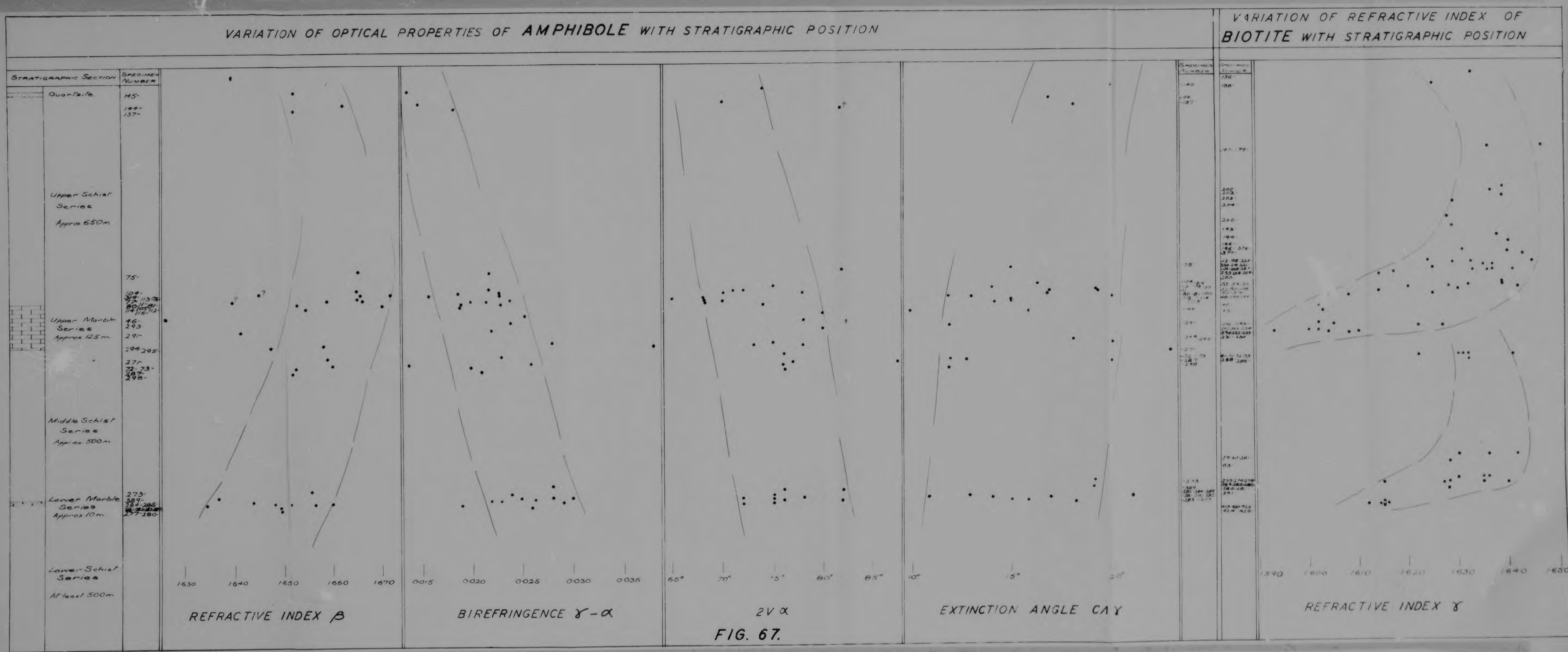

VARIATION OF OPTICAL PROPERTIES OF AMPHIBOLE WITH STRATIGRAPHIC POSITION
VARIATION OF REFRACTIVE INDEX OF BIOTITE WITH STRATIGRAPHIC POSITION
STRATIGRAPHIC SECTION
SPECIMEN NUMBER
Quartzite
Upper Schist Series
Approx 650m
Upper Marble Series
Approx 125m
Middle Schist Series
Approx 500m
Lower Marble Series
Approx 10m
Lower Schist Series
At least 500m
1630 1640 1650 1660 1670
REFRACTIVE INDEX β
0·015 0·020 0·025 0·030 0·035
BIREFRINGENCE γ-α
65° 70° 75° 80° 85°
2V α
10° 15° 20°
EXTINCTION ANGLE CΛγ
1590 1600 1610 1620 1630 1640 1650
REFRACTIVE INDEX γ

FIG. 67.

In the top portion of the Upper Schist Series, there is possibly a slight drop in the iron content of the amphibole. (See Fig. 67). Four possible explanations for this are as follows:-

1) The material deposited during the formation of the original sediments became increasingly more ferruginous towards the end of the period of deposition.

2) During deposition, the compaction of the sediments caused water to percolate upwards through the beds. This water could have dissolved iron from the lower rocks and deposited it higher up, after compaction and therefore movement of water of deposition, had ceased. (Hedberg has stressed the importance of compaction in mobilising water of deposition in sediments; Ref. 1936.)

3) After the sediments had been compacted they were compressed laterally and strongly folded. Any resulting decrease in total volume must have been slightly relieved by a movement of water upwards to regions of lower pressure. Temperatures were probably high, facilitating solution of iron at depth.

4) Heat applied at a deep horizon in the folded sediments, drove a front of iron and magnesia-bearing solutions upwards. The source of the heat could be:-

a) Friction due to movement between bedding planes during folding.

b) Friction due to the movement of the sediments over a decollement during and after folding.

c) Increased pressure on the lower part of the sediments, due to thickening of the crust of sediments through folding.

d) The effect of inherent heat of the interior of the earth, becoming intensified due to the folded and thickened mass of sediments sinking down into the earths crust.

Of the above, a combination of 3) and 4) is thought to be the most reasonable explanations. In a paper by P. Lapadau-Hargues, as quoted by Read, (Ref. Read, 1948) analyses show that MgO and FeO content gradually increase away from granite, through augen gneiss, perthite gneiss and plagioclase gneiss to schist.

Between the last two rocks, the FeO increase is greater than the MgO increase. From schist through slate to "original sediment" the FeO increase is less than the MgO increase. Thus the variation in composition of amphibole is possibly a symptom of regional zoning.

A progressive change in the composition of biotite does not seem to exist although there is a certain rhythmic change, in sympathy with the change from calcareous to non-calcareous sediments. (Fig. 67). Therefore it is possible that the iron and magnesia content of the sediments became fixed during the late stages of folding, and after the formation of biotite. Local changes of composition, near granite contacts, may have occurred later.

3) The Grades of Metamorphism in the Area.

Table No XIX and Fig. 66 show the types and positions of the different zones of metamorphism. The probable original rock types are indicated in the table.

Impure dolomitic limestones have given rise to phlogopite marbles which in turn have been changed to amphibole marble and finally to amphibole-pyroxene rocks. Partial analyses of specimens of marble (Table XX) show that the MgO - CaO ratio is too low for the rocks to be classed as dolomites. They are probably dolomitic marbles.

Argillaceous and calcareous sediments gave rise to biotite granulites, amphibole granulites and amphibole-garnet granulites.

Calcareous nodules in shaly beds are changed to amphibole-pyroxene-scapolite "Pseudo-diorites". Similar rocks have been described from the Appalachians (Ref. Ross, 1935, and Emmons and Laney), the Gold Coast (Ref. Conybeare), and the Karroo system (Ref. Walker and Poldevaart, page 627). Some acid pegmatite dykes (No. 270) lie near the pseudo-diorites, and could possibly be connected with their formation. Mottled actinolite diopside-epidote bands (No. 271) have been formed in the schist adjacent to the dykes. Solutions emanating from the nearby granite body could have caused the pseudo-diorite metamorphism, which is post-tectonic, judging from the haphazard orientation and unsheared condition of the minerals.

TABLE XIX.

TYPICAL METAMORPHIC ROCKS.

STRATIGRAPHIC POSITION	PROBABLE ORIGINAL SEDIMENT	MEDIUM GRADE METAMORPHISM	NO.	HIGH GRADE METAMORPHISM	NO.
Top of Upper Schist Series	Felspathic sandstone Felspathic sandstone	Cordierite-orthoclase quartzite Orthoclase quartzite	145 191		
Above the top marble band and below the quartzite	Impure sandstone Impure sandstone Calcareous shale Shale Calcareous shale	Quartz-biotite schist Knotted quartz-biotite schist Epidote-quartz-actinolite rock Cordierite-biotite hornfels	200 199 319 377	Anorthite-actinolite granulite	137
Above the Blue Marble zone and below the top marble band	Sandy Shale Sandy shale Sandy shale Shale Dolomitic shale Impure dolomitic limestone Arenaceous limestone Impure arenaceous limestone	Biotite schist Biotite schist Quartz-biotite schist Knotted cordierite biotite schist Quartz-cordierite-actinolite schist Bytownite-actinolite granulite	52 108 255 83 76 105	Anorthite-diopside granulite Grossularite-diopside rock	112 116
Immediately above the Blue Marble Zone	Pure limestone Carbonaceous limestone Impure dolomitic limestone Impure dolomitic limestone	Pure marble Graphite marble	134 253	Vesuvianite-diopside rock Grossularite-diopside-wollastonite rock	69 101
Black and dark blue marble on top of the Blue Marble Zone	Ferruginous limestone Impure carbonaceous limestone Impure arenaceous limestone Impure limestone	Ferruginous marble Graphite marble. Quartz-biotite marble Muscovite marble	51 258 260 300		
Top Black Line	Shale	Biotite schist			
Top Blue Marble	Pure limestone Slightly impure limestone Sandy marble Impure dolomitic limestone Dolomitic limestone Impure dolomitic limestone Impure dolomitic limestone Impure dolomitic limestone	Pure marble Orthoclase marble Calcareous granulite Actinolite-biotite granulite Grossularite-fluorite rock Actinolite-diopside rock	252 49 57 80 85 77	Tourmaline-actinolite-diopside rock Actinolite-diopside-anorthite granulite	217 113
Middle Black Line	Calcareous shale	Calcareous biotite schist	249		
Bottom Blue Marble	Pure limestone	Pure marble	47		
Intermediate Marble Zone	Arenaceous limestone Dolomitic limestone	Calcareous quartzite and quartzitic marble Actinolite marble	247 46		

TABLE XIX (continued)

TYPICAL METAMORPHIC ROCKS.

STRATIGRAPHIC POSITION	PROBABLE ORIGINAL SEDIMENT	MEDIUM GRADE METAMORPHISM	NO.	HIGH GRADE METAMORPHISM	NO.
Brown Marble Zone	Arenaceous limestone	Calcareous quartzite	245		
	Impure limestone	Biotite marble	243		
Yellow Marble Zone	Pure limestone	Pure marble	238		
	Arenaceous limestone	Quartzitic marble	240		
	Impure limestone	Biotite marble	232		
	Impure dolomitic limestone	Actinolite-diopside-orthoclase Granulite	291		
	Dolomitic shale			Amphibole-garnet rock	292
Middle Schist Series	Shaly sandstone	Biotite schist	261		
	Dolomitic shale	Actinolite-biotite-orthoclase Rock	73		
	Dolomitic shale	Actinolite-diopside-cordierite Rock	271		
	Impure calcareous nodule	Actinolite-scapolite-epidote garnet nodule (Pseudodiorite)	287		
Lower Marble Series	Arenaceous limestone	Marble	263		
	Impure limestone	Orthoclase-phlogopite marble	264		
	Dolomitic shale	Orthoclase-actinolite-diopside-cordierite rock	389		
Lower Schist Series	Arenaceous shale	Biotite schist	422		
	Arenaceous shale	Tourmaline-muscovite-biotite schist	413		
	Dolomitic shale	Orthoclase-cordierite-biotite-actinolite granulite	282		

TABLE XX

PARTIAL ANALYSES OF MARBLE.

No.	263	243	117
MgO	1.52	5.91	0.69
CaO	48.16	32.40	53.54
TOTAL	49.68	38.31	54.23
TYPE	White Lower Marble	Brown Marble	Blue Upper Marble.
LOCALITY	Brak R.	Brak R.	Western Schist granite contact.

This is an example of strongly selective metamorphism.

The work of solutions in forming amphibole-feldspar rock is illustrated as follows. Selective metamorphism of certain calcareous bands in the schists is common. Rarely, however, irregular masses of amphibole-bearing schist extend into calcareous wall-rock from bands of para-amphibolite. (See photo, Fig. 68). These masses usually have narrow quartz-feldspar-calcite veins in their centres, and the concentration of amphibole decreases away from the veins. This condition is similar to that found at Lough Anure, County Donegal, Ireland, and described by W.S. Pitcher, (Ref. 1950), and suggests that mobile solutions have contributed towards much of the metamorphism in the area.

4) Thermal Metamorphism at the Granite Contact.

A well defined metamorphic zone lies in the schist and marble along the granite contact. The metamorphism is strongly selective, and the main effects are seen in the bands of impure marble, which are altered to coarse grained vesuvianite-diopside rock. (Nos. 69 and 79) (See Map, Fig. 40). Amphibole-garnet rocks are found in the adjacent schists. This metamorphic zone is rarely more than 200 metres wide, and if it is accepted that the granite was injected in the form of a phacolith, the true thickness of this zone would be less than 50 metres.

The constant close spatial relationship between the granite contact and the high grade metamorphic rocks indicates that the metamorphism was caused directly by the beat of the granite. Addition of substance by means of solutions probably took place, because ther was not enough silica in the original limestones to form the calc-silicates.

More rarely, wollastonite and garnet are found, together with diopside or vesuvianite, as metamorphic products of limestone. (Nos. 101, 102).

A dark diopside-garnet skarn rock (Nos. 116 , 224) is developed at the rare places where granite is in direct contact with marble, and forms a selvedge between granite and marble. The garnet is grossularite or andradite. (Nos. 113, 114, 116).

Anorthite and bytownite, products of high grade metamorphism of impure limestone, were found in Nos. 76, 105, 112, 113, 114 and 137. However the presence of epidote and all these specimens indicates that the highest grade had not been attained (Ref. Harker, 1932, page 255).

B) The Granites.

Analyses, modes and norms of the three main granite types are given in Table No. XXI.

The analysis of No. 326 is comparable with two granites analysed by W.P. de Kock, (Ref. 1934, page 97), and No 373 is similar to an average for 40 granodiorites, given by Daly, (Ref. 1933 page 15.)

The analysis of aplitic granite (No. 326) bears some resemblance to an aplite listed by E. Kaiser (Ref. "Die Diamantan-Wuste", Vol. 1. page 304), and is markedly similar, both in analysis and mode to a granite that Coetzee (Ref 1941) states as having caused the metamorphism of a sediment into a granodiorite.

The analysed granites are compared diagrammatically with granites from South West Africa and Namaqualand in Fig. 69.

Field examination of the granites shows a well-defined series, starting with two ages of granodiorites (including No. 100) and quartz diorites. These rocks are intruded by biotite granites (including No. 373). The youngest granitic rocks are aplites (No. 326) and an alkali granite (No. 388).

The quartz diorites and granodiorites are rarely found in contact with the sediments, and are generally separated from them by biotite granite. Microscopically, some of the granodiorites resemble granitised sediments, as they contain poikilitic amphibole crystalloblasts. (No. 210) microperthite (No 313), and the shape of the constituent grains is usually irregular. Some altered sediments found near the biotite granite contact resemble quartz diorites (e.g. No. 80).

Schist "xenoliths" in the older granodiorite are mostly aligned parallel with the schists of the nearest sediments, and thus are possibly skialiths.

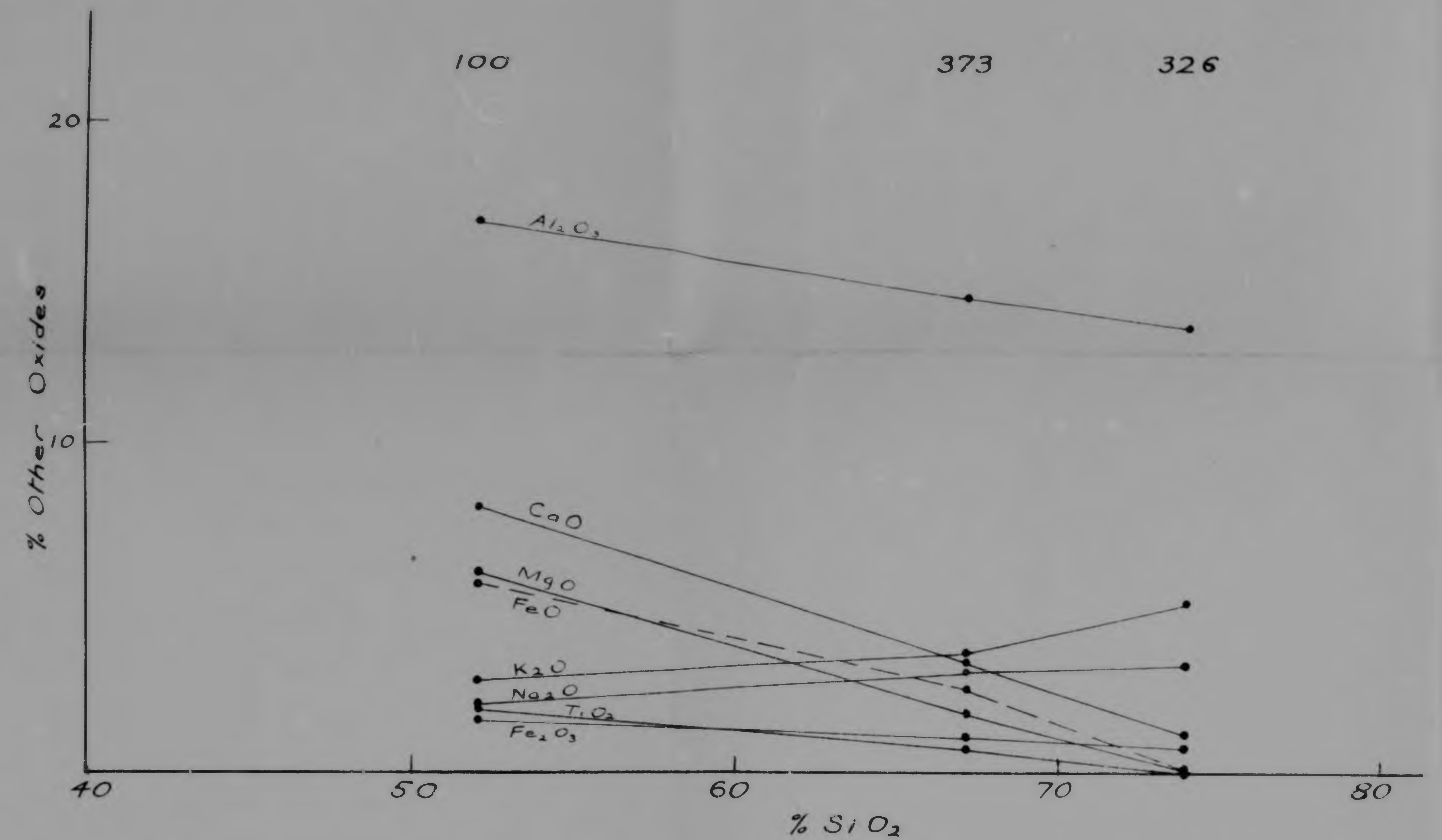
Thus the evidence points towards a metamorphic origin for some of the older granodiorite. However a variation diagram (Fig. 70)

TABLE XXI

ANALYSES, NORMS AND MODES OF GRANITES & DOLERITE.

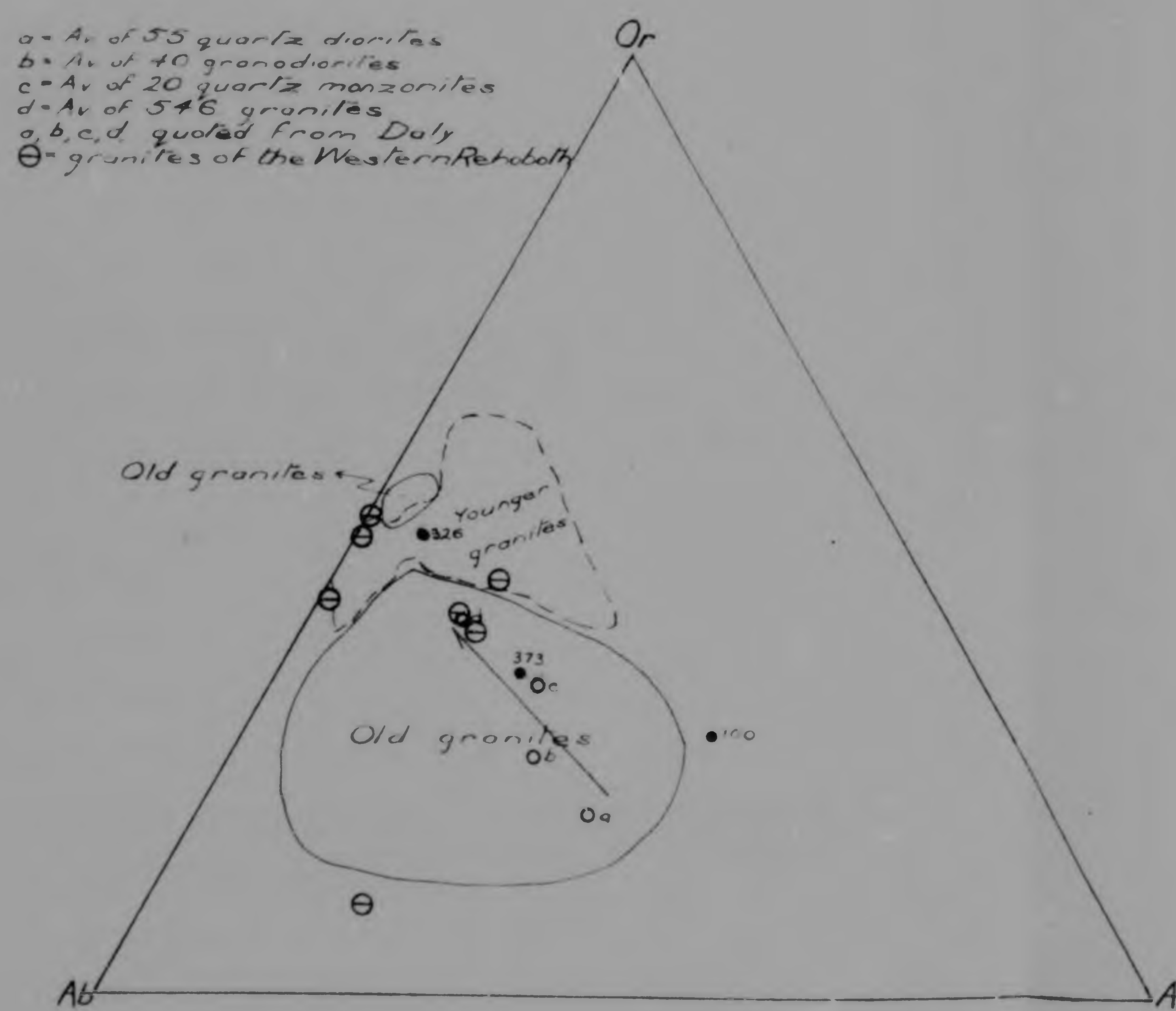
Analyst: C.J. Liebenberg.

