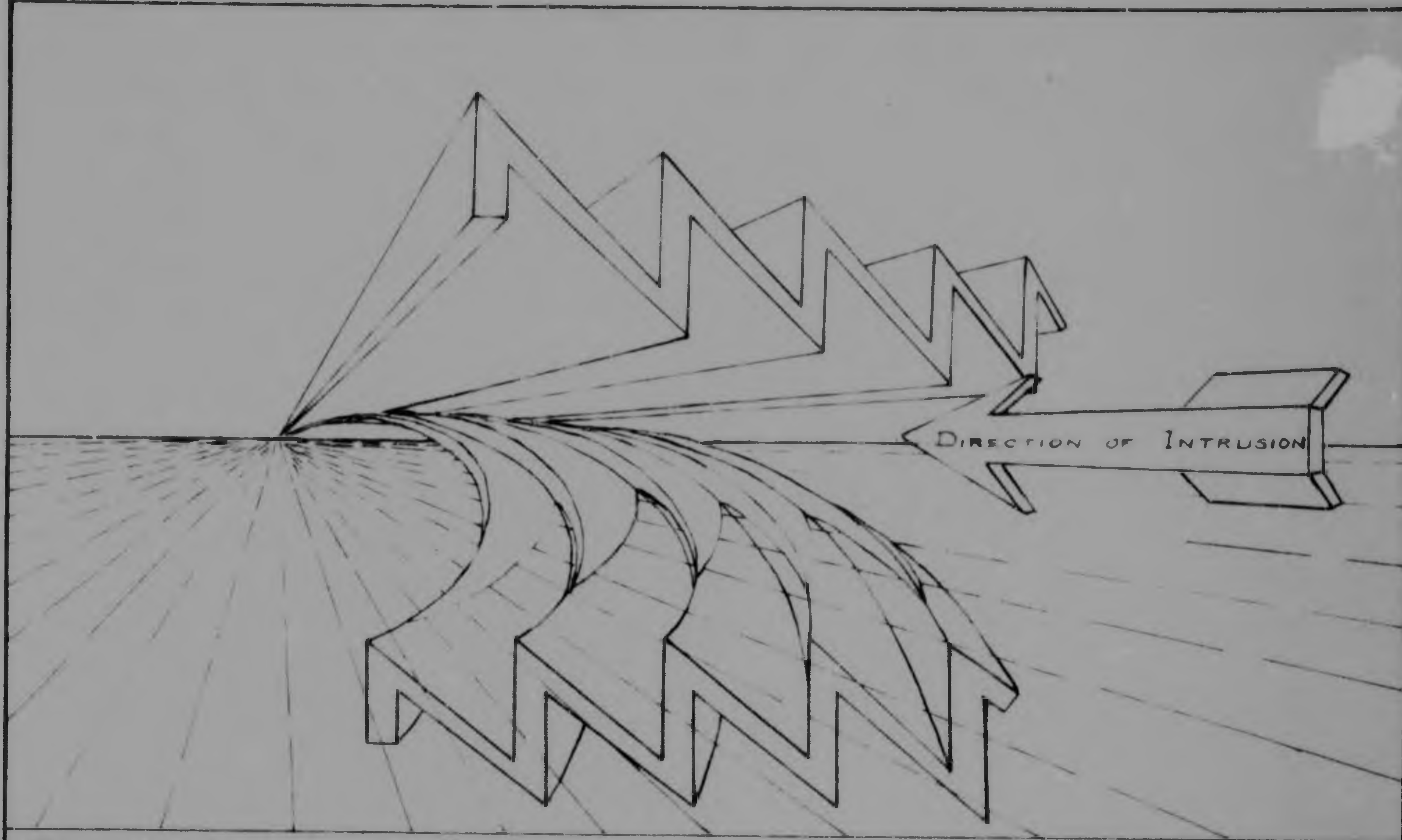
In both areas the change in strike is accompanied by the plunging of the folds to the southwest.

5) The effect of the Intrusion.

The facts indicate that the structures were caused by granite intrusion. (See Figs. 46 and Section, Fig 71). The leading edge of the granite magma was intruded into a horizon lying about 100 metres above the top of the Upper Marble Series. The pressure of the granite forced the floor of the phacolith downwards. Because the axial planes of the folds were inclined towards the east, at angles between 50° and 60°, the series of folds were bent downwards around dip lines on the axial planes, and not around a horizontal hinge-line. (See Figure 50).

The resultant movement, along the direction of least resistance was downwards and towards the west, and increased proportionately to the thickness of the phacolith. The angle at which the folds, as shown on the map, appear to have been bent is exaggerated owing to the effect of the horizontal plane of erosion cutting folds that are both overturned and pitching. The line along which the folds start bending towards the west marks the limit of intrusion of the phacolith. Figure 50, which shows a sharp bend away from the original direction, is diagrammatic, but is roughly comparable in effect with the probable section in the area south of the Zerissenes Mountains. The bending actually took place over a horizontal distance that was long enough for the sediments to bend in a gentle curve without rapture.

50



Diagrammatic sketch showing deflection of floor of phacolith, caused by intrusion into a bedding plane of overturned folds.

Fig. 50.

Surface exposures indicate that the vertical distance through which the sediments were depressed was at least 1,000 metres, and it may be assumed that the phacolith was of a greater thickness. The overlying schists must have been thousands of metres thick. Thus, the minimum amount of material removed by erosion since granite intrusion can be roughly gauged.

The locality of the opening through which the granite was intruded is not known, but it was probably in an area weakened by the original folding. The south-west corner of the schist country is possibly on the line of the break-through. (See map, Fig. 40).

The main objection to the above theory of the manner of emplacement of the granite is that the pressure of the intruding granite found relief downward, whereas in similar intrusions the pressure is normally relieved in an upward direction. It must therefore be assumed that space became available below the sediments. This space was possibly provided by the removal of granite from below. A simple exchange of space, motivated by the lower specific gravity of the granite relative to the sediments, could have occured, in which case high pressure in the granite would not have been necessary. (Billings, 1942, pages 277 and 311).

The absence of high pressure during intrusion is indicated by the absence of faulting or other structures that could be caused by pressure.

It is improbable that the sediments had been warped down during the original folding. No similar structure exists away from the granite.

The east-west hinge-line about which the folds are warped coincide approximately with the line of the edge of the phacolith. This line possibly formed a venue for pegmatite intrusion, and it is perhaps significant that the rare pseudo-diorites were found best developed in the area of down-warping. (See also under Petrology).

A small portion of older granite mapped north of the Brandberg belongs to a large mass of granite lying to the east and north.

Where shown on the plan it has the form of a tongue lying within a schist syncline pitching towards the east. This intrusion is at a higher stratigraphic horizon than the main granite body lying to the west.

6) Acid Intrusions.

Apart from the one example of a small acid lava pipe north of the Brandberg West Mine, all the acid pegmatite intrusions take the form of dykes and sills within 4 km. of granite contacts.

Sills are the more common form and vary in strike length from 3 metres to 1,700 metres. The thickness varies between 0.6 metres and 3 metres.

A peculiarity of these intrusions in the western part of the area, not repeated by the later basic plutons, is that several acid dykes follow the crests of marble anticlines. Much evidence, as shown above, points to the emplacement of the main granite body above the schist, and it is possible that the source of the dykes lay above their present positions and that they represent apophyses lying along the channels of weakness of the anticlinal axial planes. However, an instance of granite cutting across an anticline of marble, in the southwestern corner of the schist and marble area, indicates that granite could have been intruded along bedding planes within the folded marble, and could then have risen along lines of weakness to the crests of anticlines.

The scarcity of pegmatites indicates a state of compression of the folded sediments at the time of granite intrusion, and possible planes of pegmatite intrusion resulted from the force of the granite intrusion. The line of weakness along the hinge-line in the folds has been intruded by pegmatites, which probably originated in a granite body at depth.

C) General Structural Features.

1) Cleavage.

Cleavage is not well marked in most of the marble components of the two marble series, but it is usually present in the schistose components, and in the rocks of the schist series.

The usual attitude of the cleavage is in planes parallel with the bedding planes of the sediments, where it is particularly well developed along the lower limbs of overturned synclines.

The cleavage is formed generally by the parallel alignment of biotite flakes. More rarely, the quartz grains are elongated parallel with the cleavage. All gradations are found, from non-aligned grains, through elongated grains, to elongated and optically aligned grains.

In rare cases, a secondary cleavage can be seen forming at an angle to the true cleavage, through the growth of biotite flakes oriented in a different plane. (Nos. 63, 285).

The direction of the false cleavage is approximately parallel with the axial planes of the folds. In the area to the northwest of Brandberg West Mine, this cleavage becomes sufficiently well developed to be called a true cleavage, and the bedding planes are almost obliterated, remaining only as a ghost structure.

Similarly, in the Sesob River area, a nearly horizontal cleavage is developed, with a low dip towards the southeast. This cleavage is usually somewhat crumpled and in places almost obliterates the bedding planes.

Both of the above subsidiary cleavage directions grade into false cleavage.

2) <u>Ellipsoidal Structures</u>.

Intimately connected with the cleavage directions are the ellipsoidal structures, mentioned under "Geology", which are found in the western part of the area. These appear to have originated in lenses of material slightly different in composition from the surrounding sediments. During the formation of the cleavage, movement along bedding planes rolled the lenses, resulting in a rounding of the edges. A simultaneous effect was the relative elongation of the lenses, in the direction of the fold axes. This effect is strongly marked in the pseudo-dioritic ellipsoids described under "Petrology". Thus the ellipsoids were possibly formed by the forces that caused the folding.

3) <u>Joints</u>.

The false cleavage mentioned above grades into a close-joints cleavage lying in a near-horizontal plane.

A second direction of close-joints cleavage, that is universally developed in the sediments, lies at right angles to the fold axes.

(See photo, Fig. 51). The combined effects of these two sets of joints and the bedding cleavage is to split the surface rock into regular angular blocks. As a result the Yellow Marble shows mural jointing where exposed as a cliff face. (See Photo, Fig. 16). A close-joints cleavage parallel with the axial planes of the folds is rarely developed in the schists. In places the horizontal and vertical joints are 8 to 10 metres apart. (See Photos, Figs. 51 & 52).

Radial joints occur in anticlinal structures in the Blue Marble, (See photo, Fig. 14), due to tension during folding, but normally joints are rare in the Blue Marble band.

Folding was the major cause of most of the cleavages and joint systems. The bedding cleavage was probably the earliest to form, during the early stages of folding. The vertical joints were then formed, apparently as tension fractures related to pressure perpendicular to the lines of the folding.

The axial plane jointing followed, after the folds had become closed and were being overturned. This jointing probably represents an early stage of shearing due to rotational stress. The horizontal joints were possibly formed during the same stage of the folding. They develop into a true cleavage in the Sesob River area, where, perhaps significantly there seems to be a "hump" in the floor of the folds. They are possibly due to the same forces that overturned the folds and produced the thickening of overturned limbs of anticlines, i.e. they are shears formed by rotational stress.

4) <u>Drag Folds</u>.

Minor drag folds are common throughout the area, and are seen on almost any exposed face of schist. The axes of the drag folds are mostly parallel with the major fold axes, but rarely a second oblique set of drag folds is superimposed. (See photo, Fig. 16)

The drag folds take the form of evenly spaced smooth ridges, with a wavelength between a few centimetres and two metres. The smaller drag folds resemble ripple marks, from which they can be distinguished by their consistent parallelism in successive layers.

Drag folding is strongly developed in bands in the Upper Marble series where it takes the form of crenulations and contortions. (See Photos, Figs. 38, 47).

Most of the drag folds are minor features caused by the initial major folding, and the drag folds in the schist were all found to be congruous with the major folds.

5) Faulting.

There are no major faults in the area, but within the area of the marble outcrops are many near-vertical faults which exercise a strong control over the physiography. Almost invariably they strike transverse to the axes of the folds, in a direction within twenty degrees of northwest. Although the fault zones are up to 7 metres in width and are filled with breccia the maximum vertical displacement observed was only about 30 metres. Commonly there is evidence of a downthrow to the northeast, the amount of throw decreasing towards the ends of the faults. In the area south of Brakputz, such faults run en echelon, suggesting as a cause a couple formed by forces acting northwards on the eastern side of the faulted zone and southwards on the western side.

Strike faults are not easily detected in the strong folding, although they are known to occur in the area. Some minor strike faults of small throw occur at the galena occurrences discussed under "Economic Geology". (See map, Fig. 85).

Age of the Faults.

The largest fault found running between and parallel with the Gemsbok and Sesob Rivers, can be traced for thirteen km, and runs parallel with a swarm of Karroo dolerite dykes. Had the fault preceded the dykes intrusions it would surely have been filled with dolerite, but no dolerite has been found in the fault planes. Therefore this fault and most of the other transverse faults are probably post-Karroo in age, and are possibly connected with the earth movements which accompanied the Brandberg intrusions.

6) Structure of the Quartz Veins.

Quartz veins are very common, especially within the schist area. All are pre-Karroo and many seem to be older than the old granite.

The oldest period of quartz intrusion usually takes the form of bedded veins, now somewhat contorted. Some run at a small angle to the bedding.

Younger sets of quartz veins are of at least three ages, and and are probably later than the old granite. Their origin is probably a granite underlying the schists, or possibly the granite body which is cut by the course of the Goantagab River, north of the Ugab River.

The quartz veins occur in a well-defined fracture pattern. They form in plan a criss-cross arrangement, at angles between 50° and and 90° to the axes of the folds, their planes intersecting along a line more or less parallel with the axial planes. (See Fig. 86). They are almost entirely confined to anticlines. A further set of quartz veins is interbedded in the schist and is probably younger than the bedded veins mentioned above. The structure of these veins at the Sesob River galena occurrences has been described under "Economic Geology".

Structure of the Basic Intrusions.

The majority of the dykes in the area are Karroo age, but there are a few that may be considerably older. The possibly older dykes are usually associated with swarms of Karroo dolerites, and follow similar directions.

D) The Karroo Dykes.

These dykes have two main trends - parallel with the strike, and roughly at right angles to the strike. The latter trend is common in the western part of the area, and the former is most common near the Brandberg. The central area, from the Zerissenes Mountains to the Amis River, is comparatively free from intrusions. Possible explanation for the presence of dyke swarms in certain areas have already been given.

1) The dykes of the Western Area.

These belong to at least three different ages.

a) The porphyritic or amygdaloidal diabases, which follow a more or less sinuous course, roughly at right angles to the general strike. They are older than

b) Olivine dolerites of Karroo type, which are usually vertical, striking at right angles to the bedding, and repeatedly pinching out and continuing an echelon. They cut diagonally across the strata in a zig-zag manner, as alternate dykes and sills. These dykes are cut by

c) Dolerites of Karroo type, which are usually thicker than the older dykes, and which run in a fairly straight course across the strike of the sediments. Some of these dykes are kilometres in length.

Exceptions to the above relationships occur, because of the somewhat variable composition of the dykes.

Except for the sills, all these intrusions are usually within 10° of vertical. A fourth set of intrusives occur as flat sheets dipping at angles between 30° and horizontal. These sheets are common in the western area, but are rare towards the Brandberg. They are probably of Karroo age, younger than (b) above, and appear to follow cleavage joint planes. The thick sills lying in the lower Karroo sediments or at the base of the Karroo rocks, are possibly younger than the other basic Karroo intrusives. A few thick dykes (up to 20 metres thick) of short strike length (up to 400 metres) are possibly feeders of the thick sills.

2) <u>The Area near the Brandberg</u>.

The normal strike direction of these dykes is northeast, parallel with the folded schist. They do not invariably lie along the bedding, but tend more towards the vertical than to parallelism with the bedding. In their thickness and persistence they resemble the younger Karroo dykes of the western area. Where they cut obliquely to the strata, they resume their original course within a short distance.

As mentioned above flat sheets are rare in this area. One such sheet lies to the west of the Amis River, 13 km from the Ugab River, and is about 250 metres below the level of the base of the nearest Karroo rocks.

3) <u>General</u>.

The manner of intrusion of Karroo dykes appears to follow a pattern similar to that which has been described in the Union (Du Toit, etc). Primary feeder dykes supplied material to the areas of least resistance, such as bedding planes in the Karroo sediments and possibly horizontal and vertical joints in the Damara beds. After all these possible avenues of intrusion had been filled, the dolerite magma was forced to occupy planes of weakness, mostly vertical, lower down in the Damara beds.

Rarely, the vertical dykes forced their way up into Karroo lavas. It is possible that, much later, erosion of the upper portion of the Karroo rocks permitted further emplacement of flat sh ts and sills, mainly at the basal contact of the Karroo rocks with t older rocks.

It is possibly significant that the dykes of the eastern and western areas, and some of the faults, strike roughly towards the Messum Alkali complex.

E) The Karroo sediments and Lavas.

These rocks all show flat bedding and a low dip, except near faults, where drag has caused the dip to be as steep as 60°. Faulting in the Karroo rocks is rare except near the Brandberg, but a system of joints is common in material such as quartzitic sandstone. There are usually two sets of joints at about 90° to each other, one running 50° west of north, and a weaker set at 40° east of north. These joints are repeated higher up in the lavas, where the vertical fracture is pronounced.

F) The Brandberg Intrusion.

The mode of intrusion of the Brandberg has been fully dealt with by Cloos (Ref, 1931). to whose work nothing can be added.

G) Structural History of the Area.

The earliest known event in this area is the folding of the schists and their movement towards the northwest over a decollement. The folding was probably due to isostatic adjustment in a large and deep geosyncline, and this area probably occupied a position near the centre of the geosyncline.

The folding was accompanied by some shearing and the formation of drag folds, ellipsoidal structures, joints, and cleavage. Limited strike faulting may have occured in the folded schists, due to thrusting. Towards the end of the folding some quartz veins were formed.

The next major event was the granite intrusion, as a composite phacolith above the Upper Marble horizon. Probably, other granite phacoliths were intruded at deeper levels.

Accompanying the granite intrusions or immediately after them, acid dykes and sills were emplaced near or at the granite-schist contact, and quartz veins later invaded the whole area, mostly in anticlinal structures, either as typical anticlinal cross-veins, or as bedded veins.

Little further movement took place up to Karroo times.

Karroo sediments were deposited, followed by intensive outpourings of lavas and by at least three ages of dyke intrusions along fractures following well-defined directions in the schist. The pattern was less regular in the granite. Then followed, after a comparatively short interval, the Brandberg intrusion which was accompanied by minor earth-movements in the form of gravity faults.

TABLE VII.

ROCKS OF THE LOWER SCHIST SERIES.

