

THE DEVELOPMENT AND CONTROL OF
POCKET-MINERALISATION
IN THE ROOIBERG QUARTZITES

by

John Lister DINSDALE

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ABSTRACT

Pocket mineralisation is the name applied to pod-like bodies of coarse-grained rock which are the result of alteration of sediments. In some areas pockets are cassiterite bearing, and these pockets have been mined at Rooiberg Mine.

Rooiberg Mine is one of four operating mines in the Rooiberg Tin-field which is situated 64 km west of Warmbaths, Transvaal, South Africa.

In general observations, many pockets were observed to be different; therefore research was started to discover any trends which may be useful to guide a mine geologist as to where tin may be found. Although much general research has been done on tin no one has attempted to classify pocket types.

All the pockets studied are situated in the Boschoffsberg quartzite member which is part of a sequence of sediments consisting of feldspathic quartzite, arkosite, shale and volcanic deposits. These deposits constitute the pendant which is entirely surrounded by Bushveld granite.

In Rooiberg Mine itself a thickness of 150 m of feldspathic quartzite can be observed, and all the pockets at Rooiberg occur in this unit.

The intrusion of the Nebo granite is believed to have caused fracturing of the roof rocks (Stear 1976), and the subsequent settling of the sediments caused much of the normal faulting and gravity sliding which is seen at Rooiberg; this intrusion and subsequent tectonic adjustments were accompanied by recrystallisation of the sediments.

All the pockets are associated with structural features such as faults, joints, and even stylolites. They can occur in many shapes, but are usually rounded. The macroscopic characteristics of pockets enable them to be classified, as some are uniformly textured while others have different types of halo development and well-developed cores. There is also a considerable variation in mineralogy.

By means of macroscopic and microscopic characteristics of pockets, trends can be observed in their relation to the fissure system. Along fissures there is a recognisable sequence in the occurrence of the pocket types with respect to the metalliferous mineral content.

The pockets were also noticed to occur in a much wider zone of sedimentary alteration than was originally recognised.

All these factors were found to help a mine geologist in determining the location of ore.

UITTREKSEL

Nesvormige mineralisasie verwys na die peulvormige afsettings van grofkorrelrige minerale wat die gevolg is van verandering van die omsluitende sedimente. Op plekke is die neste kassiterietdraend, en sulke neste word by die Rooibergmyn ontgin.

Rooibergmyn is een van vier werkende myne in die Rooiberg-tinveld wat 64 km wes van Warmbad, Transvaal, Suid-Afrika, geleë is.

Algemene waarnemings het getoon dat die neste van mekaar verskil en daarom is navorsing begin om enige neigings vas te stel wat nuttig mag wees in die plaaslike opsporing van tin. Alhowel daar al baie navorsing oor tin gedoen is, het niemand nog probeer om die nessoorte te klassifiseer nie.

Al die neste wat bestudeer is, is in die Boschoffsberg-kwartsiet geleë, wat 'n gedeelte is van 'n opeenvolging van sedimente wat uit veldspatiese kwartsiet, arkosiet, skalie en vulkamese afsettings bestaan. Hierdie afsettings vorm 'n dakhanger wat geheel en al deur Bosveldgraniet omring word.

In die Rooibergmyn self bereik die veldspatiese kwartsiet 'n dikte van 150 m en al die neste by Rooiberg kom in hierdie eenheid voor. Die word gereken dat die intrusie van Nebograniet die breukvorming van die dakgesteentes veroorsaak het, en die daling van die sedimente na die indringing van die graniet het met baie van die afskuiwings en swaartekragglyding wat by Rooiberg gesien

word, gepaard gegaan. Die magmatiese indringing en die daaropvolgende tektoniese aanpassing is ook vergesel van herkristallisering van die sedimente.

Al die neste is geassosieer met strukturele verskynsels soos verskuiwings, naatgroepe en selfs stiloliete. Hulle kan in baie vorms voorkom, maar gewoonlik is hulle afgerond. Die makroskopiese kenmerke van die neste maak dit moontlik om hulle te geklassifiseer want party het 'n gelykmatig tekstuur terwyl ander verskillende tipes van kransontwikkeling en goedontwikkelde kerns het. Daar is ook 'n aansienlike variasie in die mineralogie.

Die makroskopiese en mikroskopiese kenmerke van die neste openbaar bepaalde neigings wat in hulle verhouding met die naatsistiem opgemerk word. Langs nate is daar 'n herkenbare volgorde in die voorkoms van die tipe nes met betrekking tot die inhoud van die metaalhoudende minerale.

Deur chemiese ontleding is dit ook vasgestel dat die neste in 'n veel wyer sone van verandering in die sedimentêre gesteentes voorkom as wat aanvanklik geblyk het.

Dit is vasgestel dat al hierdie faktore vir 'n myngeoloog in sy alledaagse werk van hulp is om erts te vind.

INTRODUCTION

Purpose of Investigation and Importance of Pockets

1.1. Pocket mineralisation is the name applied to pod-like bodies of coarse mineralisation of elliptical or annular form which are the result of alteration of the sediments. The mine which has been chosen for the study of pocket mineralisation is Rooiberg Mine. Of the tin produced at Rooiberg, pocket mineralisation provides a major source of cassiterite ore. The cassiterite-bearing pockets are only one group of pockets in the sequence of pocket development. Of the pockets formed, 30 per cent are not cassiterite bearing. For mining it is important to understand where cassiterite pockets are localised. For this reason a study of pocket development was started. It was hoped that different pocket-types could be recognised and some possible answers as to their formation could be found. By establishing a sequence in pocket types it was hoped it could be used as a guide-line to locate ore.

Geographical Situation of Rooiberg

1.2. Rooiberg Mine is one of four operating mines in the area known as the Rooiberg Tin-Field situated 64 km west of Warmbaths. The other mines are those of Leeuwpoort, Nieuwpoort and Vellefontein. The tin is found as cassiterite in a sedimentary sequence of arkosites and feldspathic quartzites which are part of a roof pendant of the Bushveld granite (Fig.1). The sediments of the roof fragment form a plain, except for a small hillock called the Smelterskop, the sediments of which are surrounded by granite. On the northern boundary are the hills of the Elandsberg, on the south-east are the Rooiberg and on the west are the Boshoffsberg. The cassiterite occurs as lodes in

near-vertical fissures, bedding plane thrusts and in pockets. It is the latter mineralisation which concerns this thesis.

Previous Work on Bushveld Tin Deposits

1.3. Considerable research has been carried out on tin occurrences in the Bushveld Complex. However, the deposits are so varied that there is much research still to be done. At Rhenosterkloof, tin has been found in the Rooiberg felsite and mined at Hoekberg tin mine. At Rhenosterhoekspruit the principal lode is found above the Rhenosterhoek shale band in the felsites. This lode has been mined at Century Tin Mines. Reports were made on these as early as 1909 by Kynaston and Mellor. Tin has also been mined in the granites at Zaaiplaats and at Stavoren in granophyre. In 1904 tin ore was found at Enkeldoorn Spruit in the red granite in a series of cross-cutting veins. They were recorded by Merensky (1908) and also studied by Hall (1905). More work was recorded about Stavoren by Steyn (1962) and the Potgeitersrus by Strauss (1954).

Previous Work in the Rooiberg Area

1.4. Research was also started at an early date in the Rooiberg area by Kynaston and Mellor (1912). At Vellefontein it was recorded that "some large pockets usually occur at the intersection of larger fissures". At Leeuwpoort the area called 'The H.G. Workings' was described as a large pocket of material with cassiterite disseminating into the country rock. Other work recorded was by Leube and Stumpf1 (1963) and Stear (1977).

Previous Work on Pocket Mineralisation

1.5. In 1963 Leube and Stumpf1 completed a major work covering the two distinct classes of deposits "firstly those ore bodies formed by replacement within the feldspathic quartzites, as a result of ore-carrying fluids gaining access through a system of shear and tension fractures": and secondly the ore bodies or "lodes which are the result of fissure filling".

It is the former type of deposit in which the writer has developed considerable interest. Replacement ore bodies are very varied and complex (Butler 1913).

Leube (1960) and Rastall (unpublished mine reports), discussed the variety and the zoning of the pockets and were of the opinion that they were structurally controlled by a network of small fissures and cracks.

Labuschagne (1970) first recorded the polyascendant zoning at Rooiberg, and also the fact that the pockets of Rooiberg and Blaauwbank show different characteristics.

Pipes and pockets have been found and studied elsewhere. In the Olifants River tin-field, pipes of stanniferous ore ranging from 50 mm to 5 m in diameter were mined in the granophyre. As at Rooiberg, albitisation, silica remobilisation and chloritisation were common processes of alteration. The quartzites above the granophyres were mineralised along the major fractures.

In the Zaaiplaats area tin has not only been found disseminated in the granites, but in pipe-like ore bodies (Steyn 1962). The pipes are, on average, 1 m to 2 m in diameter. The pipes are characteristically zoned similar to those of Rooiberg. Pockets or pods of mineralisation are also present as coarse crystals up to 10 mm in size in vug-like occurrences in the granites.

Pipe-like ore bodies also occur in tin fields outside South Africa. At Musang Taud mine in Nasan District, pipe-like ore bodies were mined (Hosking 1969). The pipes, 3 m to 4 m wide, were in argillaceous sediments and quartzites. Pipes of ore from the New South Wales granites in Australia have been described (Blanchard 1947). Pipes in limestones

occur in the Kinta Valley in Malaysia (Scrivenor 1928) and in Finland at Orijarvi (Trustedt 1907).

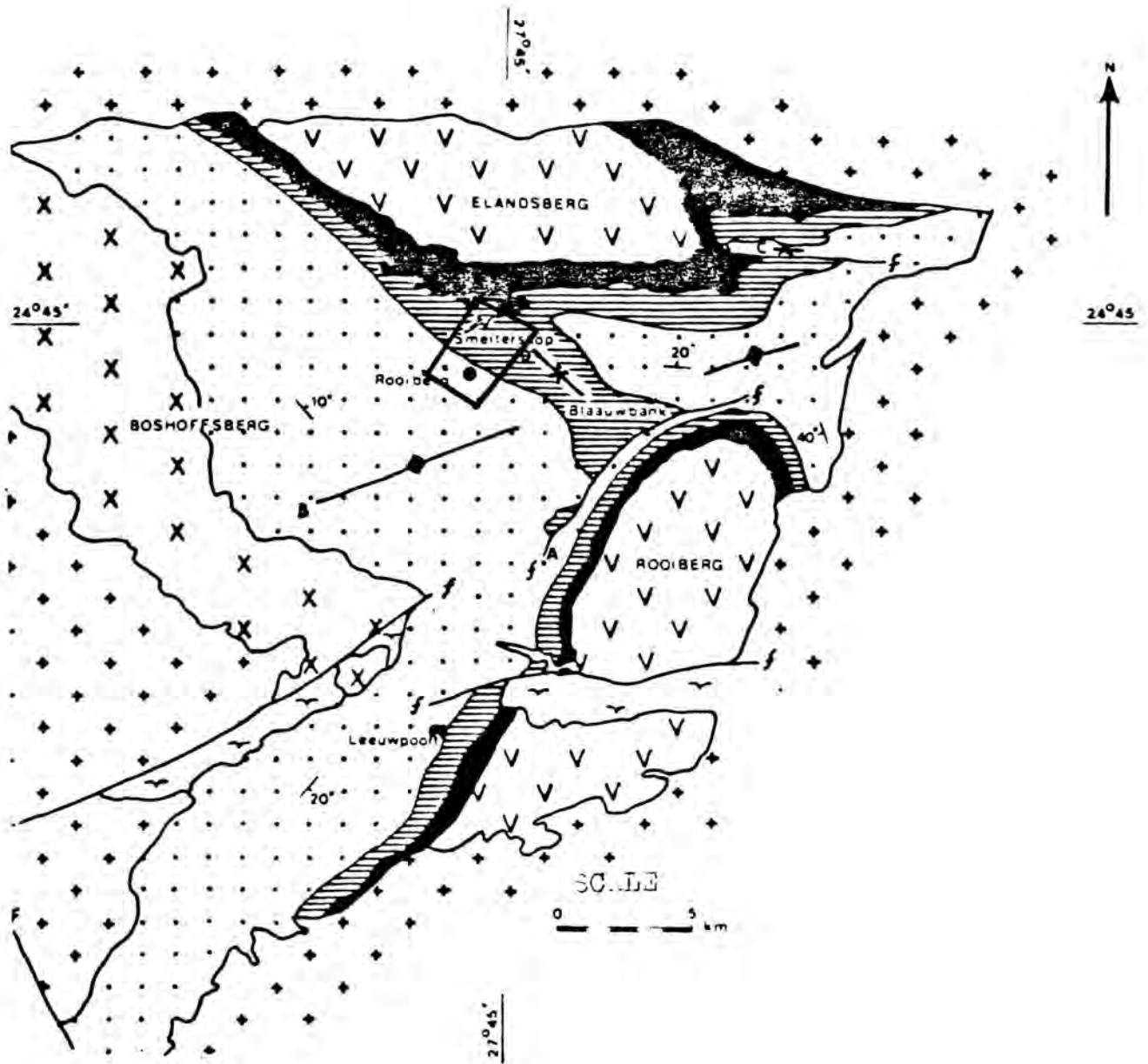
Similar pipes have also been mined in China in Southern Hunan in dolomitic marble. They are of a cassiterite-arsenopyrite variety (Wang and Hsiung 1935).

Nowhere, however, do the pockets and pipes seem to be so varied or complex as those occurring at Rooiberg.

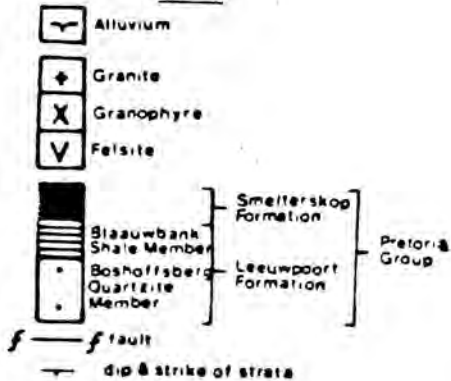
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LEGEND



Area under Investigation for this Thesis.

- A South Parallel Fault
- B Rooiberg Anticline
- C Elandsberg Fault and Syncline
- D Blaauwbank Syncline

Locality Map Adapted from Research by W. Stear
Figure 1.

CHAPTER II

The Methods of Investigation

Underground Mapping

2.1. Pocket mineralisation which is visible on the surface in the area west of A7 shaft (Fig.7) usually weathers with a slight positive relief. Although the coarsely crystalline nature stands out, little else is to be observed because of the weathering. A general geological surface map was produced by Stear (1977). However, the lack of significant outcrop makes underground observation the essential part of research. Extensive underground mapping of mineralised fissures on fifteen different levels was carried out by the writer in his duties for the Company. Examples of mapping for different levels are shown in Figs.8,9,10 and 11.

Selection of Pockets

2.2. From different areas, samples of different pockets were noted for detailed examination. In order to compare those which came from cassiterite-bearing areas with those which do not, a petrographic study was made.

Cassiterite was not always readily visible to the naked eye and its quantity was difficult to assess. A process to distinguish rocks which contain tin from those which do not was carried out by a mining practice known as "blast sampling". This is the process of grid sampling of broken rock after it has been blasted on a P.I.F. Analyser. At present, areas blasted are solely judged by a visual appraisal with a few guide lines. By this method of blast sampling many cassiterite-bearing areas were recognised.

Petrographic Study

2.3. The petrographic study was firstly macroscopic; this the writer considers the most valuable as this can be used as an aid to future geologists working underground. By the macroscopic study an attempt was made to classify pockets to serve as a guide to help in the location of cassiterite ore.

2.4. The macroscopic investigation was followed up with a microscopic investigation using magnification up to 700X so as to try and establish relationships between different pockets and discover trends. Modal analysis was carried out using a comparison with a calibrated graticule. Rutile was estimated by counting the grains per mm^2 - in a similar way using a calibrated area.

The minerals in the different pockets were compared in situ relative to major fissures by underground observation so as to establish any trend which may be of future use.

Chemical Analyses of Wall Rock and Pockets

2.5.1. Chemical analyses of rocks were used to establish the changes that had taken place in sediments in areas where pocket development had occurred. Analyses were made of the changes in the surrounding sediments by two methods; these were governed partly by the equipment available at the time as well as suitability.

The first method was direct electron excitation X-ray spectrometry, to compare the outer halo with the altered sediments. The samples were crushed and mixed with 20 per cent graphite to make them electrically conducting. This was mixed in a tungsten carbide disc mill. The resulting mixture was compressed into a recessed lead disc at 10 tons pressure. An X-ray spectrometer, which

had been previously calibrated with samples of known pure minerals which contained elements wanted in analyses, was used. K_{α} radiation was measured for the various elements in the sample while applying to it a maximum beam voltage from the spectrometer. Concentrations were found from counts using a desk counter, (Roberts and Davis 1977).

The alteration in the country rock was studied by using chemical analyses and an inductively coupled plasma source spectrometer.

The sample was fused with lithium metaborate and then was immersed in a specified concentration of HNO_3 and $La(NO_3)_3$ to form a solution (Walsh and Howie 1980).

The solution was pumped into the spectrometer in the form of an aerosol and sprayed into the centre of an argon plasma which was at a temperature of $6,000K^{\circ}$ to $10,000K^{\circ}$. The flame produced was stable and of high enough temperature to dissociate the chemical bonds and produce a very large number of spectral lines. The light emitted and its intensity was directly related to the concentration of the various elements. The various spectral lines and their intensity were measured by computer by comparison with known standards already stored in the computer. This enabled the concentrations to be calculated and these were then put out from the computer on a teletype. (Walsh and Howie 1980).

Chemical Analysis of Tourmaline and Ankerite

2.5.2. In the study of tourmaline and ankerite replacement, elemental determination was used. The minerals were decomposed chemically and lanthanum and potassium added

to the solutions as a releasing agent and ionisation suppressant respectively; an acetylene-nitrous oxide flame was used. (Price 1979).

Electron Microscope Analyses

2.5.3. A simple study of cassiterite ore was made using a scanning electron microscope. Samples were first prepared by a standard method. The selected specimen was then glued to a mount and examined using a scanning electron microscope. (Hearle, Sparrow, Cross 1972).

CHAPTER III

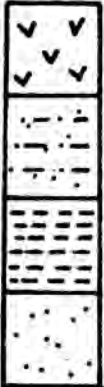
GEOLOGICAL SETTING OF THE ROOIBERG MINE

3.1. Rooiberg Mine is about 6 km across and is situated in the pendant of sedimentary rocks which occupy an area roughly triangular in shape, approximately 35 km at its maximum dimension east-west and approximately 35 km north-south (Fig.1). Drilling has revealed the sediments to be over 1000 m thick, and the mines are entirely within the sedimentary sequence.

The pendant consists of a sequence of arkosites, shales, andesitic lava and pyroclasts (Stear 1977). It has a thin limb stretching south which touches another fragment called the Crocodile River fragment. They are totally surrounded by Nebo granites.

TABLE I

Stratigraphic Succession

	<p>FELSITE</p> <p>QUARTZITES WITH SHALY VOLCANIC HORIZONS</p> <p>BLAAUWBANK SHALE MEMBER</p> <p>BOSCHOFFSBERG QUARTZITE MEMBER</p>	<p>ROOIBERG GROUP</p> <p>SMELTERSKOP FORMATION</p> <p>LEEUWPOORT FORMATION</p>
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3.2. The Boschoffsberg Quartzite Member

The basal group of sediments is named the Boschoffsberg Quartzite Member (defined by Stear, 1977). The Boschoffsberg Quartzite is the member in which tin is mined at Rooiberg. At the base of the quartzite are conglomerate bands; however it is

largely made up of cross-bedded arkosites, the individual grains of which have been extensively re-crystallised as a result of metamorphism.

Although the arkosites are cross-bedded, the cross-bedding is difficult to see, except where later selective alteration has taken place. The two main forms of alteration which show up the cross-bedding are replacement by sericite and tourmaline. The trough cross-bedding indicated flow directions towards the south-west for the major part of the arkosites. There is very little evidence of any deep channelling. There are, along some of the bedding-plane partings, undulations showing shallow fluvio channels of very passive waters.

Rooiberg Mine itself consists of a network of tunnels, vertical stopes and cavities where the ore is mined. In the mine a thickness of 150 m of sediment can be observed in detail. There were no easily observable marker horizons in the sediment, and the quartzite units are on average 300 mm to 1 m in thickness. Some beds were locally more than 2 m thick. Although the original grain size was largely destroyed some sedimentary structures are preserved; ripple marks are rare, but where they are present (in the A2 shaft area in particular) they show the same south-west direction of current flow.

Towards the top of the arkosite member, shale bands occur, some only 10 mm wide. This is the start of a transition into shaly beds. The calculated thickness of the Boschoffsberg main quartzite is at least 1400 m. The sediments dip towards the north-east 5° to 10° . (Fig.1, page 5).

3.3. Blaauwbank Shale Member

This member succeeds the main quartzite. It has been studied in detail on the Rooiberg Fragment by Stear (1977). Near Rooiberg Mine it is best exposed in a river bank near "Bottom Dam". The shale is purple-grey to dark olive-green in colour. The lowest part of the Blaauwbank shale has been observed in boreholes as 20 - 30 mm bands interbedded with arkoses. At Rooiberg Mine it is assumed to have acted as a barrier to upward migrating hydrothermal fluids. The shale partings are micaceous. It contains mud cracks, balled-up structures and ripple marks. It has an estimated thickness of about 200 m.

3.4. Smelterskop Formation

The Blaauwbank shale is locally overlain by a series of flaggy quartzites with thin shaly partings, andesitic lavas and agglomerates. The lower part has a basal conglomerate while the upper part has thin limestone bands and preserved nodular layers. The succession has been named after a prominent hill, the Smelterskop, where it is exposed. The Smelterskop hill was so-named after the finding of the remains of a stone-age man's workings and their remains of tin smelting. Boardman (1946) estimates the thickness of the succession to be of the order of 275 m. The nodular layer looks to be of pedogenic origin and is near a mud flake conglomerates band.

3.5. Rooiberg Felsites

To the north and south of the area the Smelterskop Formation is succeeded by felsite. The felsites are, in general fine-grained and exhibit flow banding. The felsites have been described by Labushagne (1970).

3.6. Structure

The Nebo granite, on intrusion, is believed to have reactivated some of the existing structures related to the major lineaments (Stear 1977). Compression from the S.S.E. is believed to have formed the major arch which crosses the fragment. This arch which is shallow dipping has smaller synclines superimposed on it. The Blaauwbank syncline is across the back of the main arch; their axial lines intersect at 60° .

Other minor synclines are the Elandsberg syncline in the north of the Rooiberg fragment and the Rooiberg syncline in the south of the fragment. They show a 60° intersection with the main arch. (Leube 1960, Stear 1977). These interference folds show that there was a varied force pattern operating at different times.

These folds, with the many associated faults, are the effects of re-settling and re-adjustment of the roof rocks. It is considered that the flexuring was the result of horizontal forces (Boardman 1946, Leube 1960, Stear 1977), and that the same forces were responsible for the activation of major thrusts on the Rooiberg fragment.

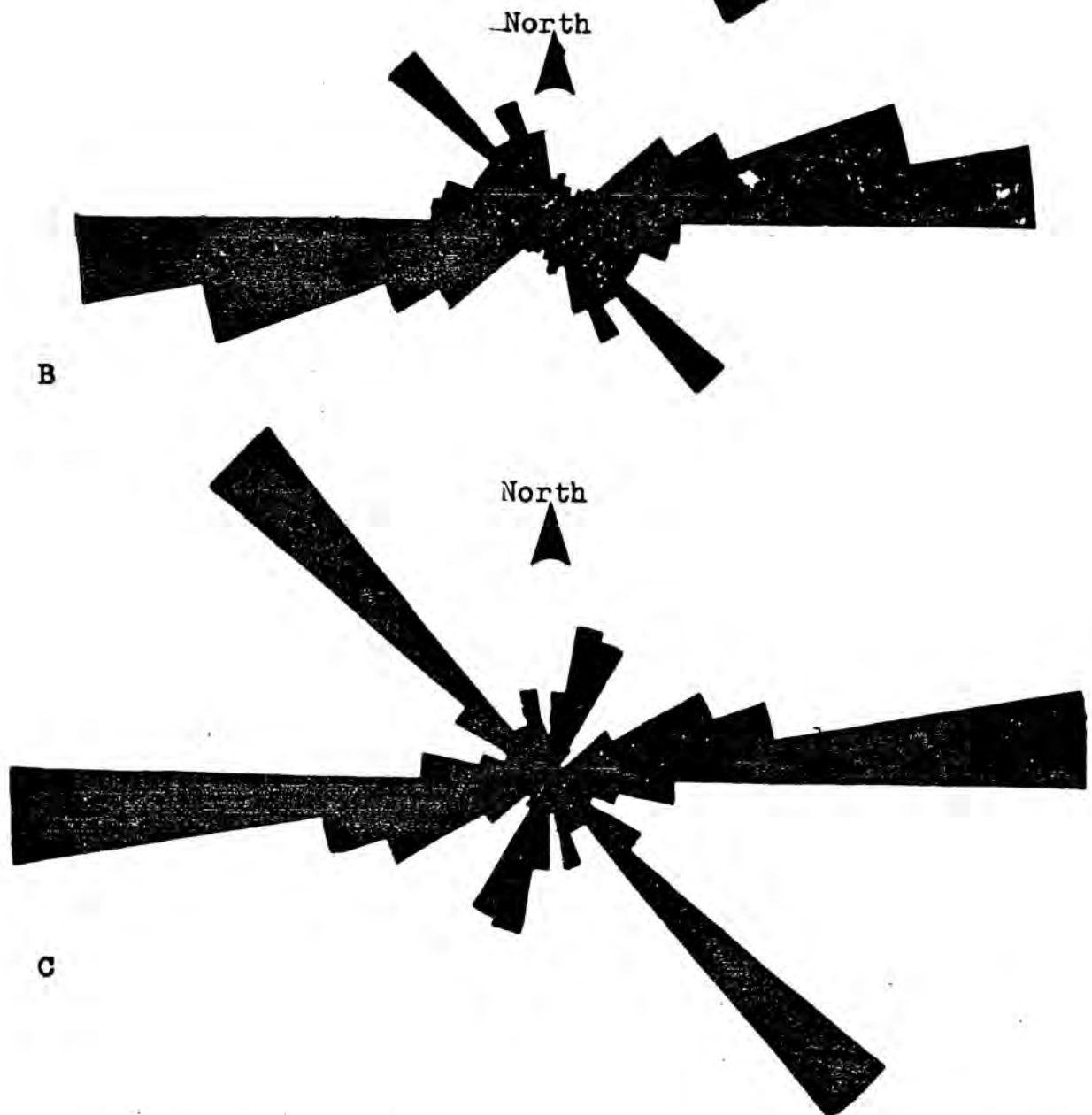
The main thrust faults show a similar variety of directions to the latter synclines. The South Parallel fault which has a strike N.N.E. - S.S.W. runs along the western flank of the Rooiberg syncline and can be traced over a distance of more than 20 km. The Stewart fault is developed along the south-east extension of the Blaauwbank syncline, and the northern thrust fault which is parallel

to the Elandsberg syncline, can be traced over 15 km (Labuschagne 1970). Crocker et al (1976) found intrusive granite along fault planes bounding the fragment. This illustrates the early nature of some of the fault systems and this, in some cases, is a probable reflection of the early basement features (Crocker et al 1976).