No.	326	373	100	359
SiO_2	72.86	67.10	52.05	46.00
Al_2O_3	13.63	14.30	16.95	14.32
Fe_2O_3	0.30	1.11	1.60	6.55
FeO	0.14	2.59	5.75	6.47
MgO	0.08	1.82	6.13	6.36
CaO	1.22	3.40	8.18	12.34
Na_2O	3.36	3.20	2.11	1.70
K_2O	5.25	3.70	2.79	0.50
$+H_2O$	0.40	0.67	1.59	1.72
$-H_2O$	0.12	0.13	0.21	0.28
CO_2	0.60	0.50	0.30	1.44
TiO_2	Trace	0.75	2.00	1.80
P_2O_5	0.03	0.26	0.16	0.24
MnO	0.02	0.07	0.10	0.21
TOTAL	99.51	99.60	99.92	99.93
NORMS:				
or	31.14	21.68	16.68	2.78
ab	28.30	27.25	17.82	14.14
an	3.61	13.90	28.36	30.02
il		2.89	3.80	3.50
cc	0.90	1.10	0.70	3.30
Mg		1.62	2.32	9.51
di			8.28	17.48
hy		7.24	17.25	10.31
Q	32.16	24.42	2.64	5.64
TOTAL	96.11	100.10	97.85	99.68
MODES:				
K-Feldspar	39.8	17.7	0.3	
Plagioclase	23.9	41.8	47.3	45.1
Quartz	34.5	29.9	7.7	
Biotite		10.6	12.6	
Muscovite	1.8			
Amphibole			30.8	
Pyroxene				41.1
Ore, etc.			1.3	13.8
TOTAL	100.0	100.0	100.0	100.0

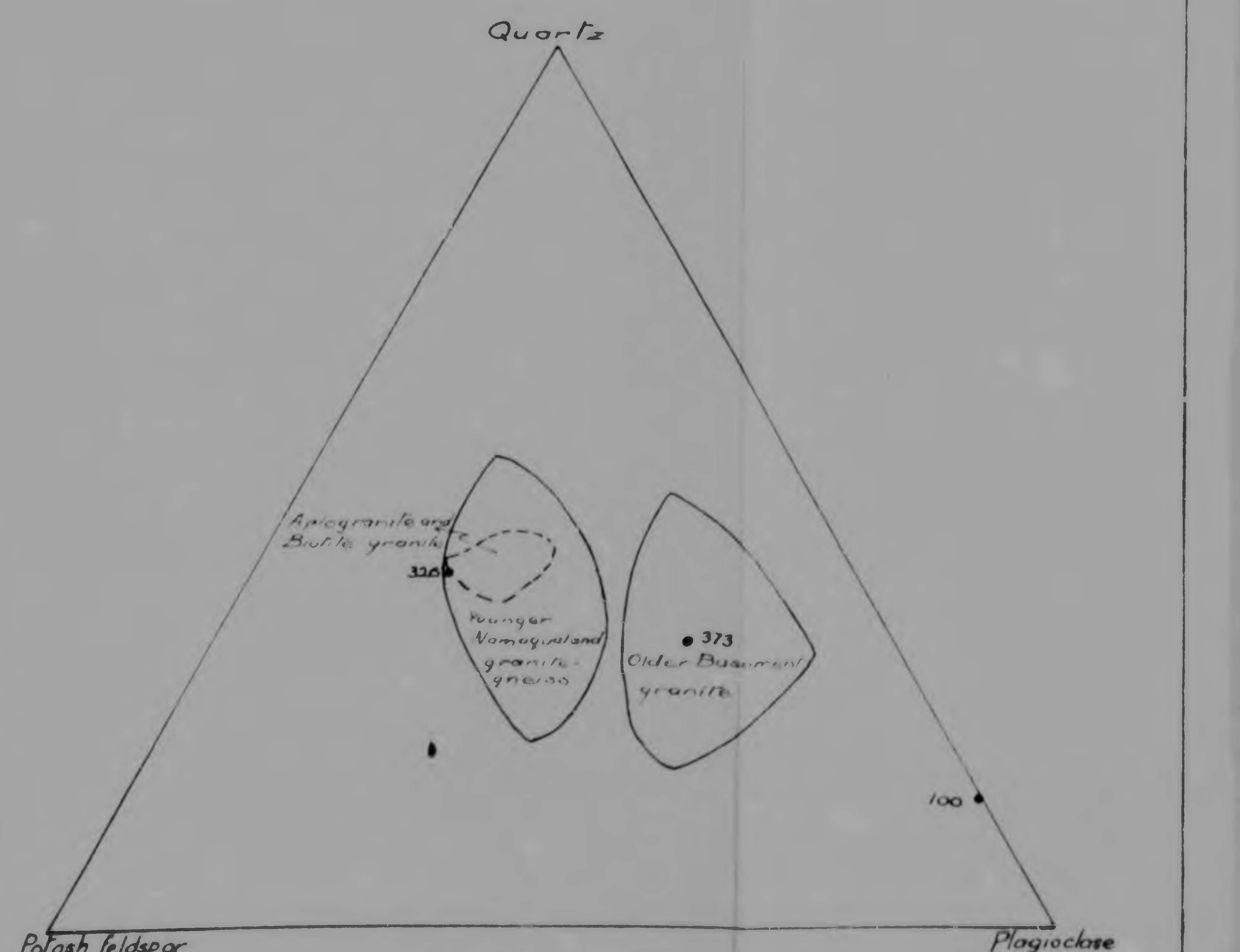


Variation Diagram of granites 100, 373, and 326

Fig. 70.



Norm compositions of granites 326, 373, and 100, compared with granites of South Africa and Western Rehoboth.



Modal variations of the felsic minerals in 326, 373 and 100 compared with the Namaqualand granites.

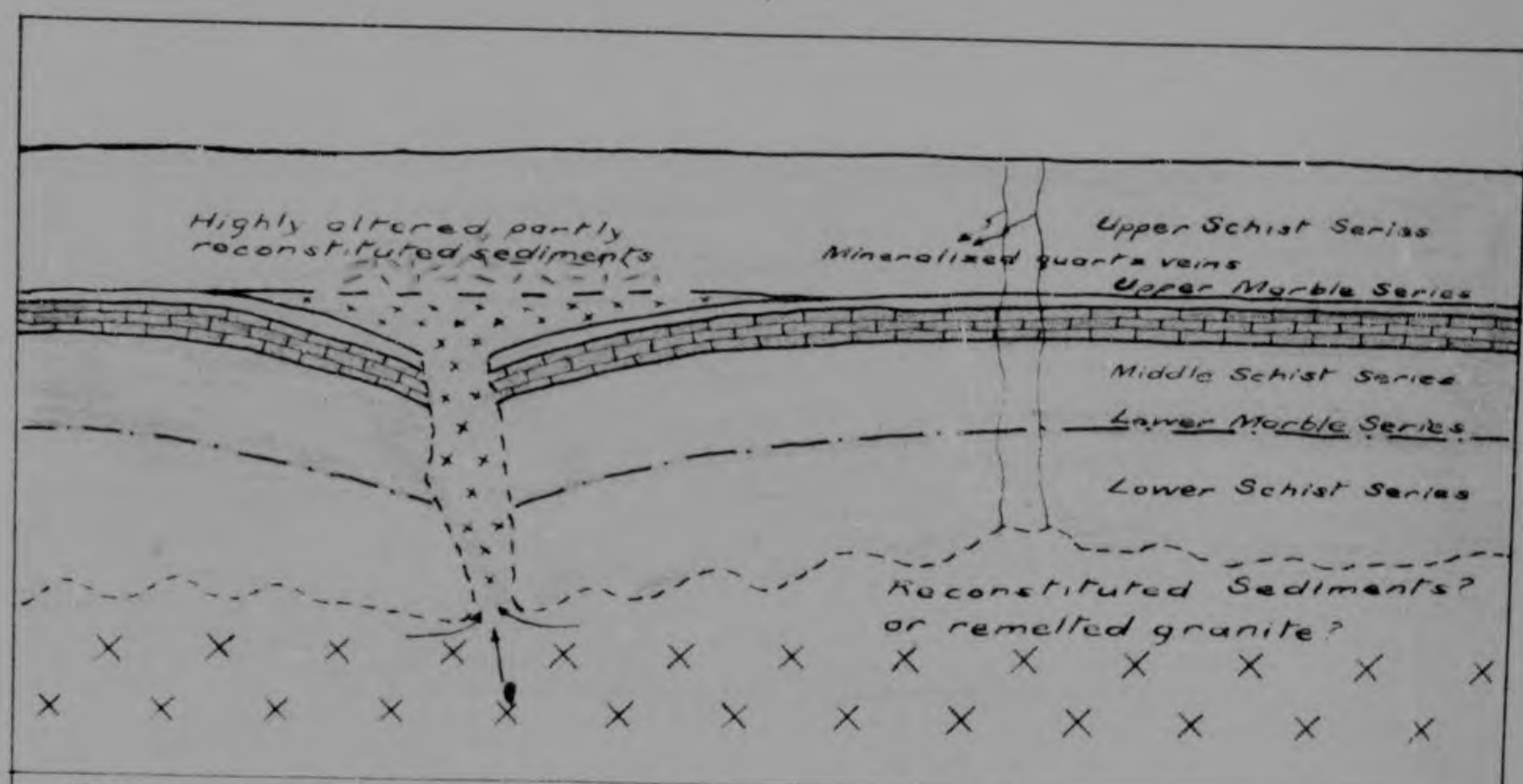
Fig. 69.

of the three analysed granitic rocks shows an almost straight-line relationship between them, indicating that they could all be products of differentiation of one parent magma. Field and microscopic evidence indicates that the younger granodiorites and the biotite granite are subsequent and not synchronous bodies. The intrusive nature of the biotite granite is demonstrated by its relationship to the fold structures of the Damara sediments.

The origin of these younger granites is not known. They are apparently products of differentiation, because they themselves show the effect of differentiation, the three stages represented being increasingly acid.

The biotite granite was the major intrusion, and immediately preceded the more acid aplitic granite, the pegmatites, and most of the quartz veins. The amount of quartz veining in the schists is far greater than that found in the granite, but much of the quartz could have originated in the sediments themselves.

Therefore it seems possible that all the younger granites and pegmatites, and many of the quartz veins, originated in a parent granitic magma at depth. This magma could have been formed either by differentiation of the basic magma at great depth, or by differentiation of granitised sediments at moderate depth. A portion of this magma could have been mobilised and moved upwards along a vertical plane of weakness in the Damara sediments, with the following results: when the Upper Marble horizon had been pierced, the granite silled laterally along strike into the form of a composite phacolith, while the sediments beneath the phacolith slumped downwards, creating space for intrusion. The roof of the phacolith, located over the centre of the highest point of the ascending granite, was supported by the pressure of the granite, and was partially reconstituted into granodiorite and quartz diorite. (See Section, Fig. 71) The assimilation of calcareous rocks could have contributed towards the formation of granodiorite. Present day erosion has exposed mostly the floor contact of the phacolith, and thus there is an irregular strip of biotite granite between the schists and the granodiorite.



Diagrammatic section, parallel with strike, showing possible mode of emplacement of the granite phacolith

Fig. 71.

Where the roof-contact of the phacolith is exposed, the schist is highly altered into biotite hornfels, rarely containing cordierite (No. 377), and is commonly indistinguishable from granodiorite in the hand specimen.

The processes that possibly led to palingensis of the sediments at depth were as follows.

a) Heat was produced by mechanical friction and increase in load, as described under "Regional Metamorphism and Zoning", section (4). This heat must have affected a large amount of material, in spite of the low conductivity of the rocks.

b) Exothermal reactions, one started, supplied more heat.

c) The folding caused the sediments to occupy about one third of their original area, and therefore the present vertical thickness must be about three times the original thickness, the volume remaining the same. If the original thickness of the Damara sediments was 30,000 metres, as is probably the case in the Windhoek district, (Ref. Gevers, 1934, p. 230), then an addition of double this thickness would have caused the mass of sediments to sink to a depth where the basal sediments would be granitised and possibly mobilised, over a large area. Island arc structure and sharp down-warping of the crust, as postulated by Umbgrove, (Ref. 1947) would not be needed in order to bring the sediments into the depths where palingenesis would take place.

The main mass of granite that is now exposed probably ascended later than the solutions which had caused regional zoning.

Summing up, certain factors affecting the granite problem in this area can be evaluated as follows:-

a) Much of the granite is intrusive into the sediments.

b) Peripheral lenses are absent.

c) Contacts are fairly sharp.

d) Pegmatites are comparatively rare, (cf. Uis, Erongo), and aplite dykes occur in amounts almost equal to the pegmatites.

e) Most of the xenoliths are parallel, but some are deoriented.

f) There is a well-defined contact zone.

g) Metamorphic minerals are rare in most of the granitic igneous rocks, but some of the granodiorite microscopically resembles a metamorphic rock.

h). The roof of the phacolith was probably flat.

i) The granite is generally massive, but marginally has directive structures.

j) "Lit-par-lit" injection is absent.

k) Serial differentiation is indicated, with evidence of four injections of magma.

l) Contamination through incorporation of country rock is not general in the biotite granite.

m) The remaining roof portions of the phacolith consist of highly altered schist and granulite, some of which resemble granodiorite.

n) Some of the metamorphic rocks in the area resemble granodiorite.

o) Examples of the work of metasomatism exist throughout the area of Damara sediments.

p) A form of regional zoning exists in the Damara sediments, and possibly indicates the presence of a widespread body of granite at depth.

q) The mineral occurrences of the area suggest the presence of an acid granite at depth.

The above factors suggest that the exposed granite is a subsequent and not synchronous body, that is, it does not consist of sediments granitised in situ. The critera used here are those suggested by Sullivan (Ref. 1946).

Factors which cannot be evaluated are as follows:-

a) The origin of the exposed granite.

b) The position and structure of the southern edge of the phacolith.

c) The total volume of granite intruded, and its original extension and form above the present erosion surface.

d) The depth and origin of the postulated parent magma.

e) The response of the roof of the phacolith to the action of the intruding magma.

f) The method by which the granite ascended.

Further work in the adjoining areas will probably throw some light on b) and f).

C). Aplites, Pegmatites and quartz veins.

As mentioned under "Tectonics", the aplites and pegmatites bear a close structural relationship to the granite contact. They appear to be related to the granite, and probably represent the final acid phase of the granite intrusion. Their consistent composition and mode of emplacement support this view.

Many quartz veins, especially those near the granite contact, are probably genetically related to the granite. Some of those that occur in the sediments away from the granite contact are possibly the result of emanations from the postulated deep granite body that was the parent magma of the exposed granite. The galena, wolframite and cassiterite-bearing quartz veins probably belong to this category. Hydrothermal solutions, originating partly in the deep granite, and partly in the counrty rock, ascended along planes of weakness set up during folding. Much of the water that constituted the hydrothermal solutions could have been derived from the alteration of kaolinitic material to feldspar as suggested by Goodspeed, (Ref. G.E. Goodspeed, page 151).

D) The Karroo Rocks.

1. Metamorphism of the Sediments.

Low grade metamorphism is evident in most of the Karroo sediments. The main cause of this metamorphism is the widespread intrusion of dolerite dykes and sills. Percolating hot waters have produced much alteration. Some of this type of alteration is probably connected with the Stormberg volcanism; the presence of stilbite in an indurated mudstone (No. 363) is attributable to this cause.

The Karroo rocks are all affected by the basic intrusions. All the mudstones and shales are indurated, and the sandstones are quartzitic.

The Karroo hills surrounding the Brandberg show a somewhat higher degree of metamorphism, with spotted and mottled indurated mudstones and shales and highly siliceous quartzites and conglomerates. The Karroo rocks at the Brandberg contact zone show medium to high-grade metamorphism. These rocks have been described by Cloos and Chudoba (Ref. 1931).

2. The Stormberg Lavas.

Although slightly differing varieties of lava occur in the present area, there is no evidence for the differentiation in the lavas that is described elsewhere. (Refs. Du Toit, 1939, Gevers, 1932, Reuning, 1925).

Examination of a section 400 metres thick showed that only basalts and porphyritic basalts were present. The lower, basic portion of the lava flows is probably thicker here than in other areas, and the upper portion has been eroded away.

The numerous amygdaloidal basaltic dykes were possibly feeders of the lava flows. These dykes are commonly cut by dolerites, and are always much more weathered than the dolerites. Many of them strongly resemble the lavas, both microscopically and in the hand specimen.

3. The Karroo Dolerites.

Examples of the Perdekloof and Hangnest type of dolerite dykes, and several picrite dolerites, were found in the area.

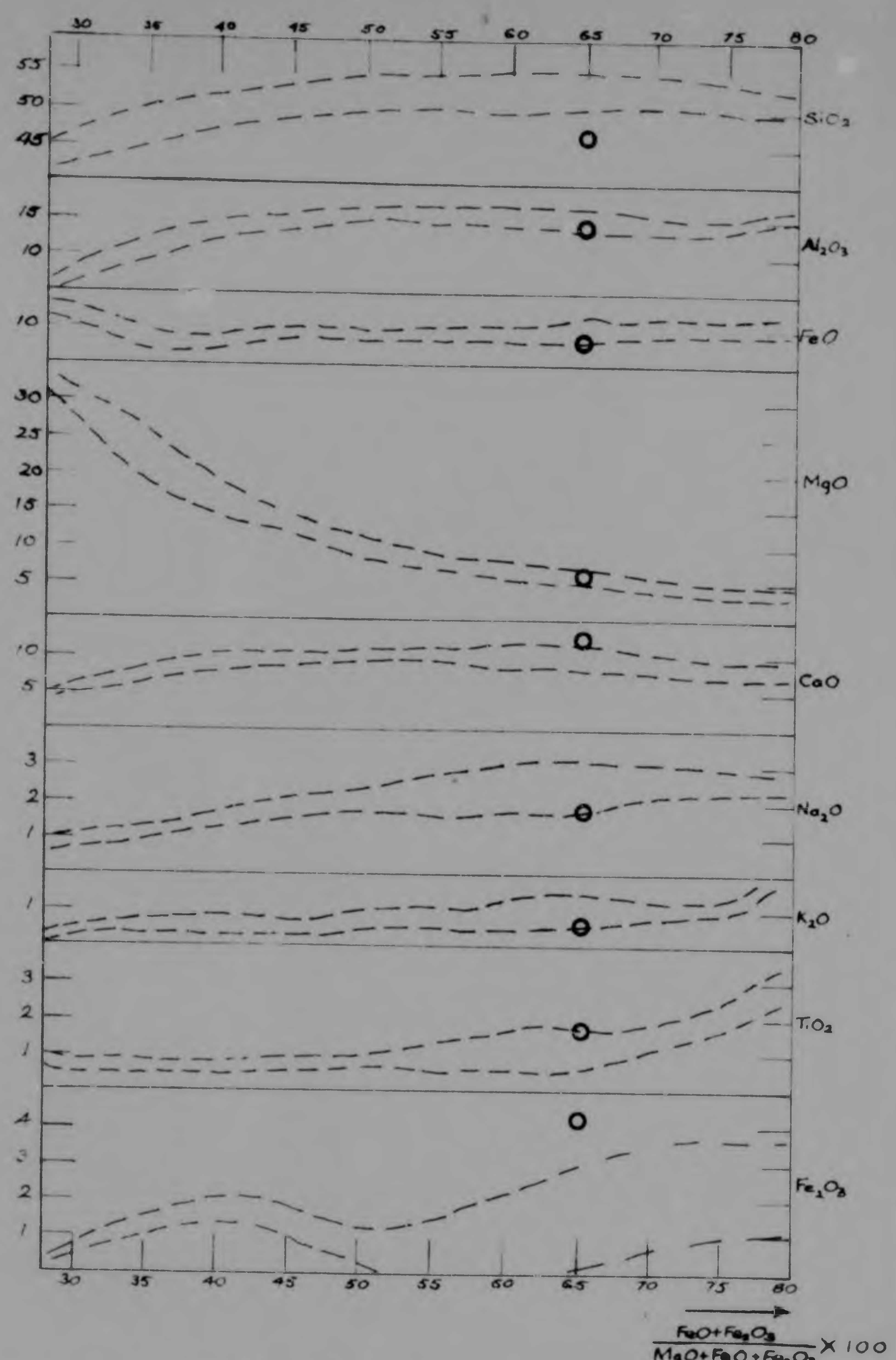
The relationship between the dolerites and the lavas indicates, as in other areas, that both rocks originated from the same magma. (Ref. Walker and Poldervaart, 1949, page 648)

The analysed dolerite, (No. 359, Table XXI and Fig. 72) differs from the average Perdekloof type being richer in Fe_2O_3 and CaO, and poorer in SiO_2 and MgO. The variation from the average is reflected in the modal composition of the rock. Olivine is absent and iron ore is plentiful. Some of the iron ore has evidently been oxidised to haematite. The pyroxene is probably a sub-calcic ferro-augite (see figure 73, after Hess, 1949, page 634) and is of unusual composition for this area. Generally, according to their plotted positions above the course of crystallisation, the pyroxenes of the Karroo dolerites here are probably rich in TiO_2.

In Figure 72, the chemical composition of No. 359 is plotted against the chemical variation diagram of the Karroo magma, (simplified after Walker and Poldervaart, 1949, page 653). With the exception of SiO_2 and FeO_3, the rock falls well within the limits given.