NO.	LOCALITY	AMPHIBOLE					PYROXENE				BIOTITE		EPIDOTE		FELSPAR			EXTRAS AND REMARKS	ESTIMATED MODE (Shown graphically)
		$2V\alpha$	$c\wedge Z$	$\gamma-\alpha$	β	Colour and Pleochroism	$2V\gamma$	$c\wedge Z$	$\gamma-\alpha$	β	$\gamma-\alpha$	γ		$\gamma-\alpha$	$2V$	R.I.	Type		
265	Brak River										.048	1.634						Rare tourmaline	Q B → Cc
277	South of	82	16	.019	1.649	Pale green	58	48	.028	1.725			Clino-zoisite		69-	Low	Microcline		Q F P+A → E, Cc
278	Zerrissenes Mts.					✓				✓			✓					Well developed amphibole	Q F A E → P
279	"	72	14	.022	1.635	Pale green							Epidote					Much cordierite	Q C A → E
280	"	72	15	.026	1.650	α Pale green to γ light green						1.640						Cordierite and calcite.	Q C B A → Cc
281	"	78	11	.0265	1.648	Light green						1.627		.026			Orthoclase	Cordierite, 2V82-. Sphene and calcite.	Q C F B A → S
282	" Light part	72	15	.025	1.651	Pale green								.026				Much cordierite	Q C F A → E
	" Dark part	76	18	.028		Pale green					.035				70-	<C.B.	Orthoclase		Q C F B A
283	"	75	21	.019	1.660	Pale green					Rare				78-		Microcline	Cordierite and sphene.	Q C F A → B, S
284	"	75	17	.023	1.656	α Pale green to γ green	64	39	.023	1.707			Rare zoisite		68-	<C.B.	Orthoclase	Cordierite and sphene	Q C F P A → S, E
391	South of Goantagab R. mouth.											1.631						Tourmaline, apatite, rutile and calcite.	Q B → T, Ap, R, Cc
404	Brandberg West Mine																	Mostly tourmaline and quartz.	Q T
409	"																	Mostly tourmaline and ore.	Q T O
413	"											1.612						Much tourmaline and muscovite.	Q M T B O
414	"																	Much tourmaline and muscovite.	Q M T O
417	"											1.616						Little muscovite.	Q M B
420	"											1.615						Tourmaline and much muscovite.	Q M B T O
422	"											1.615							Q B
424	"											1.614						Tourmaline, apatite, Fluorite, muscovite and ore.	Q B O → T, A, M, Fl
429	"											1.615						Rare fluorite.	Q B → Fl

All the above rocks contain quartz.

Q = Quartz
B = Biotite
Cc = Calcite
F = Felspar
P = Pyroxene
A = Amphibole
E = Epidote, zoisite etc.
C = Cordierite
S = Sphene
T = Tourmaline
Ap = Apatite
M = Muscovite
Fl = Fluorite.

(C.B. = Canada Balsam)

CHAPTER V.

P E T R O G R A P H Y.

(A) Methods:

Axial angles, extinction angles, birefringence, and refractive indices were measured on a five-axis universal stage, using the graphs of Emmons. (Ref. 1943). Sodium light was used for the refractive index determinations, and the indices of the immersion liquids were checked with a Leitz-Jelley refractometer.

In the refractive index determinations, a modification of the method described by Emmons was used. The grains were mounted on a universal stage and immersed in a liquid of refractive index within the $\alpha - \gamma$ range of the mineral. The grain was oriented and then rotated in one of the optic planes until the index of the liquid corresponded with the index of the grain. The birefringence and axial angle being known, it was then possible to find the three major indices, with an accuracy of $\pm$ .003. Checks were made on different grains from the same rock, and results were averaged.

Optic axial angles were measured with an accuracy of $\pm 2^{\circ}$.

Modal compositions, where measured with a Leitz integration stage, are accurate to $\pm$ 2%. Where estimated, the modal compositions are accurate to $\pm$ 10%, and are shown graphically on the tables.

The mineralogy and modal composition of each group of rocks will be tabulated before the description of the rocks.

All the rocks are described in approximate order of age, starting with the oldest.

(B) Rocks of the Damara System:

1. The Lower Schist Series. (See Table No.VII).

Macroscopic.

The Lower Schist weathers to a dark brown colour and is brownish grey on fresh surfaces. Weathering produces either typical foliated schist or angular blocks, bounded by cleavage and joint planes. The rock is fine grained and the schistosity is usually well developed.

The more highly metamorphosed varieties of the Lower Schist contain bands and patches of speckled and spotted schist or mottled hornfels.

Typical examples of these rock types, as seen in thin section, are given below.

No. 424. Biotite Schist.

Texture: fine-grained schistose.

The rock consists of roughly equal proportions of biotite and quartz. The schistose texture is due to the parallelism of the biotite flakes, and to a lesser extent, of the elongated quartz grains. Many of the biotite flakes contain dark pleochroic spots. The quartz grains show no optical parallelism. Altered feldspar grains and muscovite flakes are present in small amounts. Anhedral fluorite, apatite, and ore, and subjedral tourmaline are accessory minerals.

No. 413. Tourmaline-muscovite schist. (See photo, Fig. 53).

Texture: coarse grained schistose.

Ragged poikilitic flakes of muscovite constitute about 40% of the rock, and contain rounded inclusions of quartz and ore.

Greenish-brown elongated crystals of tourmaline containing ore inclusions, constitute about 25% of the rock, and an equal amount of quartz grains, of average size 0.1 mm., is mostly interstitial. Generally, the tourmaline is elongated parallel with the schistosity, and the muscovite cleavages lie at 45° to the schistosity.

Ore and light brown biotite flakes, in proportions of about 7 to 3, constitute the remainder of the rock. The ore occurs mostly as ragged grains arranged along the boundaries of the tourmaline and muscovite, and marks out the direction of schistosity.

No. 277 Diopside-orthoclase-quartz granulite:

Texture: poikiloblastic.

About one half of this rock consists of poikilitic growths of diopside, altering to almost colourless, skeletal uralite. The remainder of the rock consists of large poikilitic growths of microcline and orthoclase, containing quartz inclusions, in a mass of rounded quartz grains. × Some of the microcline twinning appears to spring from inclusions. Irregular grains of epidote and subjedral grains of sphene and apatite are accessories.

There are some scattered patches of calcite.

No. 278. Actinolite-epidote granulite.

Texture: medium grained poikiloblastic.

This rock contains well-developed oikocrysts of actinolite up to 2.5 mm., in length, and scattered grains of epidote associated with ore, in a ground-mass of interlocking quartz and plagioclase grains.

There are some rare grains of calcite and sphene.

No. 279. Actinolite schist.

Texture: medium grained poikiloblastic.

Almost half of this rock is composed of oikocrysts of actinolite averaging 1.0 mm., in length, and containing inclusions with pleochroic halos. The actinolite occurs in sheaf-like and radiating forms showing no preferred orientation, and is not altered.

The groundmass consists of a mosaic of angular grains and an altered mineral which is probably cordierite. There is about 3% sphene in scattered subhedral grains, and some small scattered apatite grains. Epidote is present in rare irregular grains, and there are some scarce rounded or irregular grains of zircon which cause pleochroic spots where present as inclusions in the actinolite.

Tourmaline is rare, in rounded grains.

No. 280. Actinolite-biotite schist.

Texture: porphyroblastic schistose.

The prophyroblasts consists of euhedral to suhedral elongated crystals of actinolite up to 1.0 mm. in length, and containing pleochroic spots and inclusions of biotite, quartz and sphene. The actinolite crystals show a poorly marked preferred orientation, parallel with the schistosity.

Subhedral grains of sphene constitute about one percent of the section.

The schistose groundmass consists of biotite flakes averaging 1.0 mm in length, and showing marked parallelism. The biotite is set in a groundmass of somewhat elongated quartz and altered cordierite grains, and contains rare pleochroic spots around inclusions. The quartz grains show parallel optical orientation. There are a few scattered grains of apatite and calcite.

No.281 Actinolite granulite (See photo, Fig. 54).

Texture: porphyroblastic granular.

This rock is similar to No. 280, but contains scattered needles of tourmaline and some interstitial orthoclase. There is no general preferred orientation of the grains, but a slightly banded effect ~~of~~ caused by concentrations of biotite and roughly parallel growths of actinolite.

No. 282 Contact of biotite-actinolite schist and actinolite schist

The Biotite-actinolite schist.

Texture: porphyroblastic schistose.

This section consists of numerous flakes of biotite, altering to chlorite, and showing marked parallelism. The groundmass consists of a mosaic of minute (up to 0.05 mm) quartz and cordierite grains, with some interstitial calcite. Much of the cordierite is altered to sericite. There are a few grains of apatite and sphene and rare tourmaline needles.

A few scattered porphyroblasts of actinolite, containing dark pleochroic spots, and some poikilitic growths of orthoclase also occur.

The actinolite schist.

Texture: porphyroblastic, partly poikilitic.

Actinolite occurs in sheaf-like bunches, or in laths with ragged ends, showing a roughly parallel arrangement. Some of the actinolite shows simple twinning, and dark pleochroic spots are common. There is no biotite in the actinolite schist, but the groundmass is similar to that of the biotite-actinolite schist. There are poikilitic patches of orthoclase, and rarely of diopside, and scattered grains of epidote. There are a few grains of sphene.

No. 283. Actinolite-microcline granulite.

Texture: medium grained prophyroblastic.

Most of the porphyroblasts consist of actinolite, arranged haphazardly. There are some rare oikocrysts of diopside.

Microcline, partly untwinned and similar to orthoclase in appearance, occurs in poikilitic growths, containing quartz inclusions. There is a smaller amount of orthoclase, showing similar poikilitic growth. In parts of the section, the feldspar oikocrysts form an almost uninterrupted mosaic.

Quartz, in small and generally rounded grains, makes up most of the remainder of the rock, and calcite, sphene, apatite, and biotite are found in small quantities. Epidote and cordierite are rare.

No. 284. Amphibole-diopside-orthoclase hornfels. (Irregular mass found in the schist similar to No. 281.

This rock is similar to No. 283, but the growth of the porphyroblasts is not so well developed. Diopside altering to amphibole and calcite is more common. The orthoclase shows microcline twinning at the contacts of poikilitically enclosed grains.

There are some patches of haematite with which are associated irregular grains of zoisite.

2. The Lower Marble Series. (See Table No. VIII).

Macroscopic. The Lower Marble Series consists of a band of bluish-grey medium grained marble, underlain by alternating brownish-black and yellowsih-white marble bands. The alternating marble bands are somewhat schistose.

Description of typical examples of these rocks are given below.

No. 263. Fine-grained light grey translucent marble. (Weathers pale brown.

This rock consists of a mosaic of calcite grains, averaging 0.05 mm. in diameter, with about 2% quartz grains.

No. 264. Schistose brownish black marble.

Texture: schistose.

This section consists of a mosaic of elongated calcite grains, with about 4% irregular quartz and orthoclase grains. The calcite grains average about 0.2 mm. by 0.1 mm. in size.

There are some rare biotite flakes.

No. 390. Bluish grey marble.

Texture: granular.

This section consists of a mosaic of calcite grains, with a roughly parallel arrangement of the more elongated grains. Most of the calcite grains are twinned. There are some grains of quartz, and a few laths of mica, probably muscovite. Ore occurs as small scattered specks.

TABLE VIII

ROCKS OF THE LOWER MARBLE SERIES.

NO.	LOCALITY	AMPHIBOLE					PYROXENE				BIOTITE		EPIDOTE			FELDSPAR		EXTRAS AND REMARKS	ESTIMATED MODE (Shown graphically)
		$2V\alpha$	$c\wedge Z$	$\gamma-\alpha$	β	Colour and Pleochroism	$2V\gamma$	$c\wedge Z$	$\gamma-\alpha$	β	$\gamma-\alpha$	γ	$2V$				Type		
263	Brak River																	Mostly calcite, with a little quartz	Cc, Q
264	Brak River											1.615					Orthoclase	Mostly calcite, with a little quartz.	Cc →Q,F,B
285	South of Zerrissenes Mts.	75	13	.030	1.644	Light green					.060	1.628						Sphene. No calcite.	Q, B, A →S
389	North of Brandberg	82	19	.024	1.637	α Pale green γ Brownish green	64	44½	.025	1.722			80+	(Zoisite)			Orthoclase	Cordierite.	F, C, A, P →E,Q
390	West Mine																	Mostly calcite, with quartz, muscovite and ore	Cc →Q
408	Brandberg West Mine											1.595	Rare clino-zoisite					Mostly calcite with a little quartz, muscovite and ore.	Cc →Q,M,O

Cc - Calcite
Q - Quartz
F - Feldspar
B - Biotite
A - Amphibole
S - Sphene
C - Cordierite
P - Pyroxene
E - Epidote, zoisite etc.
M - Muscovite
O - Ore

No. 235. Biotite-actinolite-quartz schist. (See photo, Fig. 55).

Texture: porphyroblastic.

The biotite occurs in two sizes. The smaller flakes average 0.1 mm. by 0.2 mm. in size, and are oriented parallel with each other in the direction of the plane of schistosity. The larger biotite flakes average 0.2 mm. by 0.15 mm. in size, and although their direction of elongation is parallel with that of the smaller flakes, their Z-directions are oriented roughly by right angles to the common direction of elongation.

Some porphyroblasts of actinolite penetrate the large biotite flakes, and some are oriented continuously with the biotite. Sheaf-linke bunches of actinolite crystals are common. The actinolite shows no preferred orientation.

The rock contains over 40% quartz and probably no feldspar.

There are some rare minute tourmaline and apatite crystals, oriented parallel with the schistosity, and some sphene.

No. 389. Diopside-actinolite-orthoclase granulite.

Texture: poikiloblastic.

The porphyroblasts consist of growths of diopside, actinolite and orthoclase. Some of the actinolite is twinned, and some grains show undulose extinction. Frayed ends and edges to actinolite grains are common. Actinolite is idiomorphic against diopside and orthoclase, and commonly contains a row of inclusions along the centre of a grain.

In part of the section orthoclase, poikilitically enclosing numerous inclusions, forms a mosaic, and in other parts orthoclase occurs as rare oikocrysts, and the remainder of the light minerals consists of a mosaic of minute interlocking grains of altered cordierite.

Non-ferrian zoisite occurs in numerous small euhedral to subhedral grains, commonly associated with diopside, and penetrated by actinolite laths.

There are some rare apatite and sphene grains.

Quartz is probably absent.

3. The Middle Schist Series. (See Table No. IX).

Macroscopically, the Middle Schist is similar to the Lower Schist, except that the colour of the weathered schist is more a reddish brown than a dark brown.

TABLE IX.

ROCKS OF THE MIDDLE SCHIST SERIES.

NO.	LOCALITY	AMPHIBOLE					PYROXENE			BIOTITE		EPIDOTE			FELDSPAR		EXTRAS AND REMARKS	ESTIMATED MODE (Shown graphically)
		$2V\alpha$	$c:Z$	$\gamma-\alpha$	β	Colour and Pleochroism	$c\Lambda Z$	$\gamma-\alpha$	β	$\gamma-\alpha$	γ	$2V$	$\gamma-\alpha$	β	$2V$	Type		
59	Sesob River										1.630					Orthoclase and Plagioclase	Calcite and Biotite partly alt. to chlorite.	Q F → B
60	Sesob River										1.642					Altered	Apatite	Q F B → A
61	Sesob River										1.631					Altered	Sphene, ore, altered feldspar and calcite.	Q F Cc B → S, O
63	Sesob River										1.628							
71	Sesob River									.040	1.622							
71A	Sesob River																	
71B	Sesob River																	
72	Sesob River	88	12	.014		Pale green					1.632					Altered	Calcite and sphene.	Q F Cc A → S
73	Sesob River	77	13	.026	1.660	α Pale green to γ light green				.052	1.630					Orthoclase	Sphene. Quartz recrystallised.	Q F → S
75	Near granite S.W. of Gemsbok River	82	15	.022	1.665	α Pale green to γ light green											Much cordierite; ore and garnet.	Q C A → O, G
261	Brak River										1.637					Altered	Apatite, sphene, calcite, ore.	Q F B → Ap, S, Cc, O
271	South of Zerrissenes Mts	76	23	.023	1.659	Pale green α greenish blue	39	.024	1.734			85-	.016			Orthoclase	Cordierite and sphene.	Q C A P → S
273	"	76	19	.028	1.656	γ Pale green					1.636						Much cordierite, 2V 77° - Sphene and ore.	Q C Cc A → B, S, O
274	"										1.635						Cordierite, tourmaline and ore.	Q + F B → T, O
286	"										1.633						Apatite and sphene.	Q B → A, S
287	"	76	20	.020	1.653	α Pale brown-green to γ green						79-	.012	1.723			Garnet, RI= 1.771, Tourmaline Scapolite, O= 1.592, E =1.559	Q Sc A T C → Al, E
288	"									.043	1.641						Calcite and rare amphibole and cordierite.	Q F Cc B → A, C
298	"	76	12	.021	1.652	α Pale brown-green γ pale green						80-			58-	Orthoclase	Much cordierite. Sphene.	Q C F A → S, E

All the above rocks contain quartz.

Q - Quartz.	S - Sphene.	P - Pyroxene.
F - Feldspar.	O - Ore.	T - Tourmaline.
B - Biotite.	C - Cordierite.	Sc - Scapolite.
A - Amphibole.	G - Garnet.	Al - Allanite.
Cc - Calcite.	Ap - Apatite.	E - Epidote.

Some of the rocks have a quartzitic appearance. The more highly metamorphosed varieties are identical in appearance with the corresponding rocks of the Lower Schist Series.

The microscopic feature of typical specimens taken from the Middle Schist Series, are as follows:

No. 59. Schistose biotite granulite.

Texture: Schistose.

Most of the biotite is this section is altered to chlorite.

The mica flakes are oriented in thin layers parallel with the schistosity.

Quartz and feldspar grains form a mosaic, and show banding but no pronounced optical parallelism. The feldspar consists of oligoclase and orthoclase in about equal amounts, and is rather altered. Scattered subhedral grains of apatite are found throughout the rock, and interstitial calcite is fairly common. There are some flakes of muscovite.

No. 61. Calcareous biotite schist. (In contact with conglomerate).

This is a schistose biotite granulite, similar to No. 59, but containing much interstitial calcite. The biotite is unaltered.

There are small amounts of sphene and ore.

No. 63. Biotite schist.

This section, cut across the cleavage, shows biotite of two sizes aligned at an angle to each other. The smaller, and apparently older generation of biotite occurs as minute parallel laths in a matrix composed of a mosaic of fine quartz grains. The younger generation of biotite is seen as basal flakes oriented with their Z-axes lying at about 60° to the direction of lineation of the older biotite. The larger flakes contain rare pleochroic spots.

Much of the lineation is due to lines of black dust, possibly composed of carbon.

There are numerous scattered subhedral grains of sphene.

No. 71A. Biotite-chlorite-actinolite granulite. (Pebble from conglomerate).

The biotite is partly altered to pale greenish grey chlorite in nests and flakes, and poikilitically encloses chloritised amphibole. The chlorite is not pleochroic, but contains pale grey pleochroic spots around inclusions.

Under crossed Nicols, the chlorite is dirty greenish grey, and the pleochroic spots are violet, with dark greenish rims.

The actinolite occurs as spray-shaped arrangements of pale greenish needles in the quartz and feldspar groundmass.

Rare laths of clinochlore are found optically continuous with the chlorite, and in similar patterns.

Sphene is fairly plentiful, and occurs as irregular masses.

Apatite, calcite, and epidote are accessories. Calcite replaces quartz at contacts between quartz grains.

No. 71B. Biotite-chlorite-actinolite quartzite. Pebble from Conglomerate (See photo. Fig. 56).

This section is similar to No. 71A, except that the groundmass is a quartzite composed of interlocking grains of quartz. The quartz grains contain inclusions, many of which are arranged peripherally and apparently delineate the original outlines of the grains. (See photo.Fig.56) The quartz is partly replaced by calcite along the contacts of grains.

Most of the biotite is altered to chlorite. There are a few grains of apatite.

No. 71C. Biotite-chlorite-actinolite quartzite. (Pebble from Conglomerate).

This rock is similar to No. 71B, but the actinolite is better developed. There are rare grains of apatite and epidote, and of subhedral to euhedral garnet. Some of the chlorite plates formed by alteration of biotite, show a poikilitic structure. There is some interstitial calcite.

No. 72. Actinolite granulite.

There were apparently two generations of actinolite in this rock. The earlier has been completely replaced by calcite which appears in the form of optically continuous poikilitic pseudomorphs. The later actinolite occurs as feathery aggregates containing some dark pleochroic spots.

There are a few similar feathery aggregates of pale greenish chlorite similar to that described in No. 71A. The inclusions that cause the pleochroic spots are here identified as rounded zircon grains.

There are a few flakes of muscovite and some rare pale brown biotite flakes.

No. 73. Actinolite-biotite granulite.

Texture: Fine grained porphyroblastic.