Although these early features are in the region of Rooiberg Mine, where the writer was carrying out his research the dominant fault pattern is of a very different nature. The most prominent faults are normal faults some with a slight tear movement. These faults, when interpolated, indicate a typical block faulting.

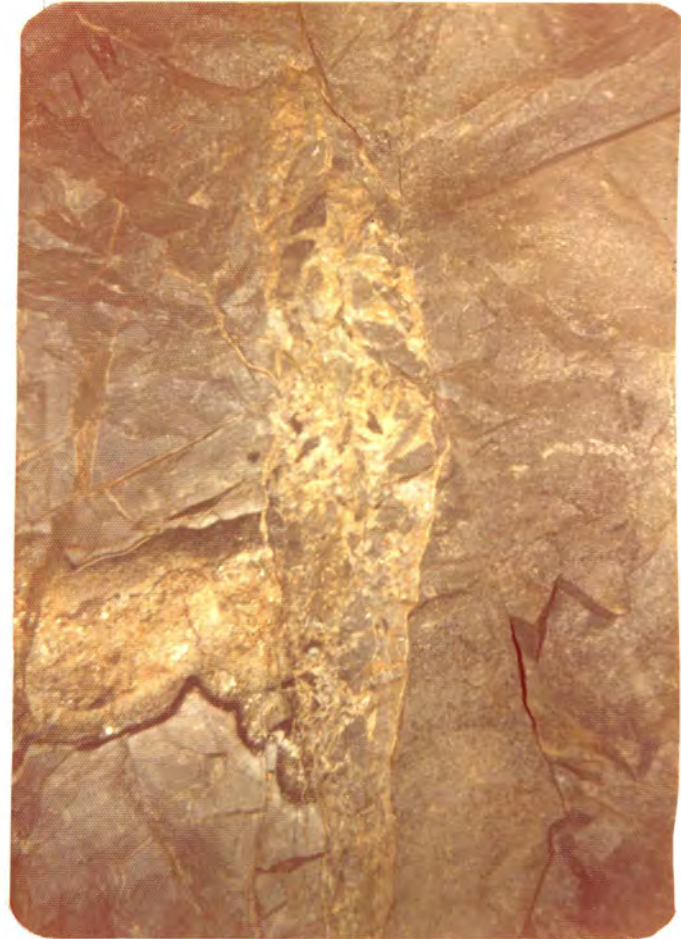
Lack of sedimentary marker horizons made detailed mapping necessary to locate faults and work out the structure. Many of the faults and joints had been rejuvenated and mineralised so it was found necessary to map mineralised joints as well. Because the pocket mineralisation was also adjacent to joint fissures it was expected that they also played a part in the mineral zoning.

The block faults are not isolated to Rooiberg, but are common over much of the fragment studied by Meinster (Stear 1977), who explains the fracturing as due to regional subsidence with the Rooiberg fragment in a central position. The writer's impression is that some of this faulting is associated with small scale gravitational sliding. The blocks in many areas downstep to the north and south forming horst blocks. (Locality Map, Fig.7, page 23).



Rose diagrams showing the variable fracture pattern in the Rooiberg A Mine. Diagram A represents A7 Shaft area (387 fractures), diagram B the 19 North area (687 fractures), diagram C the U30 area (303 fractures).

Figure 2






A Scale 100mm  B Scale 100mm 
Photograph A post dyke period thrusting. It is seen to have vertically displaced the dyke. Photograph B a later period of ankerite mineralisation has cut an earlier pocket. In this case the later ankerite shows no sign of causing a later period of pocket development or replacement of part of the earlier pocket.

Figure 3



Scale 100mm 

A dyke following a fissure (dashed - -).
Pockets either side of fissure by dyke
which shows them to be from an earlier period
of mineralisation.

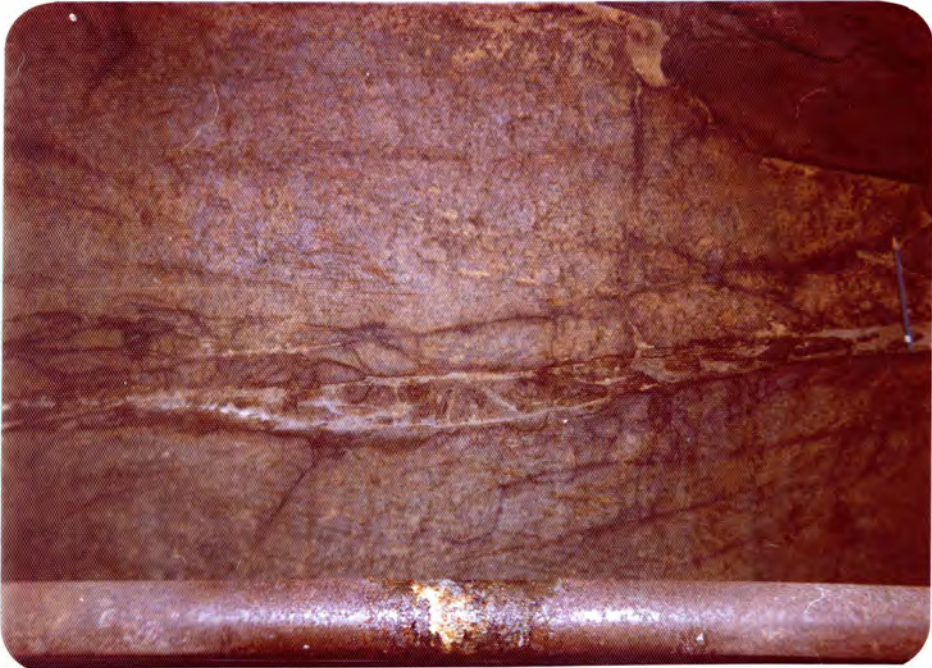
Figure 5



A

Scale 100mm ↵

A multiple-haloed pocket with a typical altered arkosite core of decayed feldspar with a golden speckled pyrite halo (a), and black tourmaline outer halo (b). It shows a post mineralisation fault.



B

Scale 100mm ↵

A typical bedding plane fault showing a lens of breccia. These lenses of breccia are not common. The filling is often altered and sometimes mylonitic.

Figure 5

Bedding-plane partings in many areas are slicken-sided, showing bedding-plane faulting. Some are inclined a few degrees to the bedding-plane, and are a common feature of Rooiberg Mine.

The second period of faulting is characterised by the opening of new joints and the closing of others. Some of the old joints have been so well filled as to be hardly discernible. Their planes have become stylolitic and slicken-sided. This later adjustment and refilling of joints has resulted in a complex fracture pattern as is illustrated by the attached plans. Figs.8,9,10 and 11 show the main block faults. Three main directions stand out as is illustrated in the rose diagrams in Fig.2.

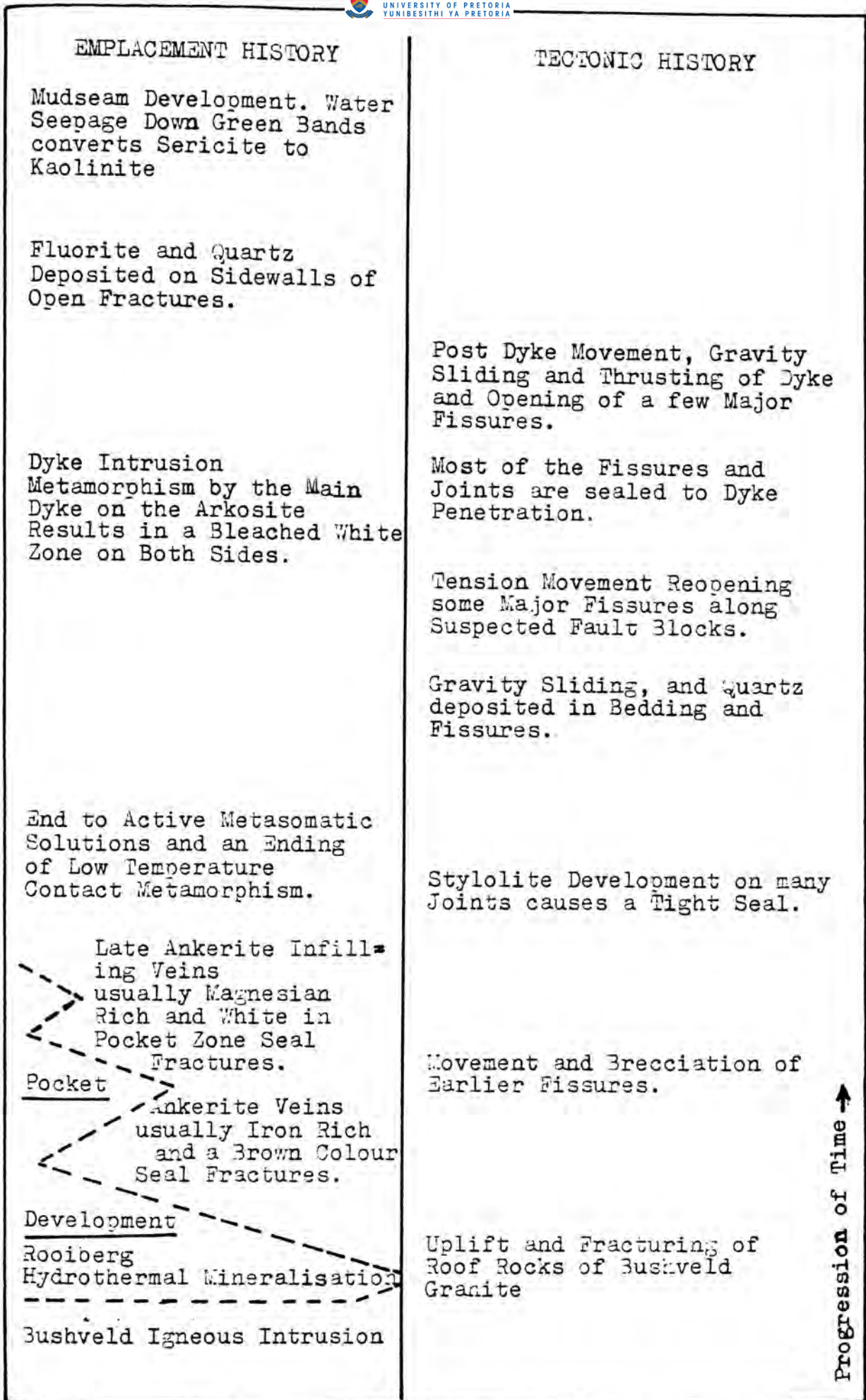
There are altogether five periods of movement to be detected after the main compressional thrusting namely

- 1) The development of block faults and joints.
- 2) The filling up of some of the older joints, and the opening of others, and in some cases, the formation of new joints. This is shown by the selective emplacement of hydrothermal mineralisation.
- 3) The next period of movement can be detected by the faulting of veins; brecciation and displacement being a characteristic feature, (Fig.5A). A second emplacement of hydrothermal filling seals the earlier faulting (Fig.3B).
- 4) A period of reactivation opens up some of the major faults with a directional trend 125° - 130° , clearly indicated by intrusions of dykes. The dykes vary from 100 mm to 7 m in thickness. They can be seen to cut earlier mineralisation (Fig.4).

5) The last obvious movements result in cavities over 200 mm wide and some are quartz lined. Gravity sliding has resulted in bedding-plane faults, (in some cases the bedding-plane faults are filled with breccia as in Fig.5B), and faulting of dykes (Fig.3A); also there is displacement of a bleached white quartzite belt which follows the Master Dyke (Figs.9 & 10). The suggested history of events related to mineral emplacements can be represented diagrammatically in Fig.6.

There are three main directions of faults. They are shown by notation A - A⁰, B - B⁰, and C - C⁰ on Figs.8, 9, 10, 11. In different areas, different fault directions are dominant. However, it is true to say over Rooiberg they can generally be classified into three sets (1) the '19 north direction named after a dominant fault underground (065° - 075°) represented as A - A⁰ on structural plans. They are parallel to the axial trace of the regional arch. (2) The master dyke direction which is well illustrated on the plans which trend N.W. - S.E. represented on structural plan as B - B⁰, (3) A set of north south fractures and N.N.W. to S.S.E. fractures which can be classed as the "cotton lode" and 'O' lode direction represented as C - C⁰ on the structural plans. See Locality Map, page 23, Figs,7,8,9,10 and 11.

With all the faults, fissures and joints mapped pockets are associated. Thus one can deduce the change in the pocket distribution throughout the mine in different areas. However of the pockets associated with the many fissures mapped fewer than 10 per cent will be of economic importance and

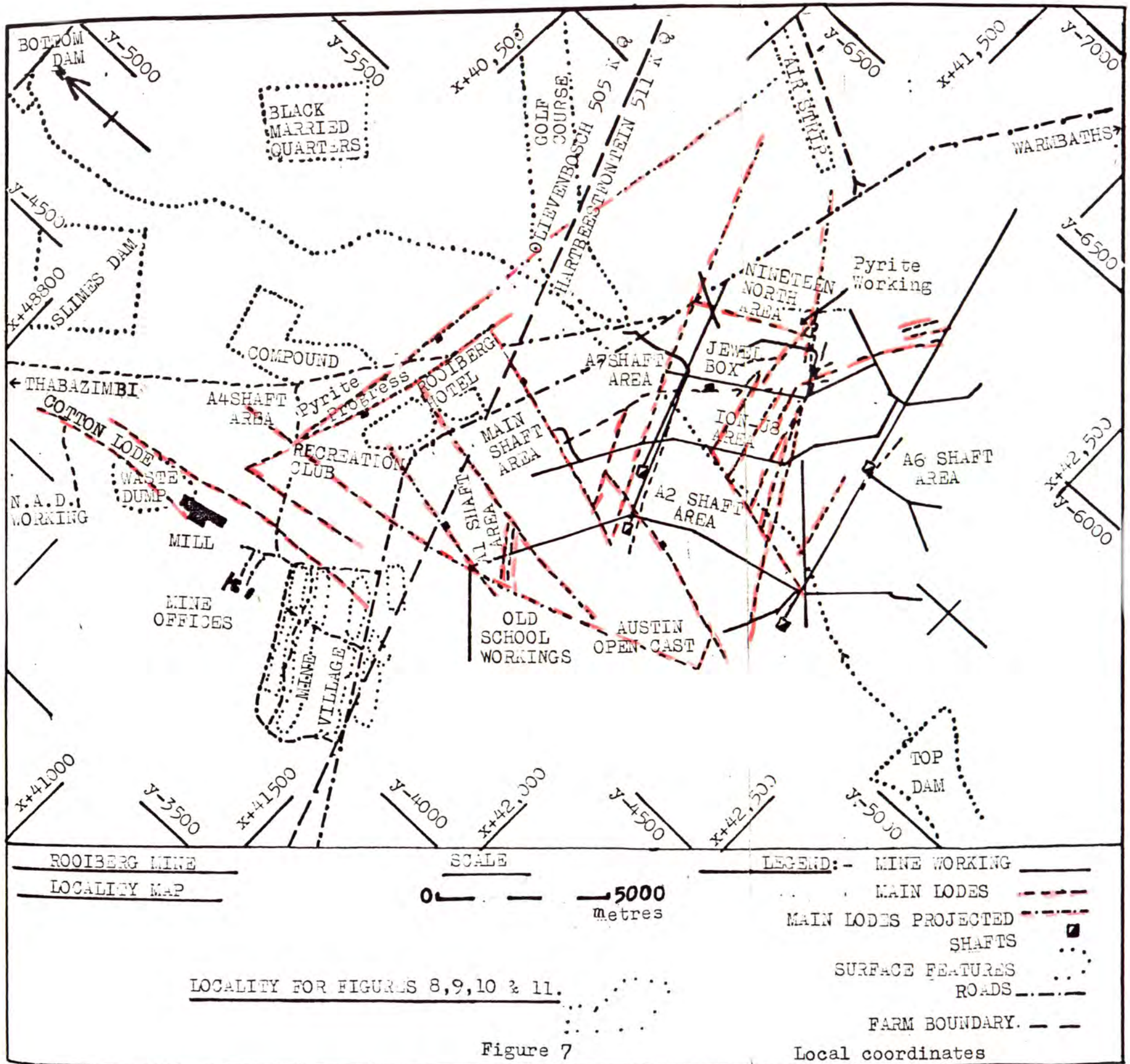


SUGGESTED HISTORY OF EVENTS OF ROOIBERG MINE

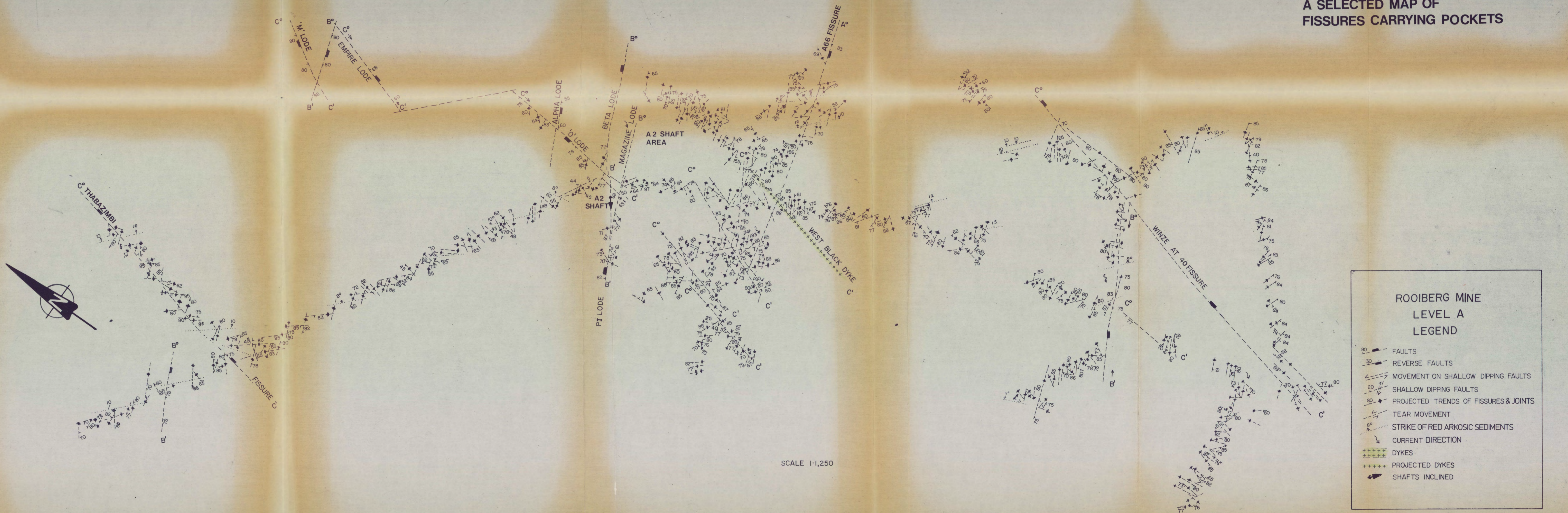
Figure 6

yield payable cassiterite. The fissures of economic interest on the relevant levels have a very complex distribution and the planar distribution of tin changes from level to level. This can be deduced from the fissures mapped along tunnel exposures in the search for cassiterite.

Folding on Rooiberg Mine was not visible; there was only a slight variation in strike over the whole mine and a little drag folding near the Master Dyke.



A SELECTED MAP OF FISSURES CARRYING POCKETS

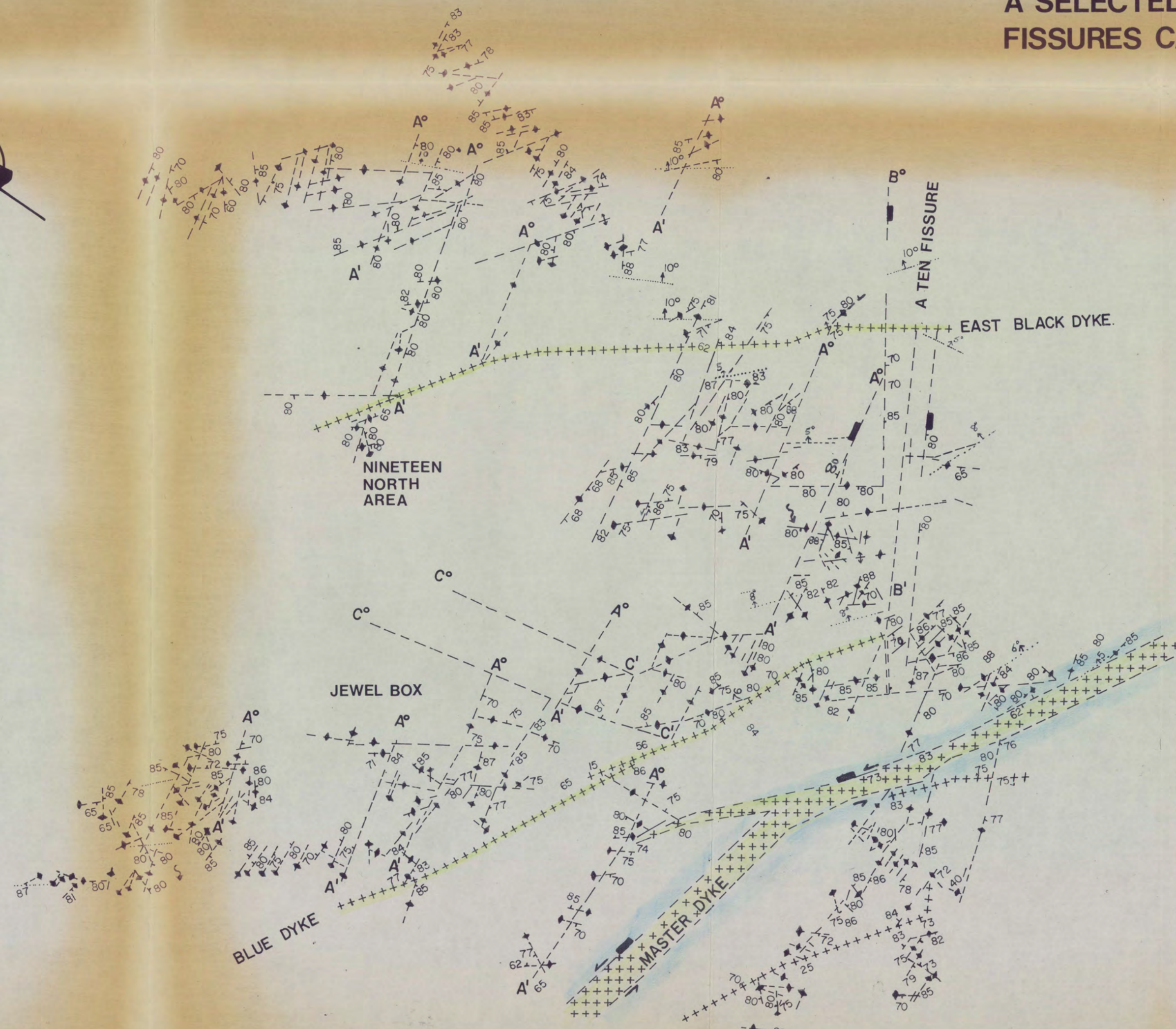


**ROOIBERG MINE
LEVEL A
LEGEND**

- FAULTS
- REVERSE FAULTS
- MOVEMENT ON SHALLOW DIPPING FAULTS
- SHALLOW DIPPING FAULTS
- PROJECTED TRENDS OF FISSURES & JOINTS
- TEAR MOVEMENT
- STRIKE OF RED ARKOSIC SEDIMENTS
- CURRENT DIRECTION
- DYKES
- PROJECTED DYKES
- SHAFTS INCLINED

FIGURE 8

A SELECTED MAP OF FISSURES CARRYING POCKETS



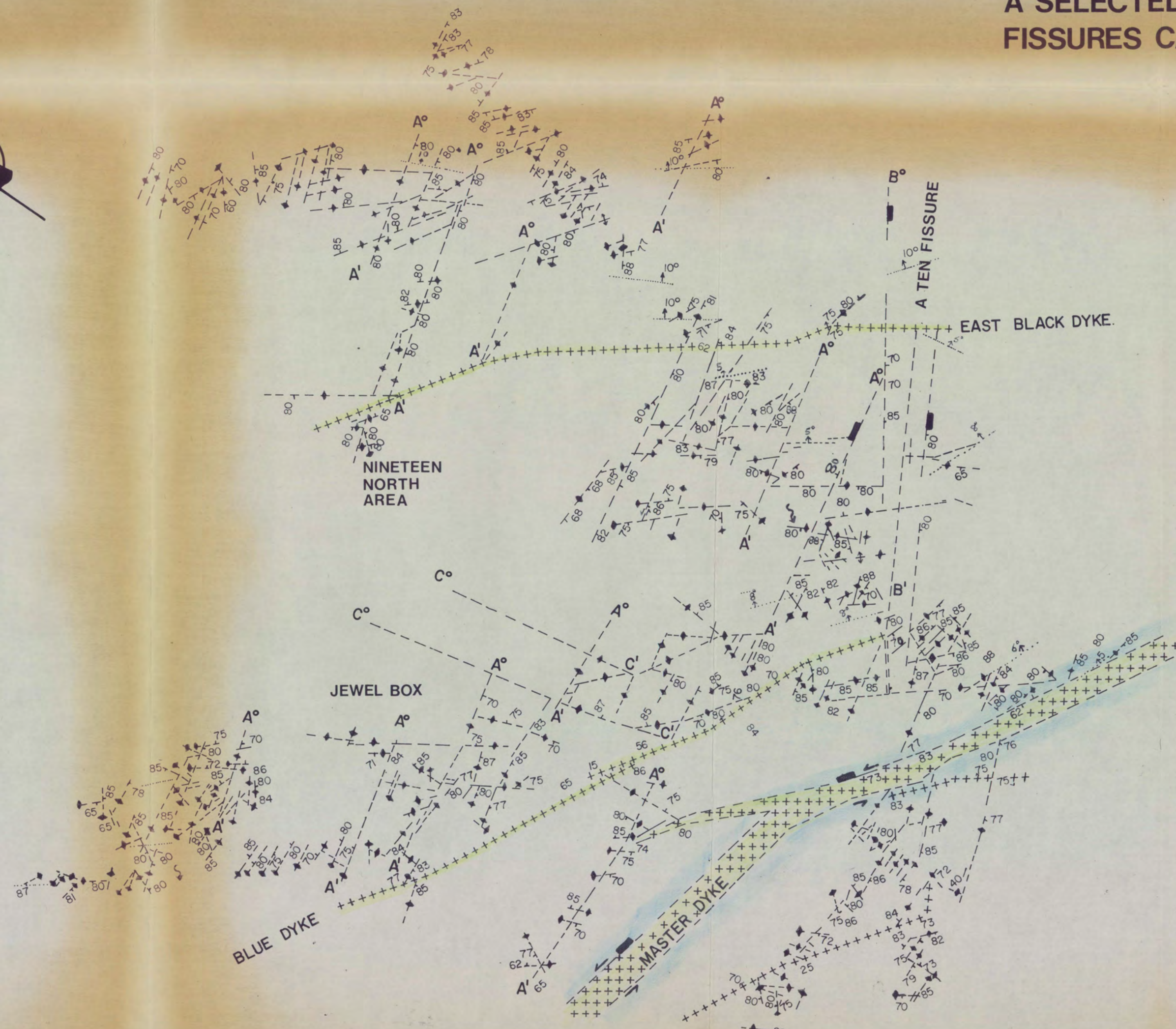
ROOIBERG MINE LEVEL C LEGEND

- FAULTS
- REVERSE FAULTS
- MOVEMENT ON SHALLOW DIPPING FAULTS
- SHALLOW DIPPING FAULTS
- PROJECTED TRENDS OF FISSURES & JOINTS
- TEAR MOVEMENT
- STRIKE OF RED ARKOSIC SEDIMENTS
- CURRENT DIRECTION
- DYKES
- PROJECTED DYKES
- SHAFTS INCLINED
- WHITE QUARTZITE ZONE