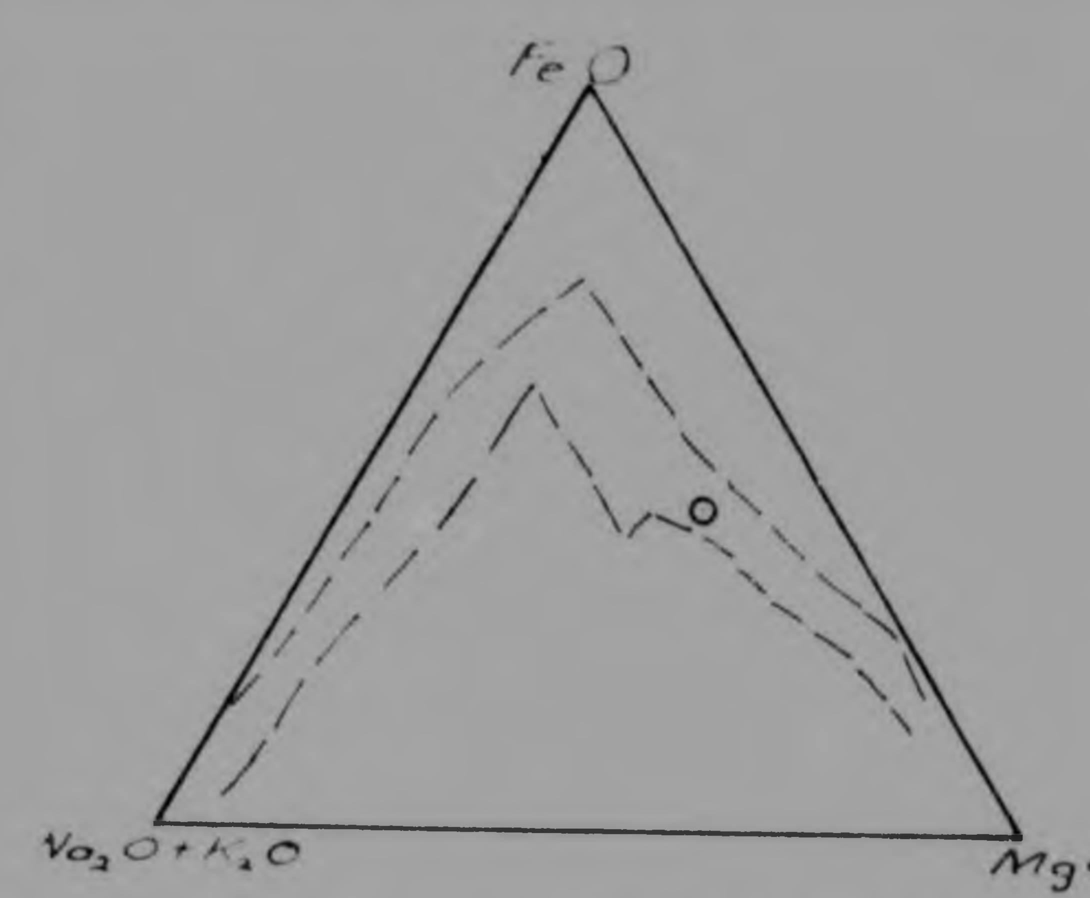
Differentitation in the Karroo Dolerites.

The analysed dolerite (No. 359) is fairly representative of the Perdekloof type dolerites found in the area.



Position of No.359 in the chemical variation of the Karroo Magma

Fig. 72.



Position of No 359 in differentiation trend of Karroo dolerites

Fig. 74.

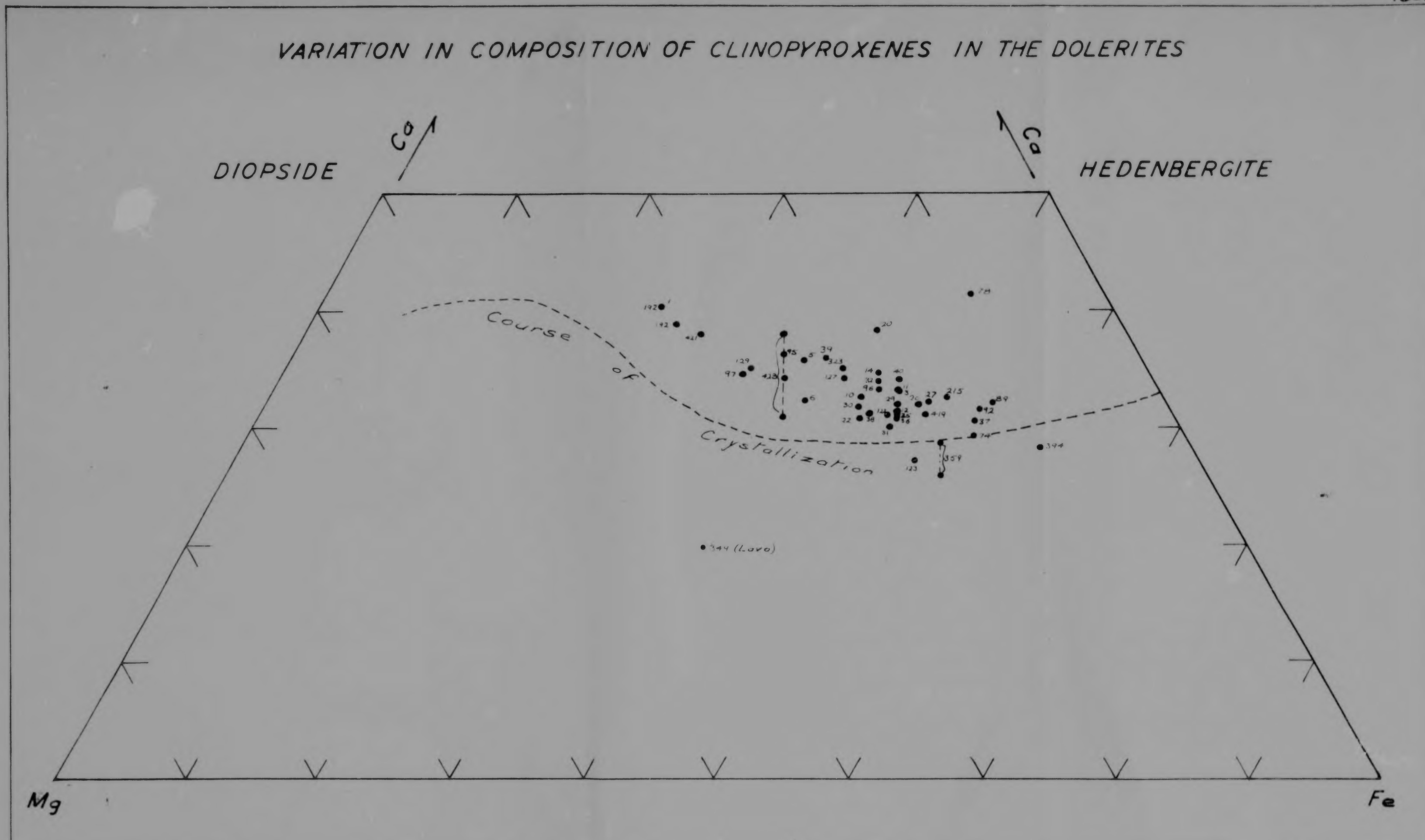

VARIATION IN COMPOSITION OF CLINOPYROXENES IN THE DOLERITES
DIOPSIDE
HEDENBERGITE
Ca
Ca
Course of Crystallization
344 (Lava)
Mg
Fe

Fig. 73.

Plotted on the differentiation trend **diagram** of Karroo dolerites (Fig. 74, simplified from Walker and Poldervaart, 1949, page 657), No. 359 appears to be a comparatively early product of differentiation of the Karroo magma. This is in conformity with the fact that several picrite-dolerites occur in the area. Most of the picrites are apparently early differentiates of large and possibly floored masses of dolerite magma. One example, near the Brandberg, is in the form of an extensive dyke, (No. 192). It is possibly significant that the strike of this dyke is directly in line with the Messum alkali complex. The only occurrence of Hangnest type dolerite (No. 13) was found in a large plug-like body, and it is therefore possible that differentiation processes could have contributed towards the formation of the rock.

It is almost certain that differentiation took place in some of the thick sills that lie near the base of the Karroo beds in the western part of the area. A directive texture can be seen in the plagioclase laths in No. 78, which was taken from one of these sills.

CHAPTER VII.

ECONOMIC GEOLOGY.

Three types of mineral occurrence are found in the area. Tin and tungsten are mined at the Brandberg West Mine, and tin has been mined near the Brandberg, southeast of Kubugabis. Small lead occurrences are found in the Zerissenes Mountains and in the area west of them. None of the lead occurrences have been worked.

A) The Brandberg West Tin-Tungsten Deposit.

1) The Vein Deposit. (See plans, Figs. 75, 76, 77).

The vein deposit consists of a swarm of quartz veins containing coarse cassiterite and wolframite, in an anticline of Lower Schist. The strike of the schist country rock is 25° west of south and the dip is between 35° and 70° to the southeast.

Olivine dolerite dy..s, striking north-south, cut the quartz veins.

a) Structure of the Veins.

Three ages of quartz veins are found in the mineralised area. The oldest veins are emplaced in schist bedding planes, and are somewhat contorted. The veins are lenticular, a few metres in length, and up to 15 cm. thick. The quartz is milky to grayish and contains muscovite. In the mineralised area they contain little cassiterite and probably no wolframite. Ten of the veins were sampled in the .dit, and averaged 0.17% Sn. WO_3 was found only in traces. In the areas sampled, the average tin content of 36 quartz veins, younger then the quartz-mica veins, was 0.62% and the average WO_3 content was 0.48%. Wall-rock alteration by the older veins is not noticeable.

The later generation of quartz is the main bearer of economic minerals. These veins occur in the form of a swarm, the main mass of which occupies an area of 250 metres by 350 metres adjoining No. 3 stream bed. (See plan, Fig. 75). The veins are lenticular, pinching and swelling, and they strike at about 70° west of true north, and d.. towards the north-east at angles between 70° and 80°.

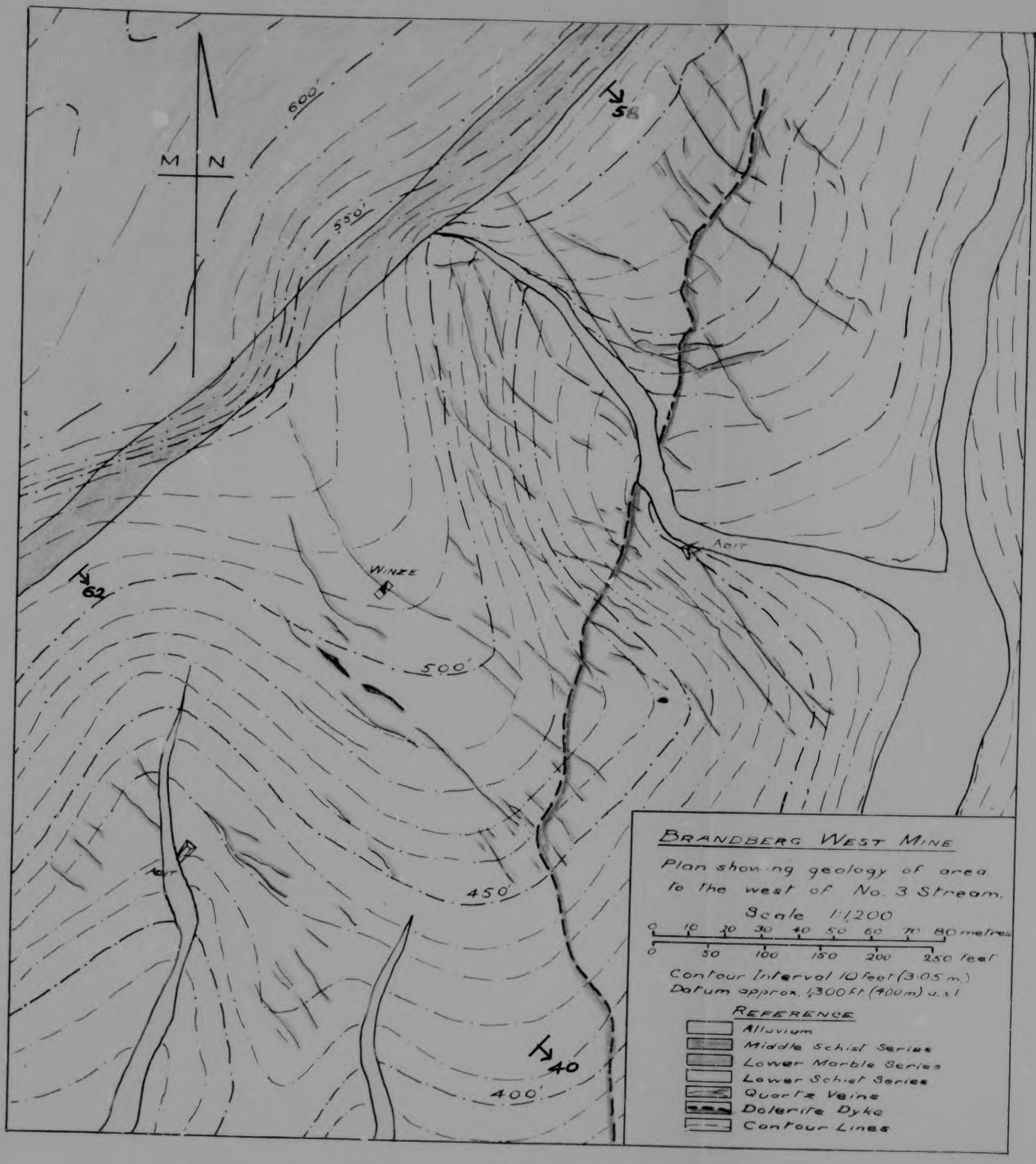
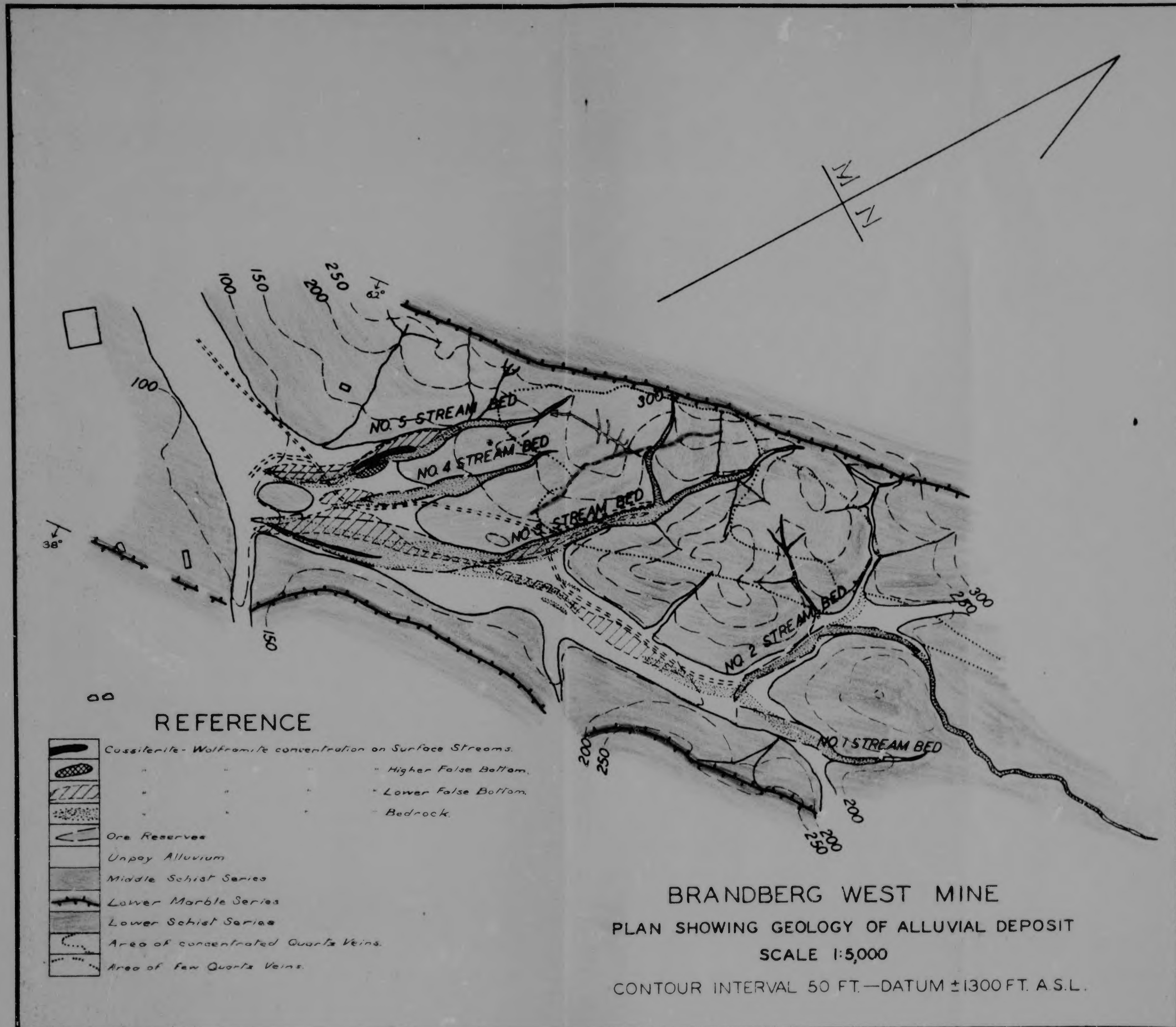

M N
600'
550'
500'
450'
400'
58
62
40
WINZE
ADIT
BRANDBERG WEST MINE
Plan showing geology of area to the west of No. 3 Stream.
Scale 1:1,200
0 10 20 30 40 50 60 70 80 metres
0 50 100 150 200 250 feet
Contour Interval 10 feet (3·05 m.)
Datum approx. 1,300 ft (400 m) a.s.l
REFERENCE
Alluvium
Middle Schist Series
Lower Marble Series
Lower Schist Series
Quartz Veins
Dolerite Dyke
Contour Lines

Fig. 75.



N
M
100
150
200
250
82°
38°
300
NO. 5 STREAM BED
NO. 4 STREAM BED
NO. 3 STREAM BED
NO. 2 STREAM BED
NO. 1 STREAM BED
REFERENCE
Cassiterite - Wolframite concentration on Surface Streams.
" " " " Higher False Bottom.
" " " " Lower False Bottom.
" " " " Bedrock.
Ore Reserves
Unpay Alluvium
Middle Schist Series
Lower Marble Series
Lower Schist Series
Area of concentrated Quartz Veins.
Area of few Quartz Veins.
BRANDBERG WEST MINE
PLAN SHOWING GEOLOGY OF ALLUVIAL DEPOSIT
SCALE 1:5,000
CONTOUR INTERVAL 50 FT.—DATUM ±1300 FT. A.S.L.

Fig. 77.

Their thickness varies from 0.3 cm to 1.3. metres, and they range from a few metres to 60 metres in length.

The swarm of veins is bounded to the northwest by the Lower Marble Band, and occupies a position about the axial plane of the anticline.

The individual veins are not straight, but follow curved paths, both small and large scale. (See underground plan, Fig. 76, and surface plan, Fig. 75). The undisturbed condition of the schist indicates that the curving of the quartz veins is inherent, and not caused by the folding after the veins had been emplaced. These veins constitute 10.3% of the total rock exposed in the adit. Dolerite accounts for 4%, and the quartz-mica veins for 2% of the total. Biotite schist and some calcareous bands constitute 84% of the total. Some rare narrow flat-lying veins found in the adit contain much iron oxide and occasionally, concentrations of cassiterite. The age of these veins relative to the quartz veins is unknown.

Another unusual type of vein is found near the southern end of the adit, where a few narrow tension cracks are filled with an aggregate of schorl, garnet, quartz, and a little cassiterite.

In the area of the Brandberg West Mine, the tin-tungsten mineralisation extends for about 800 metres along strike. To the southwest, along strike, two more areas of tin-tungsten mineralization have been found, 8 and 16 km from the Brandberg West Mine. (Fig. 27). In these areas the mineral occurrences follow the same pattern as at Brandberg West Mine, but only on a smaller scale. As mentioned above, under Geology, this type of high temperature quartz-tourmaline vein is found throughout the area, but seldom carries economic minerals.

General views of the mine workings, taken from the Lower Marble outcrop between stream 3 and stream 4, are shown in Figs. 78 and 79.

b) The Ore-Minerals.

In the later quartz veins brown cassiterite and wolframite occur in isolated patches, often coarse-grained.

Crystals of wolframite with faces 10 cm. in diameter, and masses of cassiterite up to 10 kg. in weight, have been found in the underground workings and in the alluvial deposits. Scheelite is found rarely occupying cracks in wolframite and as rare greenish crystals in the quartz veins. On analysis, one of these crystals was found to contain 64.0% WO_3, 0.23% MO_3 and 9% Cu.

A specimen of wolframite assayed 70.60% WO_3, 8.05% MnO, and 13.40% FeO.

The occurrence of the minerals within the quartz veins appears to be haphazard, and is not controlled by the attitude or thickness of the veins. In spite of the coarseness of the grain, the minerals are fairly evenly distributed throughout the veins. Panning of samples of wall-rock indicates that the wall-rock is barren of ore minerals.

c) The Country Rock.

Schist:

The predominating country rock is a quartz-biotite schist, which has undergone considerable alteration at the quartz vein contacts. The thickness of wall-rock altered is roughly proportional to the thickness of the veins, and for a 30 cm. vein, is about 7.5 cm on either side of the vein. The mineralogical composition of specimens of unaltered and altered schist is given in the table below:

TABLE XXII.

LOWER SCHIST COUNTRY ROCK AT BRANDBERG WEST MINE.

Specimen No.	Where taken	% Quartz	% Biotite	% Muscovite	% Tourmaline	% Iron Ore	Extras
417	Away from quartz veins	40	55	5			
429	Unaltered schist from dump	50	50				Rare Fluorite
404	Quartz vein contact	30			70	Some	Malachite specks
409	"	20			70	10	
413	"	25	5	40	25	5	
414	"	35		10	50	5	

The tourmaline, which is in the form of schorl, gives the altered wall-rock a black "baked" appearance. The tourmaline crystals are oriented perpendicular to the plane of the vein, and their contact with the unaltered schist is usually sharp. On surface the resistance to weathering of the schorl is shown by "walls" of vein quartz frozen to enclosing slabs of schorl, the whole standing well above the surrounding schist. The prominence of these outcrops and the fact that they are often copper stained and contain large crystals of the ore minerals, would have led to an early discovery of the deposit had the district not been so difficult of access.