The actinolite is unusually dark, being pleochroic from X pale brownish green through Y apple green to Z bluish green. It occurs as poikilitic grains, which penetrate biotite flakes.

The biotite appears in a more or less banded pattern, and is partly altered to chlorite.

The groundmass consists of a mosaic of re-crystallised quartz grains and a minor amount of orthoclase grains which are at an early stage of poikilitic growth.

Apatite and sphene, the latter usually associated with ore, are accessory minerals.

No. 261. Biotite schist.

The texture of this rock is markedly schistose, but the quartz grains show no optical parallelism, although they are elongated parallel with the schistosity.

The light coloured groundmass consists mostly of elongated quartz grains, with a small amount of plagioclase and orthoclase grains.

Apatite, sphene and ore, are accessory minerals.

There are a few interstitial patches of calcite.

No. 271. Actinolite-diopside-epidote rock.

Texture: poikiloblastic.

The dark minerals in this rock consist of poikilitic growths of actinolite, diopside, and epidote, with a small amount of subhedral sphene.

The epidote occurs as inclusions in oikocrysts of diopside. Actinolite penetrates both diopside and epidote.

The light minerals consist of a mosaic of subrounded quartz grains, with interstitial altered cordierite, and some patches of calcite and scattered small apatite grains. The calcite here is an alteration product of actinolite. There are some clear orthoclase grains, younger than the altered cordierite.

No. 236. Biotite chlorite schist.

Macroscopic. This rock weathers to a rounded surface, rather like a quartzite. The weathered rock is greyish brown in colour.

Microscopic.

Texture: medium grained schistose.

The biotite flakes are arranged roughly parallel with each other and some are altered to chlorite.

The quartz is in medium-sized recrystallised polygonal grains, and contains little interstitial matter. There are a few patches of calcite, and some apatite and sphene grains.

No. 287. Pseudo-diorite nodule. (In schist similar to No.286).
(See photo. Fig. 57).

Macroscopic. This rock, which occurs in elongated ellipsoidal bodies up to 2 meters in length, has a spotted appearance. The spots appear partly in concentric zones, in one or more outside rings, and partly as haphazard groups of dark green amphibole spots up to 1 cm. diameter, within the central area of the nodule. In the nodule from which specimen No. 287 was taken, the spots are larger and more closely grouped near the bottom than near the top. The rock between the dark amphibole spots is mottled pink, due to the presence of garnet, with a pale greenish matrix probably due to the presence of epidote.

Microscopic (Spotted portion of rock).

Texture: porphyroblastic.

Dark minerals. Green amphibole, containing pleochroic spots, occurs in ragged poikilitic growths and is partly altered to chlorite and calcite. The amphibole is pleochroic from X pale brown through Y pale apple green to Z pale bluish green.

Garnet occurs in small quantities, in poikilitic patches.

Light Minerals. Scapolite occurs in radiating poikilitic clusters, intergrown with unoriented euhedral epidote crystals, and containing inclusions of sphene. The scapolite is much altered to a dirty fibrous mineral, possibly sericite.

Epidote is also found in poikilitic growths, sometimes intergrown with calcite. The groundmass consists mostly of rounded quartz grains with rare minute apatite grains and some patches of calcite. There are numerous anhedral grains of sphene and about 10% interstitial altered scapolite.

There is no iron ore.

No. 288. Nodule in schist near No. 287. Altered biotite-actinolite schist

Texture: Schistose.

The dark minerals consists of biotite, partly altered to almost isotropic green chlorite and pennine, and scattered subhedral grains of sphene. The biotite is pleochroic from pale greenish brown to brown, and the flakes show a small degree of parallelism.

The light minerals consists of calcite in poikilitic growths pseudomorphic after amphibole, and clear quartz grains with little interstitial matter. Rarely, patches of amphibole remain unaltered.

There are some rare small apatite grains.

No. 293. Actinolite granulite.

Macroscopic. This rock has the appearance of a fine grained slightly schistose quartzite.

Microscopic. Texture: porphyroblastic schistose.

The dark minerals consists of poikilitic growths of actinolite, containing pleochroic spots around minute inclusions, and arranged in a roughly banded pattern. There is much sphene and about 1% epidote, and a little biotite.

The light coloured groundmass consists of well rounded quartz grains with interstitial altered cordierite, and calcite.

Rare bands of quartz grains show optical parallelism.

There is about 5% orthoclase.

Apatite is an accessory.

4. The Upper Marble Series. (See Table X.)

As the Upper Marble Series includes many rock types, macroscopic descriptions will be given individually with each microscopic description.

The Yellow Marble Zone.

No. 238. Grey Marble.

Macroscopic.

Light grey fine-grained marble, with faint dark lines.

Microscopic:

Texture: fine grained granular.

This sections consists almost entirely of interlocking polygonal grains of calcite. Quartz grains constitute about 1% of the total and there are rare grains of plagioclase.

TABLE X

ROCKS OF THE UPPER MARBLE SERIES.

NO.	LOCALITY	AMPHIBOLE $2V\alpha$	AMPHIBOLE $c\wedge Z$	AMPHIBOLE $\gamma-\alpha$	AMPHIBOLE β	AMPHIBOLE Colour and Pleochroism	PYROXENE $2V\gamma$	PYROXENE $c\wedge Z$	PYROXENE $\gamma-\alpha$	PYROXENE β	BIOTITE $\gamma-\alpha$	BIOTITE γ	EPIDOTE etc $2V$	EPIDOTE etc $\gamma-\alpha$	EPIDOTE etc	FELDSPAR Ext. Angle $\perp 010$	FELDSPAR $2V$	FELDSPAR RI	FELDSPAR Type	EXTRAS AND REMARKS	ESTIMATED MODE (Shown graphically
43	Sesob R., near Lead occurrences											1.603								Patches of calcite, and bands of quartz. Rare clinochlore	
46	"	80	16	.0255	1.626	Pale green					.041	1.602								Mostly calcite, with clinochlore (2V 30°+)	Cc, A → B, Cl
46A																				Mostly calcite	Cc, A
47	"																			Mostly calcite. Rare carbon.	Cc → Cb
48	"											1.604								Mostly calcite. Poikilitic clinochlore.	Cc → Q, F, B, Cl
49	"																		Orthoclase	Mostly elongated calcite grains.	Cc → F
50	"											1.614								Scattered clinochlore.	Cc → Q, F, B, Cl
51	"																			Mostly calcite, with rare quartz and ore.	Cc → Q O
56	"																			Mostly calcite, with rare quartz.	Cc, Q
57	"											1.630								Mostly altered feldspar and quartz. Biotite altering to chlorite. Some calcite.	Cc, F+Q, B
58	"																			Mostly calcite, with rare quartz.	Cc, Q
69	"						60	45	.015	1.727										Vesuvianite O = 1.707. Rare calcite and quartz.	V, P → Cc, Q
77	S.W. of Brak R.	70	17	.023	1.665	α Pale brown γ Light green							84-							Cordierite, calcite, sphene, apatite and allanite	Cc, Q, C, A → S, Ap, Al, E
79	Near granite							42	.030	1.708					Clino-zoisite	24	80+	> z	Andesine	Sphene	F, P → Q, S, E
80	"	68	20	.020	1.639	α Pale green γ Green							87-		Epidote	36½	83+	> z	Labradorite	Allanite and sphene.	Q, F, A → B, Al, S, E
81	"	65	13	.024	1.665	α Pale green	60	43	.026	1.717										Cordierite, 2V78°-. Sphene, garnet and allanite.	Q, C, P, A → S, G, E, Al, C
85	Between Sesob & Brak rivers.												82-	.014	Epidote					Mostly garnet and fluorite. Grossularite, R.I. 1.753. Vesuvianite, E 1.705, Grossularite R.I. 1.750.	Fl, G → V, E
101	Western schist-garnet contact						57	40	.029	1.719										Wollastonite 2V43°- $\gamma-\alpha$ .012	Q, G, P, W
102							58	45	.0285	1.704										Grossularite R.I. 1.742. Wollastonite 2V38°-, $\gamma-\alpha$ = .013, β 1.630 Vesuvianite O-E = .016. Some calcite.	Q, V, G, P, W
113	"	72	17	.023	1.671	α Blue-green γ Brown-green	60	52	.034	1.721			76-		Epidote		78-	> z	Anorthite	Allanite, sphene, garnet and calcite.	Q, G, P, A → Al, E, C, F
114	"	68	15	.023	1.670	α Brown-green γ Green							82-	.012	Epidote	53½	77-	> z	Anorthite		Q, F, A → Al, E
115	"	74	14	.019	1.654	Pale green	58½	41	.023	1.711			82-		Zoisite					Cordierite and sphene	Q, C, P, A → S, E

/2 ....

TABLE X (Contd.)

ROCKS OF THE UPPER MARBLE SERIES.

NO.	LOCALITY	AMPHIBOLE					PYROXENE				BIOTITE		EPIDOTE etc.			FELDSPAR				EXTRAS AND REMARKS	ESTIMATED MODE (Shown graphical)
						Colour and pleochroism	$2V\gamma$	$c\Lambda Z$	$\gamma-\alpha$	β	$\gamma-\alpha$	γ									
117																				Mostly calcite, with interstitial sericite and scattered ore.	Cc → Se, O
118																				Mostly calcite, with interstitial sericite and scattered ore.	Cc → Se, O
121																				Mostly calcite, with some quartz containing numerous inclusions.	Cc → Q, Se, O
134	Amis R., near Ugab R.																			Mostly elongated calcite grains.	Cc
135	"																			Mostly calcite, with rare quartz and magnetite grains.	Cc → Q, O
217	Enclave in granite east of Zebra R.															Altered				Tourmaline, O = 1.666, E = 1.632 Apatite, sphene and epidote.	
223	"												Some epidote							Nearly all andradite, R.I. >1.832	G → E, Q
224	"						58	45	.022	1.710			Zoisite and epidote							Mostly andradite R.I. >1.832.	G, P+A → Q, Cc, Ap
230	Brak River											1.608							Rare	Mostly calcite and quartz, rare clinochlore and feldspar.	Cc, Q, B → Cl, F
231	"										.049	1.604								Much calcite, rare quartz and clinochlore.	Cc, Q, B → Cl
232	"											1.610								Mostly calcite and biotite, rare quartz and clinochlore.	Cc, Q, B → Cl
234	"											1.593									Cc, B, Q
235	"																			Mostly calcite, some quartz and clinochlore	Cc, Q → Cl
236	"										.040	1.602								Mostly calcite, some quartz	Cc, B → Cl, Q
237	"										.036	1.600								Mostly calcite, some quartz.	Cc, Q, B → O
238	"																			Mostly calcite. Some clinochlore and muscovite.	Cc → Cl, M
240	"																			Mostly calcite, some quartz and feldspar.	Cc, Q, F
241	"																			Mostly calcite, some quartz and feldspar.	Cc, Q, F
242	"										.043	1.605								Mostly calcite, some quartz, feldspar and a little muscovite.	Cc, Q, B → M
243	"										.042	1.602								Mostly calcite, some quartz, feldspar and a little clinochlore.	Cc, B → Q, Cl
245	"																			Mostly quartz, some chert and calcite.	Cc, Q
247	"																			Alternating calcite and quartz - rich bands.	Cc, Q Cc, Q
249	"											1.625								Rare garnet.	
251	"																			Mostly calcite, some quartz and graphite.	Cc, Q → Cb
252	"																			Mostly calcite, rare quartz and graphite.	Cc → Q, Cb
253	"										.044	1.595								Much calcite, some graphite. Rare quartz, muscovite and ore.	Cc, Cb → B, Q, M, O
254	"																			Mostly calcite, some quartz and graphite. Rare biotite.	

/3 .....

TABLE X (Contd)

ROCKS OF THE UPPER MARBLE SERIES.

NO.	LOCALITY	AMPHIBOLE					PYROXENE				BIOTITE		EPIDOTE			FELDSPAR				EXTRAS AND REMARKS	ESTIMATED MODE (Shown graphically)
		$2V\alpha$	$c\wedge Z$	$\gamma-\alpha$	β	Colour and Pleochroism	$2V\gamma$	$c\wedge Z$	$\gamma-\alpha$	β	$\gamma-\alpha$	γ	$2V$				$2V$	β	Type		
258	Brak River											1.617								Mostly calcite, some graphite, rare quartz and biotite.	Cc | Cb | → B
259	"										.051	1.614								Mostly calcite, some graphite, rare quartz and biotite.	Cc | Cb | → B, Cl
260	"										.046	1.635								Calcite and quartz, with some feldspar and biotite.	Cc | Q | F |
291A	S. of Zerrissenes Mts.	80	12	.022	1.641	Pale green		43	.028	1.719									Orthoclase	Sphene and calcite.	F | P | A | → Q, S, Cc
292A	"																				
293	"	78	10	.024		Light green					.053	1.622					65-	1.522	Orthoclase	Fine grained cordierite, 2V 70°-	Q | C | Cc | B | → A
294	"	75	18	.028	1.658	α Pale green to γ light green							84+		Epidote		65½-		Orthoclase	Sphene and apatite.	F | A | → S, Ap
295	"	78	20	.038	1.647	Pale green	60	52	.036	1.718			62-		Epidote					Clinochlore patches and fine-grained cordierite. No quartz.	C | P | A | → E, Cl
299	"											1.608									Q + Cc | B
300	"																			Mostly calcite, some interstitial muscovite and sericite.	Cc | → M, Se
395	S.W. of Brandberg West Mine																			Mostly calcite. Little quartz.	Cc | Q

C - Cordierite
Cc - Calcite
A - Amphibole
P - Pyroxene
B - Biotite
Cl - Clinochlore
Cb - Graphite
F - Feldspar
O - Ore
Q - Quartz
V - Vesuvianite
Ap - Apatite
S - Sphene
E - Epidote
Al - Allanite
G - Garnet
Fl - Fluorite
W - Wollastonite
Se - Sericite
M - Muscovite.

The dark lines are stylolitic in shape, and are due to the presence of minute particles of colourless mica, and numerous specks of carbon dust. The calcite grains along the dark lines are smaller than the grains in the groundmass.

No. 240. Quartzitic Marble.

Macroscopic: A fine grained surgary pale brown marble. Shows banding on weathered surface.

Microscopic:

Texture: granulose.

Most of the section consists of a mosaic of calcite grains, averaging 0.08 mm. in size, and showing a slight elongation.

Rounded quartz grains averaging 0.2 mm. in size constitute about 20% of the slide, and plagioclase about 5%. Some of the plagioclase encloses calcite grains poikilitically.

There are some rare minute specks of ore.

No. 232. Phlogopite Marble.

Macroscopic. Black schistose marble with minute specks of phlogopite. Weathers brown.

Microscopic:

Texture: schistose.

The phlogopite flakes show a preferred spacial and optical orientation, and average 0.03 mm. by 0.01 mm. in size.

Ore is found in elongated patches up to 1.0 mm. in length, probably pseudomorphic after phlogopite. The pseudomorphs contain transverse inclusions of clinochlore. Clinochlore is scattered through the section, associated with and penetrated by phlogopite flakes.

Calcite constitutes most of the slide, as grains averaging 0.02 mm. in size. Quartz occurs interstitially between the calcite grains, and averages 0.01 mm. in size.

Ore and possibly carbon, in the form of fine dust is disseminated through the section.

No. 236. Schistose biotite Marble.

Macroscopic: Weathered spotted brown marble.

Microscopic:

Texture: schistose.

This section is similar to No. 232 except that there is less quartz. The clinochlore occupies almost 2% of the section. The spots are due to patches of ore.

No. 230. Quartzitic phlogopite marble.

Macroscopic: Brownish grey, very fine grained marble. Weathers brown and shows banding on weathered surface.

Microscopic:

Texture: granular, slightly elongated.

The calcite grains commonly have ragged outlines, and average 0.1 mm. by 0.05 mm. Quartz fills the interstices in the calcite grains.

There are rare grains of altered plagioclase.

Dark brown biotite flakes lie parallel with the elongation, and are associated with pale to colourless phlogopite, and long laths of haematite. Clinochlore occurs as scattered thin laths, many of which are associated with the haematite.

No. 291. Actinolite-diopside-orthoclase granulite.

Macroscopic: A coarse to medium grained pale green mottled rock.

Microscopic: Texture: poikiloblastic.

Porphyroblasts of poikilitic light green actinolite, up to 2.0 mm. in length, constitute about half of the section. Similar growths of orthoclase (average size 0.3 mm.) and colourless diopside (up to 1.5 mm. in size) make up the remainder of the rock. There are numerous rounded inclusions of quartz, some patches of calcite, and scattered anhedral grains of sphene.

Rare patches consisting of a mosaic of quartz and altered felds-par grains occur in the section.

No. 293. Actinolite-biotite schist.

Macroscopic: A compact dark grey fine-grained rock, containing much biotite. Weathers greenish grey.

Microscopic:

Texture: porphyroblastic schistose.

About one half of this rock consists of biotite laths (average size 0.1 mm. by 0.02mm.) arranged parallel, with many scattered larger biotite flakes (average size 0.25 mm.) which are not penetrated by the small flakes, and which are without parallel orientation.

Some of the larger flakes contain dark pleochroic spots, and a few are altered to chlorite.

There are a few scattered poorly formed poikilitic grains of actinolite, and some large (up to 0.5 mm. by 0.25 mm) grains of orthoclase, grouped in contact with grains of ore and calcite. Isolated orthoclase grains occur containing minute inclusions of euhedral tourmaline.

The groundmass consists of elongated quartz grains, averaging 0.01 mm. in length, and an altered mineral, probably cordierite. The groundmass shows no optical parallelism.

There is some chlorite, mostly in contact with ore. Calcite occurs in scattered patches and laths, some of the patches being associated with the ore.

No. 294. Actinolite-orthoclase granulite.

Macroscopic: Greenish crystalline band in yellow marble.

Microscopic: Texture: poikiloblastic.

Green actinolite, containing dark pleochroic spots, occurs in ragged poikilitic laths, and occupies about one half of the section.

About 3% of the section is composed of epidote, mostly intergrown with the actinolite.

There are a few flakes of biotite, some altered to chlorite, and numerous small grains of sphene.

The groundmass consists of minute grains of altered feldspar at least half of which are orthoclase. Quartz is absent.

Some apatite occurs, as small scattered grains.

No. 295. Actinolite-diopside-orthoclase granulite.

Macroscopic: Compact light grey crystalline rock.

Microscopic: Texture: porphyroblastic.

About one half of this section consists of poikilitic growths of diopside. Ragged poikilitic laths of actinolite cut and probably replace the diopside.

There are a few patches of calcite, probably an alteration product of actinolite, and one crystal of tourmaline associated with ore. Epidote, apatite and sphene are rare.

The groundmass consists of a mosaic of microcline and orthoclase grains. There is a small amount of fine-grained mineral possibly cordierite.

The Brown Marble Zone.

No. 243. Phlogopite marble.

Macroscopic. The fresh rock is dark brownish grey, and fine grained, with a conchoidal fracture. The weathered surface is light or dark chocolate brown, with a rough surface caused by minute projecting phlogopite grains. Banding is evident in weathered surfaces.

Microscopic: Texture: granular and somewhat schistose. Variable grain size.

The phlogopite occurs as pale brown scattered flakes, showing a preferred direction of elongation and optical parallelism. The average grain size is 0.2 mm., coarser than the groundmass. The phlogopite contains rare pleochroic haloes around minute inclusions.

The groundmass consists almost entirely of calcite as irregular shaped grains averaging 0.03 mm. in size. There is a small amount of quartz, in grains averaging 0.02 mm.

Clinochlore occurs rarely, mostly as minute laths some of which form cores to phlogopite flakes. Ore is rare.

No. 245. Calcareous quartzite.

Macroscopic: Similar in appearance to No. 243.