SCALE 1:1,250

FIGURE 10

A SELECTED MAP OF FISSURES CARRYING POCKETS



ROOIBERG MINE LEVEL C LEGEND

- FAULTS
- REVERSE FAULTS
- MOVEMENT ON SHALLOW DIPPING FAULTS
- SHALLOW DIPPING FAULTS
- PROJECTED TRENDS OF FISSURES & JOINTS
- TEAR MOVEMENT
- STRIKE OF RED ARKOSIC SEDIMENTS
- CURRENT DIRECTION
- DYKES
- PROJECTED DYKES
- SHAFTS INCLINED
- WHITE QUARTZITE ZONE

SCALE 1:1,250

FIGURE 10

A SELECTED MAP OF FISSURES CARRYING POCKETS

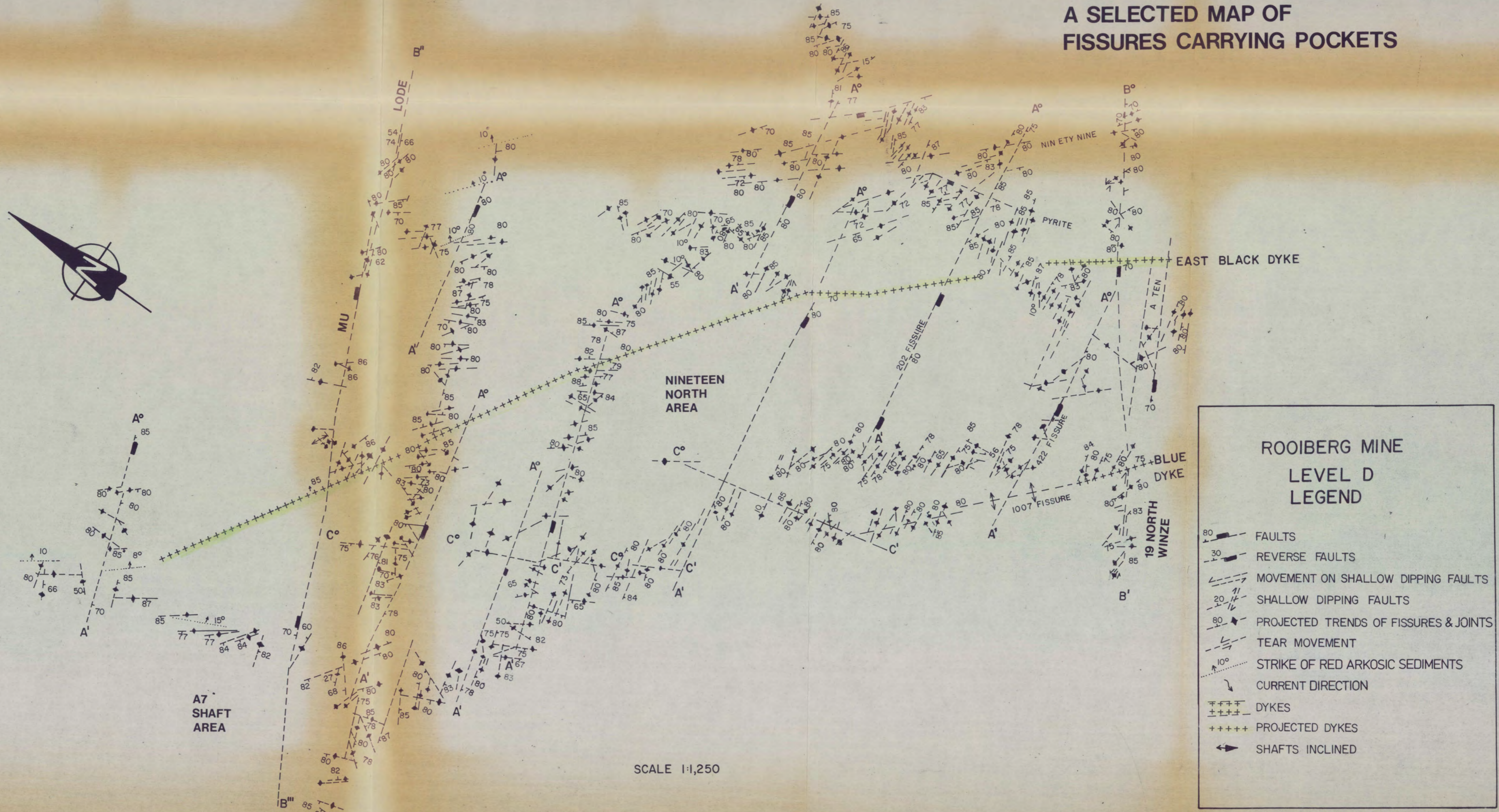


FIGURE 11

CHAPTER IV

PETROGRAPHY OF THE COUNTRY ROCKS

4.1. Leeuwoort FormationBoschoffsberg Quartzite Member

The Boschoffsberg quartzite member contains 40 - 80 per cent orthoclase feldspar, which was found to vary irregularly. The remainder of the rock consists largely of quartz and sericite with plagioclase varying between 5 and 10 per cent. The sericite content is a result of alteration of the feldspar. The quantity of feldspar suggests the rock might be better termed an arkosite. Clouding of the feldspar is due to fine specks of accessory limonite and rutile many of which were about 0,05 mm in size, (Figs. 13B & C). Strauss (1947) deduced that the intergrowth must be the result of the way that the iron was added; this he suggested as probably through the unstable feldspar molecule $K Fe Si_3 O_8$, which originally occurred in solid solution in the feldspar.

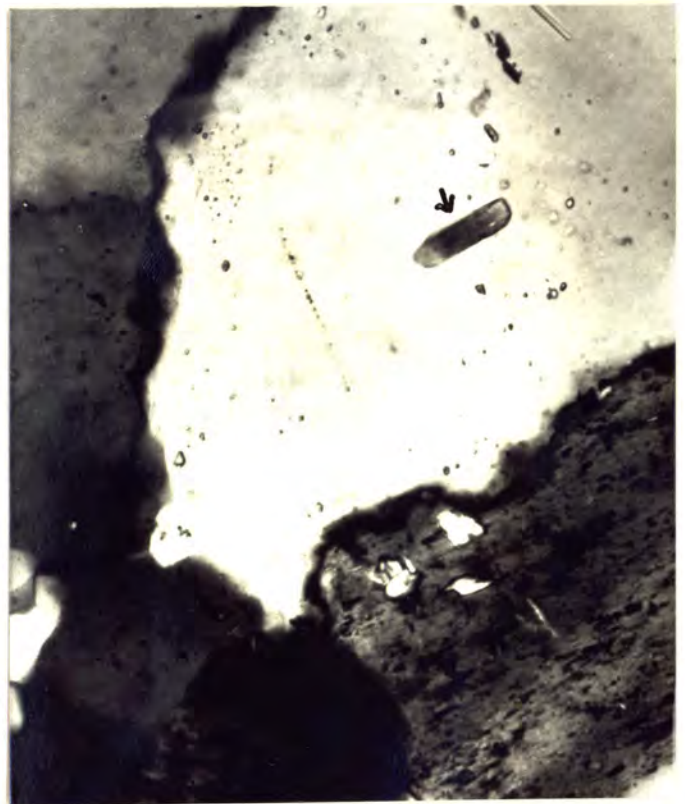
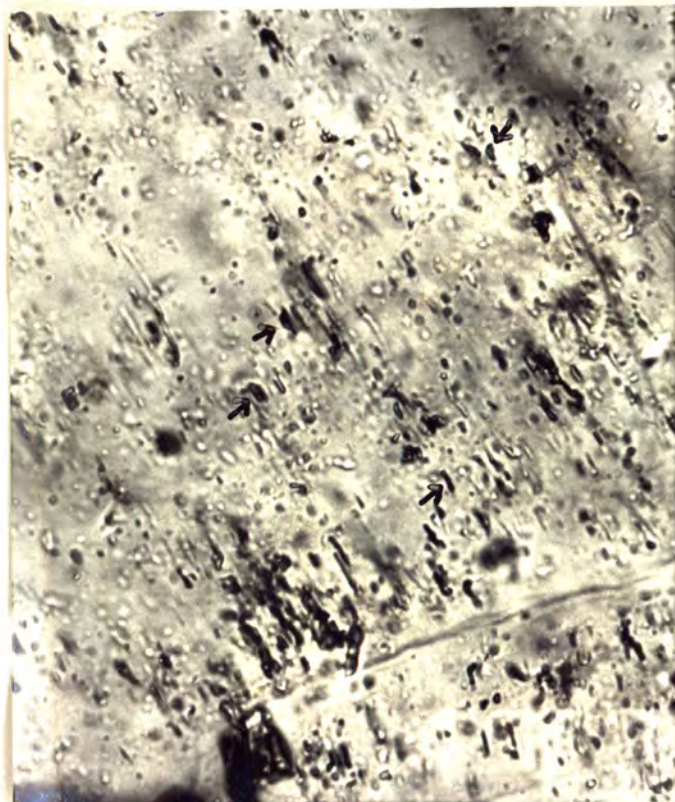
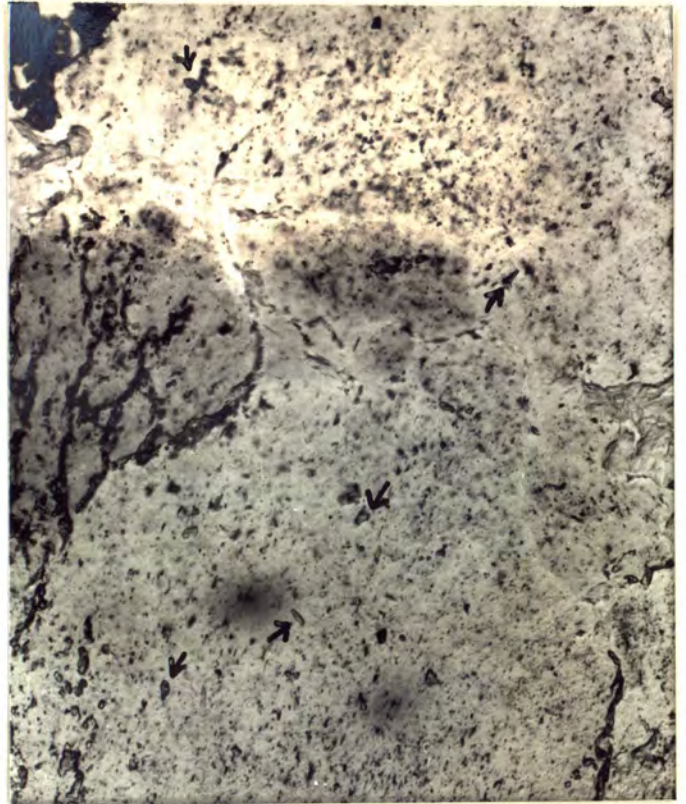
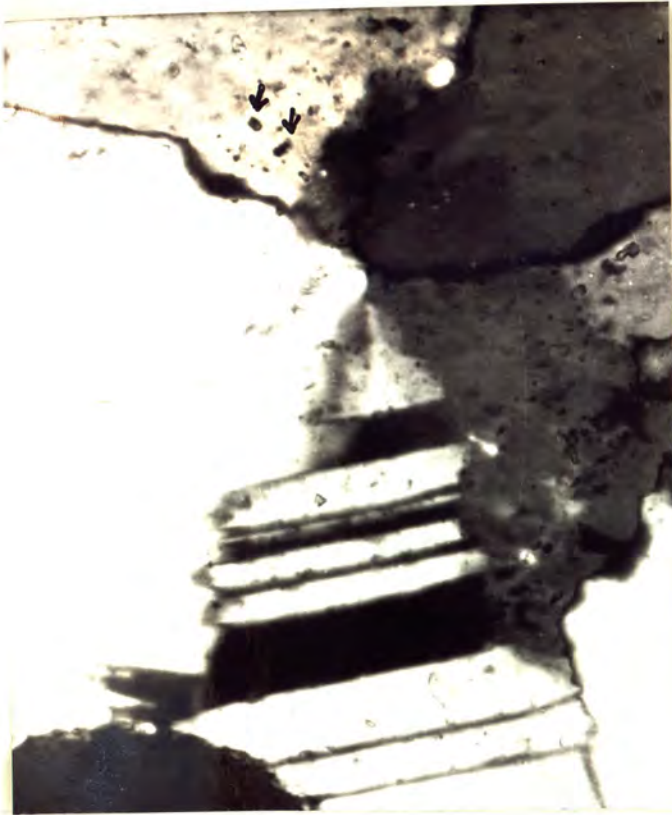
Other accessory minerals include sphene and zircon. In rare instances magnetite occurs in heavy mineral layers not as an accessory mineral but as a major constituent. Layers were found which consisted of 20 mm thick bands and magnetite in the band made up as much as 40 per cent of the rock. The magnetite grains which can vary in size from 0,1 mm to 0,2 mm are often recrystallised into laths and fused (Fig. 12).

Leube and Stumpf (1963) suggested that the orthoclase was a major sedimentary factor in the localisation of tin. However this evidence was derived from a limited number of samples.



**Magnetite grains (black) in a heavy mineral layer
in the Boshoffsberg quartzite (x 21).**

Figure 12



Boschoffsberg Quartzite.

2. A. Rutile at the top, and sphenes below as inclusions in crystals of plagioclase, (x 100, crossed nicols). B. A study of the red-coloured nature of orthoclase, ascribed to limonite and haematite speckling, also shows rutile and sphenes (some arrowed), (x 300). C. Oriented inclusions in orthoclase many of which are identified as rutile (x 300). D. Rutile in a transition to sphenes as an inclusion in orthoclase (x 300, crossed nicols).

The arkosite has a sugary texture which is observable under the hand lens and often easily seen with the naked eye. Under microscopic examination the texture is also xenoblastic.

The arkosite has a grain size of 0,3 mm to 0,5 mm and in some areas there is evidence to suggest that the grain size was originally up to 1 mm: thus its texture is also phaneric. The original grains have largely been destroyed. The present grains are in some areas interlocked and grown around each other. There is little sign of any of the original intergranular cement (Fig.13A). The scattered sericite penetrated into the feldspar grains.

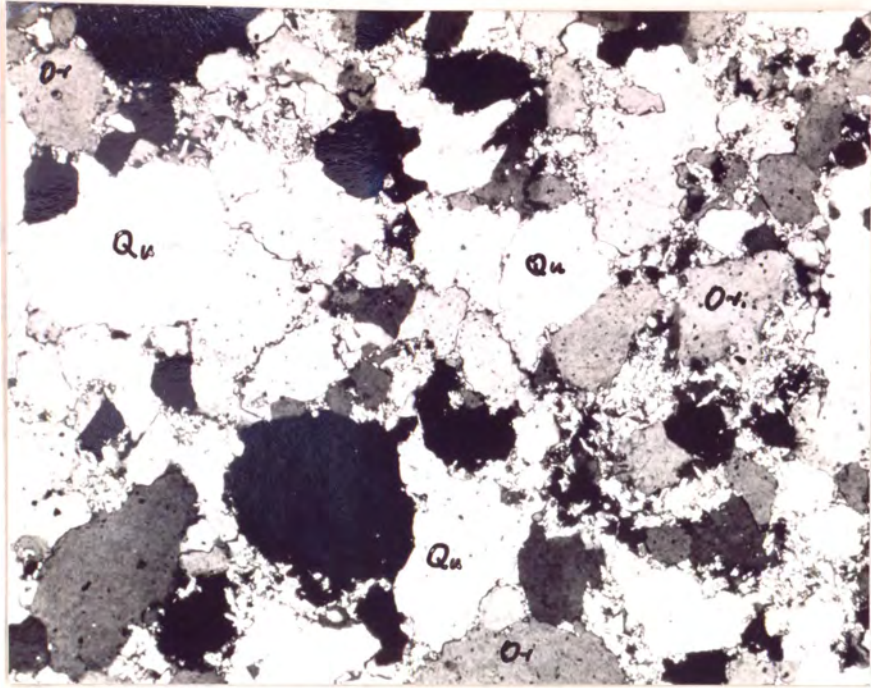
Other evidence of a general alteration is in the heavy minerals where leucoxene is with magnetite in some areas and sphene replaces rutile (Figs.13C & 13D).

An even later period of contact metamorphism affected the arkosite. Close to the intruded Master Dyke, thermal metamorphism has altered the colour of arkosite from red to white.

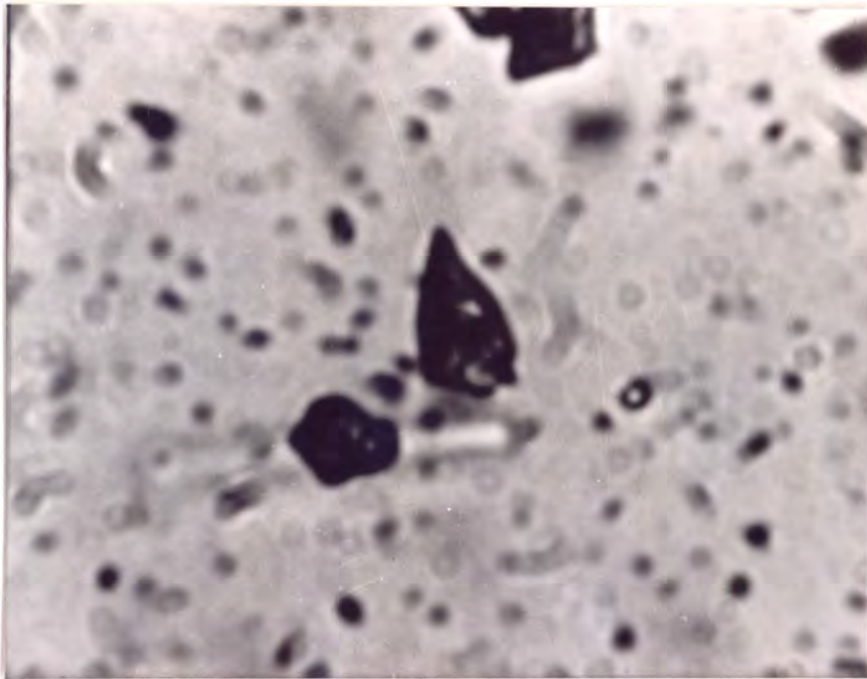
Rutile is often concentrated in the arkosite to more than 1000 grains per cm^3 ; it thus becomes readily mixed with cassiterite in crushed rock. Also near the pockets there is a zone of rutile enrichment (Fig.13B). This is not easily observed under the microscope. However chemical analysis shows the enrichment to be marked. (Table III, page 98).

4.2. Leeuwpoort Formation Blaauwbank Shale Member

The shale shows only slight signs of metamorphism. Muscovite is well-aligned along bedding-plane partings



A
Typical quartzite of the Smelterskop Formation with small specks of rutile and sphene. The grains consist of quartz (qu), orthoclase (or) and sericite (se) is an interstitial mineral. Cross polars (x 175).



B
Inclusions of ilmenite (very dark grey) in orthoclase from the Smelterskop Formation. (x 700).

Figure 14

giving a cleavage. It consists of very fine sericite with some particles of feldspar. The muscovite flakes on the cleavage plane however can be up to 1 mm.

4.3. Smelterskop Formation

The quartzite contained 60 per cent quartz, 30 per cent orthoclase and 10 per cent plagioclase. It has an allotriomorphic granular texture indicating marked recrystallisation (Fig.14A). Its grain size was 0,3 mm to 1 mm giving it a phaneric texture resembling a granite. Inclusions of ilmenite, rutile, and sphene were seen in the quartz grains as well as the feldspar grains (Fig.14B).

4.4. Stylolites in the Sedimentary Host Rocks

The interlocking junctions of stylolites take many forms, and these are the bases of a classification put forward by Park and Schot (1968). They classified the stylolite seams according to their geometry into

- 1) simple or primitive waves (Fig.15F)
- 2) suture type (Fig.15C)
- 3) rectangular up-peak type (Fig.15B)
- 4) rectangular down-peak type
- 5) sharp-peak type (Fig.15E)
- 6) seisogram type (Fig.15E)

All these types can be seen in varying degrees of development in different areas of Rooiberg Mine. The amplitude of the waves however is rarely more than 5 mm and, so far, all have been observed to be less than 10 mm. The different geometrical forms of stylolites do not have a regional distribution of type, but seem to be intermixed.

The rectangular stylolites (Fig.15B) tend to be associated more with a bedding-plane parting, while the sharp peaked types of stylolites can occur between two successive partings themselves (Fig.15E). This intricate inter-teething of the rock is separated by a thin layer usually of clay or sericite. On the one side the projecting teeth show the same lithological characteristics such as grain size as the strata of that side, while the teeth from the opposite side show a similar relationship to their own side of the strata. The rock strata on either side of the stylolite-seam appear undisturbed.

The stylolites themselves can also be classified according to rock fabrics, i.e. aggregate stylolites and intergranular stylolites, as defined by Park and Schot (1963).

Aggregate stylolites are any departure from a bedding seam usually marked by a layer of deposited material; such a feature could be called an aggregate stylolite if the height of the amplitude is greater than the width of the individual columnar units.

Intergranular stylolites are stylolite seams with an amplitude smaller than the grain size of the host rock. Such seams can range from macroscopic to microscopic.

Many of the less obvious channels feeding hydrothermal fluids into the country rock are stylolitic by forming planes of weakness for mineralising fluids, (Fig.16c), this being suggested by the alteration concentrated on stylolites.

The stylolites often seem to have concentrations of heavy minerals which remain in the parting with the sericite. There is

a noticeable segregation between the heavy and lighter minerals in the stylolite. The heavy minerals often lie below the sericite and were commonly found in the troughs. The main minerals are magnetite, rutile, sphene, and zircon.

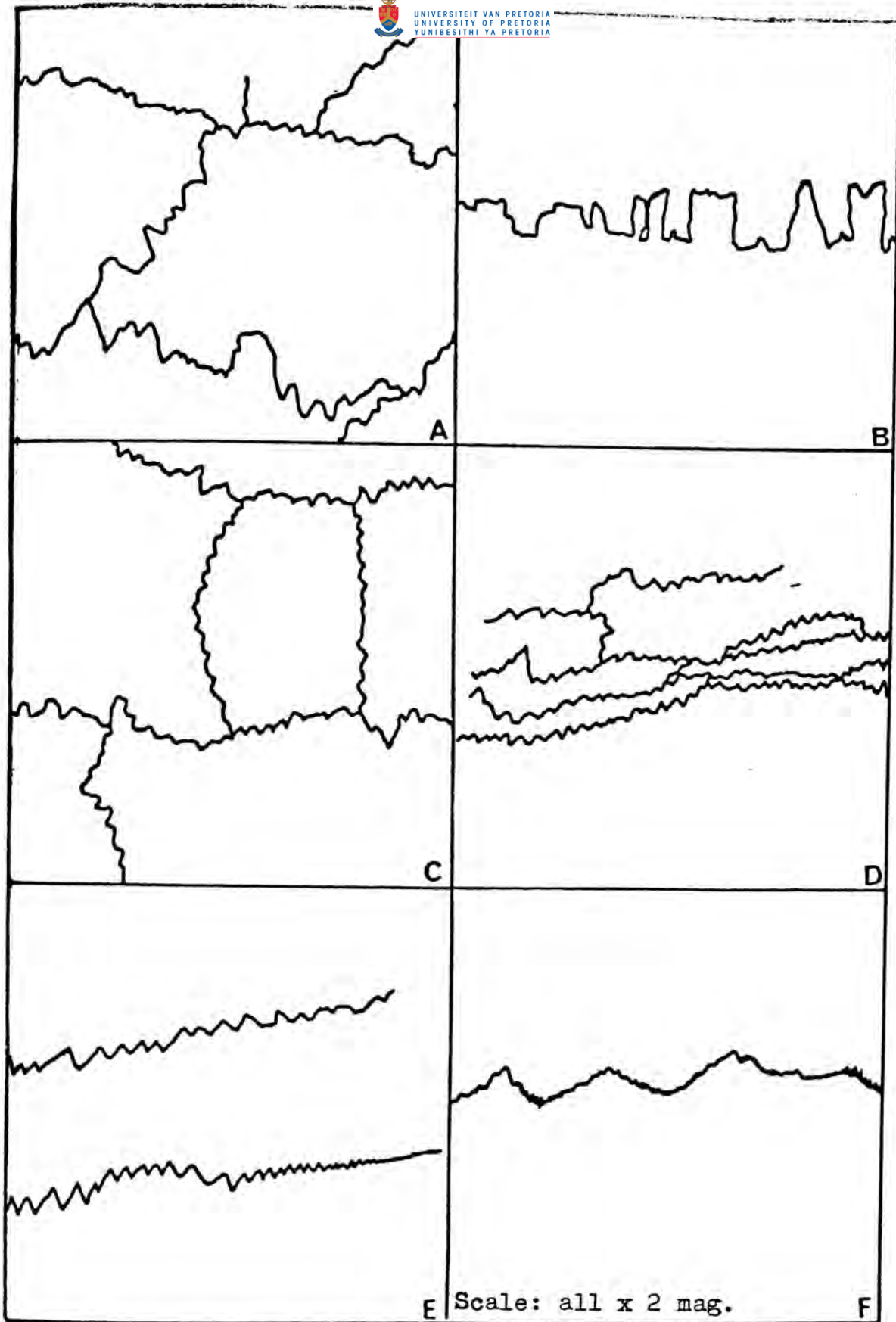
Some of the heavy minerals such as zircon and rutile are of primary origin. They occur in the sediments near the stylolites; however, the rutile found in the stylolite is of a much larger grain size than the rutile in the sediments either side of it. This growth in grain size suggests solution migration from the surrounding rock to the nuclei in the stylolite.

Stylolite peaks and troughs are sharp and well-defined. This is the reverse of the sedimentary features of the altered arkosite where much of the original grain structure has been destroyed. Many of the stylolites are well-developed in the recrystallised arkose.

Park and Schot (1968) also introduced a classification of stylolites in relation to the bedding plane, i.e.