Calcareous Beds.

A narrow brown marble band occurs in the Lower Schist anticline, some 80 metres below the Lower Marble Band, and has been cut by mineralised quartz veins.

One such intersection is seen near the small kopje lying to the east of the head of No. 3 Stream. At the contact, tourmaline, iron oxides and well-crystallised brown cassiterite occur. (No. 409). The country rock is a brown finegrained marble, containing biotite, muscovite, a little epidote and some ore and quartz. (No. 403).

Lower Marble.

A mineralised vein in the Lower Marble Band to the northwest of the winze shows a mineralogical composition similar to the altered schist wall-rock. 80% of the rock consists of a parallel arrangement of brown tourmaline crystals, and the remainder is quartz. A few grains of fluorite are present, and there are rare grains of cassiterite.

d) Petrography and Mineralogy.

An outline of the petrography and mineralogy is given below.

i) The Quartz-mica veins.

Macroscopic: The thicker veins have a core of quartz, containing some muscovite and a concentration of muscovite on each side of the core. The muscovite is usually in the form of elongated plates or small books, the plates standing perpendicular to the plane of the veins.

In thinner veins (less than 4 cm thick) the quartz core is absent, but there is a central line that appears to bisect the mica-quartz intergrowth.

No cassiterite was seen in the hand specimens.

Microscopic. A mosaic of interlocking quartz grains, with grains up to 6 mm in diameter. Muscovite occurs in smaller flakes. No cassiterite was seen.

ii) The quartz-tourmaline veins.

Macroscopic. White, somewhat milky quartz, with scattered patches up to 15 cm. in diameter of crystalline cassiterite and wolframite, and rarely some feldspar and muscovite. Rare patches of pale olive-green crystalline scheelite. Some of the wolframite is partly altered to haematite, and to scheelite along cracks. The cassiterite is usually dark brown and translucent, and is rarely transparent. Light brown and almost white cassiterite has been found.

Microscopic. The quartz occurs as a mosaic of interlocking grains, with grains up to five mm in diameter.

iii) The Country Rocks.

The Schist (Nos. 417, 429)

The composition of the schists as seen from microscopic examination has been tabulated above. The schistosity is marked and is parallel with the bedding. Rare, elongated grains of fluorite lie parallel with the direction of schistosity. Normally, tourmaline is absent. Muscovite is present as scattered flakes.

The Altered Schist (See above table.)
(Nos 404, 409, 413, 414).

In the schist adjoining the younger quartz veins, biotite is rare or absent. Muscovite is more common than in the unaltered schist. The schistosity is usually destroyed, but was found to persist in one specimen. (No. 409). The quartz content is fairly constant, and tourmaline, sometimes with biotite, constitutes the remainder of the rock. Ore is present in small amounts.

The Brown Marble (No. 407)

The groundmass consists of interlocking grains of calcite, mostly small, with a few larger grains up to 0.5 mm. Rare grains of epidote are found in the groundmass, and in a veinlet.

Scattered flakes of muscovite, biotite, ore and quartz occur in the calcite groundmass.

The Lower Marble Band.

This is the same as that described under "General Geology".

The basic Dykes.

No. 419. Olivine dolerite.

Plagioclase is andesine.

The olivine is nearly all altered to greenish yellow serpentine.

The augite is in sub-ophitic grains.

Magnetite and limonite occur as accessories.

No. 421 Olivine dolerite.

The olivine is mostly unaltered.

No. 423. Olivine dolerite.

Similar to 419, but containing less olivine. All the olivine present is highly altered.

e) Sampling.

General: The main object of the underground development at the Brandberg West Mine was to evaluate the mineral content of the quartz veins. Additional objects were to investigate the structure and quantity of the veins and to prove the continuity of values with depth.

The winze was put down in 1946, and benches were cut into the eastern side of the hill. Encouraging values found during these excavations led to the development of the adit through the hill and to the driving and raising on the reefs. Channel samples were taken of most of the veins in the adit and the drives. A tabulation of the results is given below. (Tables XXIII, XXIV, XXV).

High values have been cut to 3.0% Sn and 3.0% WO_3.

Thicknesses are given in inches.

TABLE XX111.

VALUES IN REEFS OVER 0.3% (Sn + WO_3) AT BRANDBERG WEST MINE.

Reef No.	Reef thick -ness (t) in inches.	% Sn (a)	(a xt)	% WO_3 (b)	(b x t)
2'	15	0.39	5.10	0	0.0
	36	0.08	2.88	0.4	14.4
	24	1.78	42.72	0.2	4.8
	29	0.35	10.15	0.5	14.5
	24	0.02	0.48	2.3	55.2
88'	13	1.93	25.09	T	0.0
	14	0.08	1.12	2.3	32.2
102'	24	0.44	10.56	0.6	14.4
	24	0.65	15.60	0.3	7.2
	12	2.81	33.72	2.8	33.6
	8	0.16	1.28	0.5	4.0
	14	0.62	8.68	0.1	1.4
	24	0.48	11.52	0.2	4.8
	6	0.55	3.30	0.3	1.8
Quartz-Mica	24	0.62	14.88	T	0.0
vein	29	0.16	4.64	0.3	8.7
	10	0.60	6.00	T	0.0.
	8	0.31	2.48	0.4	3.2
	10	0.48	4.80	0	0.0.
	9	1.07	9.63	0.3	2.7
	5	0.36	1.80	0.5	2.5
	7	2.80	19.60	0.3	2.1
	10	0.11	1.10	0.2	2.0
	11	0.60	6.60	0.6	6.6
	36	1.27	45.72	0.2	7.2
	12	2.13	25.56	0.4	4.8
	16	0.37	5.92	3.0	48.0
	26	0.55	14.30	0	0.0
Totals & Averages. Av.	480" = 40ft. 17.2"	0.70%	335.23	0.58%	276.1

TABLE XXIV

VALUES IN REEFS UNDER 0.3% ($Sn + WO_3$) AT BRANDBERG WEST MINES.

	Reef thickness (+)	%Sn (a)	(a x t)	%WO_3 (b)	(b x t)
	8	0.11	.88	0	0
	36	0.11	3.96	0	0
	36	0.08	2.88	T	0
	36	0.11	3.96	0.1	3.6
	14	0.17	2.38	0	0
	4	0.06	0.24	0	0
	18	0.07	1.26	0	0
QM	24	0.07	1.68	T	0
QM	17	0.06	1.02	T	0
	7	0.08	0.56	0	0
QM	10	0.14	1.40	0	0
	3	0.07	0.21	0	0
QM	36	0.25	9.00	T	0
QM	12	0.14	1.68	T	0
	12	0.08	0.96	0	0
Av. / Total	18.2" / 273"	0.12%	32.07	0.01%	3.6
From Table XX111	480"	0.70%	33523	0.58%	2761
Grand Total / Av. 17.5"	753"	0.49%	36730	0.37%	2797

QM = Quartz - Mica vein

TABLE XXV

AVERAGED VALUES OF REEFS IN DRIVES AT BRANDBERG WEST MINE.

Drive No.	Av. Reef thickness in inches	No. of Samples	Av. Sn%	Av. WO_3%
88' Dr. West	6.3	3	0.72	0.02
102' Dr. West	22.7	10	0.41	0.72
137' Dr. West	14.3	13	0.46	0.79
137' Dr. East	24.0	15	0.73	0.33
195' Dr. West	16.4	19	0.96	1.00
195' Dr. East	14.9	9	0.50	0.42
242' Dr. West	21.5	12	0.34	0.25
242' Dr. East	11.9	7	1.26	0.53
Totals and Averages	17.9	88	0.63	0.56

In the adit, the average of all reefs is 0.49% and 0.37% WO3 over 17.5".

Excluding all reefs below 0.3% (Sn + WO_3), 28 reefs average 0.70% Sn and 0.58% WO_3 over 17.2".

The remaining 15 reefs average 0.12% and 0.01% WO_3 over 18.2".

In 495 feet of driving, 356 feet were on four of the reefs and averaged 0.63% Sn and 0.56% WO_3 over 17.9".

For the whole mineralised body in the area sampled, the average values of reef running at more than 0.3% (Sn + WO_3) would be 0.66% Sn and 0.57% WO_3, i.e. a ratio of 54 Sn to 46 WO_3.

f) Ore Reserves.

Total rock in the mineralised area above adit level (taking 14.03 cu. feet per short ton) = 1,560,000 short tons. 43 reefs, of which 28 contain 0.3% (Sn + WO_3)

Total reef thickness of 28 reefs = 480", or 7.5% of length of adit.

Threfore 7.5% of total = ore reserves.

= 117,000 short tons over 0.3% (Sn + WO_3)

According to assay values, the Sn - WO_3 ration is 54:46.

Assuming that the concentrate produced has 70% (Sn + WO_3), and that the recovery is 65% for each, the ore reserves contain 1332 tons of concentrates at 37.8% Sn and 32.2% WO_3, or 503 tons Sn and 429 tons of WO_3.

g) Costs.

One long ton of mixed concentrate is composed of 0.378 tons Sn and 0.322 tons of WO_3.

0.378 long tons Sn at £500 p.t. = £189.

0.322 long tons WO_3 of which 85% or 0.2737 long tons are recoverable in a 65% WO_3 concentrate.

= 0.421 long tons concentrate at £5 per unit = £136.825.

Therefore total from one long ton mixed concentrate = £325.825

" " " 1 short " " " = £290.911

Estimated cost per short ton to mill is 37.13/-

Therefore allowing for 65% recovery of $Sn + WO_3$ in a 70% concentrate, the weight of $Sn + WO_3$ in 100 tons of ore to cover cost of production is:-

$$\frac{37.3}{20} \times \frac{100}{} \times \frac{100}{65} \times \frac{70}{100} \quad \frac{1}{290.911} = 0.69\%$$

The above figures are based on the metal prices that existed in 1949. Since then prices have risen considerably and the pay limit is now probably lower than 0.69%.

h) Mining.

The individual veins are too closely spaced and too irregular to permit mining by underground stoping. Down to adit level, conditions are ideal for opencast mining. The adit is suitable for use as a tramming way, requiring only boxholes connecting with a surface cutting. The quartz veins have a fairly good "parting" from the schist, and by limiting drilling to the schist, fines would be kept at a minimum. Most of the waste can be sorted before the ore reaches the mill.

i) Reduction Plant.

The reduction plant that the South West Africa Co. proposed to instal consists of a primary crusher, a ball mill, a rake classifier and three sand and two slimes tables. This plant is designed to treat 50 tons of ore per day. Water is to be piped 4 miles from the Ugab River, with a lift of about 400 feet.

The installation of a magnetic separator has been considered owing to high costs of wolframite-cassiterite separation in the Union.

A "Cyclone" type of heavy medium separator would probably be a useful addition to the above plant.

2) The Alluvial Deposits (Plan, Fig. 77)

a) Historical. The alluvial tin-tungsten deposits at Brandberg West were first sampled in 1945. Although more than 160 miles from rail, the deposits were found to be well worth exploiting. The production of cassiterite-wolframite concentrate started on the 7th May 1946, and from that date until the end of 1949, 410 short tons of concentrates were produced, averaging about 70% ($Sn + WO_3$) in the proportion of 56% Sn to 14% WO_3.

At first only cassiterite was produced, there being no sale for mixed concentrates.

Later, in 1946, a magnetic separation plant became available in the Union, and the cassiterite-wolframite concentrate became saleable.

The ore reserves at the beginning of 1950 were 46, 171 short tons containing 0.284% tin-wolframite concentrates, or about 137 short tons. This amount of concentrate would normally be produced in about 14 months.

b) The Main Deposits (Plan, Fig. 77)

i) Geology of the Alluvial Deposits.

The main alluvial deposit lies in five dry stream beds in the area of quartz vein mineralisation described above. The stream beds lead into a tributary of the Zebra River. (See photo, Fig 78).

Fifty-two exploratory trenches were put down in the stream beds, and sampling results disclosed that there have been at least three periods of concentration of heavy minerals, (see plan, Fig. 77 and section Fig. 33). A much older period of alluvial concentration is indicated by the raised gravels downstream from the alluvial deposits, where traces of tin have been found in a gravel bed lying on the east bank of the Zebra River, about 15 metres above present river level.

The material filling the stream beds is generally subangular, badly sorted, and not far from its position of origin. The "shoots" of gravel rich in cassiterite and wolframite are usually better sorted, and contain well rounded pebbles. They are rarely cemented, whereas cemented barren rubble is plentiful, and has been found underlying rich alluvial ore or cut into by gravels containing ore.

In the ore shoots, the richest gravel is always confined to the lower part of the shoot, which may rest on bedrock, cemented rubble or uncemented rubble. The richer ground, which contained up to 15% cassiterite and wolframite, over a layer 30 cm thick in parts of No. 3 stream, is coloured reddish brown, and there is usually a rapid transition to the paler brown overburden.

The probable history of deposition of these gravels is given under "Geomorphology".

ii) Composition of the Gravel.

The waste material is composed of -

a) Schist pebbles, cobbles, and boulders, up to 0.6 m in diameter and mostly subangular to rounded.

b) Vein quartz, up to 0.3 metres diameter, rarely carrying ore minerals.

c) Rarely dolerite boulders.

d) A matrix decomposed schist and finegrained quartz grains.

The heavy minerals consists of:-

a) Cassiterite, varying in size from dust to rounded crystals up to 10 cm in diameter. Pebbles 5 cm in diameter, and rare boulders up to 15 cm in diameter.

b) Wolframite, varying in size from dust to rounded crystals up to 10 cm in diameter.

c) Small particles of iron oxides.

The ore minerals, if fine-grained are usually free from quartz particles. The coarser ore particles (more than 2.5 cm diameter) contain small pieces of vein quartz.

The average proportions of various sizes of recovered concentrate are as follows:

Screen size:	+1"	+¾"-1"	+3/16"-¾"	+1/8"-3/16"	+1/16"-1/8"	+1mm-1/16"	-1mm
% Concentrate	13	9	23	24	13	10	8

Total 100

The following table shows the proportion of the various screen sizes of - ¾" alluvial ore, and the amount of concentrate obtained from each size:-

TABLE XXVI.

PROPORTIONS OF ORE AND CONCENTRATES AT NO. 3. STREAM BRANDBERG WEST MINE.

Size.	Ore	Concentrates			Minerals	
	% weight	% weight	% in each size	% of total ore	%Cass	% Wolf
+3/16"-¾"	25.20	29	4.62	1.16	66	34
+⅛"-3/16"	24.15	31	4.87	1.17	79	21
+1/16"-⅛"	11.38	17	5.82	0.66	98.75	1.25
+1mm-1/16"	8.27	13	6.12	0.51		
-1mm	30.00	10	1.29	0.39		
	100	100		3.89		

The above figures were obtained from experimental sampling and from production in No. 3 Stream. In the experiments on the proportions of various screen sizes in the or , 28.6 kgs of average ore was used. The figures for the concentrat resulted from experiments invloving quantities of concentrate varying from 308 kgs to 4,416 kgs.

The proportion of minerals were found by hand-picking 40 kgs of clear concentrate.

The above figures are given in graphical form in a histogram, Figure 81.

iii) Sampling Methods.

Sampling was carried out by winnowing weighed quantities of ore. Local Damara tribesmen are experts at winnowing, using a wooden dish or "skottel", similar to the Australian "Yandi". (Ref. Simpson, 1948) This method of winnowing is of prehistoric origin, its original use having been for the preparation and cleaning of cereal foods. Developed undependently in primitive countries, it is used today in dry parts of Australia, South West Africa, Burma and Central Africa for the prospecting and production of the rare heavy minerals such as gold, tantalite, cassiterite, and wolframite.

The"skottel", as used at Brandberg West is an elliptical wooden dish, about 75 cm inches long by 22 cm wide, and 5 cm deep. The skottel is filled about two-thirds full with ore, and is held by the operator with two hands, one at each end. Four movements are used in obtaining concentrates from the ore. The effects of the movement are as follows:

1) Size grading and separation of the heavy minerals. The lighter and coarser particles move to the left end of the skottel, and the heavier particles sink to the bottom in the right half of the skottel with the finer heavy particles to the extreme right.

2) Separation of the light from the heavy particles, and removal of excess fines. This moves most of the light material towards the left, and towards the operator. Very fine material is blown away. The heavy material is moved to the right and away from the operator.

3) Winnowing. The light material, with a little of the heavy material, is thrown into the air so that the wind blows the light grains away, allowing heavy grains to fall into the skottel.

4) For concentrating fine-grained heavy material. The skottel is held at an angle, right side down, and the heavy material moves to the right.

The principles underlying the action of the skottel are obscure. The "sizing" effect, (1. above) is probably analogous to that occurring in a Hardinge ball-mill. The concentration of heavy minerals at the bottom of the skottel is probably due to deflation of the surrounding light particles, the whole acting rather like a heavy liquid because of the continual motion. But certain refinements of the method, such as No. 4., do not seem to allow of explanation by any of the few stated principles applying to dry concentration.

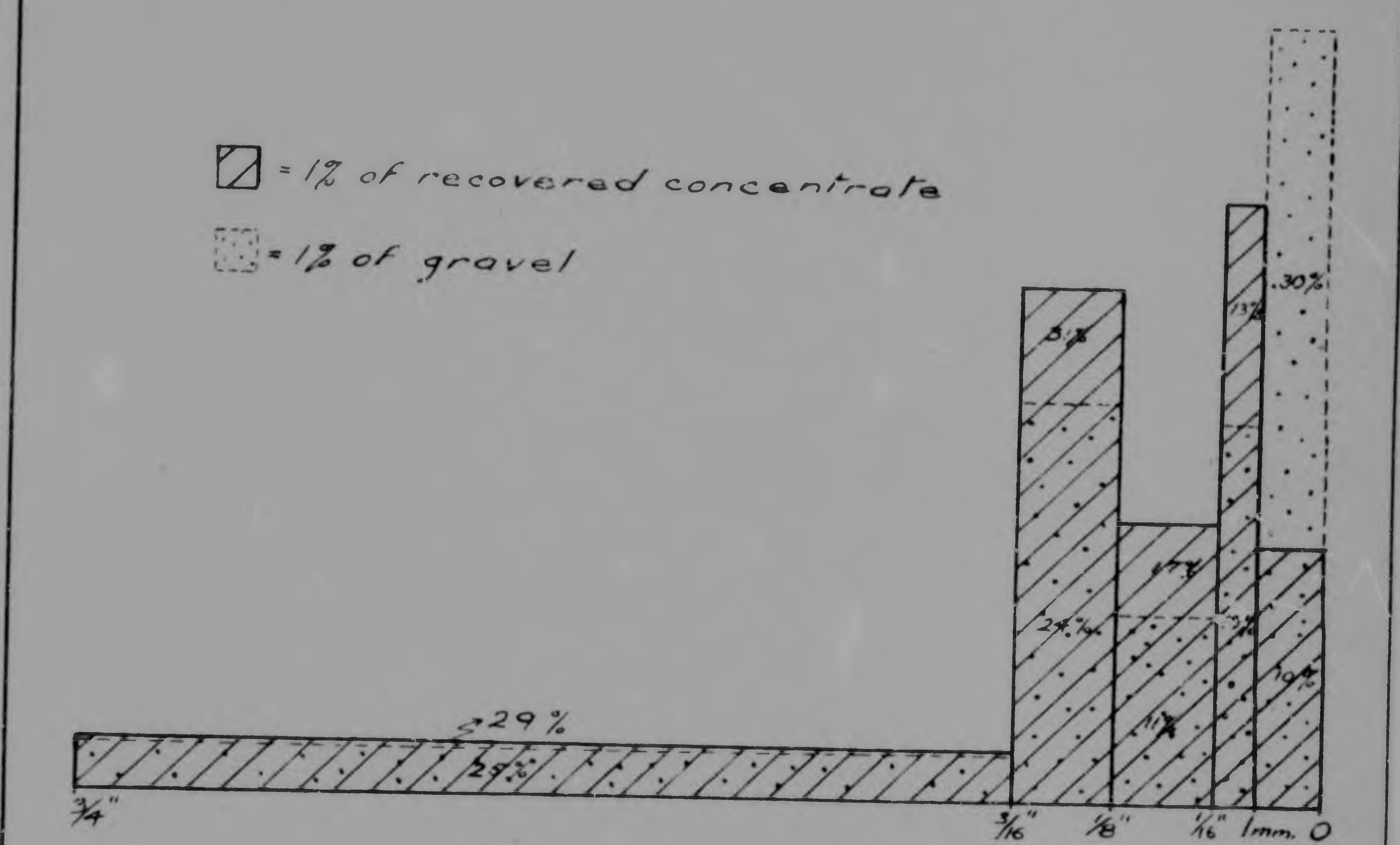
Tests showed a recovery of 75% - 80%, using the skottel, but this factor cannot be relied upon owing to the differences of skill in the operators.

Recovery was found to be more efficient when low concentrations of heavy mineral were present, than when the concentration was high. The average amount of ore skottled by one worker per 9 hour day was found to be 320 kgs, or about 5.3 cu. feet. This result was obtained from the results of 200 man-days, working on -¾", +1mm gravel which produced an average of 5.0% heavy minerals.

The concentrates require further cleaning which is also carried out with the skottel, and produces good results. One shipment of concentrates cleaned in this way assayed 71.6% (Sn + WO_3) and in an adjoining tin area which is free from wolframite, one shipment assayed 73% Sn. The average shipment assays about 70% (Sn + WO_3).

iv) Mining.

After initial trenching and sampling had been done, early in 1946, it was decided to discard all -1mm material, and to handpick the +¾" material. As shown in Table XXVI and the histogram, Fig. 81, the-1mm material constitutes 30% of the total -¾" ore, but contains only 10% of the total recoverable -¾" cassiterite and wolframite.



BRANDBERG WEST MINE

Histogram showing the relationship between size of screened gravel, and content of recoverable cassiterite and wolframite concentrates.

Fig. 81.