Microscopic: Texture: granular.

Most of this slide consists of a mosaic of polygonal quartz grains averaging 0.05 mm. in size. Calcite occurs in scattered patches, (average size 0.2 mm.)

There is a slight banded structure due to the concentration of calcite in bands.

The Intermediate Marble Zone.

No. 247. Banded calcareous quartzite and quartzitic marble.

Macroscopic: Fresh brownish white sugary fine grained marble.

Microscopic: Texture: granular.

This section consists of alternating bands containing 7% calcite to 93% quartz, and 25% quartz to 75% calcite.

The quartz is in polygonal and rounded recrystallised grains.

The calcite grains vary in shape from polygons and minute rhombehedra to ragged interstitial grains.

There are some rare muscovite flakes.

No. 46. Actinolite phlogopite marble.

Macroscopic: Grey marble containing elongated crystals of actinolite.

Microscopic: Texture: poikiloblastic.

Actinolite occurs as colourless large, (up to 4.0 mm. long) subhedral poikilitic crystals, some partly replaced by clinochlore. Some of the actinolite is twinned. Clinochore also occurs as individual laths, and in radiating nests.

The groundmass consists of a mosaic of calcite grains, average size 0.05 mm., containing scattered pale brown phlogopite flakes, averaging 0.15 mm. in size.

There are patches of ore, associated with phlogopite.

No. 46A. Actinolite-phlogopite marble. (See photo. Fig. 58).

Macroscopic: Fine grained sugary yellowish marble, with rounded greenish brown actinolite crystals averaging 5.0 mm. in length.

Microscopic: Texture: poikiloblastic.

The oikocrysts consist of large ragged growths of pale green actinolite. Pale brown phlogopite occurs as inclusions in the actinolite and is present throughout the section in a parallel arrangement.

The groundmass is an even grained mosaic of quartz and calcite grains.

There are a few medium to large grains of clinochlore, and some rare subhedral light brown tourmaline grains.

The Bottom part of the Blue Marble Band.

No. 47. Bluish-grey marble.

Macroscopic: Fine grained marble.

Microscopic: Texture: fine grained granular.

This section consists almost entirely of an even grained mosaic of calcite grains, with an average grain size of 0.1 mm. There are a few thin calcite veins, and numerous minute specks of carbon.

Middle Black Line in Blue Marble Band.

No. 249. Schistose biotite marble.

Macroscopic. Spotted fine grained brownish black schistose rock.

Microscopic: Texture: fine grained schistose, with porphyroblasts.

The porphyroblasts consist of laths of graphite up to 0.75 mm. in length, surrounded by rims of garnet.

There are also groups of quartz and calcite grains coarser than the groundmass, and numerous small poikilitic subhedral garnet grains.

The groundmass consists of very fine grained calcite grains and biotite flakes with rare sericite and chlorite flakes, all oriented more or less parallel. There are a few scattered apatite grains.

Top part of the Blue Marble Band.

No. 117. Grey marble.

Macroscopic: Coarse grained light grey marble. Weathers brownish grey.

Microscopic: Texture: medium to coarse grained granular.

The rock consists of a mosaic of calcite grains, averaging 0.8 mm. in diameter. Some of the grains show slight elongation and strain. There are a few interstitial grains of quartz and sericite, and minute scattered specks of ore.

No. 252 Grey marble.

Macroscopic: Fresh medium grained marble.

Microscopic: Texture: even grained granular.

The rock consists of a mosaic of polygonal calcite grains averaging 0.5 mm. in diameter. The grains show a slight elongation, in a common direction. The calcite is slightly discoloured, being a pale brown.

Quartz occurs rarely, as interstitial grains.

There are minute scattered haematite grains, and rare mossy growths of graphite.

No. 113. Actinolite-diopside rock.

Macroscopic: Compact greenish grey mottled rock.

Microscopic: Texture: poikiloblastic.

Most of the section consists of actinolite and diopside, partly intergrown, with minor amounts of quartz, plagioclase and calcite.

There are numerous scattered rounded grains of slightly pleochroic sphene, and scattered epidote grains. The epidote is partly intergrown with amphibole.

The actinolite contains numerous inclusions surrounded by dark pleochroic haloes. Some of the larger inclusions were identified as allanite.

The actinolite is pleochroic as follows: X pale green, Y Green, Z blue green. Much of the actinolite is altered to calcite. There is a small amount of ore.

Along one side of the section is a vein of bytownite and calcite with some ore associated with grains of diopside. Muscovite symmetrically replaces the large (up to 2.5 mm) grains of plagioclase. The feldspar is also replaced by calcite.

No. 114. Actinolite granulite.

Macroscopic: Even grained dark speckled rock.

Microscopic: Texture: poikiloblastic.

Actinolite occurs as ragged growths, some intergrown with epidote as in No. 113, and containing inclusions of allanite surrounded by dark pleochroic haloes. Some of the actinolite is altered to calcite and chlorite. The actinolite is similar in colour and absorption to that of No. 113.

The feldspar is anorthite, occurring in large grains, and as small rounded grains enclosed in quartz and having a common optical orientation.

Sphene occurs as euhedral to subhedral grains.

No. 49. Orthoclase marble.

Macroscopic: Fine grained schistose marble.

Microscopic: Texture: granular.

Most of this rock consists of a mosaic of elongated calcite grains, averaging 0.02 mm. in length.

Orthoclase occurs as large clear grains. There are some scattered laths of muscovite.

No. 77. Actinolite-anorthite granulite.

Macroscopic: A greenish grey speckled rock, with slight copper staining.

Microscopic: Texture: poikiloblastic.

Much of the section consists of partially chloritised bluish green actinolite, pleochroic as follows: X pale green, Y pale brownish green, Z bluish green. There are rare pleochroic spots in the actinolite caused by the presence of allanite.

Anorthite occurs in amounts about the same as the amphibole, and shows rare albite twinning. It is partly altered to serite along twin-planes.

Calcite forms about 15% of the rock, and quartz is present in smaller amounts.

Pleochroic sphene constitutes about 2% of the section, and apatite about 1%.

There are rare grains of epidote and allanite, and specks of chalchopyrite.

No.79. Diopside-oligoclase-vesuvianite: rock.

Macroscopic: Smiliar to No. 69. Brown crystals of vesuvianite up to 5 cm. in length in a fine grained pale green matrix. Shows a roughly columnar structure.

Microscopic: Texture: poikiloblastic.

The groundmass consists mostly of diopside and oligoclase. The diopside occurs in well developed subhedral grains up to 0.1 mm. in diameter. Some of the grains have a poikilitic structure and some show undulose extinction. One corner of the section is almost entirely a cluster of diopside grains.

About one half of the section consists of a mosaic of clear plagioclase grains, with some quartz. The plagioclase is of oligoclase-andesine composition, and rarely contains inclusions of diopside.

There are some scattered grains of sphene, and rare subhedral pyrite grains, some surrounded by a thin layer of clino-zoisite.

For a description of the vesuvianite see No. 69.

No. 69. Diopside-vesuvianite rock. (see photo. Fig. 59).

Macroscopic: Pale brown corroded crystals of vesuvianite, up to 22 cm. in length, set parallel in a matrix of pale greenish fine-grained diopside.

Microscopic: Most of this slide consists of a near-basal section of a single vesuvianite crystal, poikilitically enclosing a number of anhedral grains of diopside, oriented at random.

Some calcite and rare quartz occurs in cleavage interstices in the vesuvianite.

For a description of the groundmass see No.79.

No. 217. Tourmaline-amphibole rock.

Macroscopic: A black compact medium grained crystalline rock.

Microscopic: The main dark minerals in this rock are tourmaline and amphibole.

The tourmaline is in the form of a mush of greyish green to greyish-blue crystals penetrated by green amphibole and calcite. The tourmaline is pleochroic as follows:- O slate blue, E pale pinkish grey. The amphibole occurs in poikilitic growths, partly or wholly altered to light green chlorite and calcite, and is pleochroic as follows: X pale green to colourless, Y pale green, Z pale bluish green.

There are some subhedral grains of epidote, usually in contact with calcite, and about 3% sphene. The sphene is present as large subhedral grains up to 2.0 mm. in length. Diopside is rare.

The light minerals, consist of a mosaic of quartz grains up to 3.0 mm. in size, and altered feldspar grains. Apatite occurs in scattered rounded grains.

No. 85. Fluorite-garnet rock. (see photo, Fig. 60).

Macroscopic: A pale brownish rock with streaks of pink and pale green. Rare brown vesuvianite crystals.

Microscopic: This rock consists of about equal quantities of subhedral garnet and fluorite. The fluorite contains minute rounded inclusions of apatite, and inclusions of epidote some of which show a common optical orientation. Some of the epidote grains are partly altered to length-slow pennine and limonite.

There is a small amount of quartz and calcite and a little vesuvianite.

No. 85A.

This section is similar to No.85, but contains more vesuvianite and some diopside.

No. 80. Quartz-labradorite-amphibole rock. (see photo, Fig. 61).

Macroscopic: A light grey medium granular quartzitic-looking rock.

Microscopic: Texture: granular.

The dark minerals consist of rare amphibole, reddish brown biotite, epidote and euhedral to subhedral allanite and sphene. The allanite is generally surrounded by a rim of zoisite.

The amphibole is partly altered to calcite and pennine.

The light minerals constitute about 95% of the section, and consist of a mosaic of clear quartz with crenulated contacts and labradorite altering to sericite.

No. 81. Actinolite-diopside rock.

Macroscopic: grey fine grained speckled rock.

Microscopic: Texture: fine grained poikiloblastic.

The dark minerals consist of diopside and actinolite intimately intergrown, and in poikilitic growths. Some of the actinolite replaces diopside, and some is partly replaced by pennine.

There are numerous subhedral grains of sphene, and a few clusters of epidote grains. Ore is scarce, and there are rare grains of allanite.

The light minerals consist of a mosaic of somewhat rounded quartz grains, with sericitised cordierite. There is about 1% colourless garnet in poikilitic patches, and apatite occurs as numerous minute subhedral grains.

Top of the Blue Marble Band.

No. 57. Calcareous biotite granulite.

Macroscopic. A fine-grained compact grey rock.

Microscopic: Texture: Granular.

Most of this section consists of quartz and feldspar grains, with patches of calcite.

Biotite, partly altered to chlorite, occurs in bands and shreds. Muscovite is present in a few ragged, partly altered flakes.

Ore is fairly plentiful. There is one large grain of greenish brown tourmaline.

Top Black Line of Blue Marble Band.

No. 50. Biotite schist.

Macroscopic. Dark fine grained schistose rock.

Microscopic: Texture: banded schistose.

Light brown biotite, averaging 0.4 mm., occurs in bands with quartz and a little calcite, the biotite flakes having no regular orientation.

Scattered flakes of clinochlore are found oriented parallel with the banding, some rarely having cores of biotite with similar orientation.

The grains adjoining the biotite bands consist mostly of quartz, over a width of 1.0 mm. Farther away, there is more calcite than quartz, both averaging 0.04 mm., in size. This zone also contains numerous scattered clinochlore laths, averaging 0.3 mm. in length, and smaller flakes of biotite.

Ore occurs in interstitial patches, usually together with the clinochlore, and in cleavage cracks in the clinochlore.

Marble below Dark Blue and above Main Blue Marble Band.

No. 260. Schistose quartzitic biotite marble.

Macroscopic: Dark grey fresh fine grained schistose marble.

Microscopic: Texture: schistose.

Much of this section consists of ragged grains of calcite in a groundmass of quartz and feldspar grains. Muscovite is rare.

Biotite occurs in small amounts as chestnut brown flakes.

There are numerous scattered magnetite grains, and rare rounded grains of sphene.

Black and Dark Blue Marble Bands immediately above the Blue Marble Band.

No. 258. Black Marble.

Macroscopic: Fine grained black marble, weathering to a wrinkled surface.

Microscopic: Texture: granular.

This rock is a graphitic marble, similar to No. 253, but containing less graphite, and more calcite and quartz. There are patches of coarser calcite (up to 0.5 mm.) in a fine grained calcite groundmass.

Biotite occurs as scattered bright chestnut brown flakes.

No. 51. Black Marble.

Macroscopic: A fine grained black marble, weathering dark grey.

Microscopic: A mosaic of calcite grains averaging 0.05 mm., with rare strings of quartz grains to 0.1 mm. diameter.

Haematite occurs in patches. The dark colour is due to carbon dust, disseminated throughout the section.

No. 300 Dark Blue Marble.

Macroscopic: A dark bluish black medium grained marble.

Microscopic: Texture: medium grained granular.

This section consists of a mosaic of interlocking elongated calcite grains with some interstitial laths of muscovite and sericite. Most of the calcite grains show a parallel optical orientation. There are some interstitial grains of quartz, and rare orthoclase grains.

Numerous minute scattered grains of ore and carbon occur throughout the section.

No. 223. Xenolith in granite. Garnet Rock.

Macroscopic: Dark brown resinous crystals.

Microscopic: Most of this section consists of garnet, brownish to yellowish, with quartz, calcite and epidote in cavities and veins.

No. 224. Garnet-diopside rock.

Macroscopic: Dark brown resinous rock.

Microscopic: Garnet comprises 80% of this rock. The remainder consists of grains of pale green diopside and some calcite and quartz. Epidote occupies cavities and veins in the garnet, and green chlorite is found in cracks.

Marble Bands above the Main Blue Marble Band.

No. 134. Bluish grey marble.

Texture: Medium grained granular.

This thin section shows a mosaic of elongated grains of calcite, average size 0.5 mm. by 0.2 mm. The grains have a parallel optical orientation.

There are rare minute grains of quartz, and specks and small clots of carbon.

No. 251. Spotted Black Marble.

Macroscopic: Weathers olive brown, and shows banding and raised knots on weathered surface.

Microscopic: The thin section shows mostly calcite, with scattered quartz grains. The average grain size is 0.01 mm. There is much disseminated carbon dust, some of which is gathered into moss-like growths and clots.

No. 253. Schistose graphitic Marble.

Macroscopic: A fine grained dark grey schistose phlogopite marble, weathering dark olive-brown, with a pitted surface.

Microscopic: The graphite occurs as cloudy and mossy patches of minute particles. The calcite grains average 0.03 mm., and the rare quartz grains are of similar size.

Pale brown phlogopite occurs as strung-out lines of thin shreds and flakes, or as flakes associated with patches of haematite up to 1.0 mm in diameter.

No. 101. Altered marble band at top of Upper Marble Series. Diopside-garnet rock.

No. 223. Xenolith in granite. Garnet Rock.

Macroscopic: Dark brown resinous crystals.

Microscopic: Most of this section consists of garnet, brownish to yellowish, with quartz, calcite and epidote in cavities and veins.

No. 224. Garnet-diopside rock.

Macroscopic: Dark brown resinous rock.

Microscopic: Garnet comprises 80% of this rock. The remainder consists of grains of pale green diopside and some calcite and quartz. Epidote occupies cavities and veins in the garnet, and green chlorite is found in cracks.

Marble Bands above the Main Blue Marble Band.

No. 134. Bluish grey marble.

Texture: Medium grained granular.

This thin section shows a mosaic of elongated grains of calcite, average size 0.5 mm. by 0.2 mm. The grains have a parallel optical orientation.

There are rare minute grains of quartz, and specks and small clots of carbon.

No. 251. Spotted Black Marble.

Macroscopic: Weathers olive brown, and shows banding and raised knots on weathered surface.

Microscopic: The thin section shows mostly calcite, with scattered quartz grains. The average grain size is 0.01 mm. There is much disseminated carbon dust, some of which is gathered into moss-like growths and clots.

No. 253. Schistose graphitic Marble.

Macroscopic: A fine grained dark grey schistose phlogopite marble, weathering dark olive-brown, with a pitted surface.

Microscopic: The graphite occurs as cloudy and mossy patches of minute particles. The calcite grains average 0.03 mm., and the rare quartz grains are of similar size.

Pale brown phlogopite occurs as strung-out lines of thin shreds and flakes, or as flakes associated with patches of haematite up to 1.0 mm in diameter.

No. 101. Altered marble band at top of Upper Marble Series.

Diopside-garnet rock.

Macroscopic: The rock is roughly banded in pale brown, pink and green colours. On weathering a pitted surface is produced, but there is no appreciable colour change.

Microscopic: Texture: poikilitic, with a roughly banded structure.

The diopside occurs as grains up to 0.1 mm., diameter, some in a form of poikilitic intergrowth with the garnet, which is of grossularite composition.

Quartz occurs with a more or less banded structure, and scattered grains of sphene lie parallel with the banding.

There are rare grains of calcite and altered feldspar, and thin laths of wollastonite associated with the garnet.

No. 102. Altered marble band Garnet-diopside-vesuvianite rock. (See photo, Fig. 62).

Macroscopic: Similar in appearance to No. 101.

Microscopic: This section consists entirely of light minerals.

About 20% consists of diopside, which occurs in poikilitic intergrowths with quartz, in a more or less banded pattern.

About 10% consists of vesuvianite, which is slightly biaxial and is in parts replaced by calcite. The vesuvianite has probably replaced diopside, as it is found poikilitically enclosing optically continuous grains of diopside. Columnar aggregates of vesuvianite occur projecting into patches of quartz.

A band of matted acicular wollastonite crystals runs through the section. There are also patches of a matted "mush" of wollastonite and diopside laths. Some of the wollastonite is twinned. Large grains of grossularite garnet, containing numerous wollastonie needles, are found intergrown with quartz and diopside. Poikilitic enclosures of garnet grains in vesuvianite suggests replacement by the latter mineral.

However, in parts of the section, garnet appears to be replacing vesuvianite. Small vugs in the garnet, showing euhedral garnet outlines, are filled with calcite or quartz.

There are numerous large grains of crystalline calcite, which have partly replaced some of the diopside.

5. The Upper Schist Series.

The Upper Schist series includes those sediments lying above the Blue Marble zone. Rocks lying above the Blue Marble, but below the topmost marble band are as follows:- (See Table XI).

Schist between the top of the Blue Marble Zone and the Uppermost overlying marble band.

No. 52. Spotted biotite schist.

Macroscopic: Dark brownish grey spotted schist.

Microscopic: Texture: prophyroblastic.

The spots, which average 1,0 mm. in size, are composed of interlocking grains of calcite, pale green chlorite, and quartz, with some ore, and rare muscovite flakes. They are generally surrounded by a concentration of biotite flakes.

The groundmass consists of brown biotite flakes, averaging 0.01 mm. in length, in a more or less banded pattern, and small quartz grains, averaging 0.02 mm. in size.

There are rare minute grains of apatite, and some small patches of calcite.

No. 255. Biotite schist.

Macroscopic: Fine to medium grained dark grey schist. Weathers brown.

Microscopic: Texture: schistose.

Thirty percent of the section consists of olive brown biotite, as elongated flakes orientated parallel with the schistosity. There are some rare elongated flakes of muscovite.

The remainder of the section is composed of elongated quartz and plagioclase grains, showing no optical parallelism.

There are a few sub-rounded grains of tourmaline. About 1% of the section consists of scattered grains of ore.

No. 108. Knotted biotite schist.

Macroscopic: Dark knotted schist.

Microscopic: Texture: markedly schistose, with elongated prophyroblasts.

The knots consist of lenticular poikilitic growths of sericite, with inclusions of ore and subhedral garnet, and appear to have forced some of the biotite to their sides during growth.

TABLE XI.

ROCKS OF THE UPPER SCHIST SERIES ABOVE THE BLUE MARBLE BAND AND BELOW THE TOPMOST MARBLE BAND.