- 1) Horizontal stylolites (Fig.15F)
- 2) Inclined stylolites (Fig.15E)
- 3) Horizontal-inclined-cross-cutting stylolites (Fig.15E)
- 4) Vertical stylolites (g in Fig.16D)
- 5) Interconnecting network stylolites (Fig.15D)
- 6) Vertical-inclined-cross-cutting stylolites (Fig.18C)

All are found in the Rooiberg Mine in various stages of development. Some of the stylolites extend for tens of metres, while others are less than half a metre in length and die out into a thin sericite seam.



Drawings of some stylolites found at Rooiberg and descriptive names based on Park and Schots classification (1968). (A) Horizontal-inclined (vertical) cross-cutting stylolites. (B) Up-peaked rectangular type of stylolite. (C) Vertical and horizontal stylolite network. (D) Interconnecting network stylolites of sharp peak type. (E) Sharp-peaked type stylolite above with seismogram type stylolite below. (F) Simple primitive wave type with a superimposed seismogram type giving a sawtooth pattern of waves. Diagrams have been rotated so that the bedding plane is horizontal.

4.5. Origin of Stylolites

Many theories have been suggested to explain the origin of stylolites. (Stockdale 1923).

i) The organism theory first put forward by Eaton, (Stockdale 1923), suggested that stylolites were fossil corals; while Quenstedt (Stockdale 1923) suggested they were trace fossils, and the remains of holes formed by the upward movement of mussel shells. This is easily discounted at Rooiberg where there are no traces of fossils.

ii) The crystallisation theory first put forward by Bonnycastle, (Stockdale 1923), suggested it was new mineralisation deposited by an infiltration process; while Vanuxem (Stockdale 1923) suggested that it was a layer of sulphate of magnesium which crystallised at the time of deposition.

iii) The erosion theory proposed by Pleininger (Stockdale 1923) explained them as forming in a shore line environment where the limestone ooze was raised above water level, where a condition prevailed similar to that which would produce shrinkage cracks. On re-submersion, these cracks would fill with further limestone ooze. At Rooiberg this theory can be discounted as the stylolites cross-cut the sedimentary features. The sediments are not limestone but arkosite and they are not of the shape produced by shrinkage cracks.

iv) The bitumen theory put forward by Alberti 1853, (Stockdale 1923), suggested that the columns were formed by petroleum which pushed its way upwards in a soft rock, then being deposited as a dark bituminous layer.

However at the Rooiberg locality the stylolites have no trace of carbon and the stylolite caps are of sericite or clay.

v) A gas theory was proposed by Zelger (Stockdale 1923). He considered the structures the result of escaping gases passing through the limestone ooze. However gas bubbles observed under laboratory conditions and in lavas reveal the resulting dynamic shape of these vesicles to be very different from any stylolite formation at Rooiberg.

vi) The pressure theory for the occurrence of stylolites as put forward by Quensted (Stockdale 1923) was based on the hypothesis that successive layers of limestone would have different degrees of hardness and when compressed into each other would form the columnar structure of the stylolites. The sericite is the result of a clay layer. Over the years many modifications of the theories have been put forward (Stockdale 1923). Although many stylolites have peaks and troughs they have little resemblance to pressure cones. Some have curved apices, others are square. The hardest to explain are those which are cross-cutting.

The pressure solution theory first put forward by Fuchs (Stockdale 1923) stated that stylolites were formed in hard rock under pressure along a crack or crevice. He considered that the differential ability of the rock to resist solution resulted in the interteething of the strata along the line of solution. The often present clay cap is the result of non-soluble residue of the dissolved rock and the polished striated sides of the

columns are the result of the movement which has taken place. This idea was rejuvenated by Stockdale (1923).

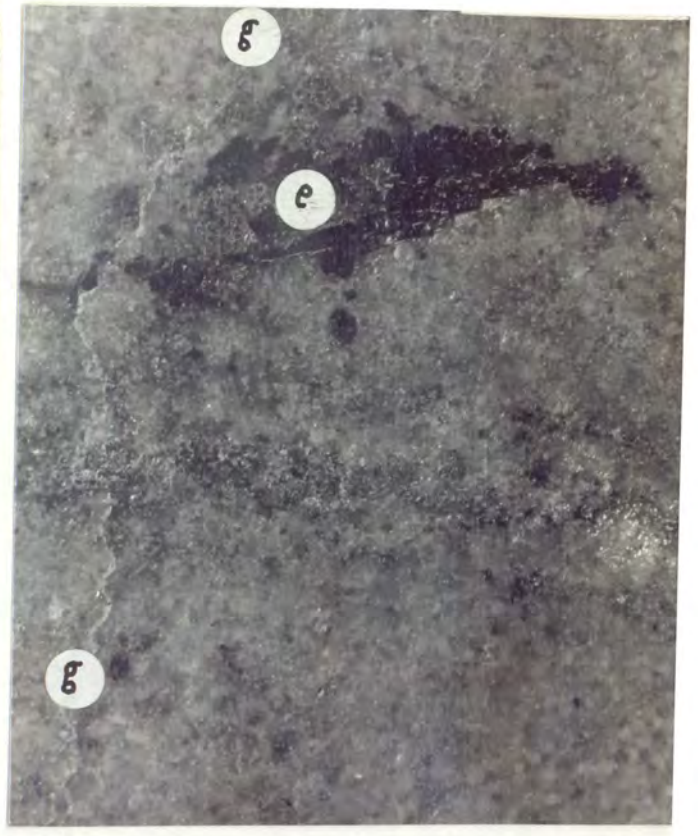
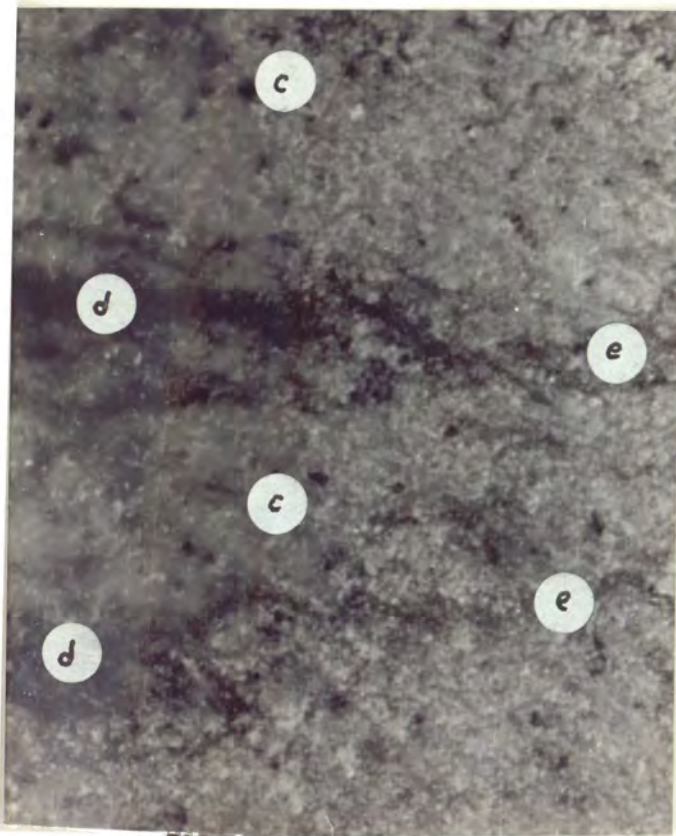
The most recent theory is that put forward by Bartlett (1970) who suggested that stylolites may also be formed by submarine solutional erosion following lithification and oxidation of the eroded surface and renewal of deposition. If this were the case, one would expect more stylolites to be associated with scour channels. At Rooiberg this cannot be the case as stylolites have been observed to cut sedimentary structures.

Stockdale (1923) stated that it is the intergranular pressure and not the overburden pressure acting on a unit area which is important. This is deduced from the fact that the latter pressure is practically constant over short distances in sedimentary rocks. However, various grains of different chemical composition and subject to different pressure may lead to a solution process and result in irregularities as solution progresses from grain to grain. This irregularity is borne out at Rooiberg. This may explain why one bed containing a series of stylolite bands, one above the other shows stylolites of different relief and the peaks and troughs bear no resemblance to each other in their vertical projection. This may lead to the unusual curved grooves on the surfaces of some of the stylolite peaks. Also the curving of sericite flakes in the stylolite suggest a changing pressure along the stylolite itself. Vertical stylolites are also not easy to explain by overburden pressure.

In the case of bedded stylolites it is still hard to explain why some horizons develop stylolites and others do not. Further investigations may reveal these variations to be related to the relative impurity of the deposits. In this connection it is noteworthy that a concentration of stylolites was found in beds rich in rutile. Also stylolite layers increase in numbers in the magnetite beds (Fig.163).

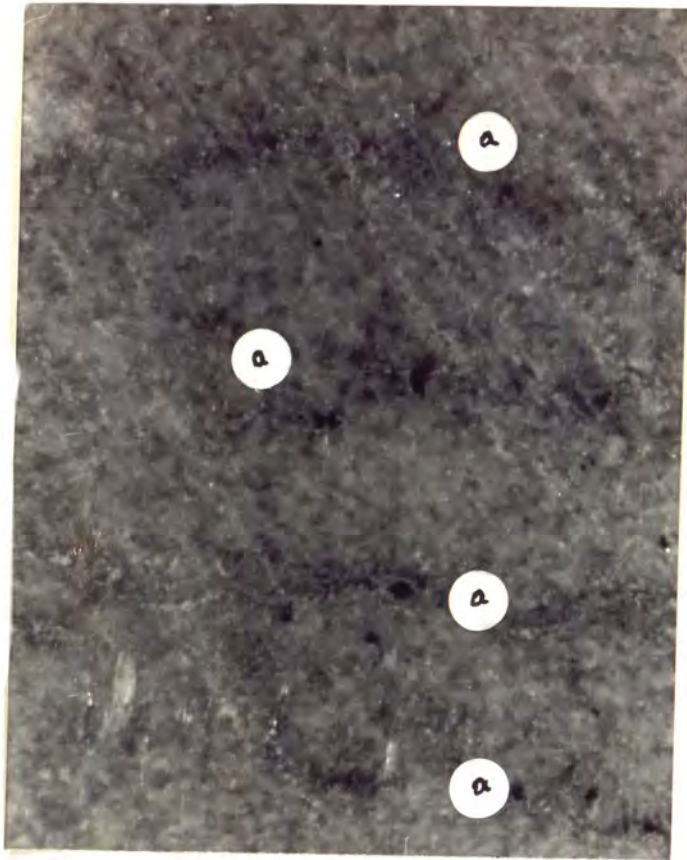
Fig.17A shows stylolites which the writer suspected were in the early stage of formation as they showed very patchy development.

In areas where early joint blocks have been pressed together, stylolitic contacts could be explained by the pressure solution theory. Some of the peaks are curved and striated, and often closely interlocked. In fact, pressure solution could explain the start of the formation of most stylolites at Rooiberg. It is, however, probably not the whole answer, as in mature stylolites there is a gap between the arkosite either side of the stylolite; in some cases it is 0,3 mm. This gap is filled largely with sericite, suggesting that a solution process has taken over where pressure solution left off. This plane of weakness is made evident by the fact that hydrothermal deposits are often found in the stylolites, showing that they offer a ready channel for migrating fluids.



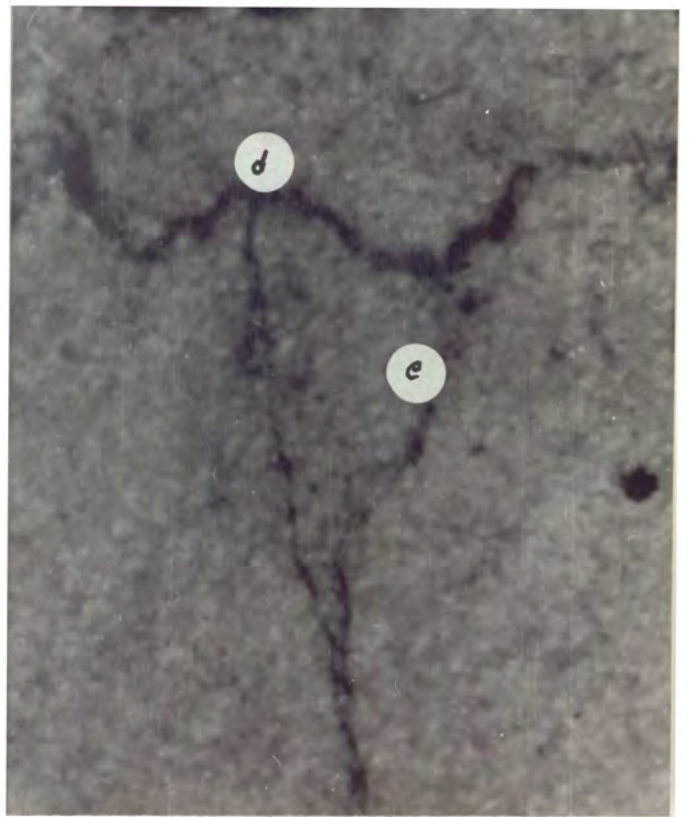
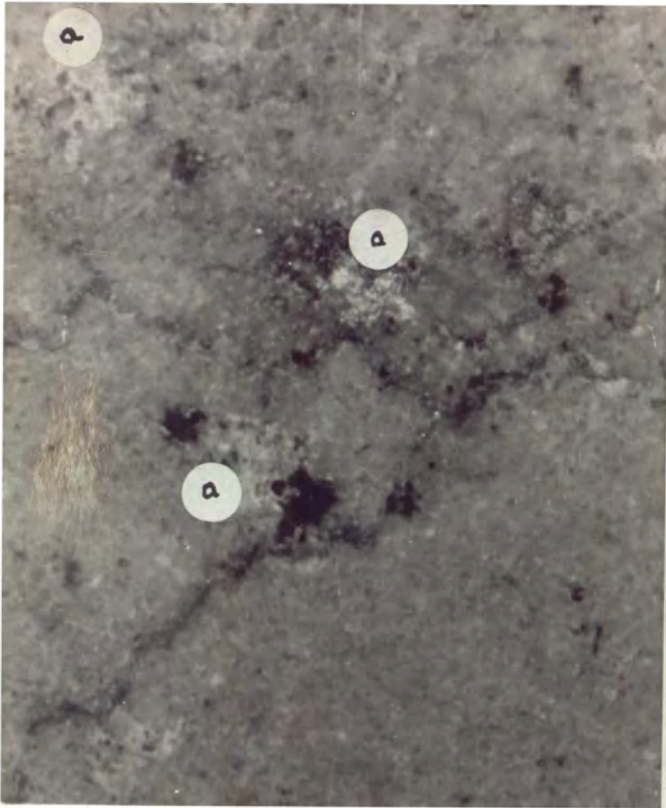
A shows a lattice-framed stylolitic parting at a (Mag.x5).
 B lower $\frac{1}{3}$ shows magnetite heavy mineral layer, stylolites above denoted by c (Mag.x5). C shows the face of a metasomatic front c advancing from left to right; the stylolite indicated by d and e. The stylolite d inside the metasomatic front is tourmalinised. D shows ankerite in stylolite g and large spot of tourmaline development on horizontal stylolite e. (Mag.x5).

Figure 16



A shows four stylolites in the processes of formation (Mag.x4).
 B shows typical well-developed stylolite (X Polars Mag.x4).
 C stylolite with microfracture Y.
 D stylolite with cross-cutting channel z represents a weak point (Mag.x8).

Figure 17



A shows intersecting stylolite cross-cutting sedimentary strata with ankerite-tourmaline spots a developed along stylolite (Mag.x 5). B shows a tourmaline spot at the end of a stylolite at b (Mag.x 5). C shows ankerite development indicated at c in the hollow step of the stylolite (Mag.x 5). D shows a stylolite intersected by a vertical microfracture at d; at e the micro-fracture is stylolitic (Mag.x 5).

CHAPTER V

POCKET MINERALISATION

Locality of Pockets

5.1. On the Rooiberg Fragment pockets have only been found in the Boschoffsberg Quartzite Member. So far they have been proved to occur in sediments of over 140 m in thickness directly below the Boschoffsberg Shale Member.

Pockets occur as lenses and orbicular bodies along the major faults and along associated structures such as secondary faults and joints. Pockets carrying concentrations of massive cassiterite have all been associated with faults and run for tens of metres at over 20 per cent cassiterite. These are, however, not common. Pockets carrying smaller quantities of cassiterite are associated with small structures and are more important, as the bulk of the cassiterite mined was from these lower concentrations. In some cases these structures were found to be hairline fractures (Figs.17c & 18d) or stylolites (Figs.17 & 18), or in bedding plane partings (Fig.19A).

Shape of Pockets

5.2. There is considerable variation in shape as can be seen from the tourmaline pockets illustrated in Figs.19 to 29. Pockets are often aligned along fractures, (Fig.20).

A common place for pocket development is the intersection of two structures such as a joint and a bedding plane parting (Fig.21). This can greatly influence their shape. In some pockets the latter is the predominant feature (Fig.23A). Usually the pockets remain oval or rounded (Fig.22), though in some cases they are elongated (Fig.23B). Pockets often reveal the joints clearly, particularly those developed on a joint corner (Fig.19B).

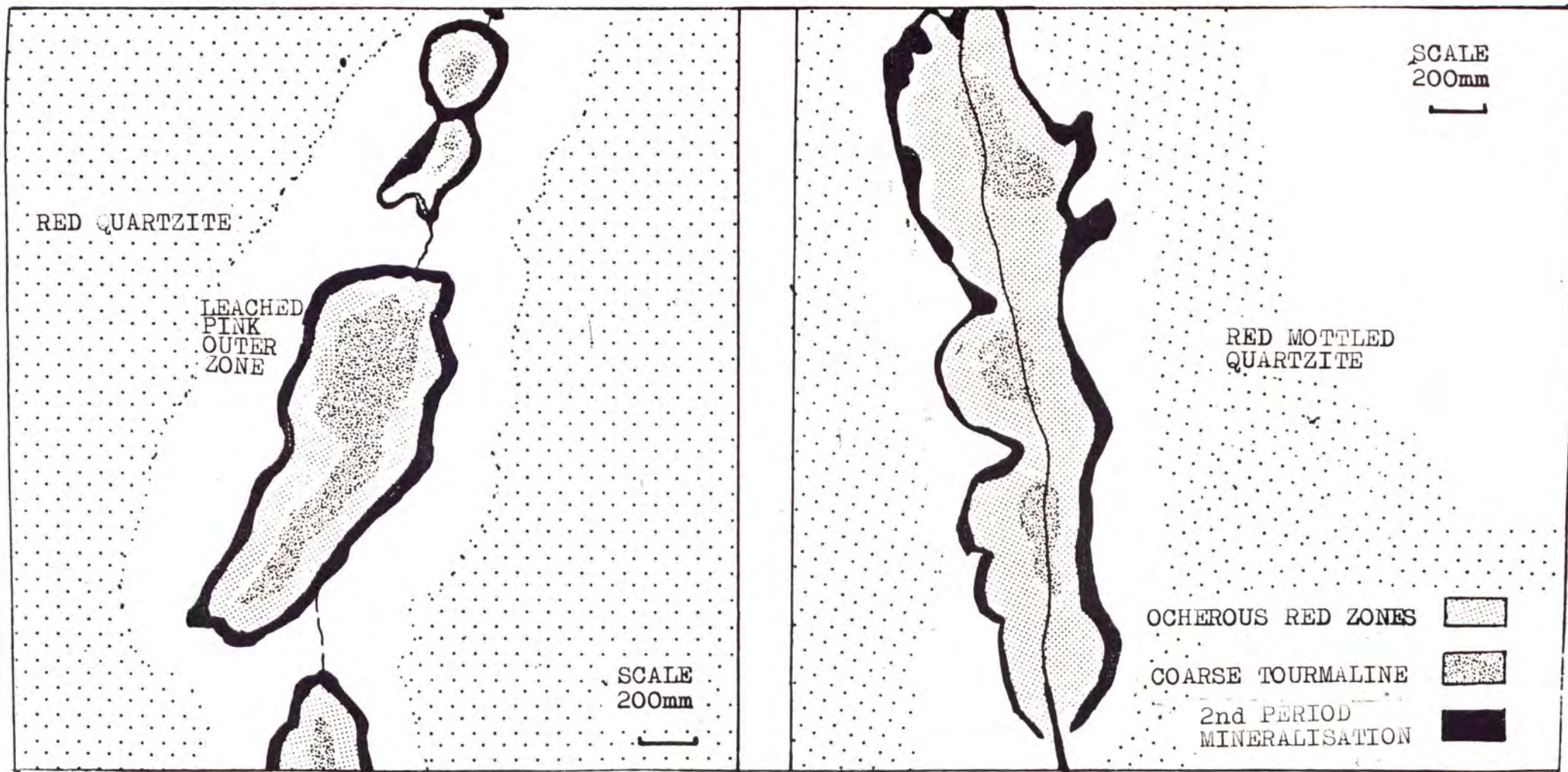


A Scale 100mm ↵
Longitudinal pockets aligned along bedding-plane partings illustrate the effects of bedding plane control. Some fade into green bands as shown at a.



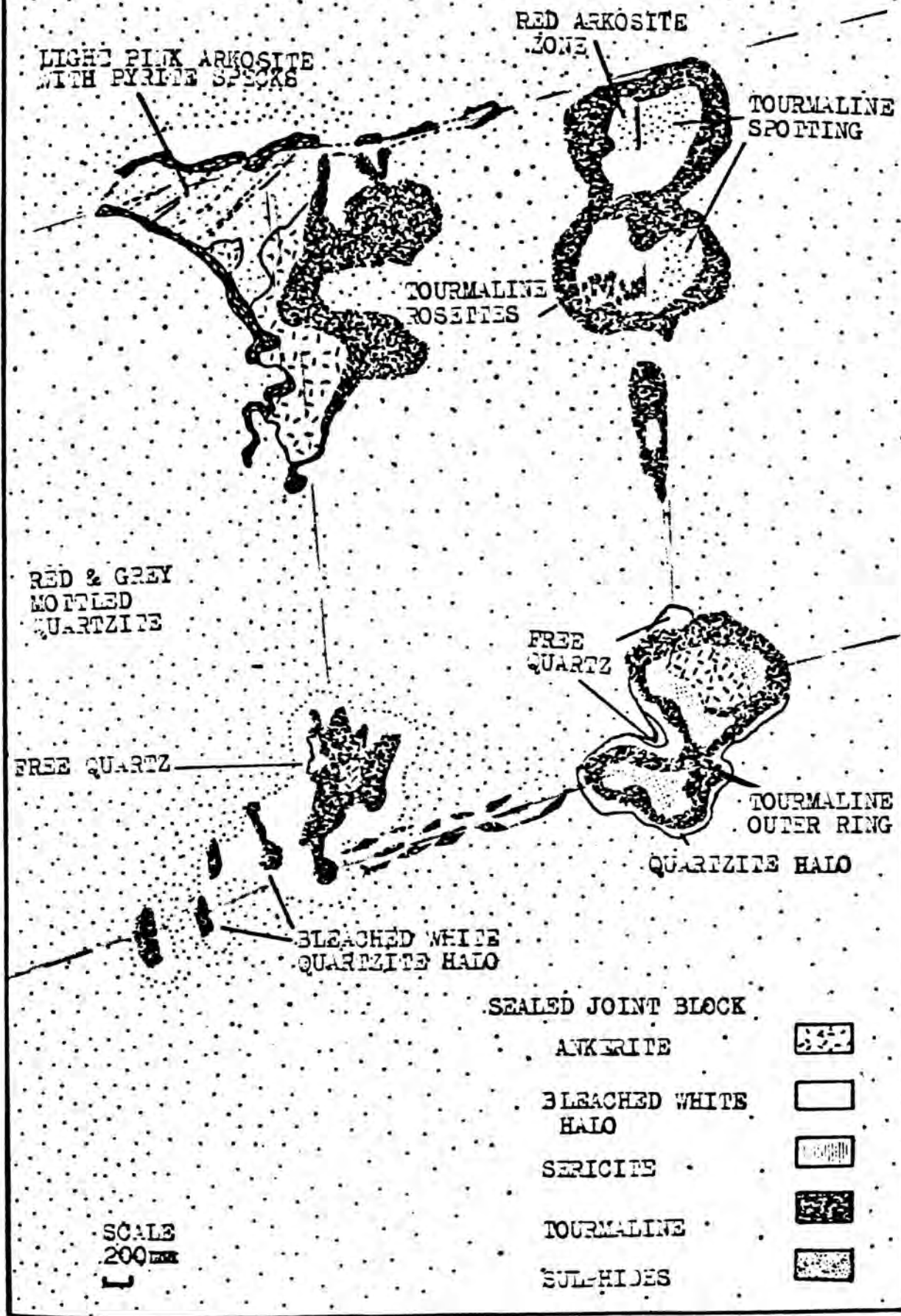
B Scale 100mm ↵
The strong influence of joint control is shown here by the tourmaline-ankerite pocket development at the intersection of two joints, giving diverging lines of mineralisation, tourmaline black, ankerite white.

Figure 19

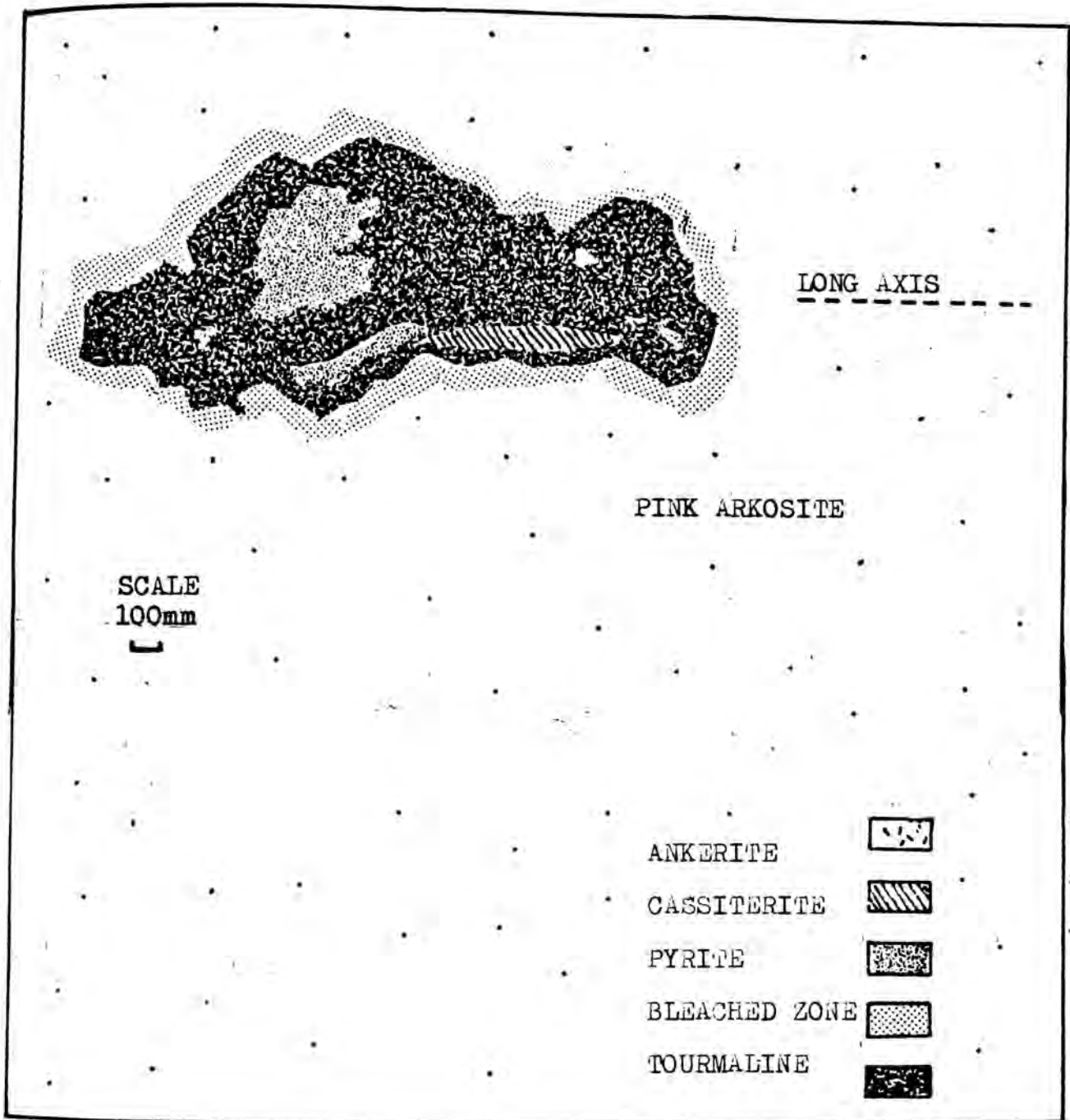


A B

Two examples of the development of typical thin-ringed tourmaline-haloed pockets show the characteristic leached outer zone. Later tourmaline core development has not destroyed the earlier features. Cores show how the nucleus for the second period of mineralisation can closely coincide with the first. A shows how the later core has spread along the length of the pocket and B shows a pocket where the late core is just starting to develop. Thus it shows how the later period of mineralisation can sometimes closely coincide with the first.