The remainder was skottled, and then sifted into two grades, +3/16" - $\frac{3}{4}$" and +1mm - 3/16". The coarser grade was hand-sorted into wolframite and cassiterite, at an average rate of 4.5 kilos per hour per work, about 4% being lost in the process. The finer grade material could not be sorted economically by hand, and was mixed with the cassiterite concentrates produced by sorting and hand-picking. The resulting concentrate when cleaned, contained up to 60% Sn. Later, when a magnetic separator become available in the Transvaal, it was unneccessary to separate wolframite from cassiterite at the mine.

The river bed was divided into paddocks (see Photos, Fig. 82, 83) and overburden was removed until sampling indicated the presence of more than 1% heavy mineral. The 1% ore, in a layer averaging about 45 cm in depth, was stripped from bedrock and sifted to a -$\frac{3}{4}$", +1mm product, which was skottled. Bedrock was cleaned with wire brushes. Sampling of ore and tailings was carried out hourly. Ore was weighed, bagged, and removed immediately to prevent theft and encourage further production.

About 30 native labourers were engaged in stripping overburden and piling ore. Twenty Damaras, about half of them women, concentrated and sorted the ore. About one hundred Damara tributers were allowed to work the quartz veins and eluvial deposits on the hillsides, and later, stream beds Nos. 1, 4, and 5. The tributers brought cassiterite concentrates in weekly for sale. The concentrates were tested by immersing a small sample in dilute hydrochloric acid in a zinc bath, and if too impure, were rejected.

The production of concentrates for each week was cleaned by skottling, bagged, and sent to the rail-head, Omaruru, by motor truck.

At the beginning of 1947, tests were carried out on a vibratory dry blower concentrator of the type described by Sweet. (Ref. Sweet, 1944). A battery of these concentrators was put into operation and proved more efficient than the skottlers, for primary concentration. It was still necessary for skottlers to treat the concentrator product. By this time the average value of the alluvial deposit had been considerably decreased, because of the depletion of the richer patches.

In 1949, a non-vibratory blower was developed by a resident of

Omaruru, Mr. Gunnar Oestlund, and was used to prepare ore for the vibratory blowers. The resulting concentrate was much higher grade than had been obtained previously, and it was possible to dispense with most of the skottlers. At the beginning of 1950, the calculated average grade of the alluvial (Sn + WO_3) ore reserves was 0.284%, and the mine had a running life of only 14 months.

c) Minor Alluvial Deposits at Brandberg West.

A small alluvial tin deposit exists 2 km northwest of Brandberg West Mine, in a small tributary of the Ugab River. (See map, Fig. 27). This deposit was worked out early in 1946, and yielded cassiterite only. The cassiterite is probably derived from the raised gravels on the right bank of the Zebra River. Cassiterite float has been found in these gravels, and probably originated in the main mineralised body whence it was washed down the old bed of the Zebra River before rejuvenation took place.

B) The Kubugabis Tin Occurrences.

A small area of tin-bearing pegmatites exist at a point 2 km south of the Ugab River at Kubugabis. (See plan, Fig. 27)

Small alluvial deposits and some of the pegmatites were worked here during the 1939 - 1945 war, but work was stopped in 1945.

The pegmatites are found over a distance of about 300 metres in a narrow band running parallel with the strike of the schists. (See Figure 83). The country rock is a spotted biotite schist, belonging to the Upper Schist Series, and containing intercalated quartzitic bands.

The schist bedding dips to the northwest at about 40° and strikes northeast.

Thin sections of the schist and quartzitic rock, Nos. 136 and 137, show that the schist is a quartz biotite schist, and the quartzitic rock is an actinolite granulite.

The pegmatites are lenticular, usually about 30 metres long along strike and all less than 1 metre thick. Most of the pegmatites are emplaced in schist bedding planes, but some dip towards the southeast and strike parallel with the bedding.

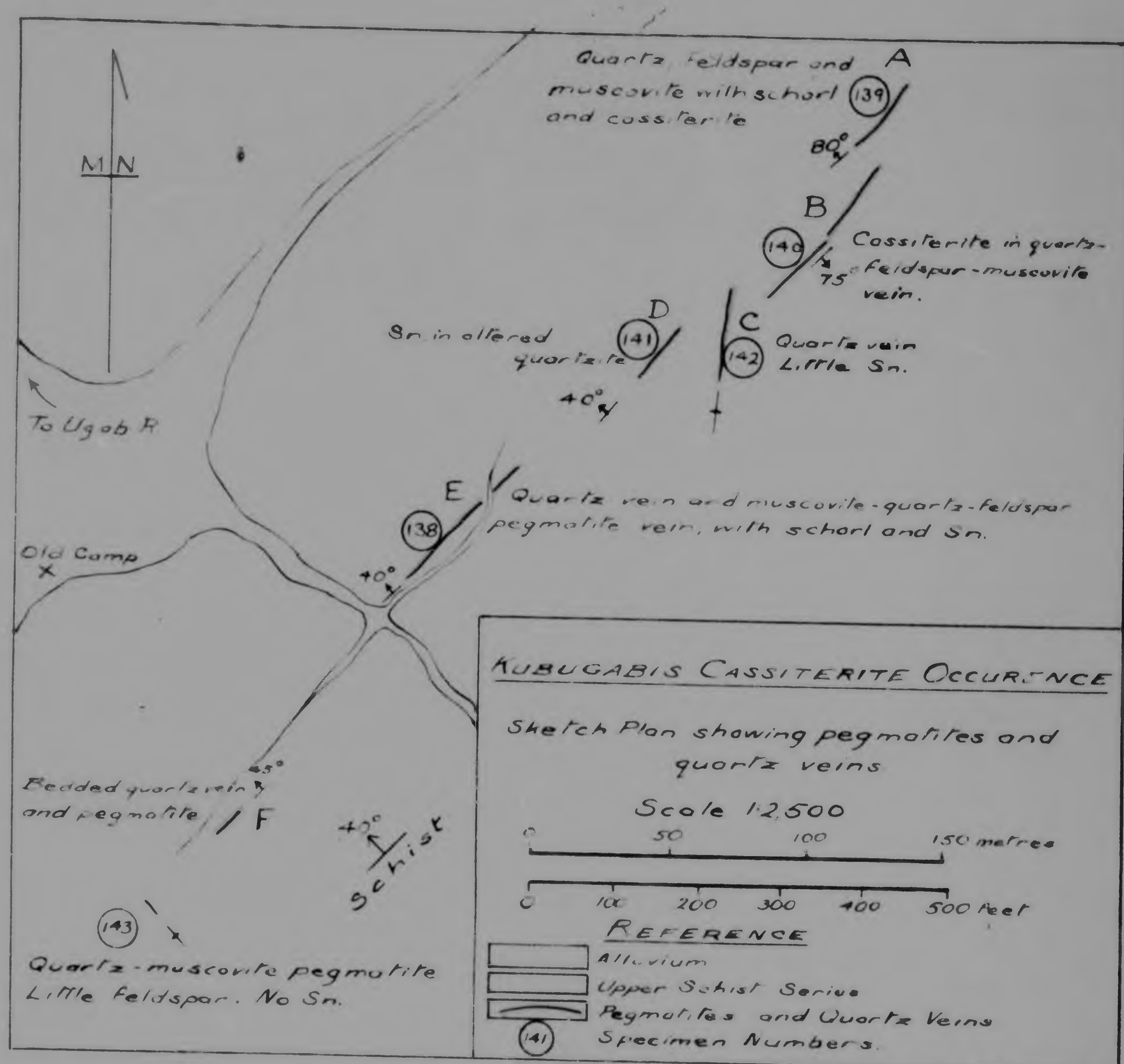

Quartz feldspar and muscovite with schorl and cassiterite
A
139
80°
B
140
75°
Cassiterite in quartz-feldspar-muscovite vein.
C
142
Quartz vein Little Sn.
D
141
Sn in altered quartzite
40°
M N
To Ugab R.
E
138
Quartz vein and muscovite-quartz-feldspar pegmatite vein, with schorl and Sn.
Old Camp
40°
Bedded quartz vein and pegmatite
F
Schist
143
Quartz-muscovite pegmatite Little feldspar. No Sn.
KUBUGABIS CASSITERITE OCCURENCE
Sketch Plan showing pegmatites and quartz veins
Scale 1:2,500
0 50 100 150 metres
0 100 200 300 400 500 feet
REFERENCE
Alluvium
Upper Schist Series
Pegmatites and Quartz Veins
141 Specimen Numbers.

Fig. 83.

One vein, (No. C) consisting mostly of quartz with little feldspar and muscovite, runs oblique to the strike of the schist and dips vertically. This vein carries little cassiterite.

The pegmatites vary in composition from almost pure quartz veins to quartz-feldspar-muscovite pegmaties, with a little biotite. Schorl is commonly present. The cassiterite is light brown, in well-developed crystals up to 1 cm diameter.

Vein No. D differs from the others in that it is banded and is finer in grain, and has a chalky appearance. It appears to be altered quartzite. A thin section shows the following composition:

No. 141. Quartz 80%

Orthoclase 15%

Rare plagioclase grains.

Apatite 2%

Pyroxene altering to Amphibole and chlorite 2%

Muscovite and Biotite 1%

Limonite pseudomorphic after Pyrite.

The quartz occurs in rounded grains up to 4mm. diamater. The plagioclase and the orthoclase, which is partly altered, are interstitial in the quartz grains. The apatite is subhedral. A few large grains of partly altered pyroxene are found. The biotite is pale brown.

The banding is due to alternations of coarse and fine-grains of quartz.

The highest concentrations of cassiterite are in the veins that strike parallel with the schist.

Underground development would be required in order to sample this tin occurrence fully. Surface exposure indicate that the tonnage available is small.

C) The Lead Occurrences.

Between the Zerissenes mountains and Salzputz, five lead occurrences have been found. One occurrence, near the large beacon on the Zerissenes Mountains is mentioned in the S.A. Department of Mines Geological Survey Memoir No. 39. "Lead Deposits in the Union of S. Africa and S. West Africa". p. 165 .

The remaining occurrences were discovered in 1946 and 1949.

None appear to be of economic interest at present.

1) The Zerissenes Mountain Lead Occurrence.

This small mineral occurrence lies on a steep east-facing slope about 60 metres to the north-east of the large cairn that marks the summit of the Zerissenes Mountains.

Country Rock. The country is schist in an anticline of the Middle Schist Series, and the vein outcrops are about 15 metres below the base of the Upper Marble Series.

Mineralisation. The lead is found in the form of galena in vertical quartz veins striking north-south. Galena was found in only one vein, and in very small quantities. This vein has a strike length of 15 metres, and a maximum thickness of 30 cm. The galena occurs in small scattered crystals in the quartz vein which also contains chalcopyrite and pyrite, and is somewhat stained by copper oxides. Copper staining was found in a second quartz vein, but galena was absent.

The wallrock has undergone alteration in a way similar to that at Brandberg West Mine. A layer of tourmalinised wallrock a few centimetres thick separates the quartz veins from the schist.

Although the presence of gold is mentioned in Memoir 39, op cit, crushing and panning of samples taken from the veins yielded no gold.

2) Galena occurrences in the Upper Marble Series.
(Plan, Fig. 85).

Three galena occurrences have been located in the area between the Sesob and Gemsbok Rivers. The general geology and positions of the occurrences are shown on Plan, Fig. 85. The three occurrences are similar in structure and mineralisation.

Occurrence A See Plan Fig. 85.

In this occurrence, galena is found with copper and iron oxides in quartz veins.

a) Country Rock. The country rock consists of the Brown Marble Band and the Intermediate Marble Band of the Upper Marble Series.

The hanging-wall of the zone of mineralised quartz veins is formed by the base of the Blue Marble Band.

The Brown Marble is a quartzitic biotite marble, containing bands of quartz grains up to 0.5 mm diameter.

The dark chocolate brown colour is due to the biotite (No. 43).

The intermediate Marble consists of alternating bands of brown marble, as above, and grey and Yellow marble. Well-developed porphyroblasts of actinolite, in haphazard arrangement, are present in some of the bands. (Nos. 46 A, 46B).

Rarely, part of the Blue Marble have been altered to a diopside vesuvianite rock. (No. 69) This specimen was found as float on a Blue Marble outcrop. The Blue Marble is normally very pure. (No.47)

The Quartz Veins.

Four types of quartz veins are found at this occurrence.

i) Bedded quartz veins in the marble. These are emplaced in bedding planes in the marble, and are similar to the bedded quartz veins at Brandberg West Mine. They consist of quartz, muscovite and a little feldspar, and contain no galena or copper minerals.

Microscopic examination of thin section No. 44, taken from this type of vein, showed the following composition:-

Mostly interlocking quartz grains, averaging 0.12 mm, with some interstitial calcite. Rare muscovite flakes and rare orthoclase.

ii) Quartz veins striking east-west. These cut (a), and rarely contain galena. They are lenticular and average 25 cm in thickness and 8 metres in length

Microscopic examination of thin section No. 64, taken from this type of vein, showed only interlocking quartz veins with crenulate boundaries.

iii) Quartz veins striking northwest-southeast branching to a north-south direction.

These cut (a) and (b) and contain galena, and copper and iron oxides. The galena occurs in masses up to 8 cm in diameter, but is present in only small amounts in most of the veins. The best exposure of galena consists of a vein 8 cm thick with a strike length of 2 metres. About 90% of this vein consists of galena, the remainder being quartz and iron oxides.

Microscopic examination of thin section No. 65, taken from this type of vein, showed the following composition:

Interlocking quartz veins, to 2.0 mm diameter, with some interstitial calcite.

Some interstitial tourmaline.

Some biotite flakes.

Half of the section consists mostly of quartz, and half of small (average 0.7 mm) rounded quartz grains disseminated in a mosaic of calcite grains.

Samples of galena from the vicinity have been found to contain 13 ounces of silver per ton of galena.

iv) Bedded Quartz veins in the Schist.

These are emplaced in bedding planes in the schist overlying a narrow dark blue marble band (No. 51) which lies immediately above the Blue Marble.

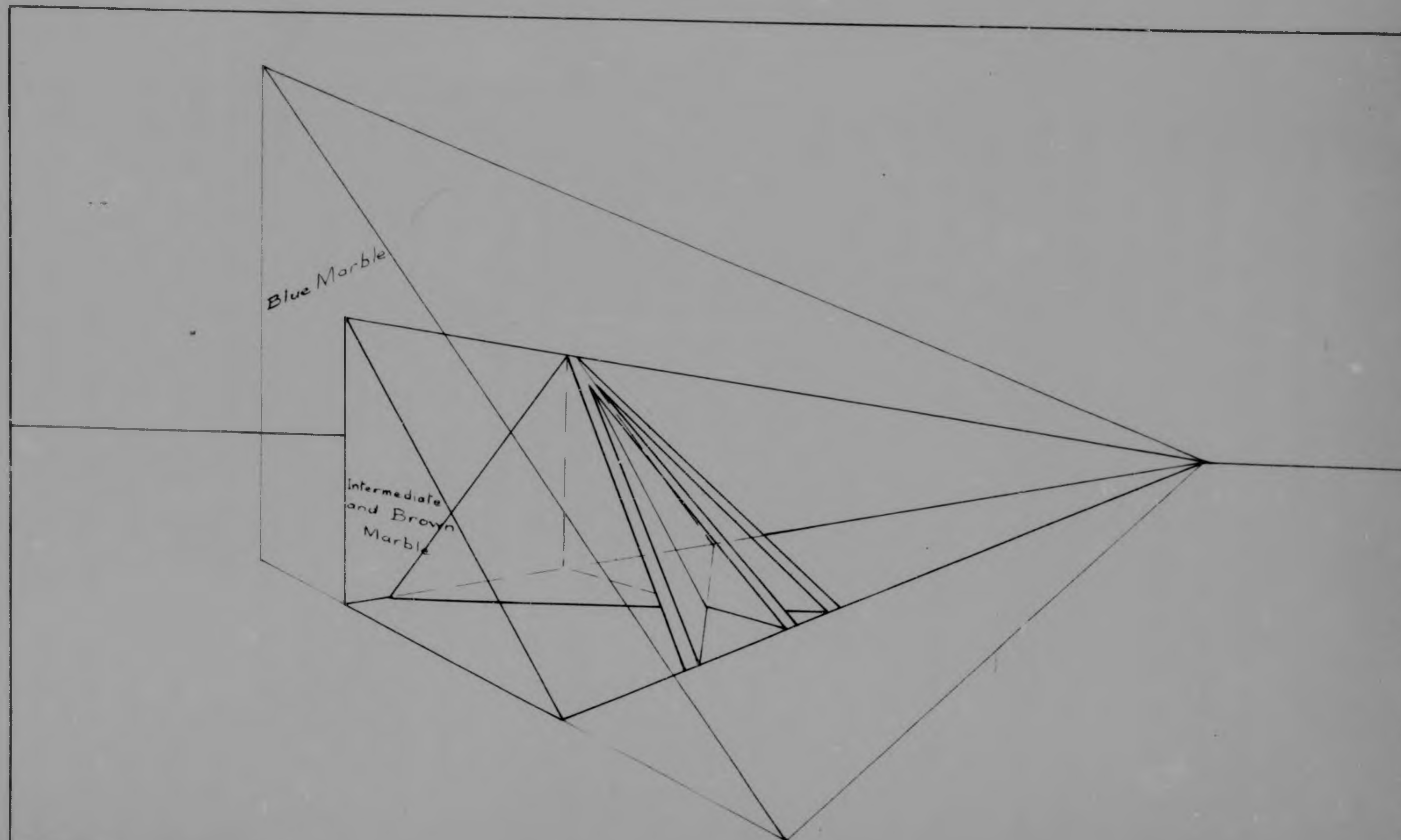
The schist is a biotite schist, some bands being spotted. (Nos. 52, 53, 54, 55.)

They consist of lenticular bodies of banded, iron-stained quartz somewhat cavernous with malachite, and iron oxides by no galena. They vary in length from one metre to three metres and are up to 20 cm thick. The malachite is in the form of acicular crystals in cavities. The age of these veins relative to the others could not be determined.

Wall-rock alteration by the quartz by the quartz veins appears to be absent. The vein outcrops stand out well above the country rock.

c) Structure of the Veins.

The quartz veins (b) and (c) form a criss-cross pattern in the Brown Marble Band in an anticline of the Upper Marble Series, and they extend to a minor degree into the Intermediate Marble Band. (See Figure 86 and Photo 87). The veins are lenticular, pinching out at the contact of the Intermediate Marble with the overlying Blue Marble. Their lower limit is not known. They are either vertical or have a steep dip, and they strike at angles between 50° and 90° to the axis of the anticline.



Diagrammatic sketch of typical quartz vein pattern in Upper Marble Anticline
Fig. 86.

This axis is practically horizontal.

The veins are spaced at intervals of from 5 to 8 metres, and the pattern formed by them is one common to almost every schist anticline, and to many of the marble anticlines in the area.

The attitude of the galena-bearing quartz veins, and their association with a single stratigraphic band in an anticline, indicate four structural controls which probably regulated the emplacement of the veins.

i) An anticline acted as a "trap" for solutions moving upwards.

ii) The Brown Marble and Intermediate Marble, brittle compared with the massive Blue Marble immediately above, were more easily fractured than the overlying band.

iii) The fracture pattern in the Brown Marble and intermediate Marble was controlled by the folding of the anticline. The lines of tension that were filled with quartz veins followed a pattern common in such anticlines (Compare:
M.P. Billings, 1942, p. 126, and W.H. Newhouse, 1942, Anticlinal Structures at 1) Bakerville, British Columbia, 2) Sheep Creek, B.C. 3) Chanarcilla, Chile, 4) Quartz Hill, Montana).

iv) The whole of the Brown Marble and Intermediate Marble outcrops are displaced towards the southeast side of the anticline, because of the thinning of the south-east limb of the anticline.

The bedded veins ((d) above) possibly originated in solutions that escaped through the "blanket" of the Upper Marble.

A striking repitition of the control exercised by a brittle band is seen in the band known as the Middle Black line, (No. 48) which lies roughly in the middle of the massive Blue Marble Band. (See Plate). In the mineralised area, the Middle Black line contains numerous lenticular quartz veins averaging about 2.5. cm maximum thickness. These veins contain a little galena, and copper and iron oxides. They appear to be small-scale representation of the main body of quartz, veins, and follow the same criss-cross pattern.

d) <u>Intrusives.</u>

The mineralised portion falls within an area occupied by a swarm of dolerite dykes. The mineralogical composition of these dykes is so variable that their age-relationship can be determined only in the field. They are mostly of Perdekloof type. (Nos. 26 to 32, and 35 to 39)

e) Faults.

Only one fault was seen at galena occurrence "A". This fault strikes at a small angle to the bedding and has a down-throw of about 3 metres to the southeast. A band of breccia 15 cm thick is developed along the fault plane.

f) Value of Occurence "A".

The quartz veins.

Only one vein, mentioned above appears to contain a high concentration of galena. In general the veins are so poor in mineral that they cannot be mined profitably at present prices of lead.

Eluvial Galena.

Galena boulders up to 15 cm in diameter, partly altered to lead carbonates, are scattered over the mineralised area. It is estimated that one ton of galena could be picked up on surface.

g) Alluvial Galena.

Waterworn pebbles of galena were found in the dry stream bed. Panning of alluvium from a shallow pit yielded a small quantity of galena.

The alluvium in the stream bed, down to a point about 65 metres from the Sesob River, is derived from the mineralised zone.

The wide portion of the stream bed near the Sesob River, contains about 2,500 tons of alluvium, down to 2 metres below surface. Most of this alluvium is probably derived from the stream cutting across strike from the south-east. This stream has a comparatively large catchment area, which contains no economic minerals. (See plan, Fig. 85).

Investigation of the alluvial trenching would not be worth while, owing to the diluting effect of the tributary stream.

The galena occurrences Band C are similar in structure to occurrence A, but probably contain smaller amounts of galena.

D) Origin of the quartz Veins.

The Sesob River lead-silver occurrences resemble strongly in structure the Brandberg West tin-tungsten occurrences. The structural controls in both areas are similar.

Tourmaline is common to the two localities, but is present only in small quantities at the lead-silver occurrences.

The galena-bearing veins of the Zerissenes Mountains form a possible link between the two areas, as they are associated with tourmalinised wall-rock, and contain galena but no cassiterite.

Thus the mineralisation is probably hypothermal in all the occurrences.

None of the quartz veins could have been derived from the nearest exposed granite, which was intruded above the Upper Marble horizon. Two possible sources of the mineralisation exist in the area.