NO.	LOCALITY	AMPHIBOLE					PYROXENE				BIOTITE		EPIDOTE		FELDSPAR				EXTRAS AND REMARKS	ESTIMATED MODE (Shown graphically)
		$2V\alpha$	$c\wedge Z$	$\gamma-\alpha$	β	Colour and Pleochroism	$2V\gamma$	$c\wedge Z$	$\gamma-\alpha$	β	$\gamma-\alpha$	γ	$2V$	$\gamma-\alpha$	Max. Ext. Angle in Zone ⊥010	$2V$		Type		
52	Sesob River near lead occurrences										.054	1.642							Muscovite and clinochlore	
53	"											1.639							Apatite, sphene and ore	Q, F, B → A,S,O
54												1.639							Apatite,sphene,ore and calcite	Q, F, B → A,S,O,Cc
55	"											1.632							Apatite,sphene,ore and clinochlore	Q, F, B → A,S,O,Cl
76	Near granite west of Gemsbok River	78	19	.016	1.664	Pale green							80+			87-	>Qz	?Anorthite	Cordierite, allanite and calcite	Q, C, A → Al,Cc,E
83	"										.0405	1.628							Cordierite 2V 76° α 1.548, β 1.549, γ 1.554	Q, C, B
103	"											1.625								Q, B, [illegible] → M,O,Ap
104	"	75	16½	.022	1.664	α Pale green to γ green	58	41	.026										Allanite and altered cordierite 2V 77°. Calcite	Q, C, B, A → S,Al,Cc
105	"	68	12	.022	1.659	Pale green							76+		44	79½	>Qz	Bytownite	Allanite, sphene and garnet	Q, F, A → Al,S,G,E
108	"										.037	1.620								Q, F, B
109	"										.047	1.621				86+	= CB.	Andesine	Feldspar much altered	Q, F, B
111	"											1.624								Q, F, B
112	"	70	15	.019	1.652	Pale green	62	45	.029	1.719			72-	.018					Cordierite, much altered to sericite. Garnet.	Q, C, P, A → G,E
116	"						58	45	.027	1.727									Grossularite, R.I. 1.753 Apatite	Q, G, P → Ap
119	"						59	40	.028	1.737			82-						Grossularite, R.I. 1.768	Q, G, P → E
255	Brak River										.048	1.633							Feldspar and tourmaline	Q, F, B → T
256	"											1.641							Feldspar	Q, F, B
257	"											1.637							Calcite	Q, F, Cc, B

Cl - Clinchlore
E - Epidote
M - Muscovite
Ap - Apatite
G - Garnet
Al - Allanite
T - Tourmaline

Q - Quartz
F - Feldspar
B - Biotite
A - Amphibole
P - Pyroxene
S - Sphene
C - Cordierite
O - Ore
Cc - Calcite

The ore is limonite, pseudomorphic after pyrite.

About 40% of the section consists of well defined biotite flakes, arranged in marked parallel fashion, and rarely containing dark pleochroic spots around inclusions.

The light minerals of the groundmass consist of a mosaic of polygonal quartz grains and orthoclase grains.

These minerals show no preferred optical orientation.

<u>No. 33. Knotted biotite-cordierite schist.</u> (See photo, Fg. 63).

<u>Macroscopic</u>: Strongly knotted, dark biotite schist. Knots average about 7.0 mm., by 4.0 mm., in size, and tend to weather out from the schist.

<u>Microscopic</u>: Texture markedly banded porphyroblastic, consisting of approximately equal amounts of light and dark minerals.

<u>Light minerals</u>. Quartz and cordierite, in about equal amounts, form a mosaic of angular grains.

Parallel with the schistosity run numerous bands of cordierite, up to 0.3 mm. wide, all the bands in each knot having a similar optical orientation. These bands contain minute flakes of prochlorite, mostly arranged transversely to the bands, and some forming a type of comb structure, extending inwards from the edges of the bands.

Porphyroblasts: Roughly elliptical patches, about 7.0 mm. by 4.0 mm. in size, contain small grains of quartz and feldspar up to 0.1 mm. diameter, in a groundmass of cordierite, which is optically oriented parallel with the bands running through the patches. Each patch has its own optical orientation in spite of the fact that the bands in both patches are parallel with the general direction of schistosity. The prophyroblasts are almost free of dark minerals.

Apatite occurs in scattered small rounded grains.

<u>Dark minerals</u>: Biotite flakes, up to 1.5 mm. long, form the dark bands. In general the lengths of the falkes are transverse or oblique to the trend of the bands. Some flakes show bending and there is a slight concentration of biotite around the porphyroblasts.

Rare, small tourmaline laths are scattered through the section. There are a few small rounded grains of ore, mostly pyrite.

<u>No. 105. Actinolite granulite.</u>

<u>Macroscopic</u>: Pale grey rock with dark green and greyish pink specks.

Microscopic: Texture: poikiloblastic.

The actinolite consists of ragged subhedral poikilitic masses, some partly altered to isotropic green chlorite, and containing rare dark pleochroic haloes round small inclusions of allanite.

The groundmass consists of a mosaic of recrystallised quartz grains, containing minute rounded inclusions of apatite. Small grains of an altered mineral, probably cordierite, are numerous in parts of the section.

There are numerous scattered round grains of sphene, and a few small irregular garnet grains. Clinozoisite and scattered calcite appear rarely.

No. 112. Quartz-diopside-cordierite rock.

Macroscopic: A fine-grained greenish grey siliceous rock.

Microscopic: Texture: granular.

The diopside occurs as subhedral grains, partly uralitised along cleavage cracks, and partly chloritised.

The groundmass consists of a mosaic of recrystallised quartz grains and cordierite partly altered to sericite. Calcite occurs as interstitial grains.

There are numerous rounded grains of sphene and apatite , and a few anhedral grains of garnet.

No. 116. Diopside-garnet rock.

Macroscopic: Dark brownish black rock with resinous lustre.

Microscopic:

Pink garnet, probably grossularite, constitutes about one half of this section, and is present in subhedral to euhedral aggregates, being euhedral against quartz.

A few subhedral grains of sphene up to 2.5 mm. in length are scattered through the section. Clear quartz and highly altered poikilitic growths of greenish diopside, with some calcite, occupy the rest of the section. There are some flakes of pennine and a few small grains of limonite.

The quartz contains rounded inclusions of epidote, and of apatite up to 0.20 mm. diameter.

Rocks lying above the topmost Marble Band and below the Quartzite are as follows:- (See Table XII).

No. 197. Biotite granulite.

Macroscopic: A compact dark grey fine-grained hornfels containing rare pyrite grains. Breaks with conchoidal fracture. Weathers reddish brown.

Microscopic: Texture: granular.

The biotite is dirty greenish brown, and shows no preferred optical orientation. At 2% of the rock consists of rounded grains of ore, and there are a few minute needles of tourmaline.

The light minerals consist of a mosaic of clear quartz grains, up to 0.2 mm. in size, and albite and microcline grains. There are a few patches of calcite, scattered minute apatite grains, and flakes of muscovite.

A vein consisting of albite grains with elongated laths of calcite runs through the section.

No. 199. Knotted biotite schist.

Macroscopic: fine grained dark grey knotted schist.

Microscopic: Texture: fine grained porphyroblastic schistose.

Porphyroblasts.

These consist of a core of small quartz grains and rare apatite grains, all surrounded by olive brown biotite flakes, arranged parallel with the schistosity. There are numerous scattered laths of pale green almost isotropic chlorite with a similar orientation.

The groundmass is a somewhat banded fine grained biotite-quartz schist, containing rare minute tourmaline crystals oriented parallel with the schistosity and rare laths of calcite up to 0.5 mm. in length, lying oblique to the schistosity. These laths are possible pseudo-morphic after amphibole.

No. 204. Calcareous knotted biotite schist.

Macroscopic: Altered fine grained knotted schist.

Microscopic: Texture: porphyroblastic schistose.

Porphroblasts.

These are composed of mosaics of fine quartz grains. The groundmass consists of about equal proportions of calcite grains and a mosaic of quartz and plagioclase.

The rock is somewhat sheared, and laths of biotite altering to green chlorite and limonite occur along the lines of shearing. Some of the biotite cuts through the knots.

No. 311. Chlorite schist.

Macroscopic: Dark brownish black schistose rock.

Microscopic: Texture: schistose.

This rock consists of sub-rounded grains of quartz in a groundmass of chlorite and ore.

There are rare grains of tourmaline.

No. 219. Biotite muscovite horfels.

Macroscopic: Compact brownish black finely crystalline rock.

Microscopic: Texture: granular.

This rock consists of an intergrowth of muscovite, biotite and quartz grains, with some plagioclase. Needle-like bodies of limonite are scattered through the section, usually penetrating biotite flakes. The biotite contains dark pleochroic spots around inclusions, probably of allanite and zircon, and is rarely altered to pale green chlorite.

There is one grain of tourmaline, 0.5 mm. in size.

There are some rare rounded apatite grains and minute rutile needles.

No. 144. Actinolite granulite.

Macroscopic: Pale grey rock, speckled with dark green and pale pink oikocrysts.

Microscopic: Texture. poikiloblastic.

The actinolite occurs as scattered poikilitic growths up to 2.0 mm. diameter, some in sheaf-like forms, and mostly altered to calcite adn almost isotropic pale green chlorite.

Poikilitic arhedral growths of garnet are present in smaller amounts than the actinolite.

The groundmass consists of rounded clear quartz grains, up to 0.3 mm. diameter, in a matrix of fine quartz grains, decomposed cordierite, small muscovite flakes and calcite.

There are rare scattered grains of altered labradorite.

Epidote is scarce, and scattered grains of ore occur throughout the section.

No. 319. Actinolite-epidote rock.

TABLE XII.

ROCKS OF THE UPPER SCHIST SERIES ABOVE THE TOP MARBLE BAND AND BELOW THE QUARTZITE.

NO.	LOCALITY	AMPHIBOLE					BIOTITE		OTHER MINERALS.	ESTIMATED MODE (Shown graphically)
		$2V\alpha$	$c \wedge Z$	$\gamma-\alpha$	β	Colour and Pleochroism	$\gamma-\alpha$	γ		
136	Brandberg-Amis R. Area							1.633		Q F B
137	"	82-	18	.019	1.652	Pale green			Plagioclase* $51\frac{1}{2}^{\circ}$, 2V 80º, = **Anorthite,** Rare epidote, 2V 75- Garnet and calcite.	Q F A → E, G
144	"	70-	17	.015	1.661	Pale brownish green green			Rare labradorite.* 38°, 2V 80º. Cordierite. Rare epidote. Andradite, R.I. 1.815.	Q C F A G → E
197	"							1.636	Muscovite, **microcline,** tourmaline, apatite and ore.	Q F B → M, O, T, Ap
199	"						.050	1.647	Apatite and quartz form porphyroblasts.	Q B → Ap
200	"							1.639	Ore and apatite.	Q F B → O, Ap
204	"							1.629	Quartz porphyroblasts. Ore, tourmaline and apatite.	Q F B → O, T, Ap
219	West of Gemsbok R.							1.637	Muscovite, tourmaline and ilmenite.	Q M B → T, O
311	Near granite between Brak and Gemsbok Rivers								Chlorite and ore.	Q Ch O
319	Xenolith " light part Xenolith " dark part	71 68	19 14	.019 .017	1.645	Pale green Deep green			Much epidote, 2V 79º, $\gamma-\alpha$ = .019, β = 1.735. Cordierite Rare garnet.	Q C F A → G, B
320	Xenolith near granite between Brak & Gemsbok Rivers.							1.629		
376	Near granite contact on road to Omaruru							1.641		
377	"							1.641	Cordierite 2V 35º to 55º – β = 1.555	Q C B

*Max. Ext. Angle in zone ⊥ 010

Q - Quartz.
F - Feldspar
B - Biotite
A - Amphibole.
E - Epidote.
G - Garnet
C - Cordierite.
M - Muscovite
O - Ore
T - Tourmaline
Ap - Apatite.
Ch - Chlorite

TABLE XIII.

QUARTZITIC ROCKS IN THE UPPER SCHIST SERIES.

NO.	LOCALITY	AMPHIBOLE					PYROXENE		FELDSPAR				EPIDOTE	EXTRAS	ESTIMATED MODE (Shown graphically)
		$2V\alpha$	$c \wedge Z$	$\gamma-\alpha$	β	Colour and Pleochroism	$c \wedge Z$	$\gamma-\alpha$	Max. Ext. ∠ in Zone ⊥ 010	2V	R.I.	Type			
145	Near Brandberg	74	20	.014	1.652	Pale green green	39	.026		67-		Orthoclase	Rare	Mostly quartz. Some cordierite and garnet.	Q F E → A, E, P
191	Near Brandberg								18	78+	∠Qz =CB	Albite and Orthoclase		Mostly quartz	Q F

Macroscopic: Grey compact rock showing slight layering.

Microscopic: Texture: poikiloblastic.

Epidote occurs as poikilitic grains in a roughly banded pattern and occupies about 40% of the section. Amphibole occurs in two varieties, one pale green and deep green. Both varieties are probably tremolite-actinolite.

Biotite flakes, partly altered to pennine are scattered through the section. The groundmass consists of a mosaic of quartz grains and cordierite altered to sericite.

No. 377. Biotite-cordierite hornfels.

Macroscopic: A dark brown compact fine to medium-grained hornfelsic rock.

Microscopic: Texture: poikiloblastic.

Dark minerals. About one third of this rock consists of brown biotite, containing dark pleochroic spots. The biotite flakes are arranged in haphazard fashion. There are rare scattered grains of ore.

Light minerals. Cordierite forms an almost complete mosaic of poikilitic grains, containing inclusions of biotite and quartz. The cordierite grains are slightly elongated in one direction, and are altered at the edges. They contain rare pale yellow pleochroic patches.

There are rare minute apatite grains.

Quartzitic bands in the Upper Schist Series near the Brandberg. (See Table XIII).

No. 191. Quartzite.

Macroscopic: Pale pinkish brown fine to medium-grained quartzite, slightly sheared.

Microscopic: Texture: granular.

Most of this rock is composed of sub-rounded grains of quartz, some of which are more or less lenticular due to the shearing. There are a few grains of feldspar, mostly albite, some of the feldspar altering to sericite.

The interstices between the grains are filled with fine quartz grains, rare epidote, muscovite and chlorite and rounded zircon.

No. 145. Actinolite quartzite.

Macroscopic: The rock has the appearance of a fine-grained pale brownish quartzite, weathering to light brown.

Microscopic: Texture: poikiloblastic.

Most of the rock consists of a mosaic of recrystallised quartz grains with a fine-grained matrix between some of the grains.

Ragged poikilitic actinolite laths are scattered sparsely through the slide and are sometimes enclosed by the quartz grains.

Diopside and garnet are also present in rare poikilitic growths.

Orthoclase is found poikilitically replacing quartz.

There are numerous apatite and calcite grains, some chlorite, and rare interstitial epidote and anhedral sphene.

(C) Post-Damara Intrusives.

The granitic rocks will be described in approximate order of age.

1. Older quartz diorites and granodiorites. (See Table XIV)

No. 100. Quartz diorite.

Macroscopic: Medium grained dark grey granular rock, with numerous black biotite flakes, average size 2.5 mm., and hornblende grains. Little quartz appears to be present.

Microscopic: Texture: allotriomorphic-granular.

Dark minerals: Pale green amphibole, some of which is twinned, occupies about 30.8% of the section, and is apparently partly altered to pale green chlorite along cleavages. Some of this chlorite is possibly altered biotite, which is commonly in continuous crystallographic growth with the amphibole. There is 12.6% of biotite, partly altered to pale green pleochroic chlorite along cleavages.

The amphibole appears to be moulded on biotite grains. The chlorite is biaxial -ve with 2 V moderate, the fibres are length-slow, and the index less than 1.64. It is probably aphrosiderite.

Subhedral grains of sphene, up to 0.75 mm. in size, are plentiful, and there are a few grains of epidote and pyrite.

Light minerals: Plagioclase constitues 47.3% of the section and is of andesine composition. Much of the plagioclase is partly altered to sericite. There is less than 1% orthoclase.

The remainder of the section consists of quartz, and there are a few grains of apatite.

TABLE XIV

POST-DAMARA GRANITIC ROCKS.

NO.		LOCALITY	PLAGIOCLASE * In	* Out	2V In	2V Out	R.I. In	R.I. Out	% An In	% An Out	Inter-growths.	K-FELDSPARS 2V	Type	AMPHIBOLE Colour and Pleochroism	$2V\alpha$	$c\wedge Z$	$\gamma-\alpha$	β	BIOTITE $\gamma-\alpha$	γ	MUSCOVITE	ORE	APATITE	SPHENE	EPIDOTE	ALLANITE	EXTRAS	ESTIMATED MODE (Shown graphically)
x 100	Older quartz diorites and granodiorites.	W. of Gemsbok River.	25°				>Qz		46					α Pale green-brown to γ green	70	15	.019	1.659		1.647		Pyrite	✓	✓	✓			Q P A B K
125		"	14°		82+	82-	<Qz		46	31		68-	Microcline and orthoclase							1.645	Rare flakes	✓		✓	✓	✓		Q P K B
130		"	28½°	19°	78+	88+			50	37	Andesine quartz	62- 58-	Microline orthoclase	α Pale green to γ green	80	20	.0215	1.643		1-638			✓	✓	Zoisite	2V ✓ 86°-		Q P K A B
216		S. of Brandberg West Mine	18½/24½/-27°		80-	82+	>CB <Qz		36/44/30 83	47				α Yellow green to γ dark green	80	17	.015	1.665		1.625		✓	✓	✓	✓			Q P A B
308		S.W. of Gemsbok River	20		86+		>CB =Qz		37			72-	Orthoclase			19			.045	1.643		Magnetite		✓ In biotite	✓		Calcite	Q P K B
366		S.E. of Brandberg West Mine	23 Zoned		84+		>Qz		43		Andesine quartz	64- 69-	Microcline and rare late orth.	α Pale green to γ green	68-	.022			.0425	1.628		Rare Pyrite	✓	In biotite	2V 84°-			Q P K A B
374		" Dark Part	19		88-	86+	High >C.B.	low	17	15	)	70-	Orthoclase	Pale green	72-	20	.024			1.629		Pyrite		✓	✓	✓		Q P K B
		" Light Part							38	42	)			α Pale green to γ green	70-	22	.018	1.658	.058	1.629					Zoisite		Calcite	Q P K A B
106	Younger quartz diorites and granodiorites	W. of Gemsbok River	15		84-		>C.B. <Qz		18		Oligoclase quartz	65-	Microcline							1.635	Rare		✓					Q P B
107		"	18				<CB		2			74- 64-	Microcline Rare orthoclase							1.634	✓							Q P B
126		"	18		83-		>CB =Qz		23		Andesine quartz	64-	Microcline							1.657	Rare flakes							Q P K B
222		Near Zebra R.	18		90		>CB <Qz		37				Microcline							1.637			✓				Zircon	Q P K B
301		S.W. of Gemsbok River	13		86-				4			88-	Microcline Rare orthoclase							1.642								Q P K+B
375		E. of Zebra R.	13		85+		=CB		10		Albite-quartz	66-	Microcline							1.639	Rare flakes		✓				Zircon	Q P K B

* = Max. Ext. Angle in zone ⊥010

/2 .....

Q - Quartz
P - Plagioclase
K - K-feldspar
A - Amphibole
B - Biotite

TABLE XIV (Contd)

POST-DAMARA GRANITIC ROCKS.