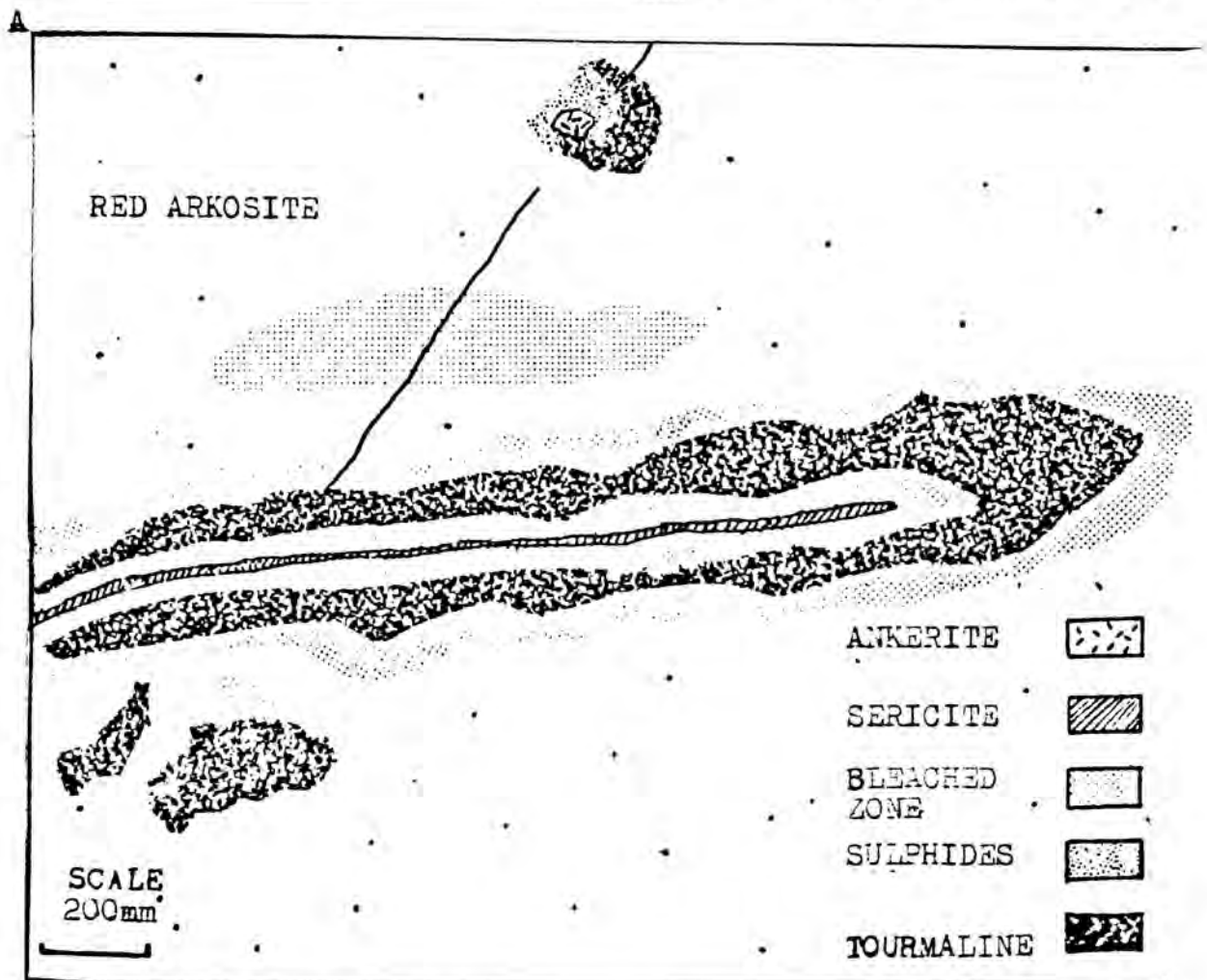
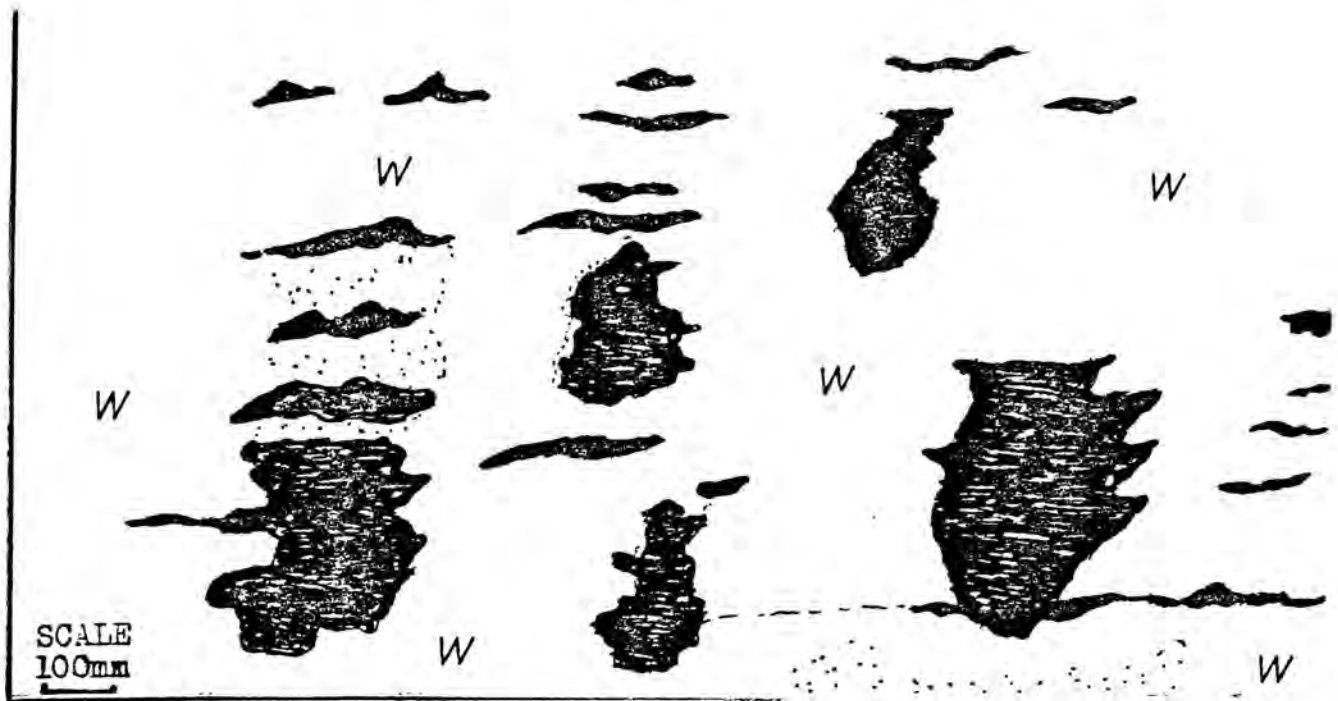


Typical pattern of simple halo pocket development with a structural control. Pocket development has occurred at the four corners of a joint block Joint block in blue.
Figure 21



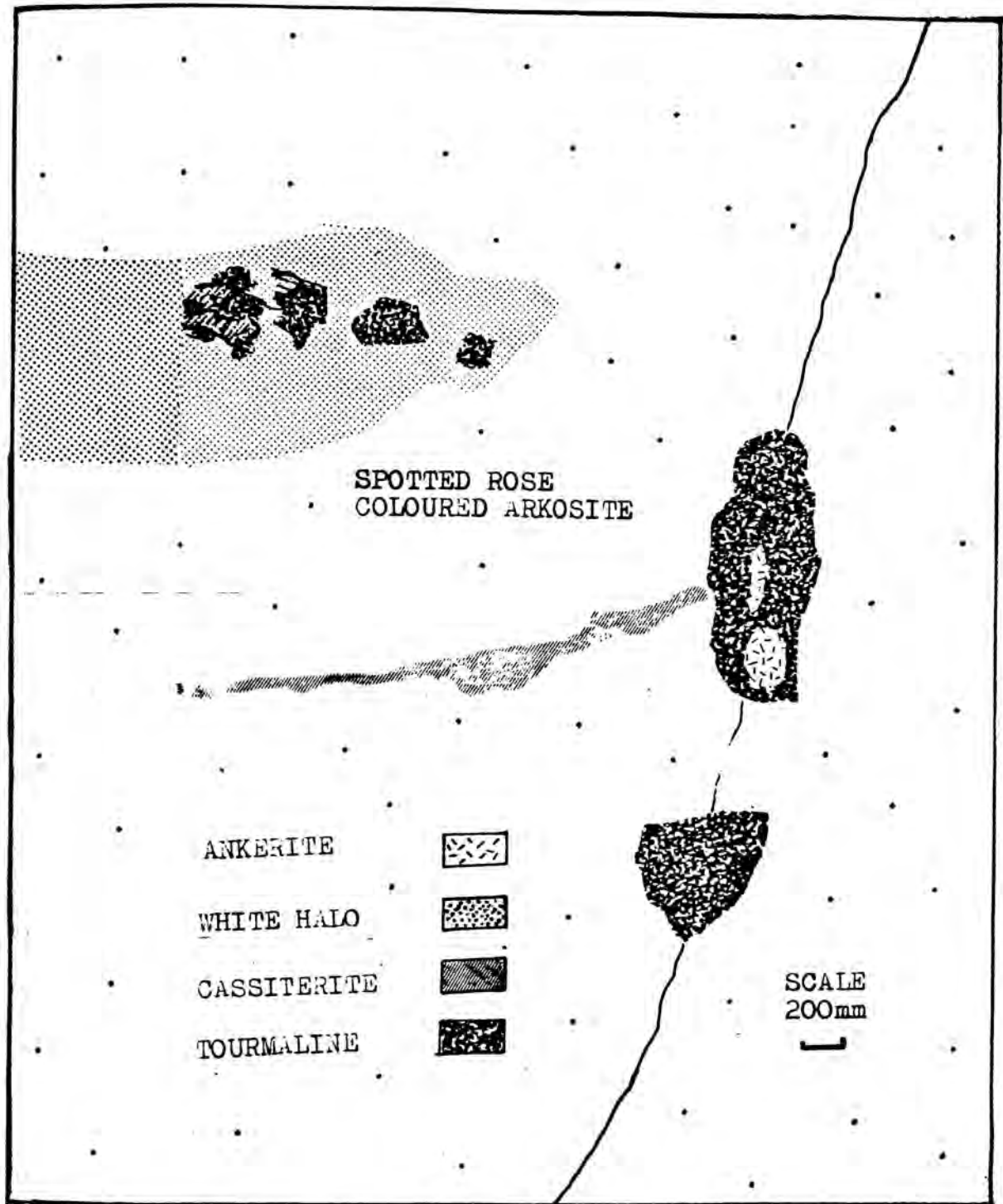
A pocket elongated parallel to the bedding and partial halo development of cassiterite and sulphide.

Figure 22



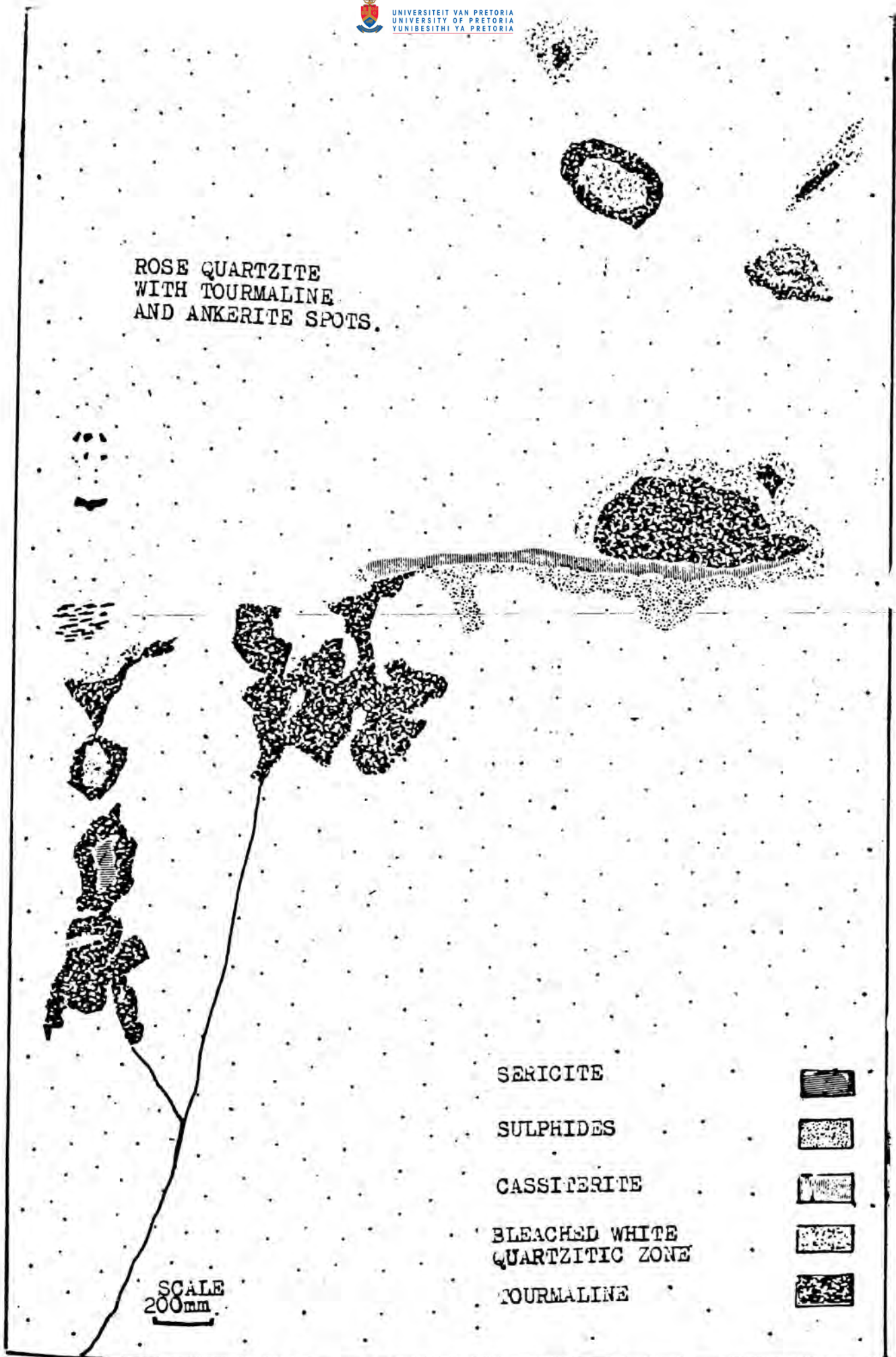
- B
- A. Scenic pocket texture, flat-topped, anvil, cloud-like pockets of tourmaline (black) in bleached white quartzite denoted by W.
- B. A horizontal bedding influence on pocket development. The sericite core is developed along a bedding parting.

Figure 23



Cassiterite along a bedding plane parting. Tourmaline pockets give a contrasting mineralogy.

Figure 24



A variety of pocket forms show the different stages of pocket development. The influence of different fractures also result in varied mineralisation.

Figure 25

In some cases, there is mineral separation along one of these structures, such as in the cases of cassiterite (Figs.24 & 25) and chalopyrite. Some pockets have flattened tops (Fig.32) and referred to earlier, also mentioned by Leube and Stumpfl (1963).

The writer's conclusion from all his observations is that the flattened tops appear to be all associated with bedding plane partings and other horizontal structures.

Structure of Pockets

5.3. The pocket body can take several forms. Some pockets are massive, others can be split into constituent parts such as a central core and an outer halo. This outer halo can be simple and gradational, or a complex sequence of well-defined rings with sharply defined boundaries. Although there is considerable variation in form, most of the pockets have characteristics in common. It is from these characteristics that a classification can be built up.

5.4. Macroscopic Description and Classification of Pockets

Pockets can be classified by their macroscopic characteristics into

1) Embryonic Pockets

2) Unzoned Pockets

2A Simple Unhaloed Pockets

2A1) Granite-textured Pockets

2A2) Red Pockets

2A3) Massive Mineral Pockets

2A3a. Massive Black Tourmaline Pockets

2A3b. Massive Cassiterite Pockets

2B Complex Pockets

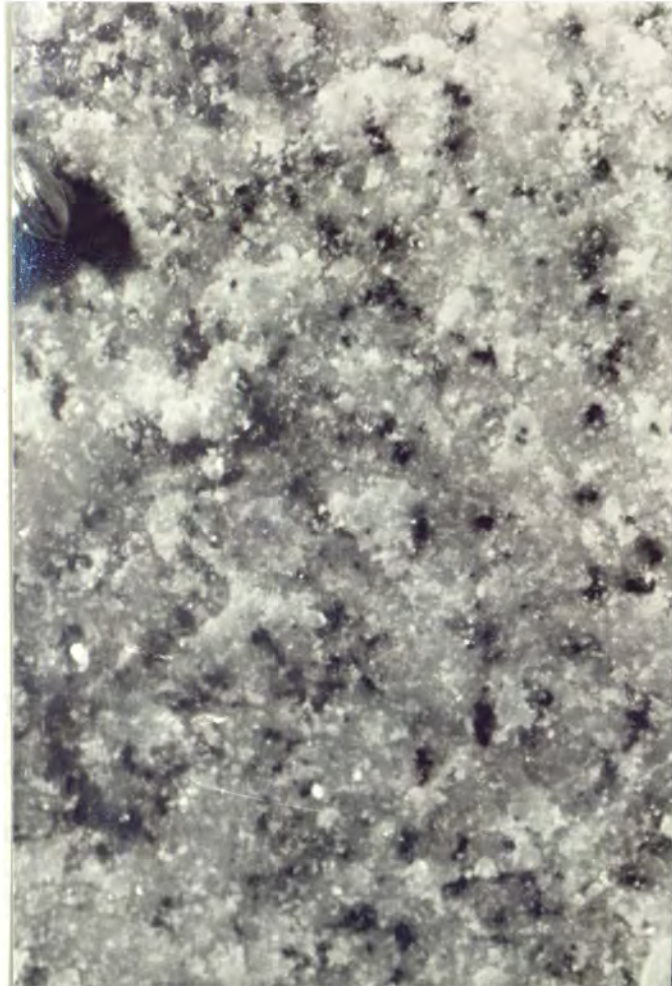
- 3) Simple-haloed Pockets
 - 3A Simple Rose-coloured Haloed Pockets
 - 3B Thin-ringed Tourmaline Pockets
 - 3C Large-ringed Tourmaline Pockets
 - 3D Simple Chalcopyrite Pockets
 - 3E Simple Cassiterite Pockets
- 4) Multiple-haloed Pockets
- 5) Complex-haloed Pockets
 - 5A Pockets with Repetitive Haloes
 - 5B Disarranged-haloed Pockets

5.5

1) Embryonic Pockets

The first stages of secondary alteration are seen as mineral spotting. Three main types of mineral spotting have been observed, namely by sericite, ankerite, and tourmaline. Sericite and ankerite can sometimes be seen to be the alteration products of feldspar. In some areas nucleations of sericite and ankerite occur to give very unusual textures of lines, dashes and spots. The spots formed are up to 10 mm in size and usually spherical or elliptical in shape and are in many cases almost monomineralic. The boundaries of the spots and dashes vary from sharp and distinct forms to a gradational form over a few millimetres. Textural variations were observed with colour contrasts of white ankerite spots 3 mm in size and with green sericite spots 1 mm in size in rose quartzite.

Tourmaline spots, unlike the earlier spots which can be the result of alteration of the minerals in the sediments, are considered to be the result of boron introduction. The rock textures formed by the alteration spots can be as equally dramatic.



Tourmaline spotted texture in arkosite.
Arkosite has a saccharoidal texture. It often
appeared bleached white in areas of tourmaline
spotting. (x 10)

Figure 26

Tourmaline spots can be seen in various stages of development. First, small specks of tourmaline in the arkosite appeared (Fig.26) and then an increase in density (Fig.58). When observed underground they look like shadows on the rock. The small tourmaline spots can be found in increasing sizes and concentration and in many areas amalgamate to form an even larger spot as in Fig.58D. These small spots of 1 mm in size can be seen in some places occupying areas of 0,5 m across. The background is white and is usually surrounded by rose quartzite. Because of their appearance, they have been called 'Ghost Pockets', having a ghostlike structure in the country rock (Figs.27 & 28).

5.6. 2) Unzoned Pockets

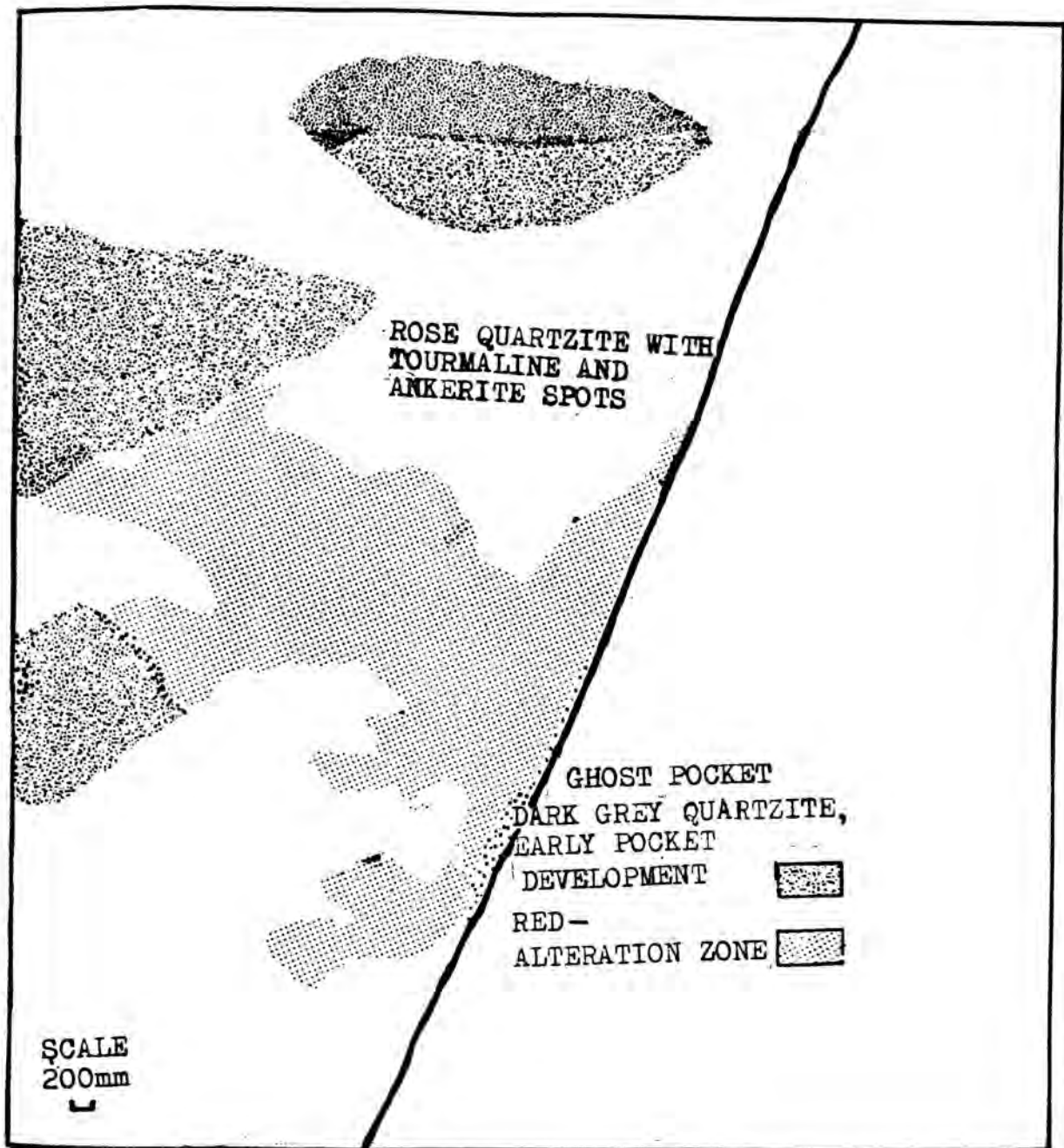
Unzoned pockets can be divided into two major categories: those which have many minerals emplaced have been called complex pockets, while those with a single form of alteration or single mineral emplaced have been classified as unhaloed simple pockets.

5.7. 2A) Unhaloed Simple Pockets

These are so-named because in trends observed they have a very simple structure. The texture is uniform.