(1) About 25 km northeast of the Brandberg West Mine, a granite body cuts the Lower and Middle Schist.

This granite is possibly the same as that exposed north of the Brandberg, where it appears to be connected with the genesis of several tin occurrences including the Kubugabis occurrence described previously. Before the emplacement of the Brandberg Granite, this older granite was probably continuous southwards to the Uis tin area.

This granite was possibly the source of the Brandberg West tin-wolfram veins and the Sesob River lead-silver veins farther to the west. This postulated zoning effect is analogous to that existing at tin-wolfram and lead-silver occurences in Cornwall and Saxony. (W. Lindgren, p. 651.)

(2) A line of doming running from Brakputz northwest into the Kaokoveld, exists about 9 km northeast of the Sesob River lead occurrences. This structure is possibly due to the intrusion in depth of an igneous body, which could have caused the mineralisation.

E) Prospecting in the Area.

The original prospecting was carried out as follows. A geologist surveyed a strip of country by traversing, at ½ km intervals where possible, and at the same time three or four Berg Damas tested all the small streams in the area traversed, by means of the skottel.

Promising looking quartz veins were sampled, and later crushed and panned. Results on a field map at a scale of 4" to 1 mile. Any discoveries of economic mineral were followed up by pitting and trenching.

General.

In most areas, outcrops constitute such a small proportion of the surface that traverse lines ½ km apart are close enough to ensure that there is littlechance of an outcropping ore deposit being overlooked. But where rock exposures constitute almost 100% of the total surface, as in the present area, the traverse intervals should be much closer together. The close pattern of erosion is another reason for detailed traversing.

If any ore deposit lies within the area, it is probably exposed and therefore every outcrop in the area should be examined. As this is for practical purposes impossible, the only answer to the problem is that the area should be aerially photographed. Such photographs would show all the areas of quartz veining, as well as the general geological structure, which would indicate areas "permissive" for the presence of ore bodies. Much unnecessary wastage of time could be eliminated, as the most promising areas could be visited immediately after a study of the photo-geology had been completed. If no ore deposit was discovered, the area could be abandoned with greater confidence than if ground traversing alone had been used.

Thus it is considered essential that aerial photography be carried out in such an area, before ground prospecting is commenced.

F) Economic Possibilities of the Area.

Tin and Tungsten.

The Brandberg West Mine is a living example of a profitable mine existing in a remote and desert area. The Kubugabis tin occurrence could possibly also be profitably worked but requires underground development in order to be proved.

The high-level gravels of the Zebra River, below the main mineralized area, possibly contain payable quantities of cassiterite, although there has been considerable dilution of the tin bearing gravels from other scources.

The cemented nature of the gravels might render them unpayable, even if cassiterite were present.

Naturally, the area lying in strike with the main deposit should be thoroughly investigated.

Other areas worth further investigation are as follows:-

Lead. The Sesob River Area.

The several structural controls that are known to be connected with lead mineralisation here limit the number of permissive areas. Aerial photography would be a great help in the search for ore-bodies.

Gold. The reported gold occurrence of the Zerissenes Mountains (S.A. Dept. of Mines, Memoir No. 39 page 165), should be investigated with a view to the possibility of finding an alluvial gold deposit.

Salt. The large salt pan southwest of the Gemsbok River should be investigated with a view to exporting to Cape Cross, where the local salt is unsuitable for preserving seal skins. A road could be made with little difficulty from the salt pan to the coastal road.

Fig. 3.
Ugab R. gorge, looking upstream, E. of Goantagab R. confluence.

Fig. 4.
Looking NE. at confluence of Ugab and Sesob Rivers, showing raised gravels.

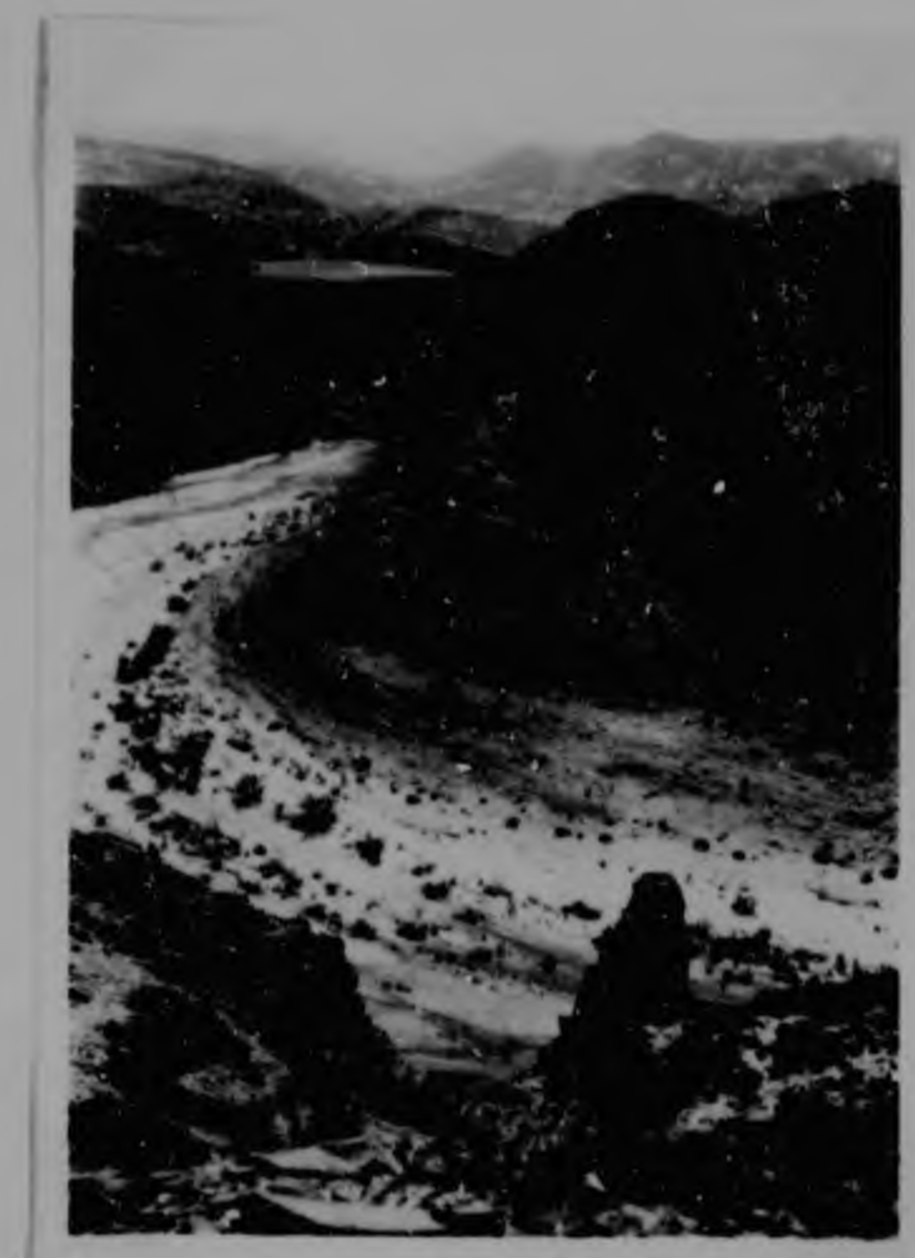


Fig. 5.
Looking E., 2 km. west of Zebraputz, showing raised valley floor.

Fig. 6.
Looking upstream at Brakputz, showing raised valley floor.

Fig. 7.
View showing raised gravels of old Sesob R. Looking NE.

Fig. 8.
Zebra R. showing raised valley floor of old Ugab R. Looking SW.

Fig. 9.
Looking N. along old Ugab valley, at Goantagab R. confluence. Present valley cuts across, from east to west.

Fig. 10.
Looking SW. across Ugab R. at Brakoutz. Zerrissenes Mts. on left. Raised gravels in foreground.

Fig. 11.
Synclinal ridge of Upper Marble. Looking southeast, up Brak River valley. Goboboseb Mts. on horizon.

Fig. 12.
Synclinal Upper Marble ridges, and anticlinal Middle schist valleys, north of Brakoutz. Looking NE.

Fig. 13.
Synclinal ridge (base of Marble Zone on Middle Schist) NE. of Sesob R., looking N.

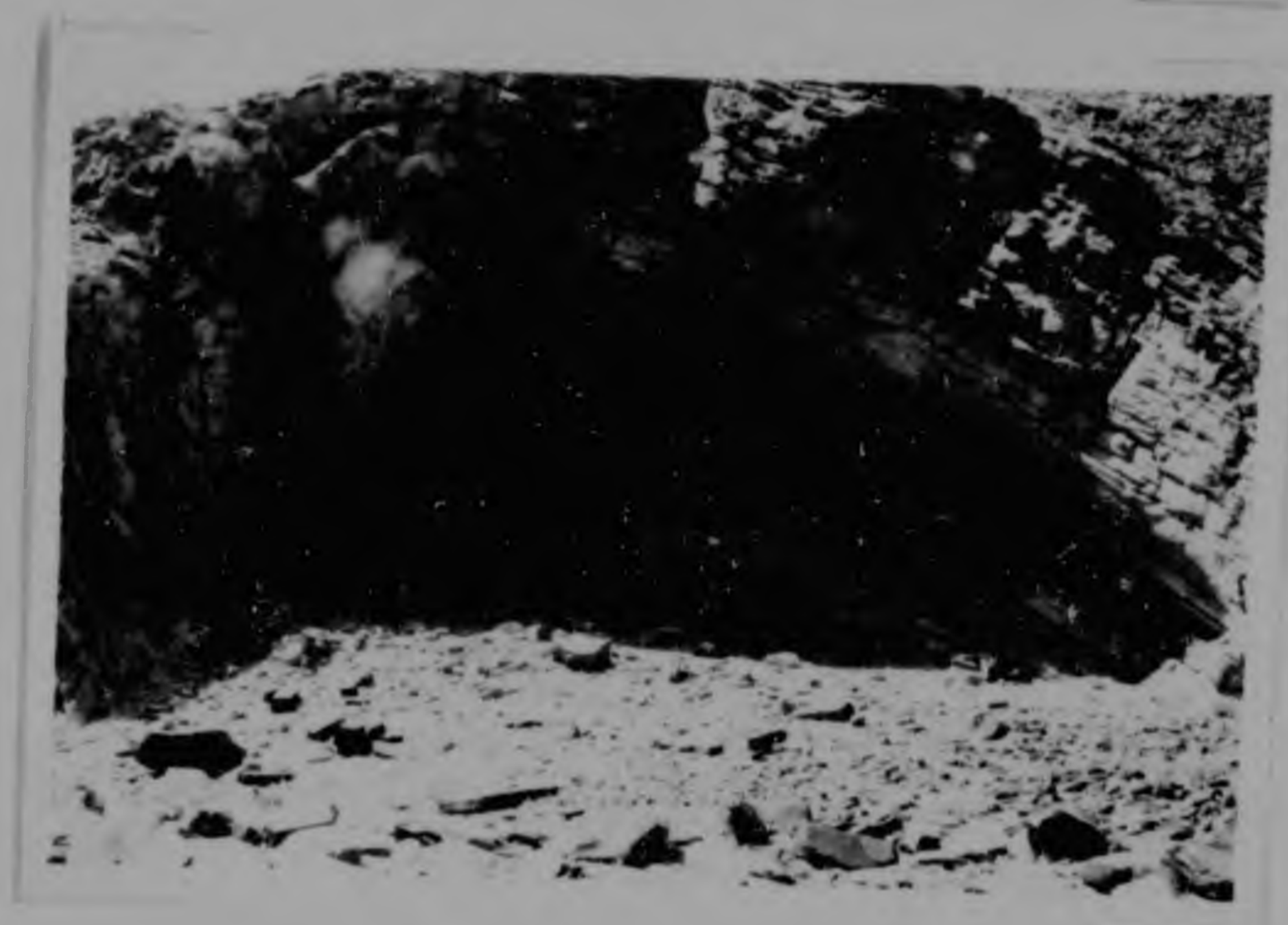


Fig. 14.
Solution cavity in Blue Marble Zone, showing radial joints. Tributary of Ugab R., west of Brak R.

N.B. Fig. 15 is placed next to Fig. 41.

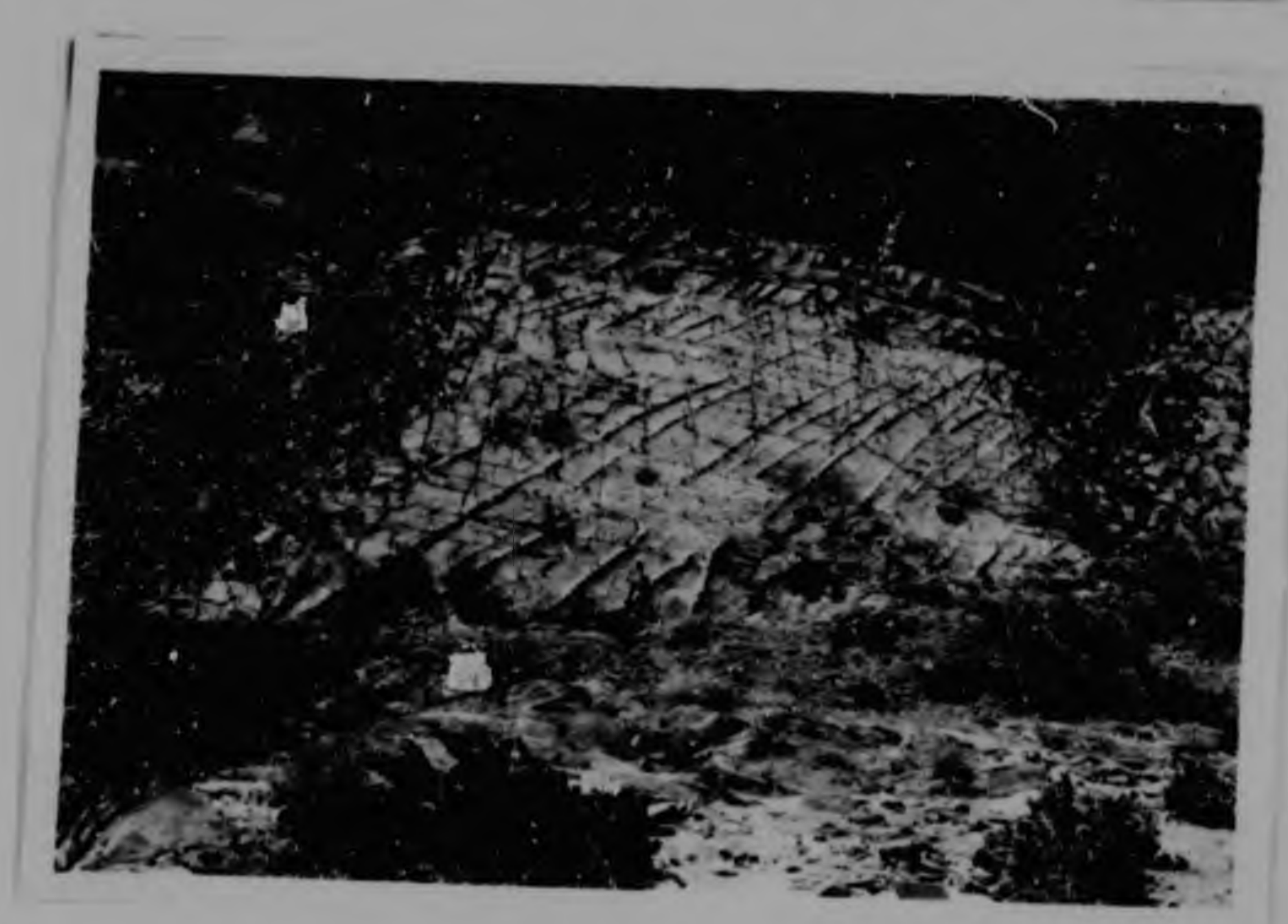


Fig. 16.
Cliff face of Yellow Marble, bounded by two faults. SE. of Brandberg West Mine, looking NW.

Fig. 17.
Streambed east of Amis R. showing Upper Schist country of shallow dissection. Welwitschia Mirabilis in foreground.

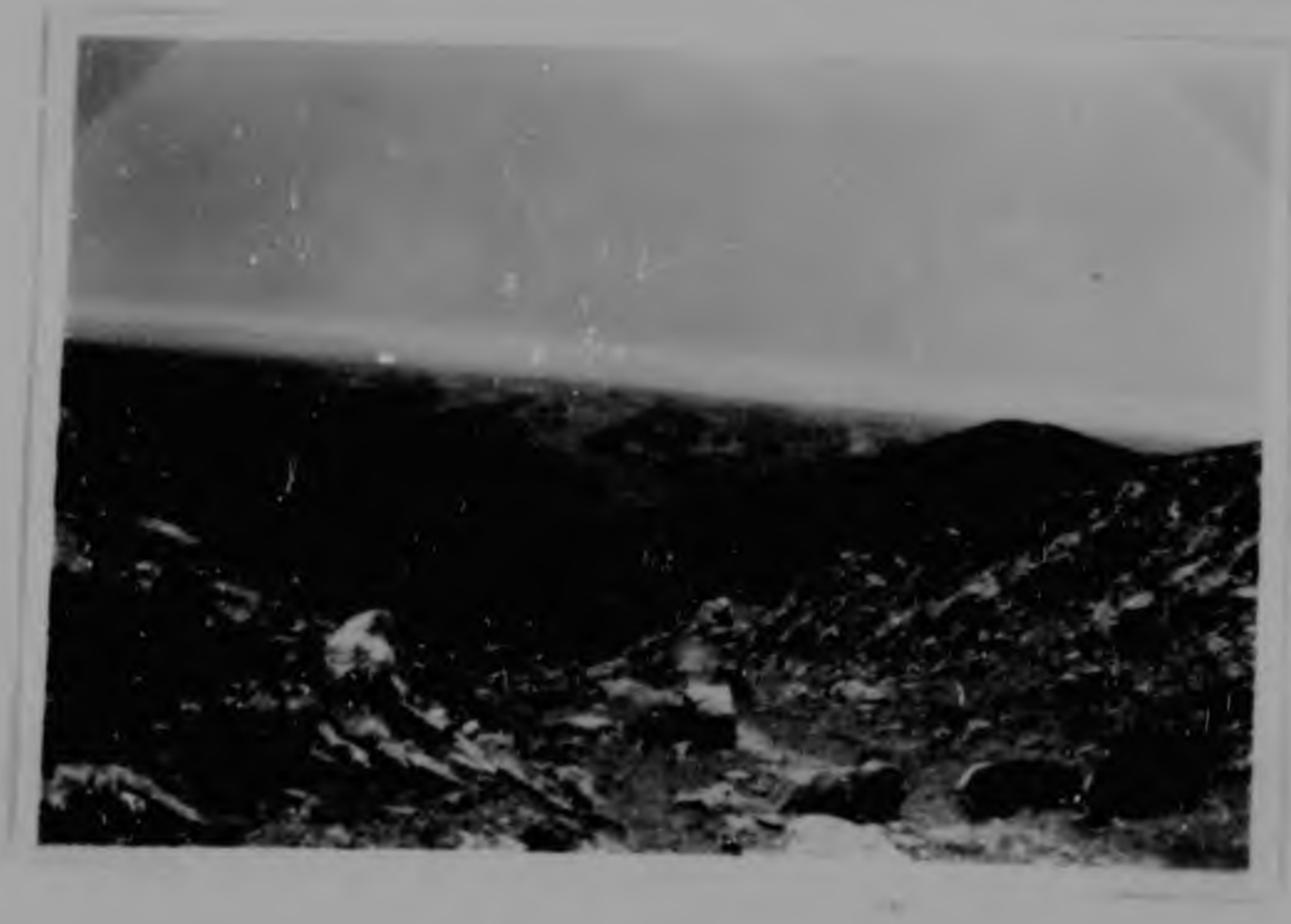


Fig. 21.
Looking SW. from Zerrissenes Mts., showing shallow dissection of pediment.

Fig. 22.
Large salt pan, SW. of Gemsbok R.

Fig. 24.
Brak R. near Ugab R., looking NE. Showing windblown sand.

Fig. 23.
Overturned Yellow Marble, SW-side of Sesob R., showing game paths.

Fig. 25.
The Brandberg, looking S.

Fig. 26.
The Brandberg, looking SE.

Fig. 29.
The Brandberg, looking south. From a point near Fig. 25.

Fig. 30.
Gravel scarp, north of Ugab R. on coastal plain.

Fig. 34.
General view of dissected schist country, looking SW.
Brandberg and Goboboseb Mts. on the horizon.

Fig. 36.
Looking to the SW, at faulted and overturned Upper Marble and Upper Schist body.
Raised gravels in foreground. Captor stream runs from left to right. Original stream ran from left background to the right foreground and towards the NE.

Fig. 37.
Overturned Upper Marble Series, Brak R., looking NE. Left to right, Blue Marble (with Middle Black line), Brown Marble, Yellow Marble and Middle Schist.

Fig. 38. Yellow marble series near Brak R. mouth.

Fig. 15.
Fine-grained black marble, showing weathered surface. X½.

Fig. 41.
Glaciated quartz pebble, (No. 90). X½.

Fig. 42.
"Worm trails" on varved shale, (No. 4). ½X.