NO.		LOCALITY	PLAGIOCLASE In | Out *	PLAGIOCLASE In | Out 2V	PLAGIOCLASE In | Out R.I.	PLAGIOCLASE In | Out %An	PLAGIOCLASE Inter-growths	K-FELDSPARS 2V	K-FELDSPARS Type	AMPHIBOLE	BIOTITE Y	MUSCOVITE	ORE	APATITE	SPHENE	EPIDOTE	ALLANITE	EXTRAS	ESTIMATED MODE (Shown graphically)
99	Biotite Granites.	W. of Gemsbok River	17	80+		4		82-	Microcline	Few grains	1.647	Some flakes	✓	✓		Zoisite	✓		Q | P | K | B
306		S.W. "	10 / 7 | 4	90 / 84- | 84+	High | Low	27 / 25 | 23	Oligo-clase quartz	58-	Microcline		1.650		✓	✓					Q | P | K
312		S.E. "	14		<Qz	9	Albite-quartz		Microcline		1.617		✓		✓	✓	2V ✓ 74°-		Q | P | K | B
313		" "	17		= CB	4	Albite-quartz		Microcline and perthite		1.610							Tourmaline	Q | P | K | B
* 373		Near Zebra R.	14 | 12	80+ |	>CB >Qz	48/42/36	Myrmekite at micro-cline contact	70-	Microcline		1.648			✓	✓			Rare garnet	Q | P | K | B
* 326	Younger Granites.	Zebra River	15		>CB <Qz	8	Albite-quartz	90	Microcline Rare ortho-clase		Rare	Rare	Haematite						Q | P | K | A
388		Between Zebra and Brak Rivers	10 / 10 | 12	74+	>CB	13		86-	Microcline			Rare							Q | P | K

* = Analysed

In = inner zone.
Out = outer zone.
Qz - Quartz
C.B. = Canada Balsam
* = Max. extinction angle in zone ⊥ 010

Q - Quartz
P - Plagioclase
K - K-feldspar
A - Amphibole
B - Biotite

No. 125. Granodiorite.

Macroscopic. Fine-grained dark grey granular rock. Weathers dark brownish grey.

Microscopic. Texture: medium grained allotrimorphic-granular.

Dark minerals. About 20% of the section consists of dark minerals, mostly biotite, partly or totally altered to light green pleochroic length-slow pennine, and containing minute inclusions, some of light brown pleochroic allanite, surrounded by dark pleochroic haloes. The biotite is partially or even totally enclosed by quartz and feldspar grains. There are some euhedral to subhedral grains of sphene, and a few irregular patches of ore. Some epidote is found, usually in the rims of the patches of ore.

Light minerals. Oligoclase, much altered to sericite, occupies about 40% of the section, and is in the form of grains interlocking with quartz grains. Some of the plagioclase is zoned, the inner zones being more calcic than the outer.

Small amounts of microcline and orthoclase are present in about equal quantities. The microcline encloses rounded grains of biotite and quartz. In some of the microcline grains, the twinning and strain effects appear to originate from the inclusions.

Small rounded grains of apatite are scattered through the section. There is one grain of pale brown pleochroic allanite, which is surrounded by a dark pleochroic halo where it is in contact with biotite.

No. 130. Quartz diorite.

Macroscopic. Medium grained dark grey granular rock.

Microscopic. Texture: medium-grained allotriomorphic granular.

Dark minerals. These consist of pale green amphibole, and biotite flakes rarely altered to chlorite. Some of the amphibole is twinned. Both the amphibole and the biotite contain dark pleochroic spots and haloes around inclusions of allanite. The allanite is pleochroic as follows:- X pale pinkish brown, Y greyish brown, Z brown, and is probably magnesium orthite. Commonly the biotite and amphibole cleavages are continuous.

Zoisite is present in cleavage cracks in the biotite, and appears to have caused the biotite to swell out.

Light minerals. Clear quartz grains occupy about 20% of the section. Plagioclase constitues 30%, and is in the form of twinned andesine. Some of the plagioclase is zoned, with interiors more calcic than the outsides.

There are small amounts of albite, orthoclase, and microcline. Some of the potash felspar shows twinning only on and near contacts of enclosed biotite and amphibole grains. The feldspar away from the grains is untwinned. There are rare patches of an intergrowth of quartz and andesine. One such intergrowth is enclosed in microcline. There are some rare grains of sphene, in large subhedral grains, and apatite. Some of the sphene is interstitial to biotite grains.

No. 216. Quartz diorite.

Macroscopic. Fine to medium grained dark granular rock.

Microscopic: Texture: coarse-grained allotriomorphic-granular.

Dark minerals. About one third of this rock consists of biotite, much altered to chlorite and calcite. The chlorite is rarely a pale green pleochroic length-slow pennine, and mostly a length-fast biaxial + ve pale green pleochroic mineral, with 2 V $\pm$ 20°. It is probably prochlorite. Basal plates of biotite commonly shows a rim of prochlorite, and magnetite grains. Pleochroic spots are absent, and inclusions are rare.

Poikilitic growths of hornblende, some altered to prochlorite and calcite, occupy about 15% of the section.

Sphene is common, totalling about 2% of the section and epidote is found as growths in biotite cleavage cracks.

Pyrite and magnetite are fairly common.

Light minerals. Almost one half of the section is composed of a mosaic or andesine laths, averaging 1.0 mm. by 0.5 mm. and partly altered to sericite. Some of the plagioclase is zoned, with interiors more calcic than the outside. Quartz occupies about 2% of the section, and apatite in scattered grains and laths constitutes 1%. Potash feldspar is absent.

No. 303. Granodiorite porphyry.

Macroscopic. Grey medium grained granular rock, with scattered phenocrysts .

Light minerals. Clear quartz grains occupy about 20% of the section. Plagioclase constitues 30%, and is in the form of twinned andesine. Some of the plagioclase is zoned, with interiors more calcic than the outsides.

There are small amounts of albite, orthoclase, and microcline. Some of the potash felspar shows twinning only on and near contacts of enclosed biotite and amphibole grains. The feldspar away from the grains is untwinned. There are rare patches of an intergrowth of quartz and andesine. One such intergrowth is enclosed in microcline. There are some rare grains of sphene, in large subhedral grains, and apatite. Some of the sphene is interstitial to biotite grains.

No. 216. Quartz diorite.

Macroscopic. Fine to medium grained dark granular rock.

Microscopic: Texture: coarse-grained allotriomorphic-granular.

Dark minerals. About one third of this rock consists of biotite, much altered to chlorite and calcite. The chlorite is rarely a pale green pleochroic length-slow pennine, and mostly a length-fast biaxial + ve pale green pleochroic mineral, with 2 V $\pm$ 20°. It is probably prochlorite. Basal plates of biotite commonly shows a rim of prochlorite, and magnetite grains. Pleochroic spots are absent, and inclusions are rare.

Poikilitic growths of hornblende, some altered to prochlorite and calcite, occupy about 15% of the section.

Sphene is common, totalling about 2% of the section and epidote is found as growths in biotite cleavage cracks.

Pyrite and magnetite are fairly common.

Light minerals. Almost one half of the section is composed of a mosaic or andesine laths, averaging 1.0 mm. by 0.5 mm. and partly altered to sericite. Some of the plagioclase is zoned, with interiors more calcic than the outside. Quartz occupies about 2% of the section, and apatite in scattered grains and laths constitutes 1%. Potash feldspar is absent.

No. 303. Granodiorite porphyry.

Macroscopic. Grey medium grained granular rock with scattered phenocrysts .

Microscopic: Texture: coarse-grained hypidiomorphic - granular.

Dark minerals consitute about 5% of this section. Most of these consist of dark greenish brown biotite containing pleochroic spots and inclusions of sphene. Some of the sphene is formed inside biotite cleavages. Some of the biotite is partly altered to chlorite, and rarely biotite flakes are enclosed in quartz grains.

Accessory dark minerals are hornblende, sphene, epidote and magnetite.

Light minerals. Quartz constitutes about 40% of the section, and is found rarely in intergrowth with andesine.

Andesine, partly altered to sericite, and orthoclase constitutes about one half of the section. Calcite is rare and occurs as an alteration product.

No. 366. Quartz diorite porphyry.

Macroscopic: Coarse grained dark porphyritic rock.

Microscopic: Texture: coarse grained hypidiomorphic granular.

Dark minerals. Dark olive green biotite laths constitute about one third of the section, and average 0.75 mm., by 0.4 mm. in size. They contain rare inclusions and some are lined with sphene on the edges. There are no pleochroic spots. The biotite is rarely altered to green chlorite or calcite along the cleavages.

Hornblende occurs in aggregates of short (Average 0.3 mm) laths, and is pleochroic: X colourless, Y green, Z bluish green.

Epidote is found as scattered grains, euhedral against biotite, and is associated with ore.

Light minerals. Andesine laths, showing albite twinning, and averaging 0.75 mm. in length, occupy 30% of the section, and are mostly altered to calcite and sericite in their centres.

There are rare intergrowths of quartz with andesine.

The quartz is mostly clear and is sub-rounded.

Orthoclase is found enclosing grains of andesine, and contains minute sericite flakes.

Apatite is found as scattered grains.

No. 374. Granodiorite.

Macroscopic: This rock consists of a grey, fine grained granular rock, containing a darker fine grained nodular inclusion.

<u>Microscopic</u>: Texture: fine grained to medium grained allotriomorphic granular.

<u>Light portion</u>. The predominant <u>dark mineral</u> here is amphibole, rarely altered to length-slow, pennine. There is a small amount of light brown biotite, partly altered to pennine. Scattered grains of pleochroic sphene occur as an accessory. There are also a few grains of epidote and some cubic pyrite.

The <u>light minerals</u> consist of a little quartz, 25% orthoclase and microcline, and 40% andesine. Some of the plagioclase is zoned, the interior being more sodic than the exterior. Calcite occurs rarely as an altered product.

<u>Dark portion</u>. The predominant <u>dark mineral</u> here is light brown biotite, rarely altered to green chlorite. Amphibole is rare. The biotite contains inclusions of pinkish brown pleochroic allanite surrounded by dark pleochroic haloes. The allanite has usually a rim of zoisite.

Rare epidote occurs at the contact between the light and dark portions.

The <u>light minerals</u> in the dark portion consist of a little quartz, about 20% orthoclase and microcline, and 30% oligoclase. The plagioclase is zoned, with the interiors more calcic than the exteriors.

<u>2. Younger Quartz Diorites and Granodiorites</u>. (See Table XIV)

<u>No. 106. Quartz diorite</u>.

<u>Microscopic</u>: Texture: allotrimorphic-granular.

<u>Macroscopic</u>: fine grained light grey granular rock.

Dark brown biotite constitutes about 4% of this section, and is partly altered to colourless chlorite along cleavage planes.

The remainder of the section consists of about equal amounts of quartz and feldspar, most of the feldspar being oligoclase, partly altered internally, and zoned with calcic interiors. There is a small amount of orthoclase and microcline. Some of the microcline contains rounded quartz grains in optical continuity. There are rare intergrowths of oligoclase in orthoclase.

A few small grains of apatite and rare flakes of muscovite are scattered through the section.

No. 107. Quartz diorite porphyry.

Macroscopic: Medium grained light grey granular rock, with large phenocrysts of feldspar.

Microscopic: Texture medium grained allotriomorphic-granular.

This rock is similar to No. 106, except that the plagioclase is albite, and there is more muscovite and albite. Zoned plagioclase is rare. There are a few interstitial grains of calcite.

Some of the potash feldspar appears to be slightly strained orthoclase when viewed with the section lying perpendicular to the microscope tube. On tilting the section by means of the universal stage, the feldspar takes on the appearance of microcline, with typical tapering lines of twinning. It is inferred that the mineral is orthoclase which is being altered to microcline by pressure phenomena. (Ref. Rosenbusch and Iddings, page 320).

No. 126. Granodiorite.

Macroscopic. Fine grained pink granular rock.

Microscopic. Texture: fine grained allotriomorphic-granular.

Dark minerals. Reddish brown biotite flakes, some altered to limonite, occupy 5% of the section.

Light minerals. Quartz, oligoclase and microcline, are present in roughly equal proportions. The oligoclase grains are partly altered to sericite internally, and some are zoned, with the centres more calcic than the outsides. There is a small amount of albite showing simple twinning. Some of the plagioclase is intergrown with quartz.

There are some well marked examples of partial replacement of quartz by microcline.

Muscovite occurs as rare flakes.

No. 222. Quartz diorite porphyry.

Macroscopic. Medium grained grey porphyritic rock. About 5% of the rock consists of tabular feldspar phenocrysts, up to 2.0 cm. in length, and pinkish grey in colour.

Microscopic: Texture: Allotriomorphic-granular.

Dark minerals. Biotite, some altered to pale greenish chlorite along cleavage planes, and some containing minute inclusions of euhedral to sub-rounded zircon, occupies 20% of the section.

The inclusions are surrounded by dark pleochroic haloes. The biotite is pleochroic: X pale greenish brown, Y yellowish brown, Z brown.

Light minerals. Clear quartz occupies 30% of the section. At one contact between microcline and biotite, quartz partially replaces the biotite at the contact, where numerous fragments of biotite are contained in the quartz, and are still oriented parallel with the main biotite grain. The replacing body of quartz joins and is optically parallel with an adjacent quartz grain.

Oligoclase, altering along cleavage cracks to sericite, occupies about 45% of the section.

About 5% of the section consists of microcline, some grains enclosing optically parallel quartz grains.

There are rare round grains of apatite, some occuring as inclusions in biotite.

No. 375. Granodiorite.

Macroscopic: Medium grained dark grey rock, with a pinkish tinge. Contains phenocrysts of feldspar up to 1.5 cm. in length. Dark mica and grains of feldspar make up most of the rock. The weathered surface is greyish pink.

Microscopic: Texture: Allotriomorphic-granular.

Dark minerals. Olive brown biotite, partly altered to green chlorite occupies 20% of this section. The chlorite is uniaxial + ve and length-slow. It is probably a variety of pennine. The biotite contains rare minute subhedral zircon grains, surrounded by pleochroic haloes.

Light minerals. The plagioclase is albite, some grains showing zoning, with the centres more calcic then the outsides.

Potash feldspars constitute 25% of the section, and most of the grains appear to be somewhat strained orthoclase, the remainder being typical microcline.

More or less radiating intergrowths of quartz and plagioclase are fairly common. Quartz occupies 15% of the section.

Replacement of quartz by microcline is common.

There are rare muscovite andapatite grains.

3. Biotite Granites. (See Table XIV.)

No. 99. Biotite granite, intrusive into No.100.

Macroscopic: Medium grained light grey granular rock.

Microscopic: Texture: medium grained allotriomorphic-granular.

Dark minerals. Greyish brown biotite, partly altered to a green chlorite, probably pennine, constitutes 7% of the section. There are some rare grains of,epidote and ore, and a few grains of amphibole. There is one grain of allanite which forms a dark halo where it is in contact with biotite.

Light minerals. These consist of a mosaic of quartz, potash feldspar and albite grains. Some of the albite shows twinning. Most of the feldspar grains are somewhat altered. There are some intergrowths of twinned oligoclase with quartz. The potash feldspar consists of strained orthoclase or microcline.

Flakes of muscovite and subhedral apatite grains are rare.

No. 306. Biotite granite.

Macroscopic. Pink medium grained granular rock.

Microscopic: Texture: medium grained hypidiomorphic-granular.

Dark minerals. Only 1% of this slide consists of dark minerals, in the form of dark brown biotite, and a little ore. The biotite is pleochroic as follows:- X pale yellowish brown, Y olive green, Z brownish black.

Light minerals. Quartz, containing lines of inclusions, makes up 30% of the section. The plagioclase is twinned and zoned, with centres altering to sericite. The rims are more sodic than the centres. Quartz is intergrown in the plagioclase, some intergrowths being arborescent in shape. The plagioclase is of oligoclase composition.

Some of the microcline appears to grade into orthoclase, with decrease in the intensity of twinning. Quartz inclusions are found in the microcline.

There are rare grains of apatite, and rare flakes of muscovite associated with the biotite.

No. 312A. Biotite granite.

Macroscopic. Coarse grey granular rock.

Microscopic: Texture: coarse-grained hypidiomorphic-granular.

Dark minerals. Biotite constitutes 4% of the section, and sphene epidote, allanite, and ore together constitute 1%.

The biotite is pleochroic as follows:- X pale brown, Y olive green, Z dark greenish brown. Some of the biotite is partly altered to chlorite. The sphene is mostly subhedral. The epidote is partly deeply coloured, and pleochroic from pale yellow to greenish yellow. The brown plrochroic allanite, which occurs as subhedral grains altered towards the edges, is commonly surrounded by subhedral masses of epidote.

A second section of this rock (No. 312B), shows large subhedral tourmaline grains.

Light minerals. Quartz occupies about 70% of this section.

Albite altering to sericite, and rarely intergrown with quartz constitutes 15%.

Microcline and stained orthoclase make up 10%.

Elongated apatite grains are found in section No. 312B.

No. 373. Porphyritic biotite granite.

Macroscopic. Coarse grained granular rock, speckled with black biotite flakes, and containing scattered tabular feldspar phenocrysts up to 2.5 cm., in length.

Microscopic: Texture: hypidiomorphic-granular.

Dark minerals. Biotite, containing dark pleochroic spots around minute inclusions, and averaging 1.5 mm. by 0.5 mm. in size, constitutes 10.6% of the section. Some of the biotite is partly or completely altered to chlorite. The biotite is pleochroic as follows:- X pale brown, Y brown, Z chestnut brown.

Sphene occurs as euhedral to subhedral grains.

Light minerals. Quartz constitutes 30% of the section. There is 18% potash feldspar and 42% plagioclase.

The orthoclase is probably all microcline, with a few grains that appear to be strained orthoclase. The plagioclase is andesine and is somewhat altered to calcite and sericite, internally. It shows albite twinning, and is zoned, with two distinct zones outside a core, the composition becoming increasingly calcic outwards.

Myrmekitic intergrowth of plagioclase with quartz is common on the rims of plagioclase grains, where in contact with microcline. Myremekite is also found in selvages between microcline grains.

The intergrowths are usually at right angles to the line of contact of the microcline on plagioclase grains.

There are some rare euhedral grains of apatite and zoned garnet, and some minute laths and patches of calcite. The apatite occurs commonly as inclusions in the biotite.

4. Younger Granites. (See Table XIV)

No. 326. Aplitic biotite granite.

Macroscopic: Fine grained even textured pinkish granular rock. Weathers brownish pink.

Microscopic: Texture: fine grained allotriomorphic-granular. Apart from the presence of a little haematite, there are no dark minerals in this section.

Quartz occupies 34.5% of the section, and is found in intergrowths with albite on a comparatively large scale. Muscovite and sericite present probably as decomposition products of the albite.

Potash feldspar constitutes 39.8% of the total, and is mostly microcline, although some appears to grade into orthoclase. The microcline contains rounded inclusions of plagioclase and quartz, apparently relicts after replacement. Albite has possibly replaced some of the quartz, as is shown by the presence of numerous quartz inclusions, optically parallel, in the rims of some albite grains, near the contact between albite and microcline.

No. 388. Alkali granite.

Macroscopic: Most of this rock consists of coarse salmon pink feldspar crystals.

Microscopic: Texture: coarse allotriomorphic-granular.

Most of this section consists of microcline, in large grains. There is a little quartz and some twinned oligoclase which is zoned with sodic rims. Sericite is present as an alteration product of feldspar.

5. Acid Dykes and Pegmatites. (See Table XV)

As shown on the table the acid dykes and pegmatites are all of similar composition, in that they contain quartz with usually a lesser amount of microcline and albite. Muscovite and biotite are usually present. Accessories such as garnet, tourmaline and topaz are rare.