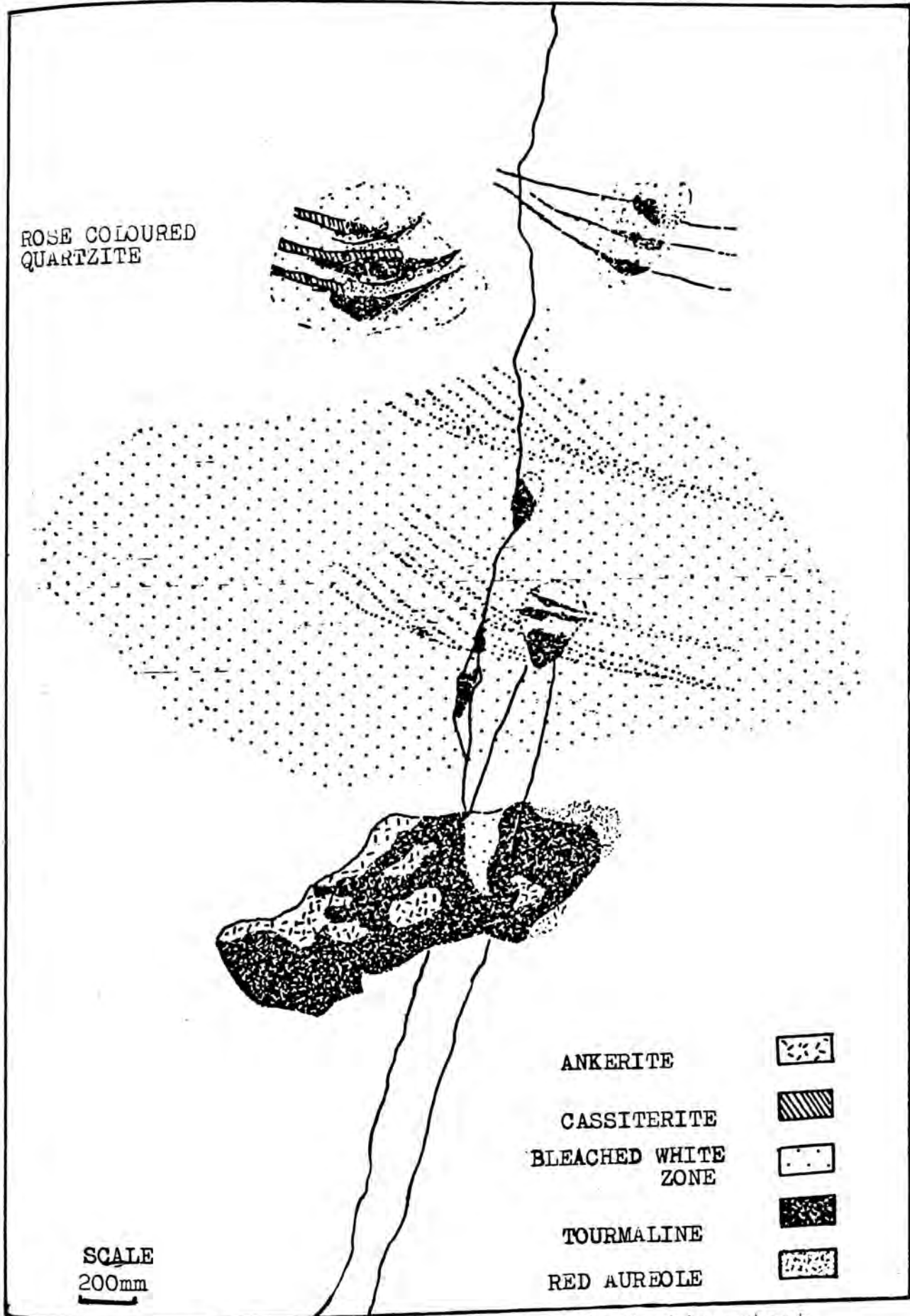
2A1) Granite-textured Pockets

The pockets have a texture in which all the grains are anhedral (allotriomorphic granular texture). The grain size causes them to resemble a phaneric granite, containing coarse-grained sericite, ankerite, orthoclase and plagioclase, with some quartz. A few pockets even appear pegmatitic. Their form suggests they are the result of reconstitution of the elements in the country rock.



The contrasting morphology of initial stage represented by the red alteration zone with a ragged boundary, and the more obvious grey spotted quartzite in ghost pockets with sharp rounded boundaries.

Figure 27



Centre and top of page illustrate typical white ghost pocket development

Figure 28

There is a sharp junction surrounding the pockets, differentiating them from the fine-grained crystalline granular sediments. In some cases the junction is accentuated by a thin sericite or chlorite layer. Next to the major fissures, where there have been intense wall-rock alterations, pockets amalgamate to form a granite-textured zone. (Figs.29 & 30).

The pockets are generally less than 200 mm in diameter.

5.8. 2A2) Red Pockets

Red pockets are characterised by their colour which can vary from a light to a very dark ochreous red and they are always darker than the surrounding quartzite.

The feldspar crystals contain small crystals of rutile, with haematite and tourmaline grains which are occasionally aligned in a parallel fashion. The scattering of these fine grains is very dense where the feldspar is an ochreous red colour. These pockets are not usually very large, some being about 300 mm across and elongated along fissures.

2A3) Massive Mineral Pockets

2A3a) Massive Black Tourmaline Pockets

5.9. In these pockets the tourmaline is massively packed, giving the pockets a black appearance. The tourmaline may be fine-grained and interlocked with some of the original sedimentary minerals. This results in a granular texture, making the pocket quite hard. Other pockets consist of a mass of tourmaline rosettes (Fig.39A).

Although the pockets are usually rounded, some very unusual shapes have been recorded (Fig.29). A more typical shape is illustrated in Fig.24.

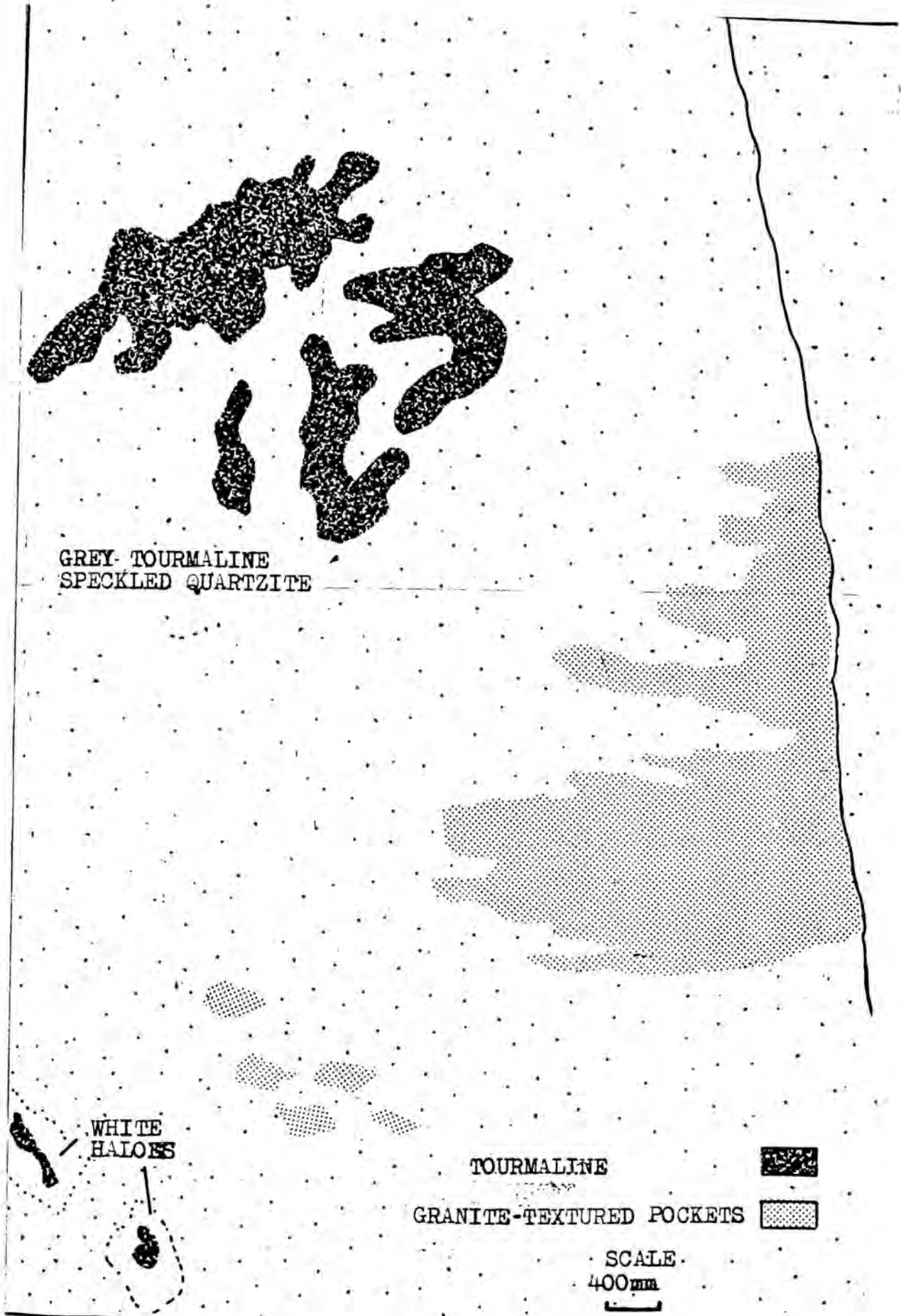
5.10 2A3b) Massive Cassiterite Pockets

An area rich in Massive Cassiterite Pockets was exposed in the Rooiberg Mine.. An example is the so-called Jewel Box (A7 shaft area). These pockets are only associated with major fissures of which most had indications of being by faults.

Large concentrations of cassiterite pockets are sometimes linked together to form pipes with widths of 1 m, and heights of 2 m, making a ribbon-like pattern. These constrict and diverge alternately through the country rock, in some cases for a distance of 30 m. Their boundaries are irregular; however the zone of replacement always spreads out from a central fissure, often resulting in a pear-shaped cross-section.

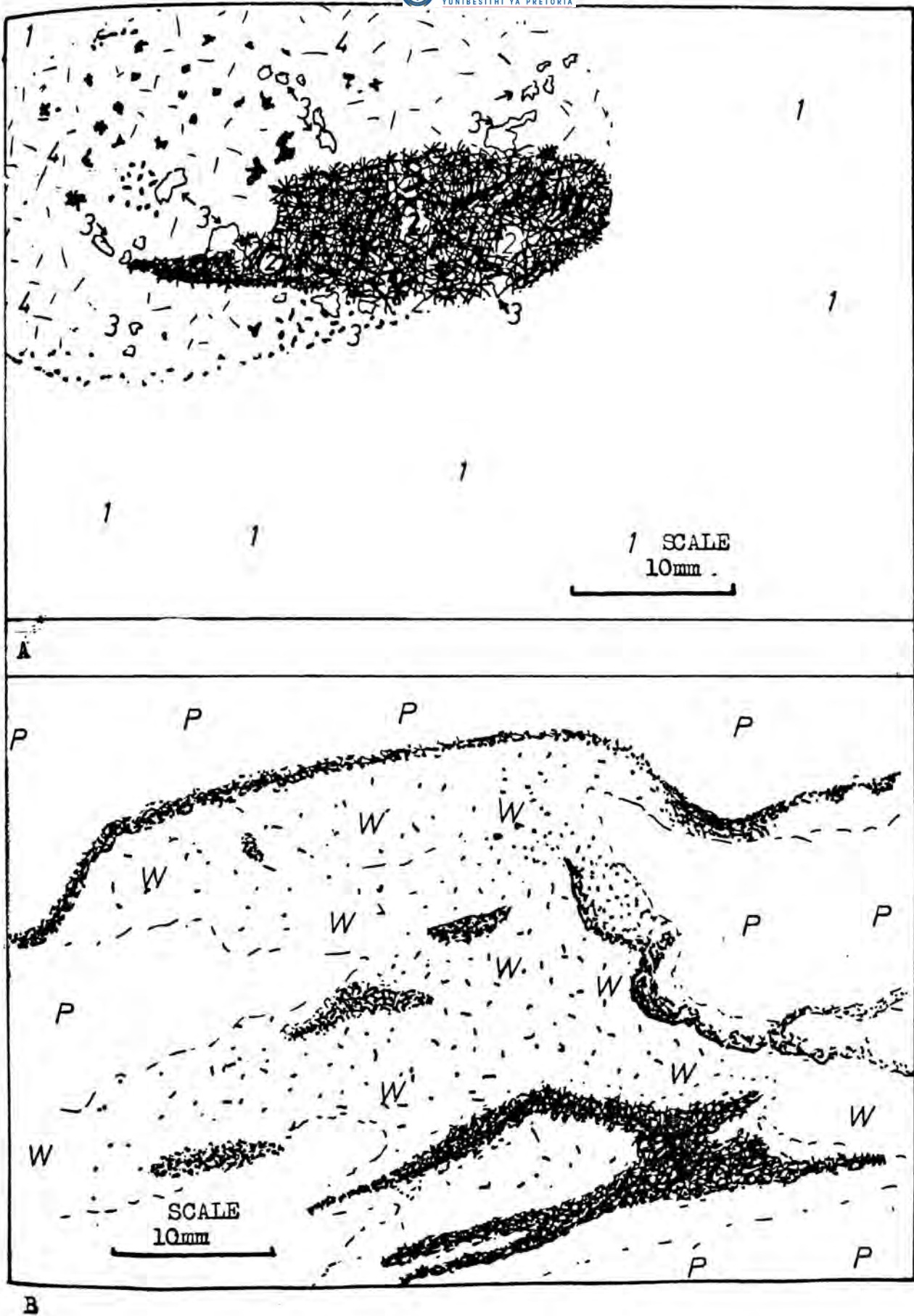
5.11 2B) Unhaloed Complex Pockets

These pockets have a variable mineral assemblage, and exhibit a complex nature. The minerals may include scattered pyrite, scattered cassiterite, and patches of sericite and ankerite; their distribution in the pocket gives an erratic mineralogical composition and textural appearance. The sedimentary structure is sometimes preserved and often accentuated by the mineral distribution. (Fig.33A).



Irregularly shaped tourmaline pockets and a granite-textured alteration zone spreading away from a fissure show the typical varied forms of wall-rock alteration.

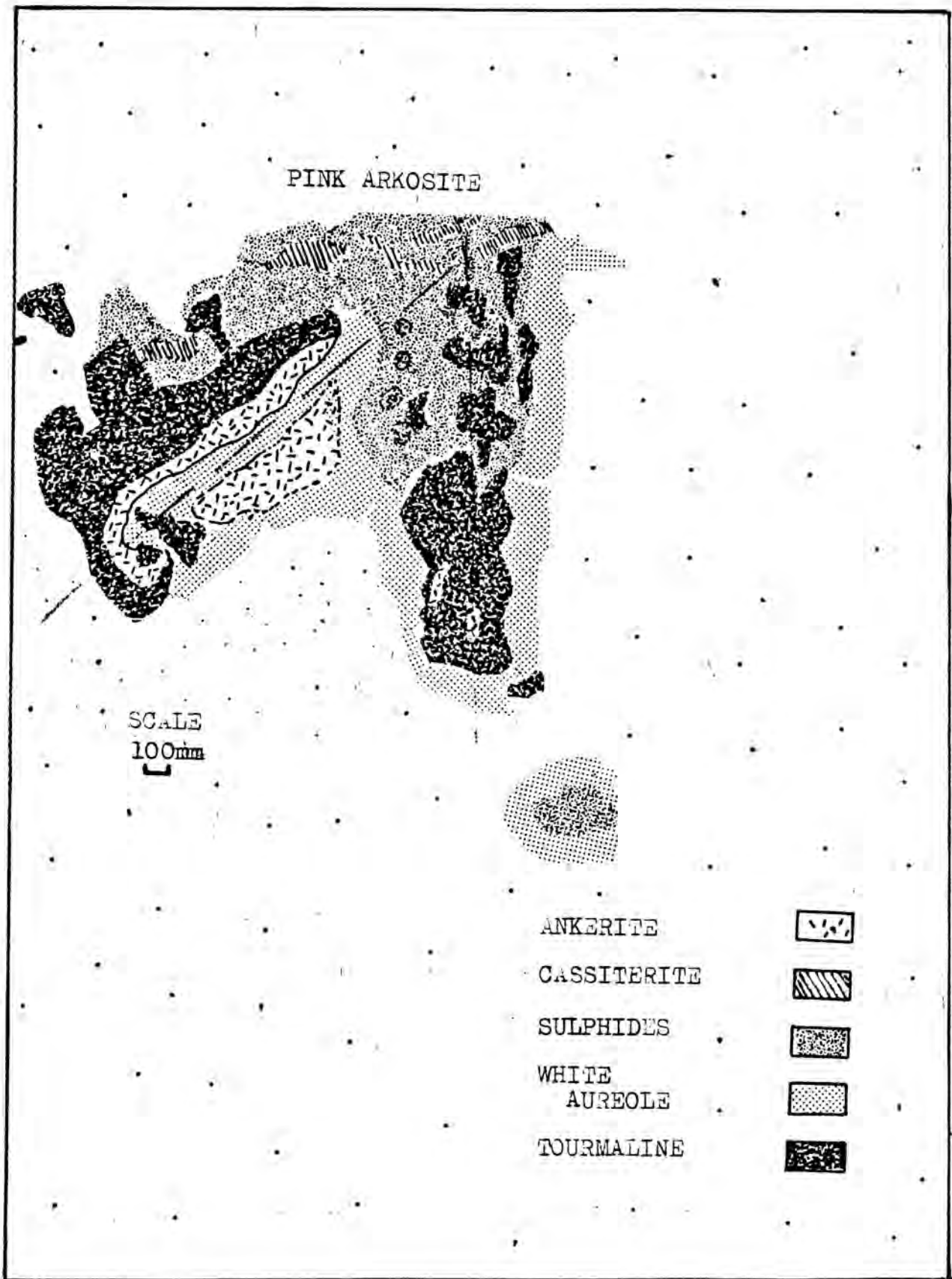
Figure 29



B

- A. A typical granite-textured pocket 4; with a later period of ankerite development 3, and black tourmaline rosettes 2, in pink fine-grained arkosite 1.
- B. The start of tourmaline halo development, black; and bleached zone W in pink arkosite.

Figure 30



Pocket development influenced by more than one fracture but separate regions of mineral development are still obvious. Lines of fracture are in blue.

Figure 31

pockets) the tourmaline ring was small and the siliceous halo was large. In some cases the outer halo is light pink with stylolitic boundaries on the sides of the surrounding arkosite. The central areas are of feldspar with sericite and ankerite. Their variety in shape has been illustrated in Fig.21.

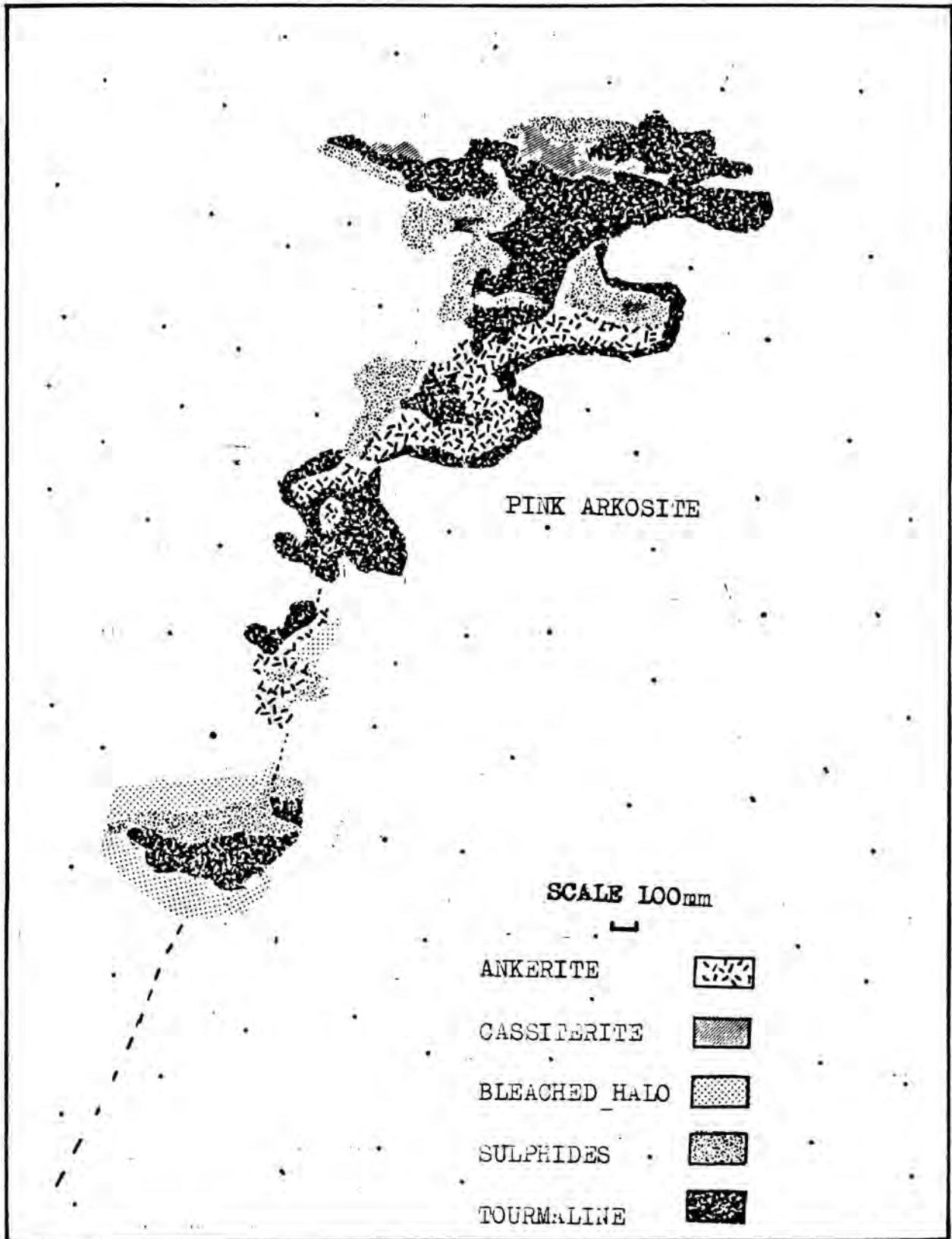
5.16 3D) Simple Chalcopyrite Pockets

These pockets are defined as simple chalcopyrite pockets when they consist of single haloes made up of chalcopyrite and pyrite rings. They are rare on Rooiberg Mine, but on Blaauwbank and Nieuwpoort mine they have been the most common type. The core and outer halo are usually very siliceous, while the chalcopyrite halo is of 10 mm or more in size. The pocket size was seen to vary from about 50 mm to 300 mm.

5.17 3E) Simple Cassiterite Pockets

Simple cassiterite pockets are defined as pockets which consist of single haloes of cassiterite. These pockets occur in localised areas on Rooiberg Mine. The maximum size of pockets seen was from about 100 mm to 150 mm and the thickness of the cassiterite halo was 20 mm. The core was usually very altered and often consisted completely of sericite as an alteration product of the country rock. Cassiterite crystals have been observed to vary in size from about 0,1 mm to 1,5 mm.

Simple pockets have no more than two haloes, an inner halo and an outer halo. The inner halo is usually an introduced mineral and the outer halo is a bleached zone.



Complex pocket aligned along an inclined fracture with protuberances along the bedding. Note its flattened top; this is on a bedding plane parting.

Figure 32



A Scale 100mm L



B Scale 100mm L

A red pocket almost completely altered into a transition phase of a multiple-haloed pocket, with scattered golden speckles of pyrite. The pockets are aligned along a vertical fracture. Photograph B, simple-ringed tourmaline pockets in two diverging lines have well-defined outer white silica haloes. The silica front has a thin green stylolitic sericite parting with the country rock. The two diverging lines of pockets indicate the earlier joint pattern.

Figure 33

Simple chalcopyrite pockets do not occur with simple cassiterite pockets and neither occurs with simple rose-haloed pockets. They occupy different areas in relation to fissures, thus zones of different types can be seen.

5.18 4) Multiple-haloed Pockets

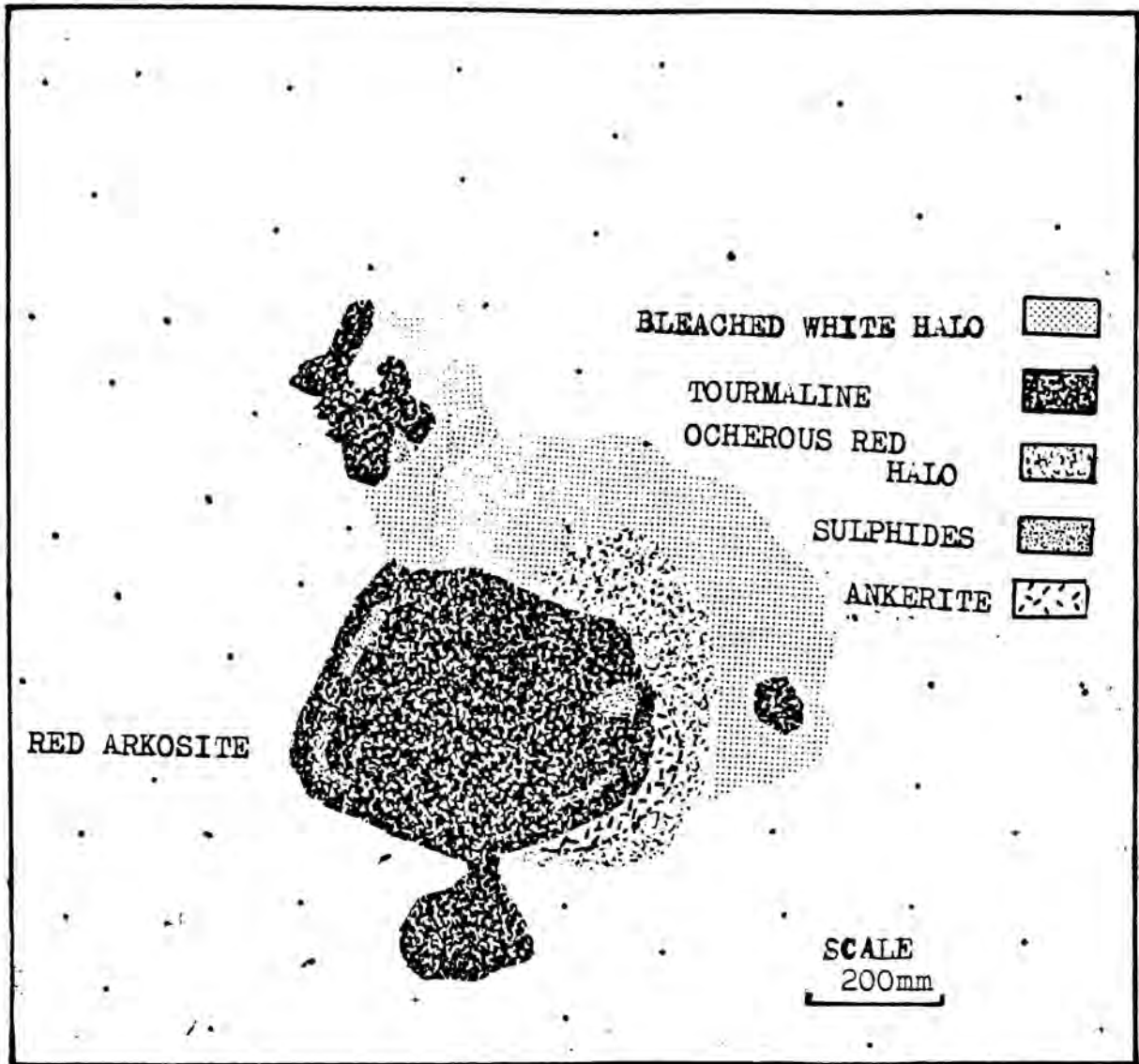
Multiple-haloed pockets also occur as simple structures; however multiple haloes are the result of an introduction of more than one mineral. Thus it is possible to get a chalcopyrite halo, followed by an outer cassiterite halo, followed again by a tourmaline halo surrounded by a bleached zone. The size of the new individual haloes varies according to the quantity of new minerals. Often one halo is incomplete and is just a small arch, such as shown by the sulphides (Fig.34). In some pockets a small quantity of the mineral only appears in disseminated specks along the edge of another halo. Chalcopyrite, cassiterite and tourmaline is the normal sequence of haloes and it is usually in that order from the perimeter to the core (Fig.35). Pyrite usually occurs with the chalcopyrite.