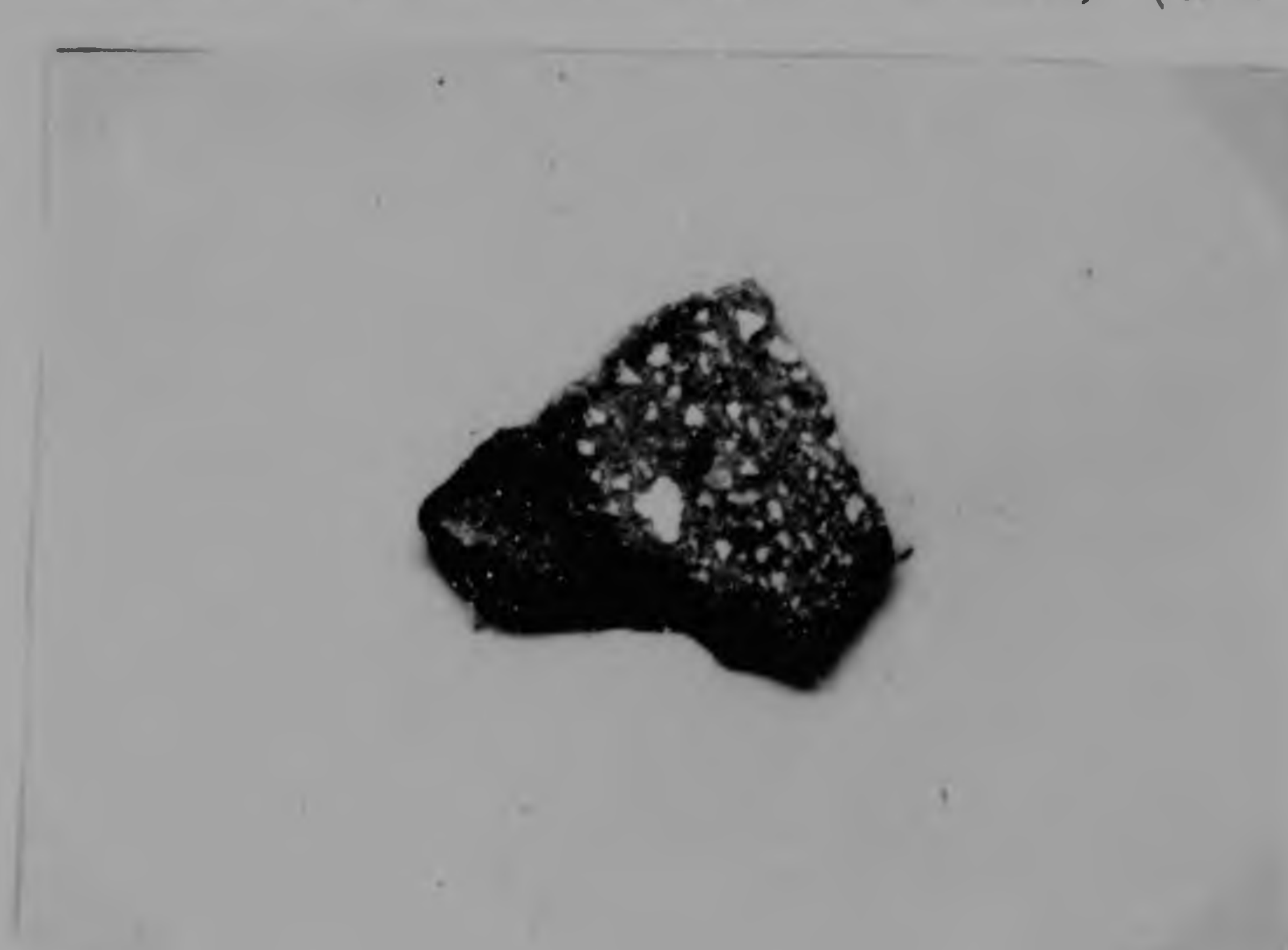


Fig. 43.
Sandstone containing broken bone matter. ½X.
(No. 381)

Fig. 44. Looking W. Altered marble xenolith.

Fig. 45.
Looking north from peak on Goboboseb Mts. Dolerite dyke in left foreground.

Fig. 47. Upper Marble, N. bank of Ugab R. E. of Salzputz looking SW.

Fig. 49 (a). Upper Marble, N. bank of Ugab R., E. of Goantagab R.

Fig. 48.
Upper Marble, S. bank of Ugab R., east of Goantagab R.

Fig. 51. Cliff of Upper Schist, W. bank of Amis R., at Ugab R.

Fig. 52.
North bank of Ugab R., near Goantagab R.

Fig. 53.
No. 413 A.
P.P.L.
25 X.
Tourmaline in quartz-muscovite schist.

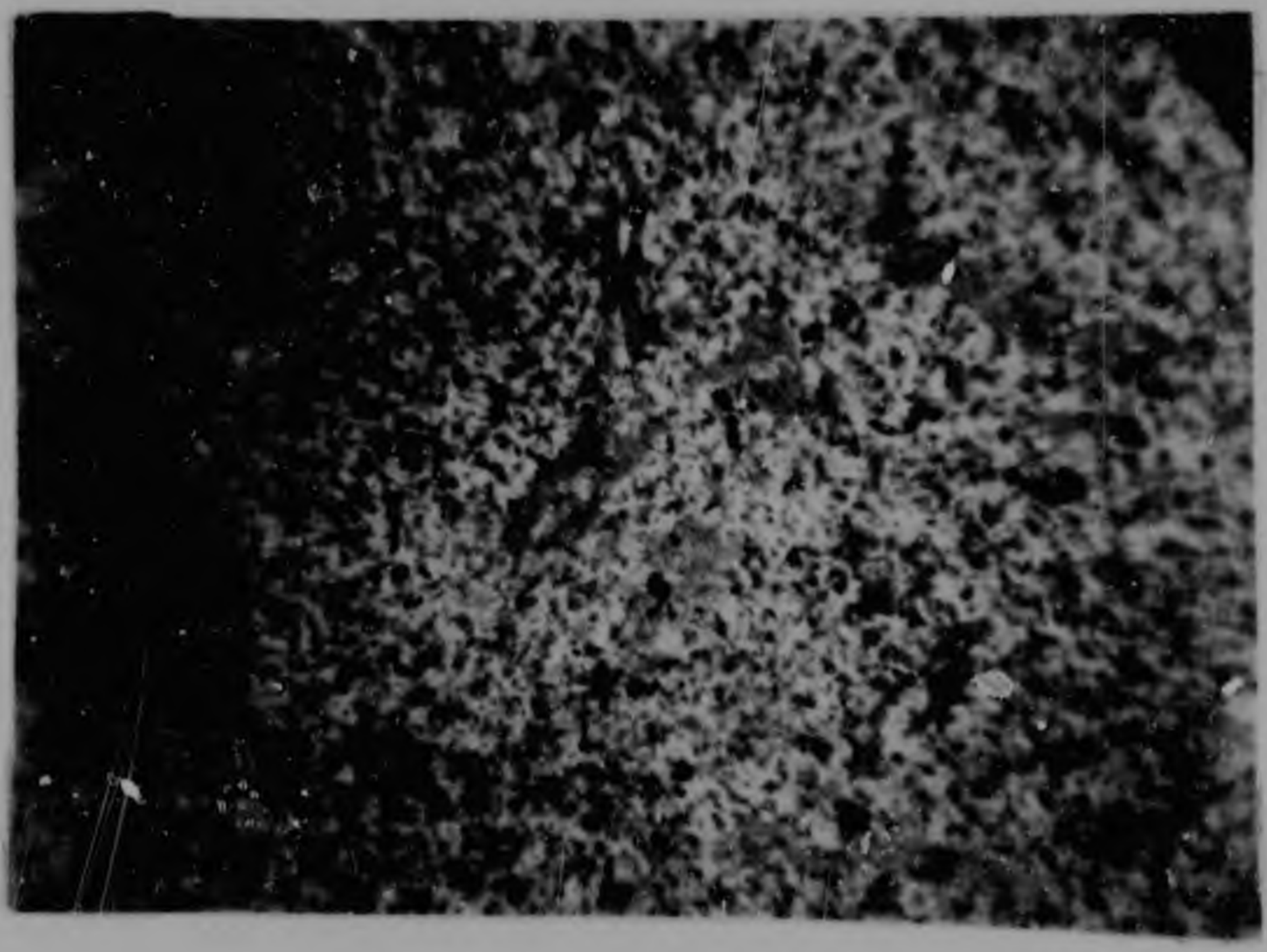


Fig. 54.
No. 281.
P.P.L.
25 X.
Amphibole in biotite schist. Section cut parallel with schistosity.

Fig. 55.
No. 285.
P.P.L.
25 X.
Amphibole in biotite schist. Section cut across schistosity.

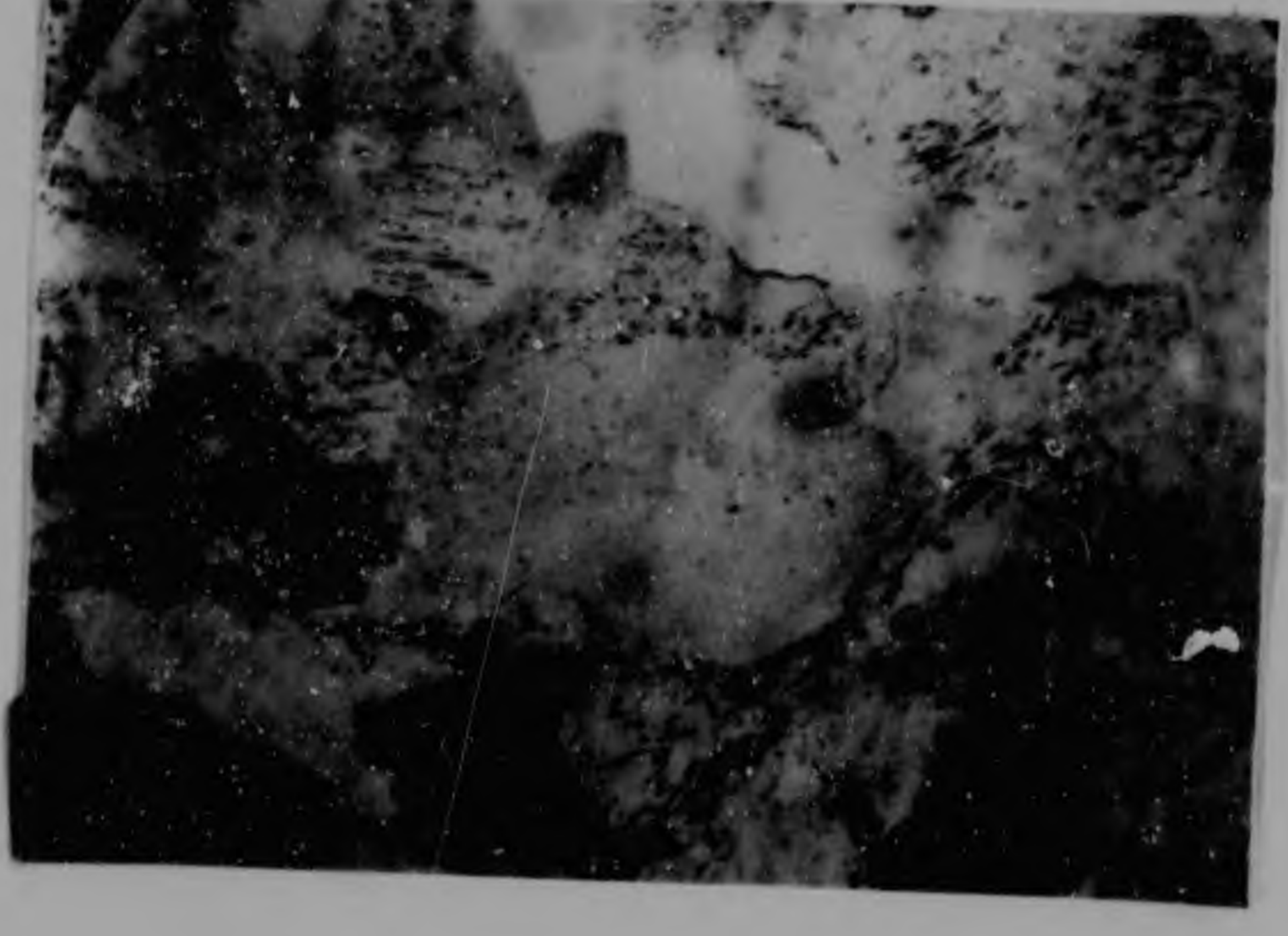


Fig. 56.
No. 71 B.
P.P.L.
80 X.
Quartzite, showing original outline of quartz grain. Dark patches are chlorite, and minute laths of amphibole.

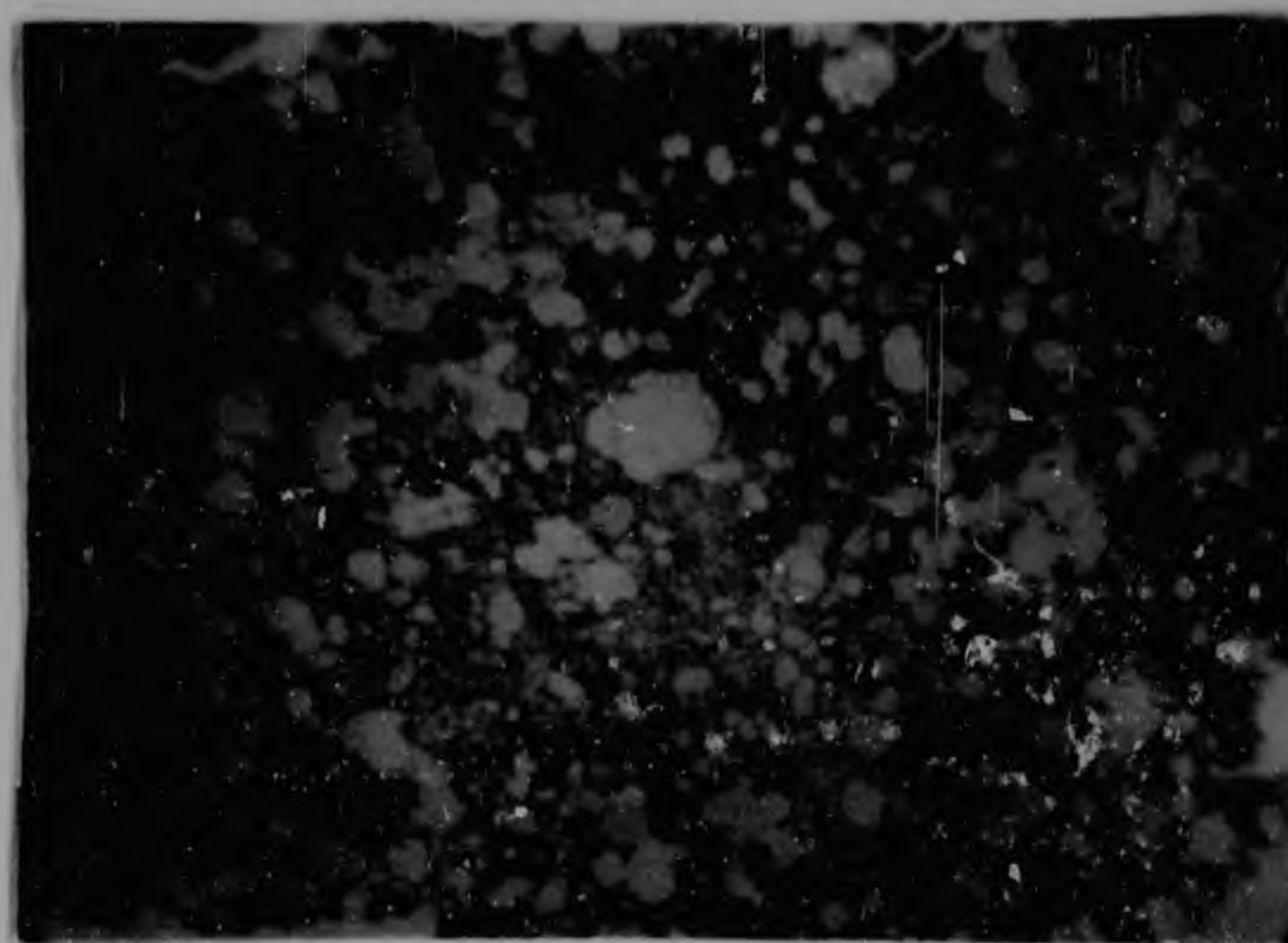


Fig. 57.
No. 287.
P.P.L.
25 X.
Quartz grains in a groundmass of altered scapolite, with scattered epidote grains.

Top.

Bottom.

Fig. 57 (a).
No. 287.
½ X.
Specimen of pseudo-diorite. Porphyroblasts of amphibole in a groundmass of scapolite, quartz, garnet and epidote. In contact with schist at bottom.

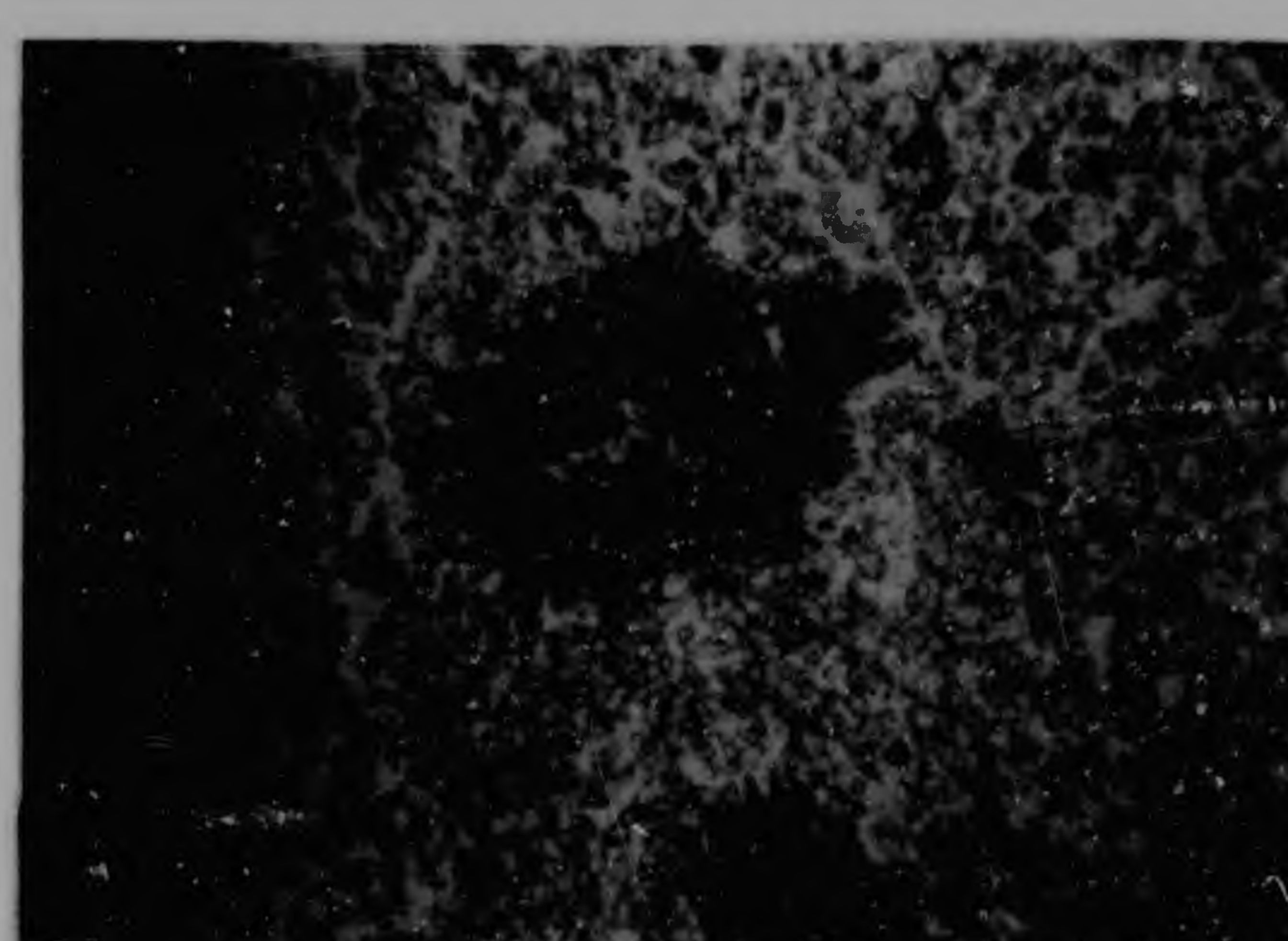


Fig. 58.
No. 46 A.
C.L.
25 X.
Porphyroblast of amphibole in groundmass of quartz and biotite.

Fig. 59.
No. 69.
C.L.
25 X.
Vesuvianite, with inclusions of diopside.

Fig. 60.
No. 85 A.
P.P.L.
25 X.
Mostly vesuvianite, with inclusions of epidote and chlorite.

Fig. 61.
No. 80.
P.P.L.
80 X.
Allanite and zoisite.

Fig. 62.
No. 102.
P.P.L.
25 X.
Vesuvianite with interstitial quartz.

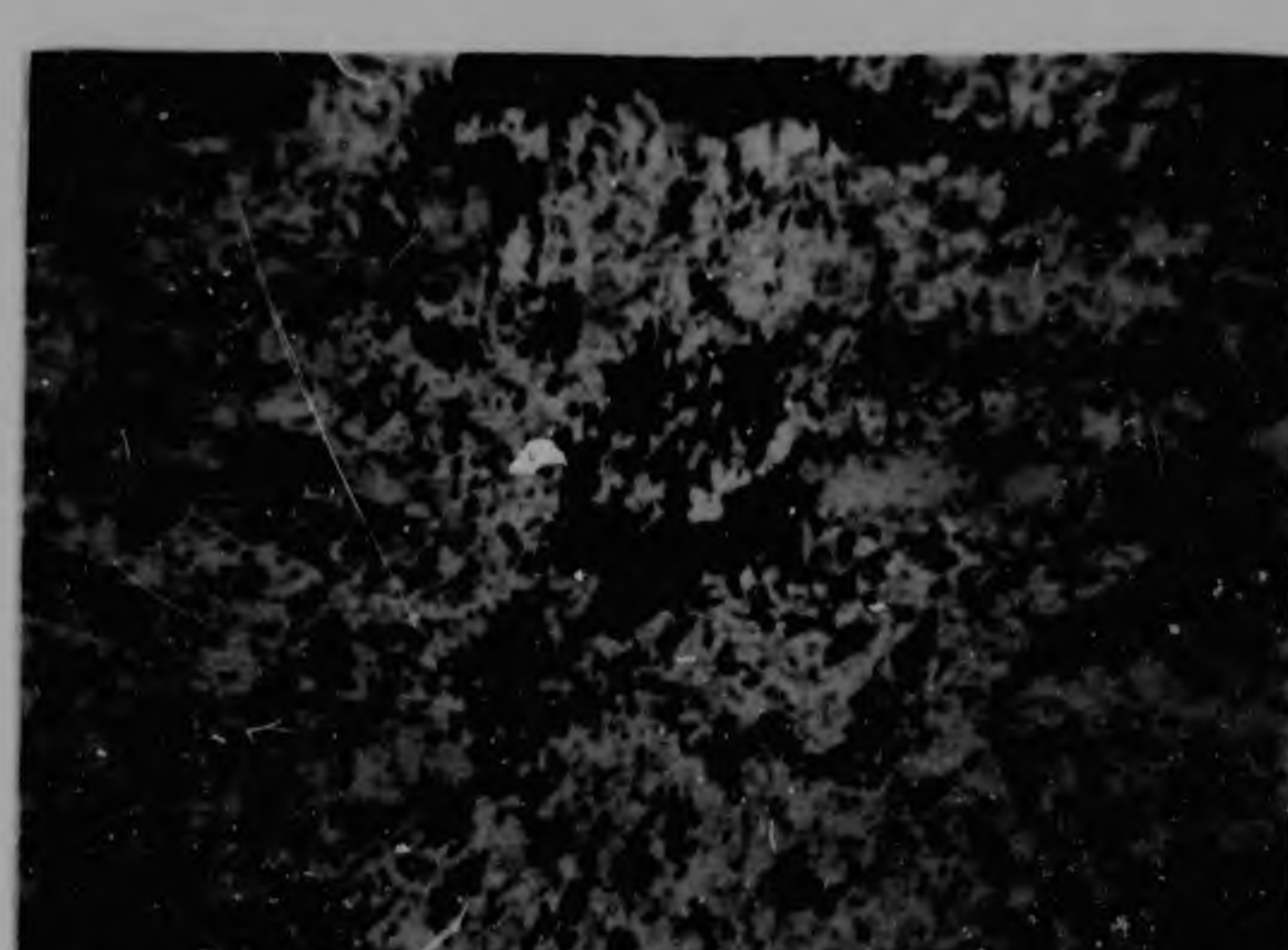


Fig. 63.
No. 83.
P.P.L.
25 X.
Bands of cordierite with biotite and ore.