TABLE XV

ACID DYKES

NO.	LOCALITY	ROCK TYPE	COUNTRY ROCK	QUARTZ	POTASH FELDSPAR	PLAGIOCLASE	MICA	EXTRAS	ESTIMATED MODE (Shown graphically)
88	East of Large salt Pan	Aplite	Schist	✓	Orthoclase	Oligoclase	Muscovite	Garnet.	Q K P
124	West of Gemsbok R.	Pegmatite	"	✓	Large microcline	Albite	"	Rare topaz.	Q K P M
132	S.E. "	Aplite	"	✓	Microcline	Albite			Q K P
133	" "	Pegmatite	"	✓	Microcline		Rare biotite.		
141	Kubugabis tin occurrence	Pegmatite	"	✓	Microcline	Rare albite	Biotite and muscovite	Pyroxene and uralite Apatite.	Q K M
226	On Zebra River	Aplite	Granite (No.216)	✓	Microcline	Albite	Rare biotite and muscovite		Q K P
270	East of Gemsbok R.	Pegmatite	Schist	Inclusions	Mostly microcline	Albite inclusions			
302	S.W. "	Pegmatite	Schist	✓	Orthoclase	Albite	Muscovite	Garnet, tourmaline and topaz.	
303	Near No. 302	Aplite	Schist	✓	Orthoclase and microcline	Albite	Muscovite and biotite	Garnet.	Q K P
304	Near No. 302	Pegmatite	Schist	✓	Microcline	Albite	Muscovite		
305	East of No.302	Pegmatite	Schist	✓	Microcline	Albite	Muscovite		Q K P M
307	East of No.302	Pegmatite	Granite (No.306)	✓	Microcline	Albite in graphic intergrowth with quartz	Biotite	Limonite.	
314	Between Gemsbok and Brak rivers.	Pegmatite	Schist	✓		Albite	Muscovite	Garnet	Q P
315	" "	Pegmatite	Granite (No.312)	✓	Little microcline	Albite	Muscovite		Q K P M
316	" "	"	Schist xenolith in granite	✓	Microcline	Albite	Muscovite	Calcite.	Q K P M
317	" "	"	Schist xenolith in granite	✓	Little microcline	Albite	Muscovite	Calcite.	Q K P
324	S. of Brak R., near Karroo contact	"	Granite	✓	Microcline	Albite	Rare biotite		Q K P
378	S.E. of Zebra R.	"	Schist	✓	Microcline	Albite	Biotite	Sericite, apatite and tourmaline.	Q K P B

Q - Quartz
K - K-feldspar
P - Plagioclase
M - Muscovite
B - Biotite

No. 83. Aplite.

Macroscopic: A pale pink medium grained granular rock.

Microscopic: Texture: medium grained allotriomorphic-granular.

A mosaic of quartz and feldspar grains makes up about 95% of this rock. Quartz consitutes about 25%. The quartz is clear and the feldspar rather cloudy or discoloured.

The plagioclase has the composition of albite-oligoclase. Potash feldspar is present in the form of orthoclase and altered microcline containing rounded quartz inclusions. Potash feldspar and plagioclase each constitute about 35% of the section.

The remainder of the slide is composed of colourless plates of muscovite, and a few small subhedral garnet grains.

No. 226. Aplite.

Macroscopic: Pale pink fine-grained granular rock, intruding granite. (No. 222).

Microscopic: Texture: granular.

Dark minerals. There are some rare patches of biotite altering to green chlorite.

Light minerals. Microcline, replacing and enclosing quartz, occupies about one-third of the section.

Albite-oligoclase, mostly altering to sericite, occurs in similar amounts. There is about 30% quartz.

There are a few flakes of muscovite.

No. 133. Pegmatite

Macroscopic: A medium to coarse grained crystalline rock.

Microscopic: Texture: poikilitic.

The whole section consists of one crystal of microcline, enclosing quartz as lengthened and rounded grains, groups of which are in optical continuity.

There are a few flakes of biotite, and some rare minute apatite grains.

No. 141. See under "Economic Geology," - The Kubugabis Tin Occurrence.

No. 302. Pegmatite. Near granite. (No. 301).

Macroscopic: Pale coarse grained granular rock, with rare crystals of black tourmaline and flakes of muscovite.

Microscopic: Texture: coarse grained hypidiomorphic-granular.

Dark minerals. There are a few euhedral to anhedral grains of greenish grey tourmaline.

Light minerals. These consist of quartz, strained orthoclase and albite with a little muscovite.

There are a few small grains of garnet.

No. 307. Pegmatite, intrusive into pink granite. (No. 306.)

Macroscopic: Pink coarse grained granular rock.

Microscopic: Texture partly fine and partly coarse-grained allotriomorphic-granular.

The mineralogical composition of this rock is similar to that of the granite it intrudes. (No.306).

The section shows a good example of intergrowth of quartz in albite. The quartz is corroded by microcline.

Dark minerals consist of biotite, partly altered to chlorite, and some ore and limonite.

(D) Karroo Rocks.

The Karroo rocks will be described from the base upwards. As many of the rocks were not suitable for microscopic examination, most of the descriptions are macroscopic.

1. The Karroo Sediments.

(a) Basal Beds:

No. 90. Pebble from basal conglomerate, between Brak and Gemsbok Rivers. (See photo, Fig. 41).

Macroscopic: This pebble is of quartz, 15 cm. long by 10 cm. wide and has a well developed sole on one side, with incised grooves running along the length of the pebble, both on the sole and along the sides.

No. 332. Basal grit. (Section 4, Fig. 39).

Macroscopic: Compact greyish brown rock, consisting of small scattered grains in a fine grained groundmass.

Microscopic: Texture: granular.

Sub-rounded to angular grains of quartz, up to 1.0 mm. in size, and rare altered feldspar grains up to 2.0 mm. in size, are set in a matrix of fine grained material and haematite. There is one grain of fine grained biotite schist and one of sheared quartzite.

A few patches of calcite appear interstitially and have replaced some of the quartz.

No. 327. Basal breccia. South of Omaruru Road.

Macroscopic: Reddish brown rock composed of angular to sub-angular cherty yellowish fragments averaging 0.5 cm. in a fine-grained reddish brown matrix. The fragments commonly have brown centres.

Microscopic: This section consists of numerous minute rounded to angular quartz grains in an extremely fine grained isotropic groundmass. The structure is that of a breccia, but under crossed Nicols the matrix cannot be distinguished from the fragments.

No. 363. Yellow weathering basal beds.

Macroscopic: Dark brownish red, very fine grained rock with darker patches. Breaks with a conchoidal fracture, interrupted by numerous curved cracks and fracture planes. Some of these cracks are filled with white material including some carbonate matter, and stilbite. The rock has an appearance similar to jasper, but is less vitreous, and weathers a bright orange yellow with a surface similar in form to that of a siliceous limestone.

Microscopic: Thin section shows only an extremely fine-grained yellowish brown aggregate of minute anisotropic grains, having an index of about 1.602. Positive identification of the grains was not possible.

(b) Sandstones and Grits.

No. 154. Altered quartzite. Brandberg foothill, south of Kubuqabis

Macroscopic: Fine grained greenish grey cherty rock. Shows banding on weathered surface.

No. 174. Quartzite from the same locality as No. 154.

Macroscopic: Fine grained light grey cherty quartzitic rock.

No. 175. Quartzite from a point near No. 174.

Macroscopic: Coarse grained pale brown quartzite with uneven grain. Grains mostly quartz with some feldspar.

No. 330. Quartzite from a point near No. 327.

Macroscopic: Reddish brown fine to medium grained quartzite.

Microscopic: Texture: even grained granular.

Most of this rock consists of even grained partly recrystallised quartz grains, with about 5% altered feldspar, and rare sub-rounded grains of tourmaline.

Haematite is common in interstitial patches, and there is some rare sericite.

No. 333 Quartzite. (See section No.4, Fig. 39).

Macroscopic. Pale fine grained quartzite containing brownish weathered specks, probably of feldspar.

(c) Shales and Mudstones.

No. 4 Varved Shale. From a point near No. 90 (See photo, Fig. 64)

Macroscopic: Greenish grey indurated, layered fine grained rock showing dark and light bands and numerous small spherical pellets scattered through the rock. The shale splits into layers each a few centimetres thick, and some of the layers show what appear to be worm trails on their upper surfaces with casts of these markings on the bottom of the overlying layers. (See photo. Fig. 42).

The rock weathers a yellowish brown.

Microscopic: Texture: fine grained granular, showing banding .

The rock consists mostly of quartz grains, with much interstitial chlorite, especially in the coarser portion. There is a marked banded structure caused by rythmic decrease in grain size upwards, from about 0.1 mm. at the base of each layer, to about 0.01 mm. at the top of each layer. The grains are notably angular. There is a small degree of preferred optical orientation in the chloritic groundmass of the finer-grained bands.

No trace could be seen of the pellet-like structures visible macroscopically.

No. 153. Indurated mudstone. From Brandberg foothill, south of Kubugabis;

Macroscopic. Very fine-grained compact dark grey rock. Breaks with conchoical fracture.

No. 155. Altered shale. Same locality.

Macroscopic. Compact light greenish grey banded rock. Very fine-grained. Breaks with a conchoidal fracture.

No. 156. Striped indurated mudstone. Same locality.

Macroscopic. A very fine-grained subvitreous dark purple rock with pinkish stripes and patches.

No. 169. Altered mudstone. Section No. 5, Fig. 39.

Macroscopic. Mottled purplish black rock similar to No. 156.

No. 170. Altered mudstone. Section No.5. Fig. 39.

Macroscopic: Mottled rock as above.

No. 172. Altered mudstone. Section No.5. Fig. 39.

Macroscopic: Very fine grained rock showing grey, yellowish and pinkish brown mottles. Conchoidal fracture.

No. 173. Altered shale. Section No. 5. Fig. 39.

Macroscopic: Very fine grained pinkish grey rock. Conchoidal fracture.

No. 328. Mudstone. Section No.9. Fig. 39.

Macroscopic: Very fine grained brownish red rock. Breaks to a dull surface with conchoidal fracture.

No. 329. Shale. Section No.9. Fig. 39.

Macroscopic: Very fine grained grey rock, with a platy fracture.

(d) Calcareous Band.

No. 334. Yellow-brown limestone. Section No.4. Fig. 39.

Macroscopic. Pale brown fine grained limestone, containing veins, and lenses of coarsely crystalline calcite. Weathers yellow-brown.

No. 342. Pink sandstone. Section No. 4. Fig. 39.

Macroscopic: Fine grained pinkish brown rock, with numerous white specks composed of altered feldspar. The brown colour is due to the material composing the matrix.

No. 335. Brown Shale. Section No.4. Fig. 39.

Macroscopic: Very fine grained purplish brown rock. Breaks into rounded chips, with sub-conchoidal fracture.

No. 382. Brown limestone nodule. Near post-Karroo fault.

Macroscopic: Fine grained somewhat glassy reddish brown quartzite, containing an elongated nodule of calcareous and ferruginous material showing a concentric structure.

No. 168. Indurated shale. Section No. 5. Fig. 39.

Macroscopic: Dark grey cherty rock, slightly banded with lighter grey.

Microscopic: Texture: Fine grained granular.

This section consists of fine grained angular quartz fragments in an extremely fine grained isotropic groundmass.

(e). Shales, Mudstones, Sandstones and Grits overlying the Calcareous Band.

No. 167. Indurated mudstone. Section No. 5 Fig. 39.

Macroscopic: Very fine grained grey rock, breaks with rough surface on conchoidal fracture.

Microscopic: Texture: fine grained granular.

This section consists of a very fine-grained aggregate of interlocking quartz and altered feldspar grains. There are numerous flakes and shreds of pale brown phlogopite, rarely containing minute inclusions of subhedral tourmaline.

No. 380. Altered sandstone. Section No.7. Fig. 39. (See Fig. 43).

Macroscopic: Light coloured purplish hard medium grained sandstone, with numerous white chalky inclusions, up to 1.0 cm. in size, in rounded, curved and hollowed shapes. These inclusions give a positive reaction for phosphate, using the Ammonium Molybdate test.

Microscopic: Most of this rock consists of rounded and corroded quartz grains, with fine grained quartzitic interstitial material. Many of the quartz grains exhibit undulose extinction. There are rare grains of chalcedony, sphene, tourmaline, and altered feldspar.

The white chalky material shows up as dirty white amorphous substance similar to chert, but with the remains of a possibly cellular structure. It is probably bone-matter.

No. 381. Altered sandstone. Section No. 7. Fig. 39.

Macroscopic: Sandstone similar to No. 380 above, but without white inclusions. There are scattered dark rings in the rock, up to 2.0cm in diameter, with cores of sandstone identical to the sandstone outside the rings. The dark material forming the rings is composed of extremely fine-grained specks of ferruginous or carbonaceous material.

No. 337. Bedded sediment. Section No.4. Fig. 39.

Macroscopic. Reddish brown slightly layered fine-grained rock, containing scattered rounded particles of fine-grained brown material.

Microscopic: This section consists of fine grained angular quartz fragments in a very fine grained matrix containing such calcite and ferruginous matter.

No. 338. Altered shale. Section No.4. Fig. 39.

Macroscopic: Fine grained compact light brown rock, breaks with subconchoidal fracture.

No. 339. Quartz grit. Section No. 4. Fig. 39.

Macroscopic: Medium grained grit consisting of rounded quartz particles, averaging 2.0 mm. in diameter, in a reddish brown fine grained matrix. The rock is strongly layered.

No. 340. Quartzite. Section No.4. Fig. 39.

Macroscopic: A fine to medium grained somewhat gritty quartzite, containing very fine grained olive brown layers.

No. 341. Quartz grit. Section No.4. Fig. 39.

Macroscopic: A coarse grit, consisting of rounded quartz grains, averaging 2.5 mm. in diameter, in a greenish grey matrix.

No. 343. Shaly Mudstone. Section No.4. Fig. 39.

Macroscopic. A finely banded pinkish grey rock. Weathers brownish grey.

Microscopic: Texture: fine grained.

The section shows small (up to 0.05 mm.) angular particles of quartz, rare plagioclase, (probably andesine) and sericite, all showing marked parallelism. The matrix consists of optically continuous chloritic material.

No. 344. Quartzite. Section No.4. Fig. 39.

Macroscopic: A fine-grained reddish brown quartzite, breaking with a sub-conchoidal fracture.

No. 345. Mottled mudstone. Section No. 4. Fig. 39.

Macroscopic: Purplish black fine grained rock with pale pinkish patches. Similar to No. 156.

Microscopic: This is a fine grained quartzitic rock, with an average grain size of 0.05 mm. The grains consist of angular to subrounded quartz, and some feldspar, in a very fine grained groundmass containing calcite, sericite and carbon dust. The feldspar grains are partly altered to chlorite and calcite.

There are some rare grains of apatite and sphene.

The pink patch contains less carbon dust, and more interstitial calcite, and also some grains of tourmaline and sphene.

No. 346. Quartz grit. Section No.4. Fig. 39.

Macroscopic: This rock consists of rounded, poorly sorted grains and pebbles of quartz, and dark cherty material, up to 1.0 cm. in diameter , in a fine grained greenish grey matrix.

TABLE XVI

KARROO LAVAS.

NO.	LOCALITY	OLIVINE		PYROXENE		FELDSPAR		GLASS	AMYGDALES	ORE	EXTRAS AND REMARKS.
		Groundmass	Phenocrysts	Groundmass	Phenocrysts	Groundmas	Phenocrysts				
358	See Fig.39		Altered			Mat of altered laths. Av. 0.2mm	Altered, to 2.0mm			Large grains	Apatite, associated with magnetite.
357	"					Highly altered mat.	Altered, to 2.5mm	Altered	Rare chalcedony (small)	Magnetite	Whole groundmass altered to spotted brown mass.
356	"					Highly altered	Altered, to 2.0mm	Altered to brown opaque material.			Altered green lava, similar to No.355.
355	"		Altered			Mat of altered laths and chlorite	Large - altered	Altered	Chalcedony and quartz, some with calcite.		Green lava.
354	"		Altered			Much altered	Rare-altered	Abundant		Much Mt.	Brown lava. Contains pseudomorphs of bowlingite, antigorite and limonite after olivine.
353	"					Highly altered	Altered to 2.0mm			Abundant	Platy lava.
352	"					Altered			Chalcedony quartz and calcite with chlorite rims		Dark brown amygdaloidal lava, Groundmass opaque, dark brown.
351	"		Altered	Yellow-brown augite laths		Mat of plagioclase laths	Altered	Abundant dirty brown	Quartz and calcite.	Mt. in groundmass	Dark brown amygdaloidal lava.
350	"						Altered	Dark - In patches	Calcite and magnetite		Dark grey amygdaloidal lava.
349	"	Rare grains		Granulitic augite and pigeonite - 2V22° +, γ1.704	Rare augite to 1.0 mm		Plagioclase altering to sericite				Dark grey lava. Fine to medium grained.
348	"			Granulitic to sub-oph. augite.		Small and large laths, to 1.0 mm	Altering to sericite		Zeolite and green chlorite		Altered amygdaloidal lava.
347	"					Medium to fine-grained altered laths.			Bright green chlorite, with chalcedony rims		Groundmass altered, dark brown.
360	"		Altered	Sub-oph. to grain aug. 2V 54+		Plagioclase laths Av. 0.2mm		Abundant	Chalcedony quartz and green chlorite.		
164	"			Granulitic augite		Small matted laths Av.0.15mm	Rare altered	Abundant	Chlorite and groups of augite feldspar chlorite and calcite grains.		Dark grey amygdaloidal lava.

Table XVII shows graphically the estimated modes of most of the dykes that were examined, together with the optical constants of the constituent minerals.

As shown on the table, most of the dykes are medium to fine-grained ophitic olivine dolerites, with variable amounts of olivine, and no orthopyroxene or pigeonite. They thus correspond more closely with the Perdekloof type than with any of the other well-known types. Nos. 22, 32, 37, 39 and 122 are apparently coarse varieties of the Perdekloof type dykes, although ferriferous pigeonite is absent.

Picrite dolerites were found at five localities (Nos. 1, 3, 10, 192 and 394). Four of these localities fall roughly along a line about 10 km. long, running north-east. The rock occurs in irregular masses, rather than in dyke-like bodies. No. 192 is from a long strike dyke near the Brandberg.

Nos. 1 and 10 are similar and consist of coarse rounded olivine grains, with little interstitial matter. Nos. 394, 192 and 3 (photo, Fig. 65.) appear to represent three stages in the growth of the crystalline groundmass, which is respectively fine, medium and coarse grained in the three specimens. In Nos. 3 and 192 the olivine forms elongated crystals up to 2.0 mm. by 0.3 mm. thick. In No. 394, some of the olivine grains are broken, and the plagioclase groundmass fills the spaces between the fragments.

<u>The Hangnest type</u> was found at only one locality (No.13), in an irregular plug-like body about 60 metres in diameter. The rock is a bronzite dolerite containing augite and a little pigeonite, more than 50% plagioclase and some rare biotite. Some of the bronzite shows graphic intergrowth. Olivine is absent.

Nos. 97 and 323, taken from horizontal sheets in the schist and granite, cannot be correlated with any of the known types. The augite in these two thin sections is exceptionally well-developed, forming an almost complete mosaic of grains, ophitically enclosing plagioclase laths. Apart from this peculiarity of texture the rock is similar to the Perdekloof type.

No. 78, taken from a thick sill in the south western part of the area, shows a well marked directive texture of the coarse plagioclase laths.