5.19 5) Complex-haloed Pockets

Complex-haloed pockets include all pockets that do not follow the normal trend or form.

5A) Pockets with Repetitive Haloes

In this halo system the haloes tend to repeat themselves. One gets tourmaline, then a barren arkositic zone, then tourmaline again. Their number varies but three appear to be the maximum.



The transition stage of a multiple-haloed pocket. Arcs and patches of sulphides are to be seen indicating the early stages of halo development. Ankerite on the outside is cross-cutting and of a later date.

Figure 34



Scale 100mm ↵

A multiple-haloed pocket with cassiterite (a), pyrite (b) and tourmaline black as a core mineral (C).

Figure 35

Repetition of tourmaline and chalcopyrite haloes is also developed up to three times with a fourth indistinct halo. Fig.36A is a drawing of a complex-haloed pocket.

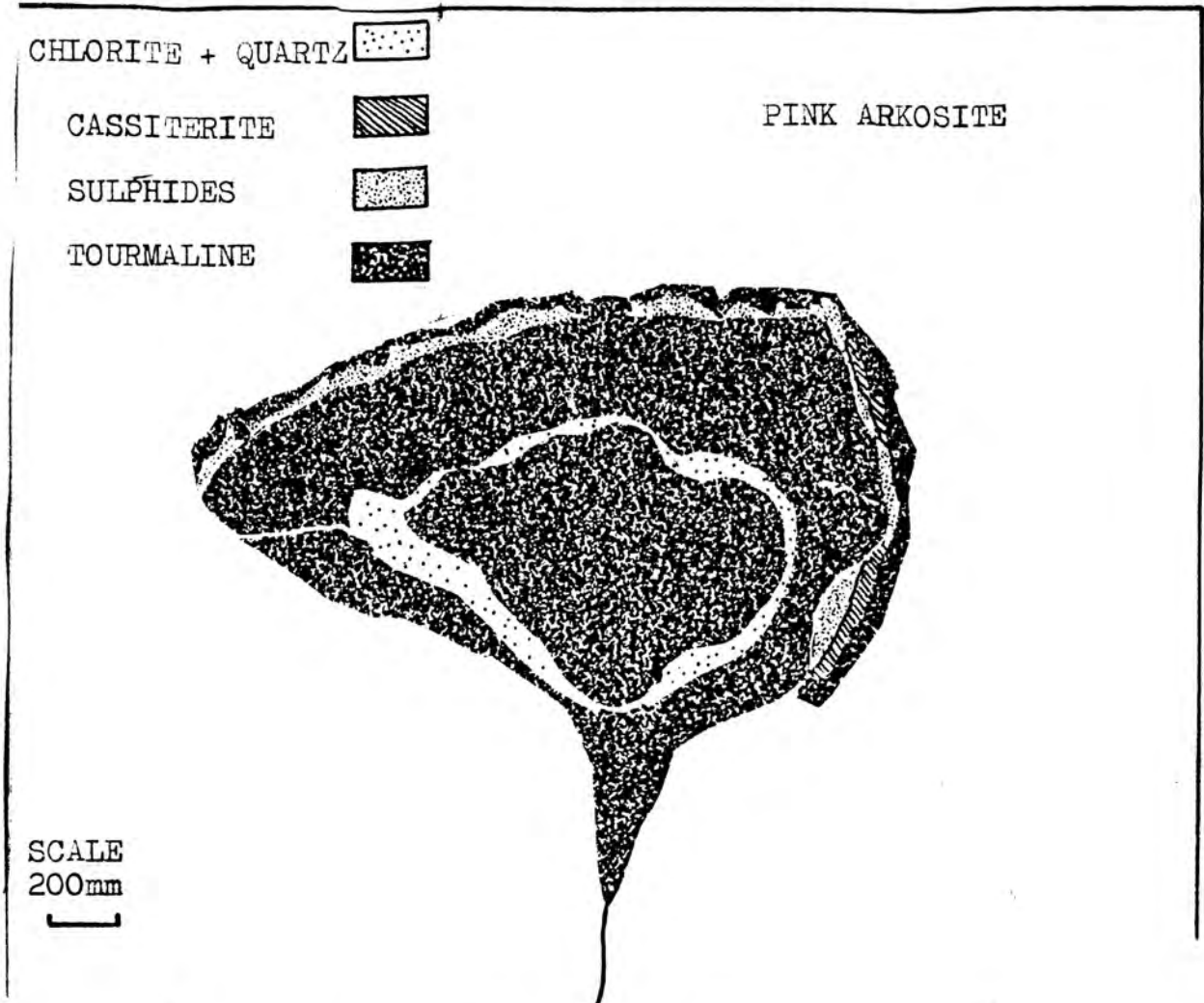
Fig.36B shows the start of an inner tourmaline halo formation.

5.20 53 Disarranged-haloed Pockets

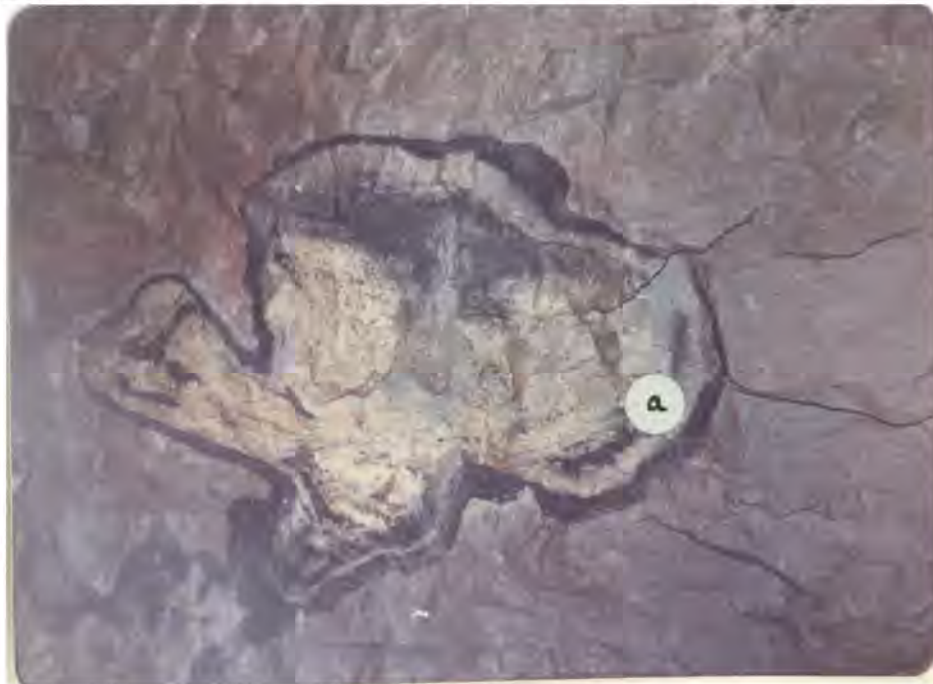
Disarranged haloes incorporate all those that do not follow the normal trend. In some cases haloes are discordant, one halo being cut off by another or by the mineralisation of one type cutting across the halo of another type. In other cases there is intermixing in the halo area itself. Some show a normal, multiple-haloed pocket with an injection of another mineral in a disordered state or out of sequence.

Late ankerite replacing tourmaline was seen in many places to occupy points of weakness in an earlier pocket structure (Fig.37). In some pockets it looks like part of a halo (Fig.38A). The junction between the tourmaline and the country rock is a plane of weakness and is an easy parting to break.

In some cases late ankerite has moved into weak points of other pockets, such as the point where the pocket is adjacent to a joint or bedding-plane parting, and preserves ghostlike structures of the earlier pocket haloes. Tourmaline appears to have been removed as it is cross-cut; chalcopyrite however remains (Fig.38B). This suggests that points of weakness in earlier pockets have facilitated later replacement by hydrothermal fluids.

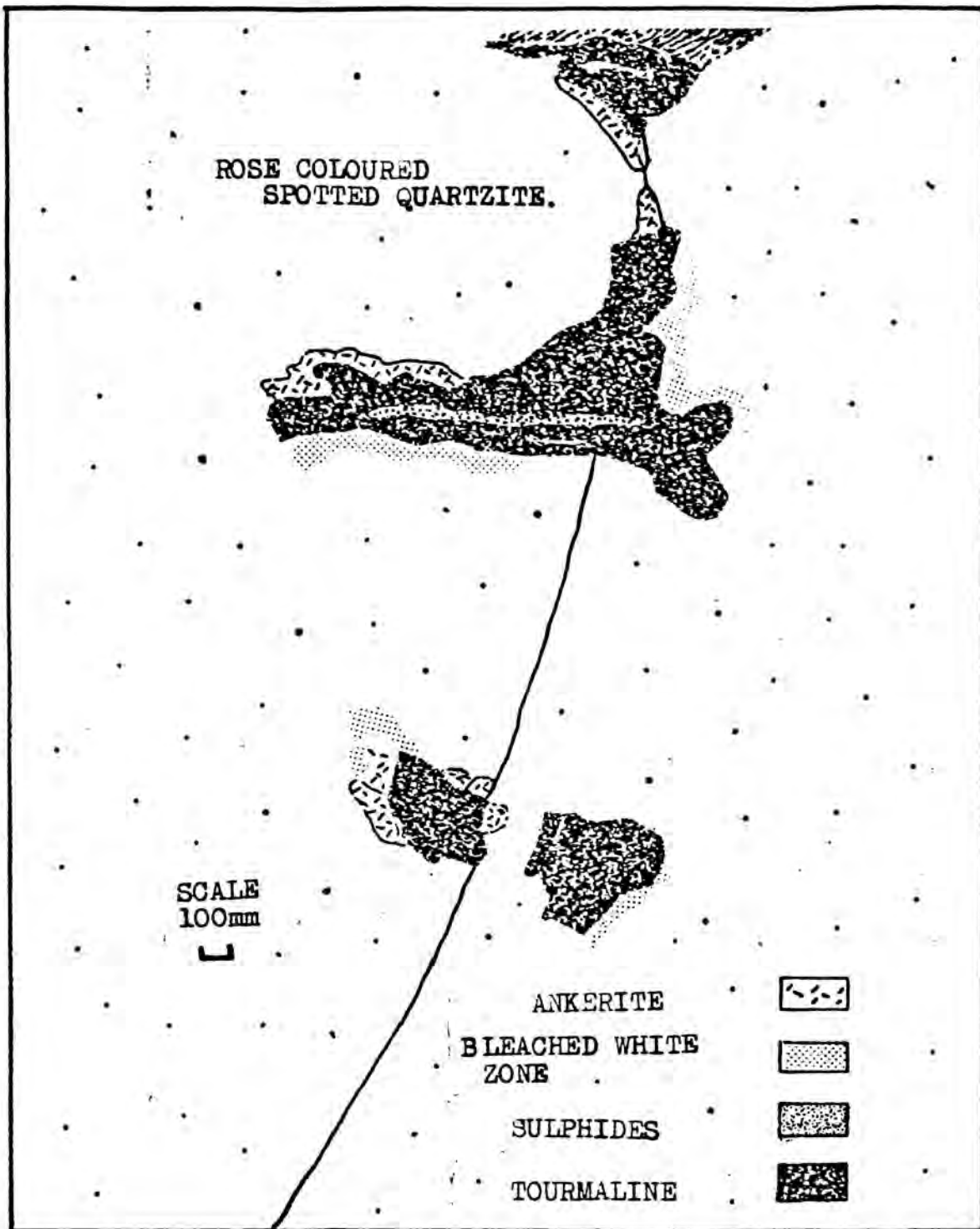


A Complex-haloed pocket with repetitive tourmaline haloes.



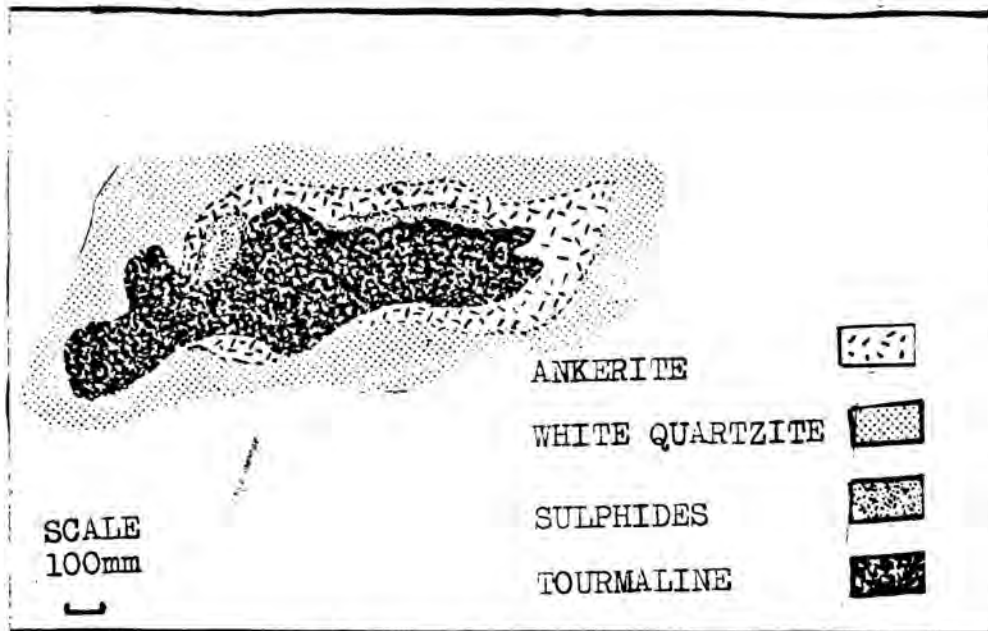
B A typical thin-ringed tourmaline-haloed pocket (trace of another halo developing at a) with a contrasting bleached core and the unaltered arkosite.

Scale 100mm

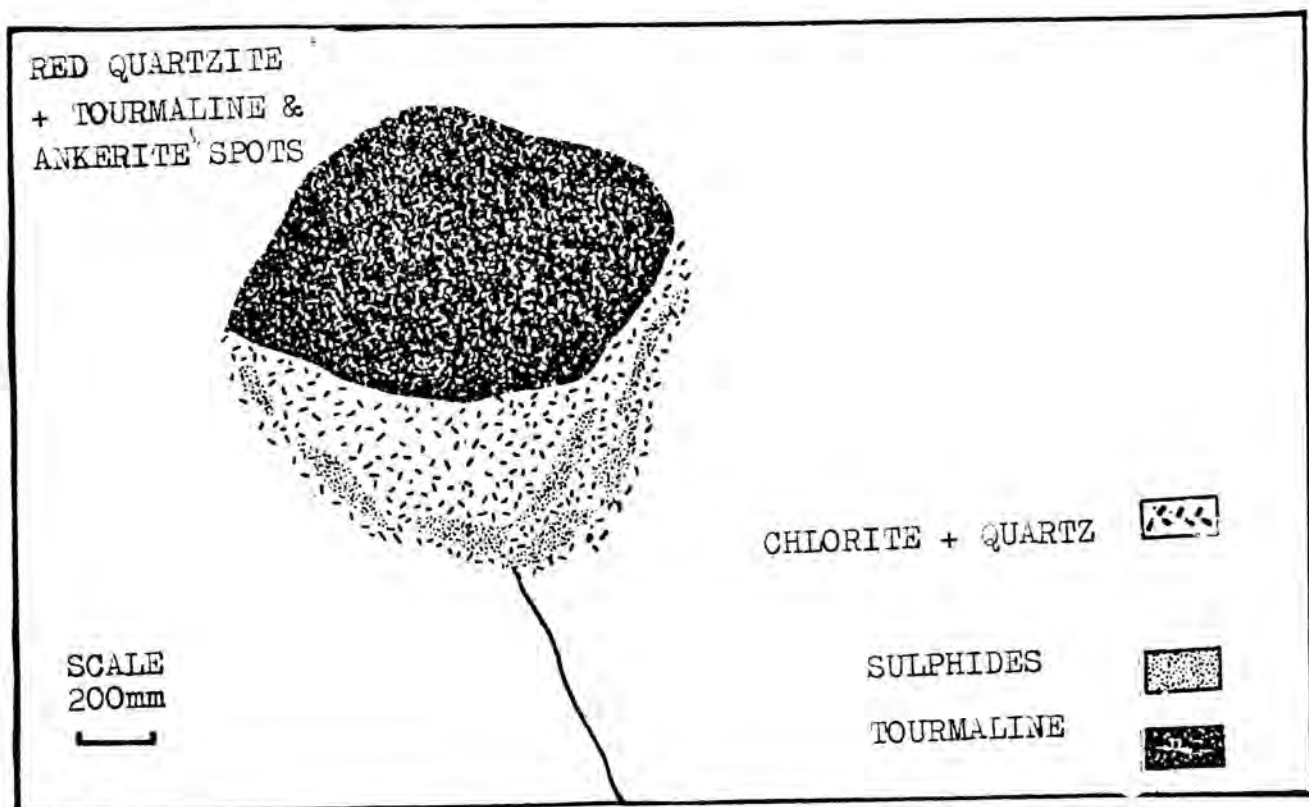


A drawing of a variety in pocket development where there is a flattened base and a typical ankerite deposition. Ankerite, usually a core mineral, indicates two periods of emplacement.

Figure 37



A. Massive tourmaline pockets showing late ankerite, sulphide development, and white quartzite area influenced by a bedding parting.



B. Pocket showing two periods of influence, as part of an early sulphide halo remains in the lower half of the pocket, and tourmaline has migrated to the top.

Figure 38

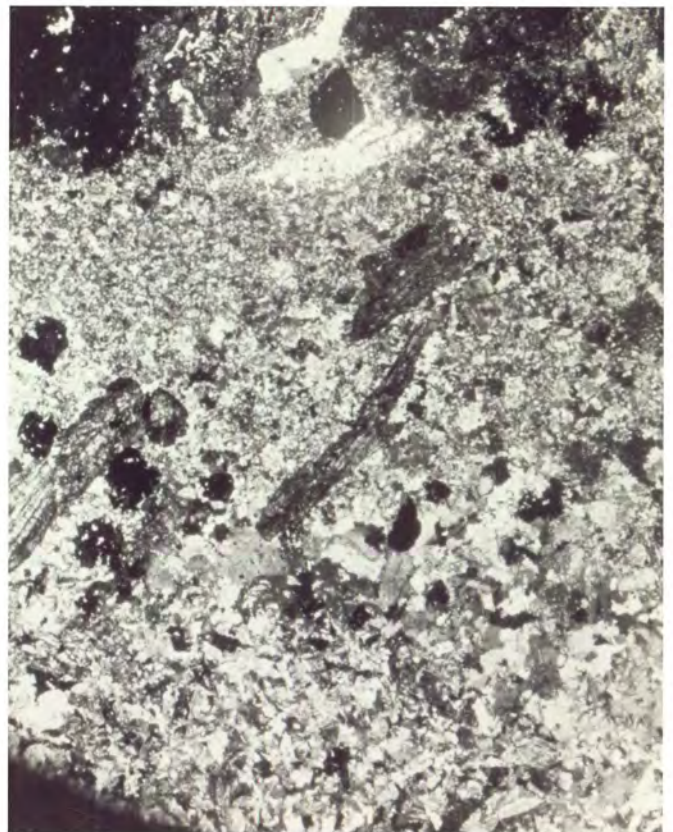
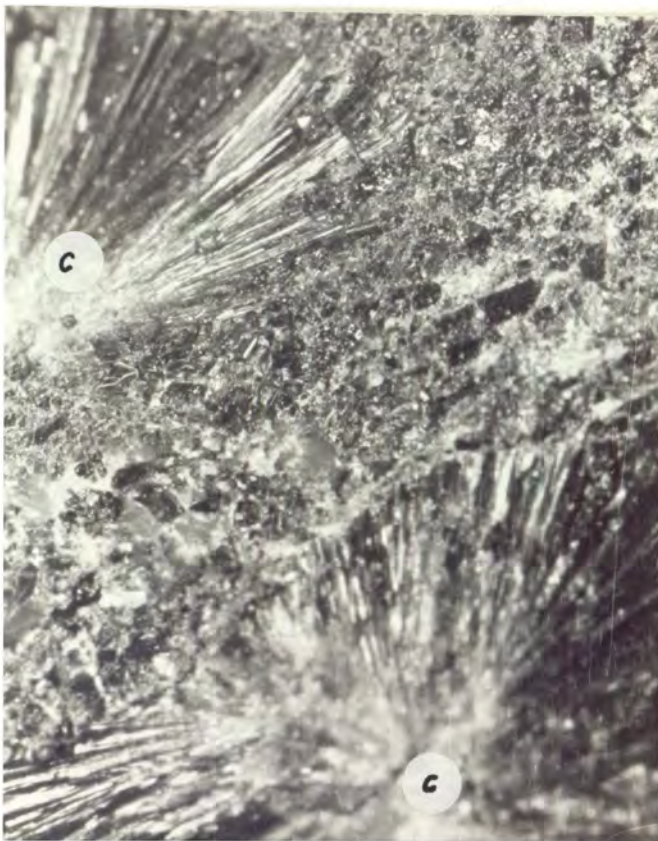
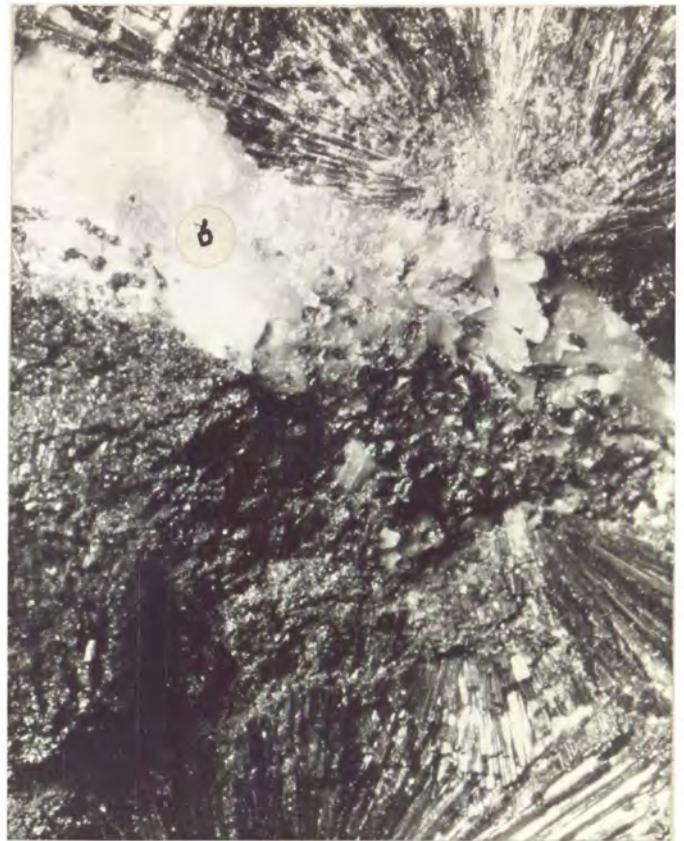
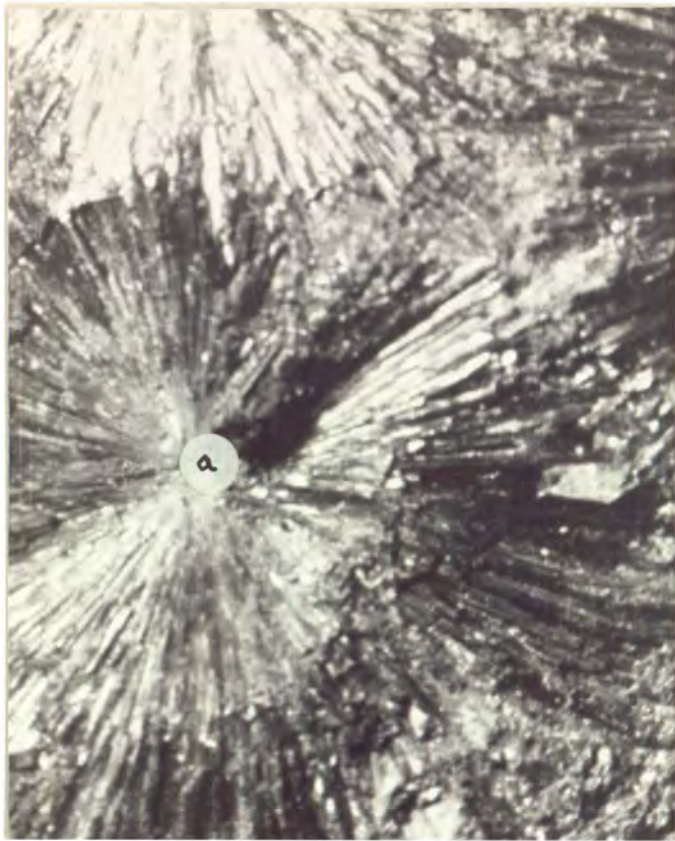
The cross-cutting nature of the deposits indicates two periods of emplacement.

Two periods of emplacement can be noticed in other pocket types. There are cases where pockets of one type, e.g. medium grained granite-textured pockets, are cut by pockets of another such as massive tourmaline pockets (Fig.30A). Others have cross-cutting veins (Fig.39).

5.21. Pocket Cores

Pocket cores also vary to a considerable extent. The main core minerals are sericite, ankerite and tourmaline. Sericite is found to be more abundant at depth in Rooiberg or in areas of near proximity to big fissures. Ankerite is common at higher levels in the pocket horizon in narrow fissures, and in the big fissures themselves as fissure filling. Fluorite is found in isolated pockets as also is galena, specularite, scheelite, and coarsely crystalline quartz. Because of the variability of pocket cores and their independence from halo structure they were not considered for the main classification of pockets. Pocket cores can lead to a second classification. The latter classification however was not found to be of great advantage for the location of cassiterite pockets, so it is of secondary importance.

Out of several thousand pockets examined macroscopically, fluorite only twice occurred in an aggregate over 10 mm in size and then as small euhedral crystals. Fewer than thirty pockets were found with fluorite at all.



A Typical tourmaline rosettes centred at a. Photo B, tourmaline rosettes cut by late ankerite, b. C. Tourmaline rosettes c separated by later tourmaline. D. Pieces of tourmaline rosettes which have been fragmented by later tourmaline to reconstitute a finer grained tourmaline. (All mag.x 5). Hand specimen.