Top.

Bottom.

Fig. 64.
No. 4.
Crossed Nicols.
25 X.
Varved shale.

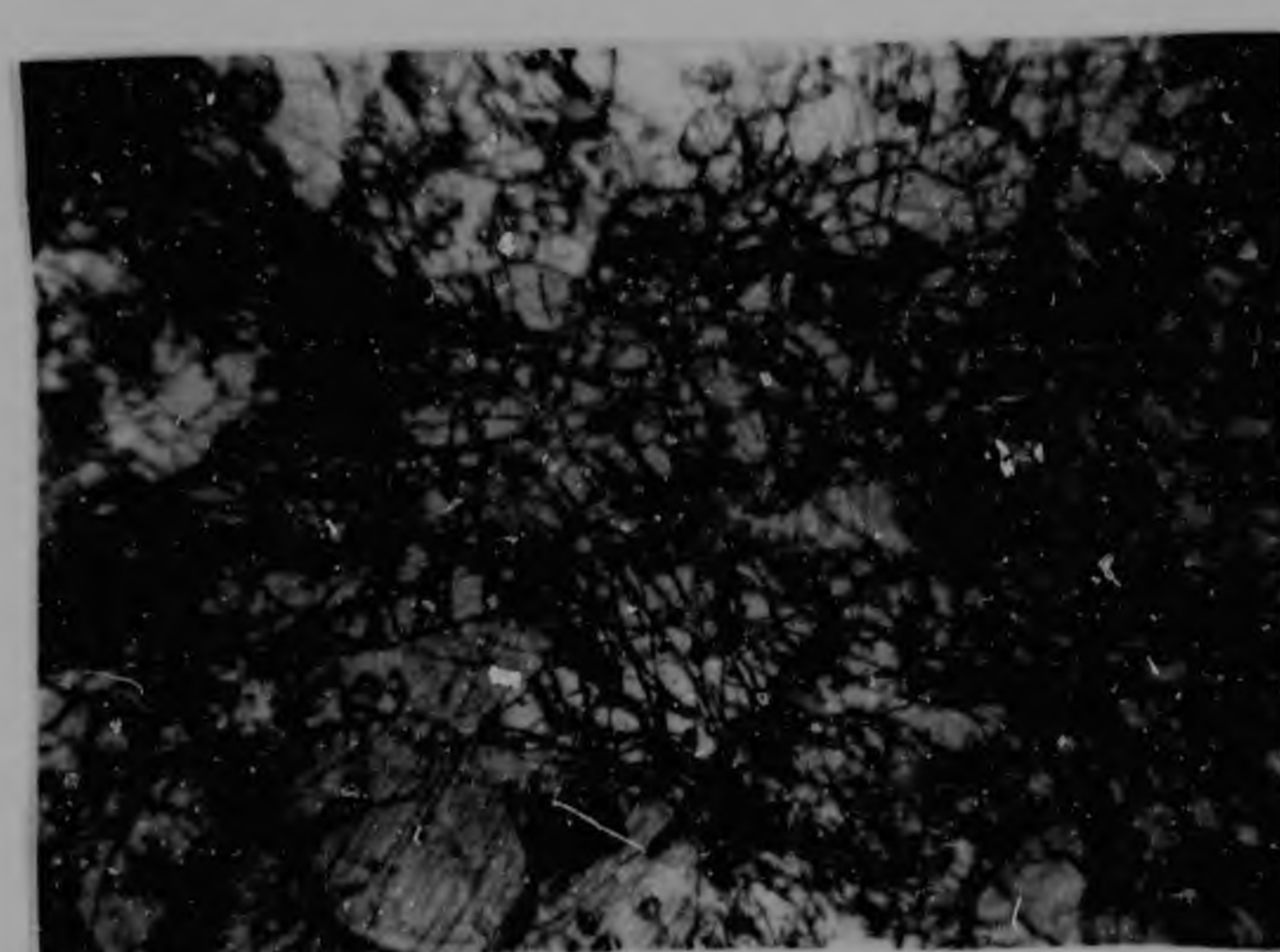


Fig. 65.
No. 3.
O.L.
25 X.
Olivine and
Augite.

Fig. 68.
No. 389.
Quartz-Feldspar-
Calcite vein
with amphibole
in dolomitic
marble. $\frac{1}{2}$ X.

FIGURE 79.

Upper part of No. 3 Stream,
Brandberg West Mine.

FIGURE 78.

General view of Brandberg West Mine, 1950, looking south.
Winze in left foreground. Adit portal near shacks in No. 5 Stream,
in right foreground. No. 3 Stream on left. Zebra River on right, above compound.

Fig. 80.
Brandberg West Mine, 1950. Looking down No.1 stream. Zebra R. raised gravels in right background.

Fig. 82.
Brandberg West Mine, 1946. Opening up No.3 stream.

Fig. 84.
Brandberg West Mine, 1946. Opening up No. 3 stream.

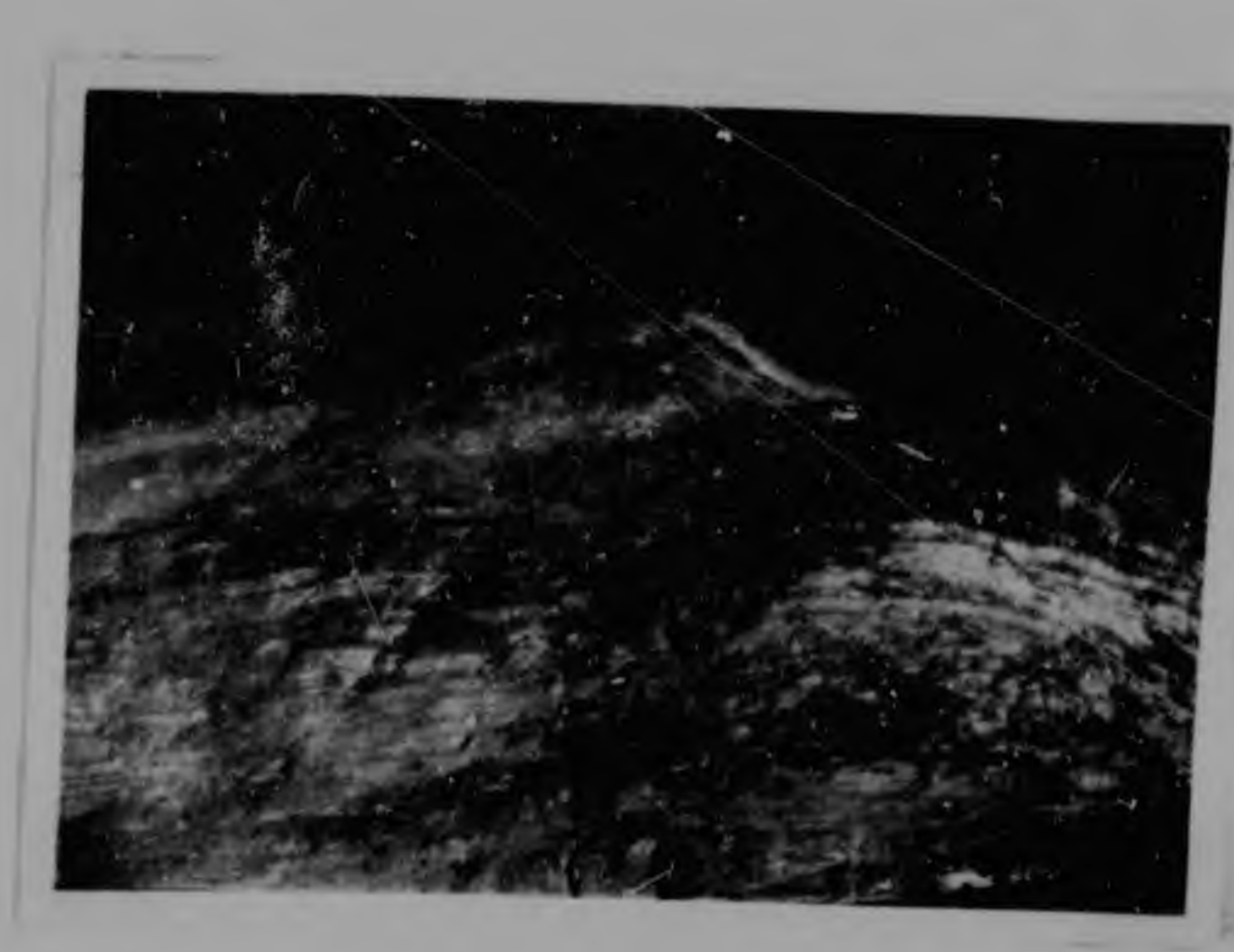
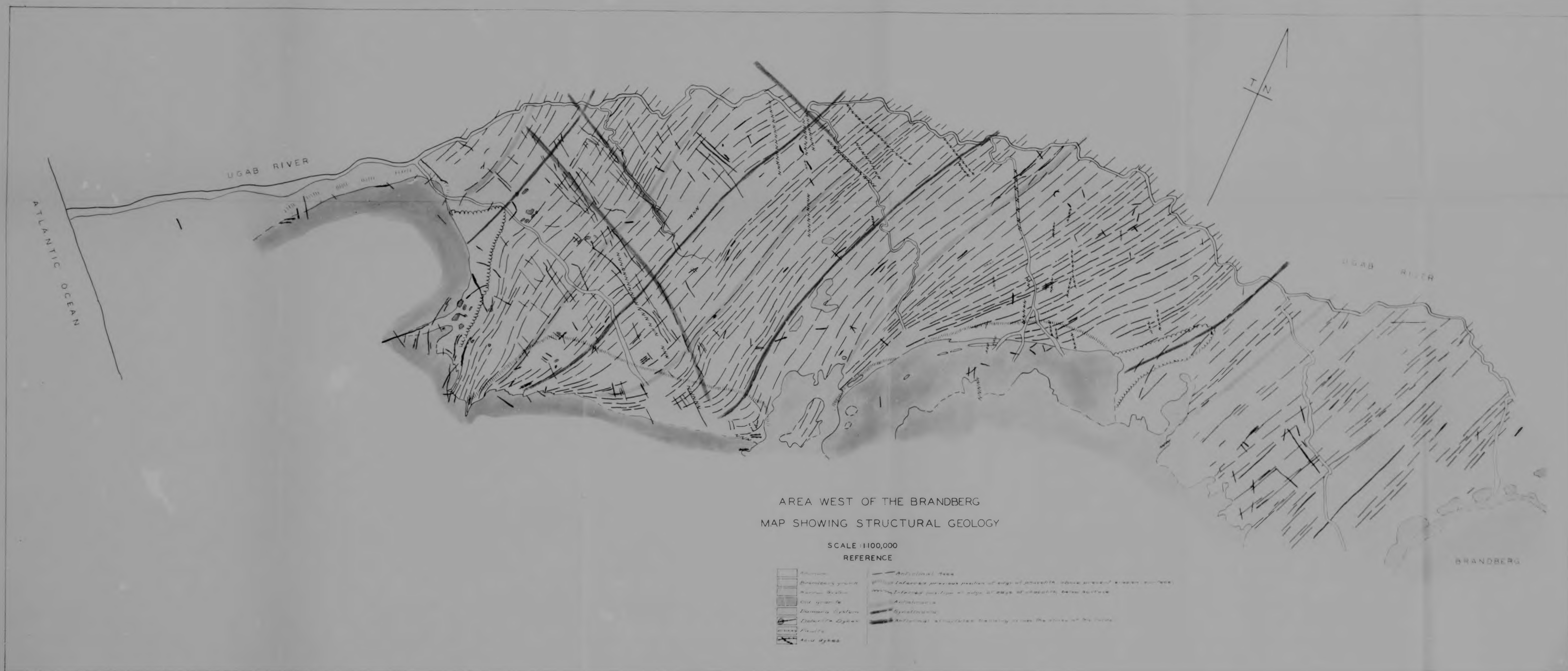
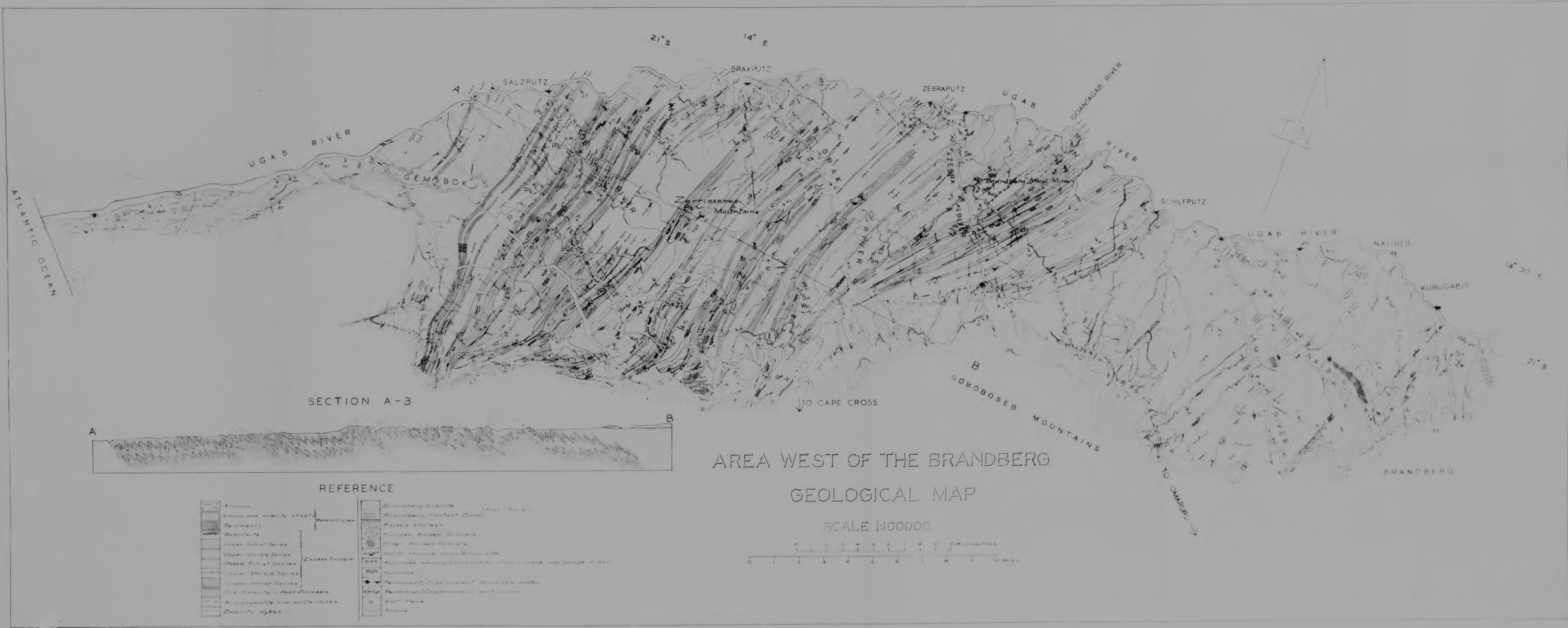


Fig. 87.
Sesob River Lead Occurrence "A" showing quartz veins in Brown Marble in foreground. Looking SE.



UGAB RIVER
ATLANTIC OCEAN
N
UGAB RIVER
BRANDBERG
AREA WEST OF THE BRANDBERG
MAP SHOWING STRUCTURAL GEOLOGY
SCALE 1:100,000
REFERENCE

FIG. 46.



AREA WEST OF THE BRANDBERG
GEOLOGICAL MAP
SCALE 1:100000
SECTION A-B
REFERENCE
ATLANTIC OCEAN
UGAB RIVER
SALZPUTZ
BRAKPUTZ
ZEBRAPUTZ
GOANTAGAB RIVER
SCHILFPUTZ
GEMSBOK
NAIDEB
KUBUGABIS
TO CAPE CROSS
GOBOBOSEB MOUNTAINS
BRANDBERG
TO OMARURU
21° S
14° E
14° 30' E

FIG. 27.

Soft grey decomposed basalt
Blue Marble Zone

SECTIONS ACROSS THE KARROO ROCKS

SCALE APPROX 1:600

LOCALITIES OF SECTIONS ARE SHOWN ON KEY MAP

FIG. 39.

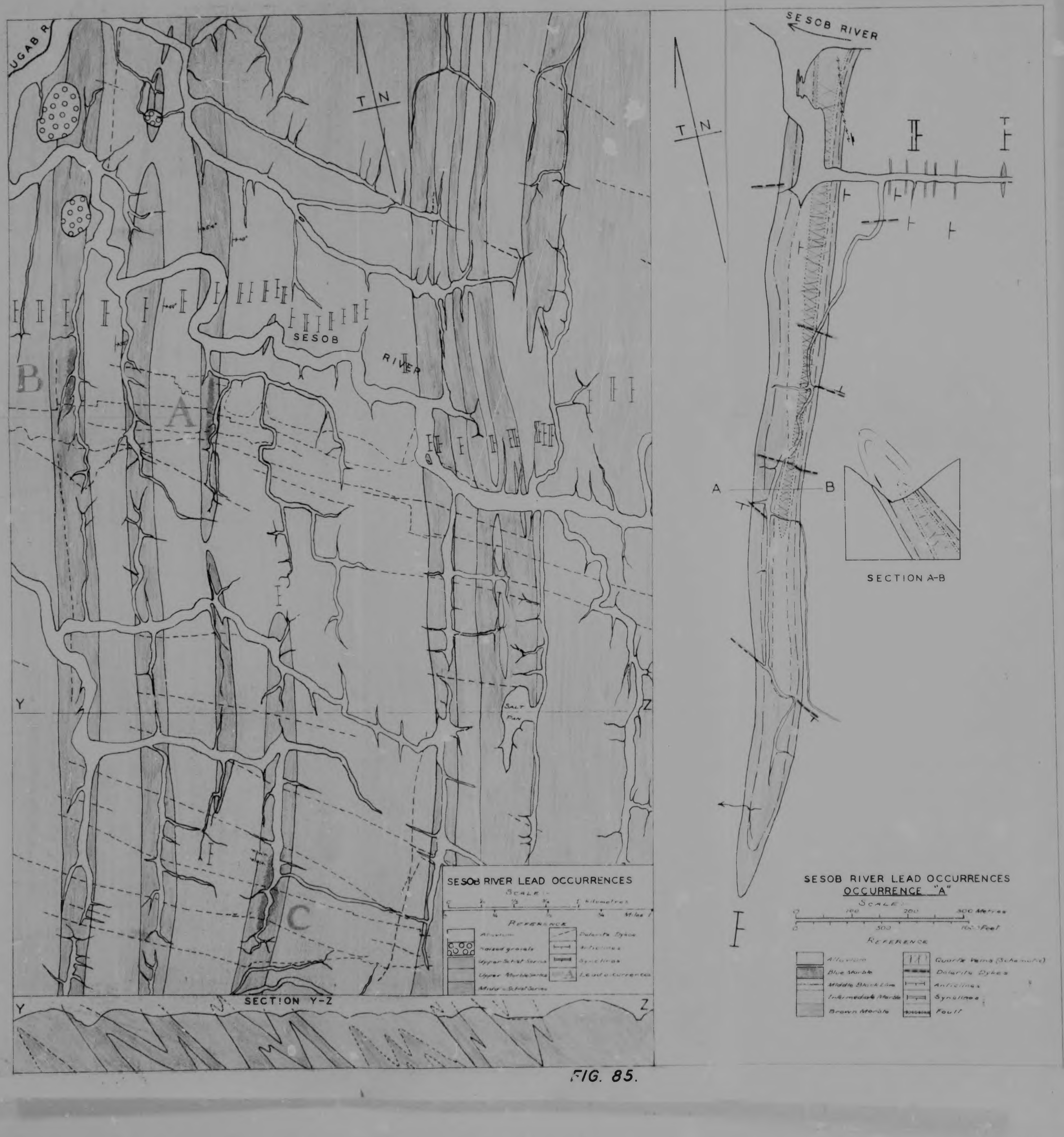

UGAB R.
T N
SESOB
RIVER
B
A
C
Y
Z
SALT PAN
SESOB RIVER LEAD OCCURRENCES
SCALE:-
Kilometres
Miles 1
REFERENCE
Alluvium
Raised gravels
Upper Schist Series
Upper Marble Series
Middle Schist Series
Dolerite Dykes
Synclines
Lead Occurrences
SECTION Y-Z
SESOB RIVER
T N
A
B
SECTION A-B
SESOB RIVER LEAD OCCURRENCES
OCCURRENCE "A"
SCALE:
0
100
200
300 Metres
0
500
1000 Feet
REFERENCE
Alluvium
Blue Marble
Intermediate Marble
Brown Marble
Dolerite Dykes
Anticlines
Synclines
Fault

FIG. 85.