TABLE XVII

THE KARROO DYKES

NO.	TYPE	LOCALITY	OLIVINE			PYROXENE			FELDSPAR			GLASS ETC.	PHENOCRYSTS AND AMYGDALES	ORE	EXTRAS AND REMARKS	NO.	ESTIMATED MODE (Shown graphically)
				2V	Mol%Fa	2Vγ	γ	Grain and Texture	% An	*	Av.Size						
1	PICRITE DOLERITES.	Near granite between Zebra R and S of Brak River	Crystals to 5.0 mm	90	18	51	1.702	Oph.	56	32	0.5			✓		1	Ol P F O
3		"	Long crystals	88+	5	49	1.722	Poikilitic	62	35	to 3.0			✓	? Iddingsite γ 1.628	3	Ol P F O
10		"		87+	5	47	1.718		56	32	0.5			✓	? Iddingsite γ 1.622 and rare Bowlingite.	10	Ol P F O
192		Amis River	Long crystals	81-	46	49	1.703	Oph.	54	31	0.4			✓	Rare ? Iddingsite	192	Ol P F O
394		West of Zebra River		83-	41	48	1.734	Poikilitic	Too	small	<0.1			✓	Rare ? Iddingsite	394	Ol P F O
13	Hang-Nest	At S-bend in Brak R				19½ 43	Pige-onite Augite	Sub. Oph.		34	0.5	✓	Bronzite to 3.0 mm 2V×71 (inside) 66 (rim) γ1.690	✓	Rare Biotite γ1.630	13	P F G O
5	PERDEKLOOF	Near W gate of Brak R. (near granite)	Altered			49	1.713	Sub. Oph. to gran.	53	30	0.3	Altered	Amygdales-calcite and chlorite	✓		5	P F C A O
6		" E. "	In. Rim. Long crystals	88+ 82-	5 45	45	1.713	Sub. Oph. to Oph.	64	36	0.3		Long Olivine phenocrysts	✓	Antigorite and Magnetite from Olivine	6	Ol P F O
11		E of 6 in Marble Ridge				49	1.722	Oph. to Sub-Oph.	61	34	0.5	Altered to chlorite		✓	Biotite γ 1.635. Rare green bowlingite	11	P F G O
12		S.E. of 6	Long crystals			47	1.722	Gran.	53	30	0.4	Little		✓	Long green bowlingite grains. 2V48°-	12	Ol P F O
14		Brak River	In. Rim Long crystals	83- 82-	41 45	50	1.720	Oph.	50	28	0.5	✓	Plagioclase and long olivine phenocrysts	✓		14	Ol P F G O
20		W of Brak River in Marble		81-	46	54	1.720	Gran. to Sub.-Oph.	56	32	0.25	✓	Olivine and much plagiocalse phenocrysts	✓		20	Ol P F G O
26		Lead Occurrence "A"		81-	46	48	1.723	Fine grained oph. to gran.	53	30	0.4		Olivine phenocrysts	✓	Brown bowlingite	26	Ol P F G O
27		"	Zoned	80-	48	49	1.725	Coarse sub-oph.& fine grained.	56	32	0.5		Plagioclase phenocrysts	✓	Greenish brown bowlingite 2V 15°-	27	Ol P F G O
29		"	? Altered			47½	1.722	Sub-oph.	60	33	0.35	Altered		✓	Antigorite and green bowlingite	29	P F G O
30		"				46	1.718	Granulitic	53	30	0.4	✓	Felted plagioclase	✓	Rare green bowlingite	30	P F G O
31		"	Altered			45	1.721	Sub-oph. to gran.	66	37	0.5	✓		✓	Antigorite	31	P F G O
35		"				47	1.722	Granulitic	62	35	0.8	✓	Amygdales-calcite with chlorite edges	✓		35	P F G O
36		"				47	1.722	Granulitic	64	36	0.4	✓		✓	Rare green bowlingite	36	P F G O
38		"	Little altered			46	1.719	Granulitic	62	35	0.4	✓		✓	Green bowlingite 2V 10°-ve	38	P F G O

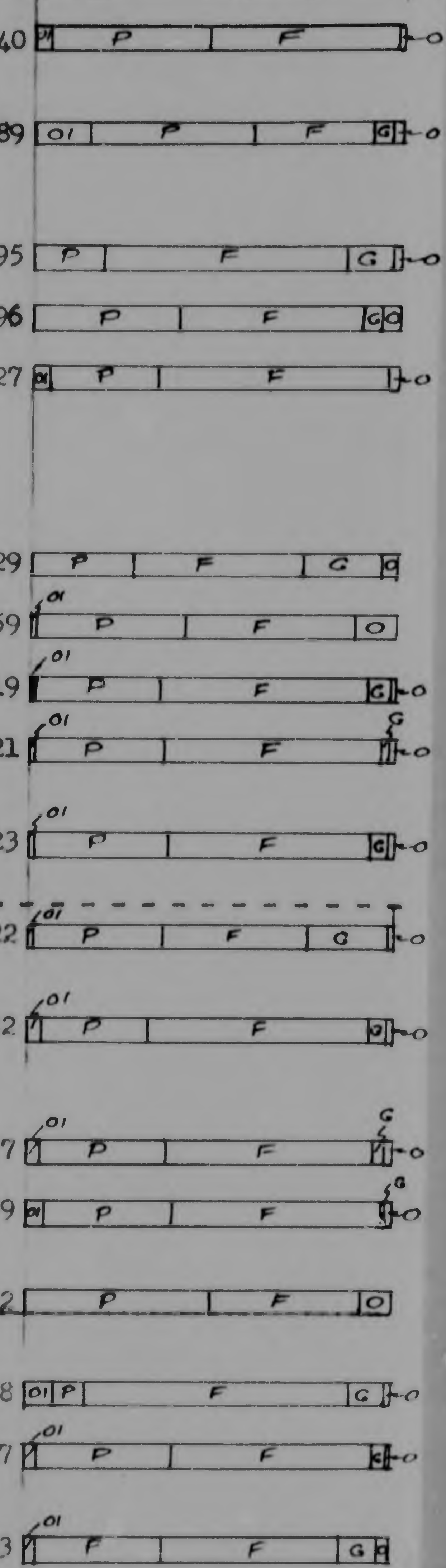
* = Max. Ext. Angle in zone ⊥ 010

TABLE XVII (continued)

THE KARROO DYKES.

NO.	TYPE	LOCALITY	OLIVINE	2V	Mol% Fa	PYROXENE 2Vγ	γ	Grain and Texture	FELDSPAR % An	*	Av.Size mm	GLASS ETC.	PHENOCRYSTS AND AMYGDALES	ORE	EXTRAS AND REMARKS	NO.
40	PERDEKLOOF	S.E. of Brandberg W Mine, near granite	Long crystals	84-	39	50	1.722	Fine grained sub-oph. to gran.	60	33	0.3	✓	Plagioclase and long olivine grains	✓		40
89		East of large salt pan	Long crystals	86+	1	51	1.730		54	31	0.4	✓		✓		89
95		Near large fault E of Brak River				49	1.712	Fine grained gran.	54	31	0.5	Abundant	Augite to 0.7 mm Plagioclase to 1.7mm	✓		95
96		North of 95				48	1.720	Sub-oph. to gran.	60	33	0.3	✓		Rare pyrite	Green bowlingite	96
127		See Map No. Fig.40	Altered			48	1.717	Fine grained sub-oph.	Altered		0.5	Altered		Rare pyrite	Biotite γ1.630. Antigorite	127
129		1 Km. N.W. of 127	Altered			47	1.709	Fine grained sub-oph.	60	33	0.15	Abundant	Rare altered olivine Euhedral augite. Much Plagioclase to 1.5 mm	Alt. to Leucoxene		129
359		See Fig. 39	Altered			45 IN 41 RIM	1.725	Sub-oph. to oph.	60	33	0.25		Plagioclase	Abundant	Analysed	359
419		Brandberg West Mine		80-	48	47½	1.724	Sub-oph.	54	31	0.5	✓		✓		419
421		"		88-	25	49	1.705	Sub-oph.	54	31	0.4	✓	Few plagioclase phenocrysts	✓		421
423		"	Altered			51 42	1.712	Sub-oph to gran.	51	29	0.4	✓		✓		423
22	COARSE GRAINED PERDEKLOOF.	Near 21 and 23 NW of Brandberg W Mine	Altered			45	1.718	Coarse oph.	60	33	1.0	✓		✓	Pleochroic augite	22
32		Lead Occurrence "A"	Altered	85+ IN 87+ RIM	1 5	49	1.720	Coarse oph.	60	33	0.5	✓		✓		32
37		"		85+	1	48	1.728	Sub-oph. coarse	56	32	0.4	✓		✓		37
39		"		85-	35	50	1.715	Coarse oph.	54	31	0.9	✓		✓		39
122		See Map No. Fig 40	Altered			47	1.721	Coarse oph.	53	30	1.1	✓		✓	Iddingsite γ1.631 (= red-brown Biotite?) Green bowlingite	122
78		See Map No. Fig. 40		77-	55	58	1.728		60	33	2.0	Abundant		✓	Rare Iddingsite γ1.635. Rare green pleochroic Bowlingite	78
97		Near No. 96	Altered			46	1.708	Coarse oph.	63	35½	0.35	✓		✓	Rare green bowlingite	97
323		Near Karroo South of Zebra River				49	1.717							✓		323

ESTIMATED MODE (Shown graphically)



* Maximum extinction angle in zone ⊥ 010

Oph. = Ophitic.
Gran. = Granulitic.

Ol - Olivine
P - Pyroxene
F - FeldsPar
G - Glass
O - Ore

The specimen was taken from about 12 metres above the base of the sill. The sill is at least 20 metres thick, and the top part has been removed by erosion.

Porphyritic basic dykes (Nos. 62, 74, 92, 123, see Table XVIII) are fairly abundant in the area, and are generally older than the Perdekloof type dykes. They usually show small (up to 2.0 mm.) phenocrysts of augite, olivine or plagioclase in a dense aphanitic purplish brown or greenish brown matrix. They resemble strongly some of the Karro lavas found in the area, but are usually less altered than the lavas.

Amygdaloidal basic dykes (Nos. 21, 23, 28, 87, 123, 146, 206 and 387) (See Table No. XVIII), are widespread, and some are possibly varieties of the normal Perdekloof type. The amygdales consist of calcite and chalcedony, with chlorite rims. Zeolite is present in No.123, which also contains plagioclase phenocrysts. All these amygdaloidal rocks are more altered than the dolerites.

The groundmass is usually of felted or variolitic feldspar, rarely together with augite laths. Glass or mesostasis is present in small amounts.

TABLE XVIII

AMYGDALOIDAL AND PORPHYRITIC BASIC DYKES.

NO.	LOCALITY	OLIVINE	PYROXENE	PLAGIOCLASE Groundmass	PLAGIOCLASE Phenocrysts	GLASS	AMYGDALES	ORE	EXTRAS AND REMARKS	ESTIMATED MODE (Shown graphically)
21	N.W. of Brandberg West Mine	Altered	All Altered to chlorite	Altered felted laths Av. 0.3mm		Much Altered	Calcite and antigorite.	Haematite	Similar to Lava No.351.	
23	" "		All altered to chlorite	Altered. Av.0.3mm		Some	Calcite and chalcedony. Chlorite at edges.	Leucoxene		
28	Sesob R. Lead occurrence "A"		Fine-grained gran.	Feathery aggregates. Av.0.15mm			Calcite and chlorite.			
62	Near Lead of Sesob R.	2V86+ Altered Phenocrysts.		Felted needles				Ilmenite	Olivine Porphyry.	
74	N. of Gemsbok R.		Zoned Augite 2V47+ γ1.728	Altered. Av. 0.5mm	Altered 1.5 mm			Pyrite and ilmenite		
87	In granite (See map) Fig 40			Av. 0.3mm		✓	Chlorite, chalcedony and calcite.	Leucoxene	Rare Picotite. Green fine-grained amygdaloidal rock.	
92	Same as 74, Farther to S.E.		2V50+, γ1.729						Same dyke as No.74, 2 Km away.	
123	See Map, Fig. 40	Altered 2V87+	Fine-grained oph 2V42+, γ1.723	*32° Av. 0.25 mm	Altered	✓		Ilmenite	Olivine-plagioclase porphyry.	
128	1 Km. S.W. of 123	Phenocrysts to 1.0mm Altered	Fine-grained altered augite. Rare Phenocrysts	Felted laths Av. 0.2 mm	Zoned labradorite to 2.0 mm		Calcite, chlorite and zeolite.	Magnetite	Olivine mostly altered to antigorite and magnetite.	
146	N.W. of Brandberg			Altered Av.0.5mm		✓	Chalcedony, calcite and chlorite edges.	Limonite	Highly altered brown amygdaloidal rock.	
206	Amis River			Altered Av.0.25mm		Altered	Calcite		Highly altered.	
215	In granite near head of Zebra R.		2V50+ γ1.726							
387	Near fault, east of Zebra River	Altered		Highly Altered Av. 0.2 mm			Abundant calcite and chalcedony, with chlorite edges.	Magnetite	Highly altered greenish brown amygdaloidal rock.	

* Max. Ext. ∠ in Zone ⊥ 010

Ol - Olivine
P - Pyroxene
F - Feldspar
G - Glass
O - Ore

CHAPTER VI.

PETROLOGY.

A) Rocks of the Damara System.

The probable origin of these sediments has been discussed under "Geology". The probable causes and processes of their metamorphism will be discussed below.

The nomenclature used in the subdivision of the metamorphic grades in the following discussion is as follows:

Grade	Grubenman and Niggli	Harker
LOW	Epizone	Chlorite zone
MEDIUM	Mesozone	Biotite zone Garnet zone Staurolite zone
HIGH	Katazone	Sillimanite zone

Map No 66 shows the distribution of the four main types of metamorphic rocks in the Damara sediments. Referred to metamorphic grades, they are as follows, in order of decreasing grade:

Old Granite Contact Zone	High grade
Amphibole Zone	Medium grade
Knotted Cordierite Schist Zone	Medium grade
Biotite Zone	Medium grade

Only two well-defined grades of metamorphism were seen in the Karroo rocks, namely the high grade rocks of the Brandberg Contact Zone and the low grade rocks of the Karroo system elsewhere.

Metamorphism of the Damara Sediments.

These rocks have been subjected to both dynamic and contact metamorphism.

1) Dynamic Metamorphism

The effects of dynamic metamorphism are present throughout the whole area of Damara Rocks, except where obliterated by later thermal metamorphism. The major cause of this metamorphism is thought to have been folding. During the folding, movement between adjacent layers in the strongly layered rocks, combined with pressure due to the weight

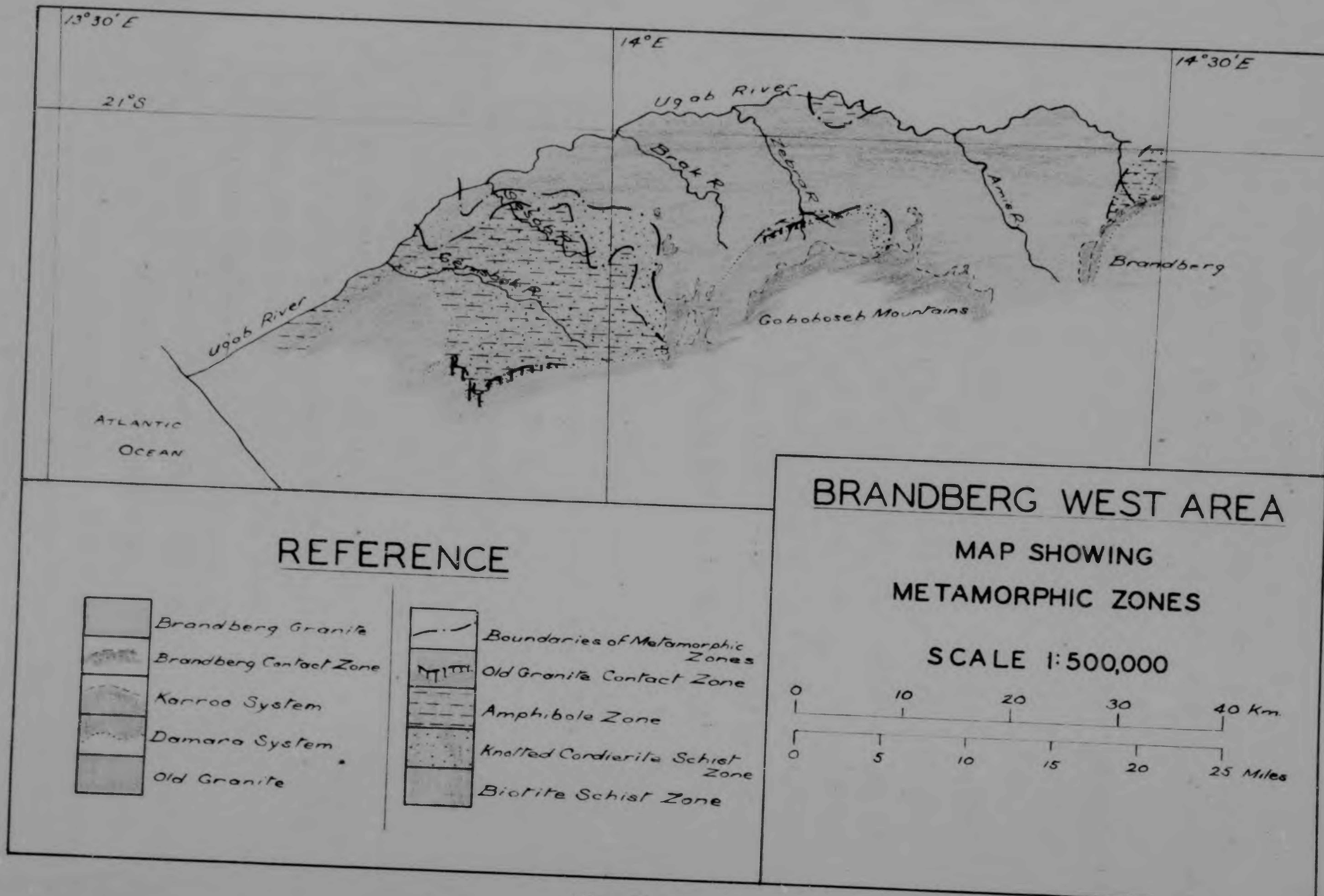

13°30'E
14°E
14°30'E
21°S
Ugab River
Brak R.
Zebra R.
Amis R.
Brandberg
Gobohoseb Mountains
Ugab River
Atlantic
Ocean
BRANDBERG WEST AREA
MAP SHOWING
METAMORPHIC ZONES
SCALE 1:500,000
0 10 20 30 40 Km.
0 5 10 15 20 25 Miles
REFERENCE
Brandberg Granite
Brandberg Contact Zone
Karroo System
Damara System
Old Granite
Boundaries of Metamorphic Zones
Old Granite Contact Zone
Amphibole Zone
Knotted Cordierite Schist Zone
Biotite Schist Zone

Fig. 66.

of the overlying sediments, produced enough heat for the formation of biotite. The biotite flakes were formed parallel with the gliding planes, which were also the bedding planes.

The relationship between the stratigraphic position of the sediments and the composition of the biotite is shown in Figure 67.

The more calcareous rocks, which were probably impure dolomitic limestones, contain mica, probably phlogopite, that is low in iron content. The biotite of the schists is richer in iron, and probably reflects the original composition of the rocks, which were slightly ferruginous arenaceous shales.

The intensity of the dynamic metamorphism appears to be proportional to the degree of overturning of the folds. For example, west of the Zerissenes Mountains the folds are appreciably more overturned than they are to the east of the mountains, and the more calcareous layers show a slightly higher degree of metamorphism than similar rocks in areas that are less strongly overfolded. (See Fig. 66) Actinolite schist and granulite, and rarely, actinolite-diopside rock , are developed.

Where rotational stress has produced a cleavage, biotite flakes are formed in the cleavage plane. The amphibole and pyroxene grains seldom show any preferred orientation, and their presence may possibly be explained by thermal metamorphism and metasomatism due to a granite intrusion after the folding had ceased.

Strongly knotted cordierite-biotite schists, which are common west of the Zerissenes Mountains immediately above and below the Upper Marble Series are also more indicative of thermal than of dynamic metamorphism, although a directive texture exists in the porphyroblasts.

2) Regional Metamorphism and Zoning.

Examination of amphibole from representative sections through the three series of schists, shows that there is a progressive increase in the iron content of the amphibole upwards from the Lower Schist Series to the Upper Schist Series.