Figure 39

MICROSCOPICAL DESCRIPTION

5.22. A Study of the Form of Pocket Boundaries

The easiest pocket boundaries to study with the microscope were those of the granite-textured pockets. From the coarse-grained pocket to the surrounding sediments there was a visible marked change in grain size, and the boundary was sharp and distinct because it was largely sericite. In some cases a sericite layer 1 mm thick was observed. The pockets cleaved along their curved boundaries, readily separating them from the country rock. Thus a three-dimensional study of their form could be made. Their boundaries were of a stylolitic nature, full of peaks and troughs, and in some cases there was an amplitude of as much as 1,5 mm from the crest to the base of the trough.

The boundaries of the tourmaline pockets were also readily observed. The junction of the country rock with pockets of fine-grained tourmaline had a recognisable stylolitic relief. The pocket boundaries of chalcopyrite and cassiterite were not so easily seen three-dimensionally and could only be studied in two dimensional sections. In rock sections, the boundary of the white ghost pockets with the country rock could only be similarly observed in two dimensions and showed a recognisable stylolitic form. The latter pockets were marked solely by a sharp contrast from white arkosite to pink arkosite. The sawtooth nature of the boundaries however gave all pockets the appearance of a stylolitic type of contact.

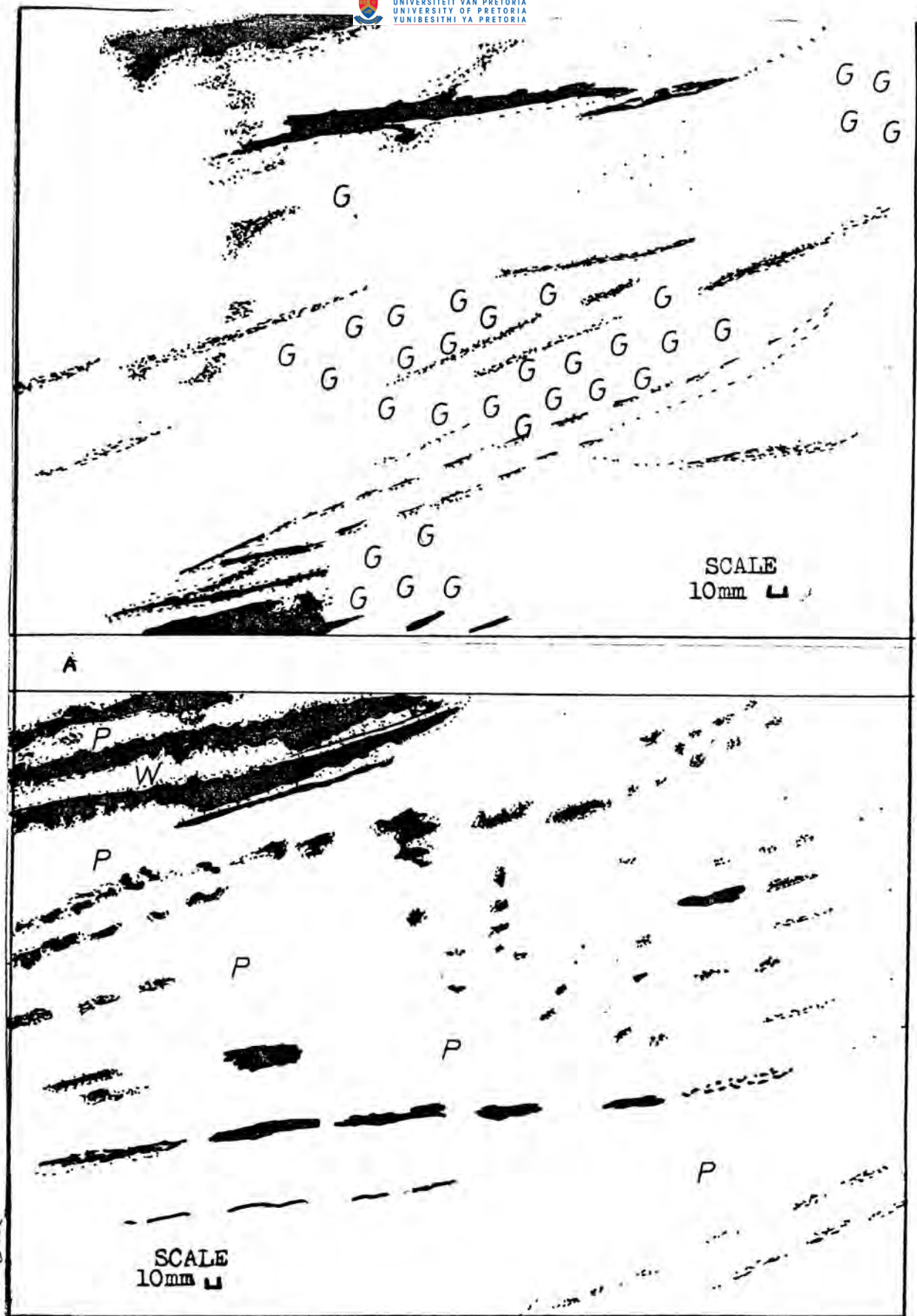
5.23.

Embryonic Pockets

Embryonic Pockets consisted of white ankerite, tourmaline, and sericite spots. On the smallest scale the alteration consisted of the replacement of the interstitial minerals between the large grains; some of these new minerals penetrated along the individual grain boundaries. Where the slightly larger spotting was present there was a total replacement of the original sediments. In some areas the spotting was noted as being more common on cross-bedding; at these points there was no recognisable sedimentary variation in the arkosite. The cross-bedding was, however, a plane of weakness in the sediments (Fig.40).

In some cases ankerite was observed in cracks in the crystal grains, though usually it was seen penetrating along the grain boundaries. Where replacement had taken place on an increased magnitude, and whole grains had been replaced, patches of ankerite were linked up. The replacement appears to spread out from intergranular margins (Fig.41).

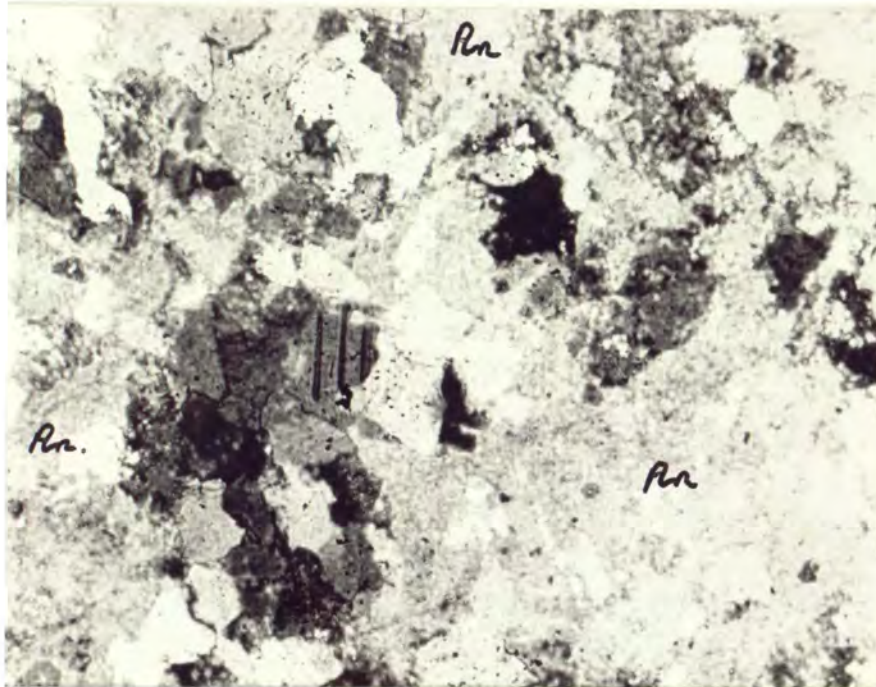
This replacement in arkosite was very patchy, i.e. in some areas it was extensive while in other areas it only existed as traces. This resulted in a spotted texture of the rock (Fig.40). The ankerite spots were 1 mm to 15 mm in size. Even large spots were often composed solely of laths of ankerite consisting of crystals of up to 0,5 mm.



B

Embryonic Pockets

A and B. The selective replacement of tourmaline (black) that sometimes takes place. In A the black spotting can be seen to have enhanced the sedimentary cross-bedding structures, which are otherwise unnoticeable; (G) green areas of sericitisation. Diagram B, a more advanced stage with pocket development on the top left corner still showing a sedimentary bedding. (W) a bleached zone P pink arkosite.



Ankerite (An). Replacement of orthoclase and plagioclase (dark grey) and quartz (white). Ankerite in some areas totally encloses the arkosite grains.

Cross nicols (x20)

Figure 41

Tourmaline spots have the same shape as spots of ankerite (Figs.16D and 18). In the areas where there are minor tourmaline replacements, the tourmaline is present as anhedral interstitial laths in the arkosite. Where tourmaline is more prominent the laths were of larger size and often subhedral penetrating the individual sedimentary grains of orthoclase and plagioclase: quartz is less readily replaced by tourmaline. The tourmaline spots are made up of a number of laths with random orientation.

Where the spots occurred in clusters the areas were called ghost pockets. The pockets are made up of tourmaline spots about 1 mm in size and 5 mm apart. Where the tourmaline has formed, the surrounding arkosite is often bleached white or a lighter shade of pink than the country rock. Microscopic examination revealed a decrease in the minerals which were giving the pigment to the arkosite, i.e. rutile and limonite. This bleached zone with tourmaline spots forms pod-like formations up to 1 m across.

Occasionally, there are cassiterite and pyrite crystals in the pockets; however they are usually confined to sedimentary partings. They cause no significant change in the overall character of the ghost pockets. The junction with the sedimentary rock is sharp and the major change takes place over a distance of 1,5 mm. The grain size is usually similar to that of the country rock over a distance of 1,5 mm. The grains are anhedral, equidimensional and up to 0,3 mm in size.

The spreading of mineralisation from intergranular partings and pores suggest that they were the result of introduction of fluids travelling between grain boundaries.

5.24. Unhaloed Pockets

Unhaloed Simple Pockets

Where the alteration in pod-like areas in arkosite was such as to show a marked contrast with the country rock the forms were classified as pockets.

(1) Granite-Textured Pockets

The granite-textured pockets consist largely of orthoclase, plagioclase and sericite, with some quartz. Usually 60 - 70 per cent of the whole pocket consists of orthoclase, and sericite has in some cases been found to be as much as 20 per cent.

The pockets are recognised because their grain size is always much coarser than the surrounding rock. The grain size can vary from 1 mm to over 5 mm. In some cases the pockets have large and small crystals giving a pegmatitic appearance.

The texture can also vary from an allotriomorphic granular texture, where almost all the constituents are anhedral, to a hypidiomorphic granular texture. There is a sharp junction surrounding the pocket, differentiating the pocket material from the fine-grained granular sediments.

There are no additional minerals to those already found in the country rock. There is just a recognisable coarsening of grain size which indicates recrystallisation of the country rock.

5.25

(2) Red Pockets

'Red Pockets' also show little mineralogical variation with the country rock; although some show a slight increase in orthoclase content and slight decrease in quartz content. Compared with the country rock however, there appears to be not more than about a ten per cent variation. The very red colour, which gave the contrast to the paler country rock, appeared to be an increase in density of fine haematite and rutile deposited in the grains of orthoclase. The specks were up to 0,015 mm in size and often less. (Fig.42A).

The texture was saccharoidal when observed under the hand lens, and allotriomorphic-granular under the microscope.

There are occasional pockets which are exactly like red pockets but have tourmaline along the perimeter. In some cases this is in the form of small arcs and other cases it is a thin halo. The tourmaline is always fine-grained and the grains are randomly orientated. Their appearance is that of a transition stage between red pockets and thin-ringed tourmaline-haloed pockets.

5.26

(3) Massive Mineral Pockets

3a) Massive Black Tourmaline Pockets

These pockets consist of tourmaline as the major mineral (over 90 per cent of the whole pocket). Sometimes there are occasional traces of the original sediment in the form of anhedral quartz grains and patches of sericitised feldspar which make up the remaining 10 per cent. The texture is variable; in some cases tourmaline is hypidiomorphic granular and under a hand lens

some appear to have a saccharoidal texture, while others show well-developed euhedral tourmaline crystals arranged in a rosette pattern.

In the first type, the saccharoidally-textured pockets, the grain size is rarely larger than 1 mm, and the tourmaline laths are randomly orientated, resulting in the pocket having a dull black appearance. The second type of massive (black) tourmaline pocket was made up of tourmaline rosettes. The radiating crystals can be as much as 1 mm in thickness and 1,2 mm long making rosettes 25 mm in diameter. They give a sparkling black appearance to the pocket. The tourmaline usually wholly replaces the country rock.

In thin section under the microscope the pocket boundary appeared less sharp and the laths penetrated the surrounding sediment for at least 2 mm and gave a serrated edge to the pocket.

5.27

3b) Massive Cassiterite Pockets

Massive Cassiterite Pockets are very rare. They contain over 50 per cent cassiterite and often up to 80 per cent; the remainder is ankerite. The individual crystals of cassiterite were often up to 5 mm in size and were commonly striated and twinned. The cassiterite-bearing rock when cleaned with acid revealed 100 mm size lumps of crystal aggregate, made up of euhedral and subhedral grains separated by interstitial coarsely-crystalline ankerite, usually of subhedral grains.

Both the pipes and pockets contained massive cassiterite and showed total replacement of the country rock. No trace of the original sediments existed in the

pipes, excepting some ghost sedimentary structures preserved as banding.

This group of pockets all have a simple structure and uniform mineralogy with no halo development.

5.28

(4) Unhaloed Complex Pockets

Unhaloed Complex Pockets consisted not only of minerals typically found in the country rock (orthoclase, plagioclase and quartz), but also a variety of other minerals, such as tourmaline, pyrite and cassiterite. The significant proportion of introduced minerals and their patchy distribution gave them a complex nature. In some there were patches of red arkosite of a similar nature to that in red pockets. The red areas were often speckled with pyrite, some crystals being up to 2 mm in size. Under the microscope, well-formed euhedral discrete crystals were observed replacing orthoclase and plagioclase. Pyrite often had the appearance of being randomly scattered, though in some cases crystals that occurred were in small clusters of subhedral or euhedral grains.

The pockets had a considerable variety of appearances because of the erratic mineral distribution; black patches of tourmaline did occur in different shapes within different pockets. The tourmaline was often in masses. However, sometimes it occurred in a subhedral form as small clusters of laths randomly orientated replacing the orthoclase, plagioclase, and quartz, of the original

sediment. Tourmaline was occasionally found as inclusions in pyrite, indicating that the pyrite was of a later period.

Cassiterite, not visible to the naked eye, was often revealed under the microscope as an interstitial mineral and in an anhedral form filling cavities between the grains of feldspar. In pockets with a high percentage of cassiterite, the latter replaced both orthoclase and plagioclase. Where cassiterite occurred in still higher concentrations, crystals were found in an euhedral form.

Small patches of sericite and ankerite occurred on a microscopic scale as an interstitial mineral between grains of orthoclase and plagioclase. Pockets with large quantities of sericite or ankerite were found in anhedral masses.

In these pockets there was little resemblance to order in the distribution of the minerals.

Pockets with significant tourmaline content often showed the characteristic start of halo development; laths of this mineral up to 1 mm in size became dense around the pocket perimeter. (Fig.33A). In some pockets further concentrations of cassiterite and pyrite in pockets were revealed in arcs and clusters resembling a halo around a mixed core, although in some cases no actual halo was visible to the naked eye.

In some pockets an intermediate stage could be seen between pockets where the mineral distribution was totally

random to those with zones. These pockets in some cases had anhedral masses of sericite and ankerite near the centre and some had clusters of minerals in arcs which gave the first semblance to a halo. There were some areas where sericite and ankerite enclosed tourmaline needles which were broken up.

The arcs of cassiterite were often of anhedral grains, and only just 0.2 mm in size. Arcs of pyrite were also very patchy. These patches usually consist of euhedral pyrite crystals often up to 2 mm in size.

5.29 Haloed Pockets

In haloed pockets there was a marked appearance of order in mineralogy which the unhaloed pockets do not appear to have. In all haloed pockets the haloes were evident on a macroscopic scale.

Multiple-Haloed Pockets

In multiple-haloed pockets the boundaries of the different haloes, like those of the pocket, were pitted and peaked. The junction of one mineral halo to another could be very sharp with a transition over a distance of 1 mm. This sharp contact gave them their stylolitic appearance to the naked eye. Even on a microscopic scale the boundary revealed a sharp contact. The change was sometimes very abrupt, but at other times a gradational contact over 2 or 3 grain thicknesses was observed.

The haloes of tourmaline varied from about 30 per cent tourmaline to 100 per cent tourmaline. The tourmaline replaced the orthoclase, plagioclase and quartz grains and spread out from intergranular positions and penetrated into the individual grains. In those haloes made up totally of tourmaline nothing of the original grain pattern was observed.

The crystal orientation of tourmaline in haloes varied from pocket to pocket; in some haloes the crystals showed a random orientation of subhedral grains of less than 1 mm, whilst in other pockets the crystals radiated from a central area to form rosettes. Haloes with rosettes were rare, unlike the massive tourmaline pockets with rosettes.

Cassiterite haloes could be over 80 per cent cassiterite; usually they consist of cassiterite mixed with tourmaline. Individual euhedral crystals were common but rarely bigger than 3 mm. Their colour varied from dark brown to honey coloured. In thin sections they proved to be markedly zoned with concentric banding. Closely packed cassiterite formed subhedral masses. The cassiterite replaced orthoclase, plagioclase and quartz of the original sediments and also tourmaline at the halo junction. Tourmaline inclusions were sometimes found in cassiterite, verifying the cassiterite to be of a later period. The cassiterite crystals were commonly found as clusters intermixed with tourmaline and pyrite. It was observed that cassiterite

in excess of about 90 per cent only occurred in haloes where there was no tourmaline in the same pocket.

The pyrite halo of multiple-haloed pockets was never observed to contain more than about 30 per cent pyrite. The pyrite rarely occurred as crystal aggregate; even in the most concentrated haloes the pyrite occurred usually as single euhedral crystals and still fewer were subhedral crystals with one or two twins. In between the pyrite crystals the ground mass of orthoclase and tourmaline was partially replaced by sericite.

The outermost halo of well-developed pockets was a bleached white zone. The halo showed grains of quartz up to 1 mm in size bonded together in a granitic texture. It also showed a zone of a higher concentration of quartz in the halo than in the country rock. The change in quartz concentration formed a very marked front with the country rock and occurred over about 1 mm in thickness. The quartz grains were up to 0.3 mm in thickness.

Modal analyses of different pockets revealed very varied results for the bleached halo, as shown in Table II.

The bleached haloes are of an anhedral granular texture.

Chalcopyrite also occurs usually in the pyrite halo.

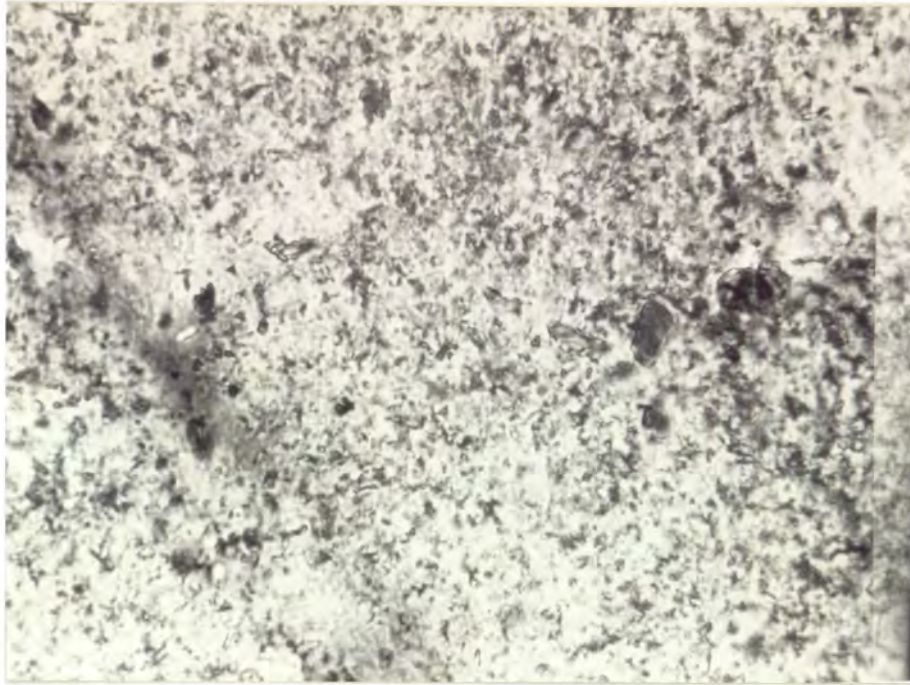
TABLE II

MODAL ANALYSES OF BLEACHED HALOES

<u>Mineral</u>	<u>Results</u>
Quartz	50 - 70 per cent
Orthoclase	25 - 40 per cent
Plagioclase	5 - 10 per cent
1 mm - 0,2 mm boundary zone	- - - - -

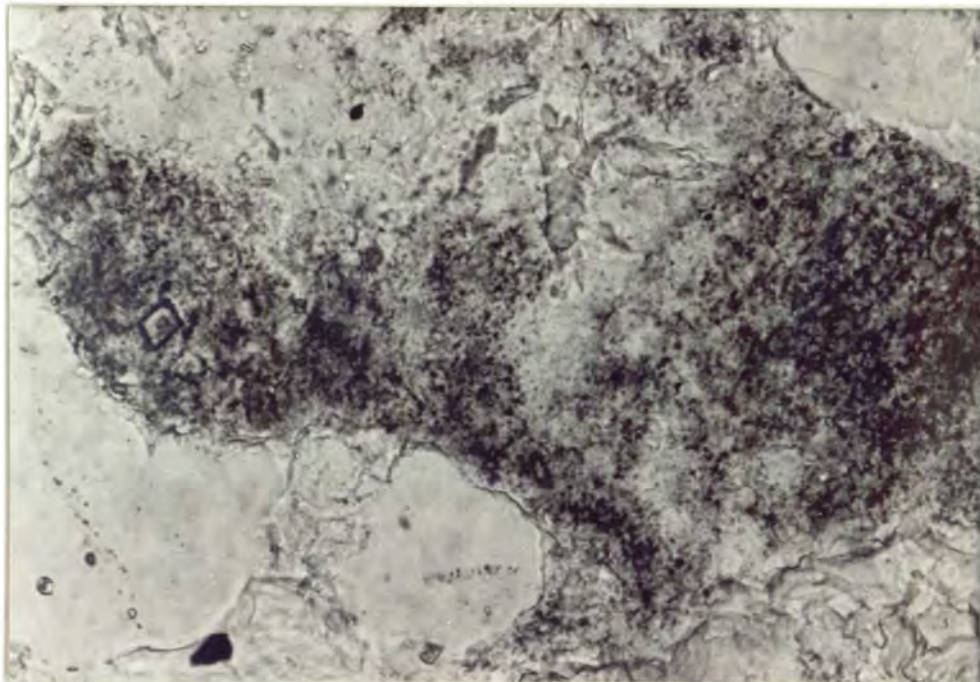
MODAL ANALYSES OF COUNTRY ROCK

<u>Mineral</u>	<u>Results</u>
Quartz	20 - 40 per cent
Orthoclase	60 - 70 per cent
Plagioclase	10 per cent



A

Inclusions in a red pocket.
Inclusions in orthoclase, many of which are rutile, give a speckled appearance and rose colour in red pockets. In some areas rutile is being replaced by sphene. (Mag.x 350)



B

Inclusions in orthoclase in the rose halo of rose-haloed pockets cause a dense speckling. (Mag.x 350).

Figure 42

5.30

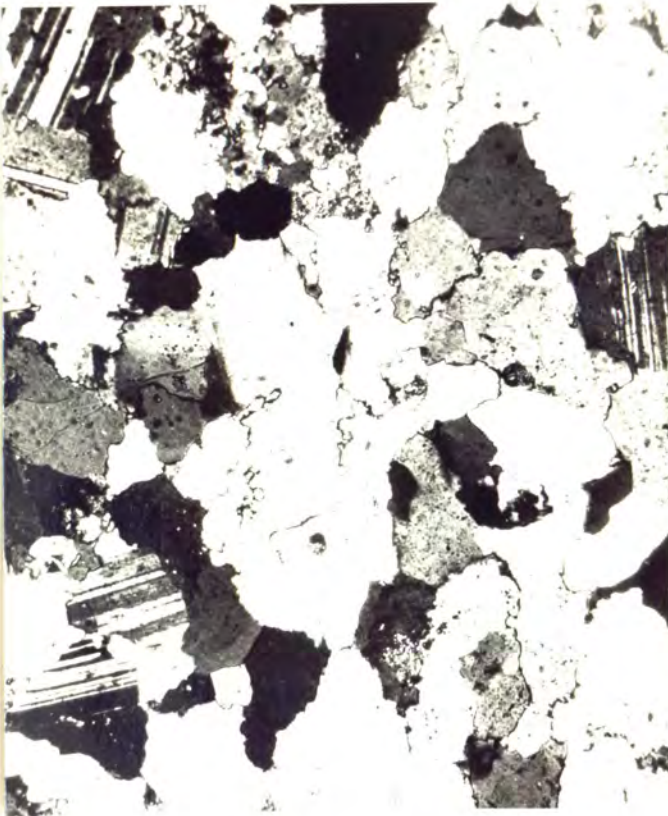
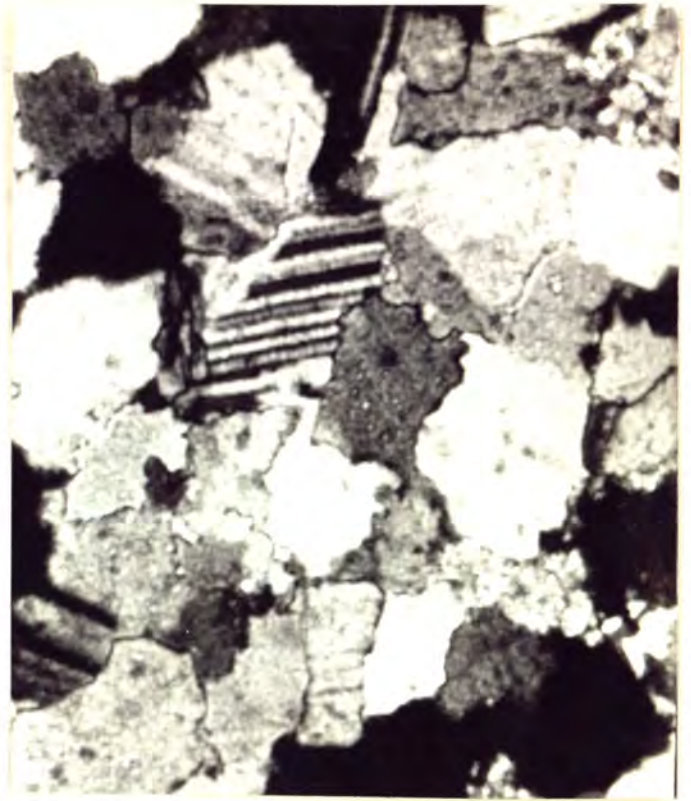
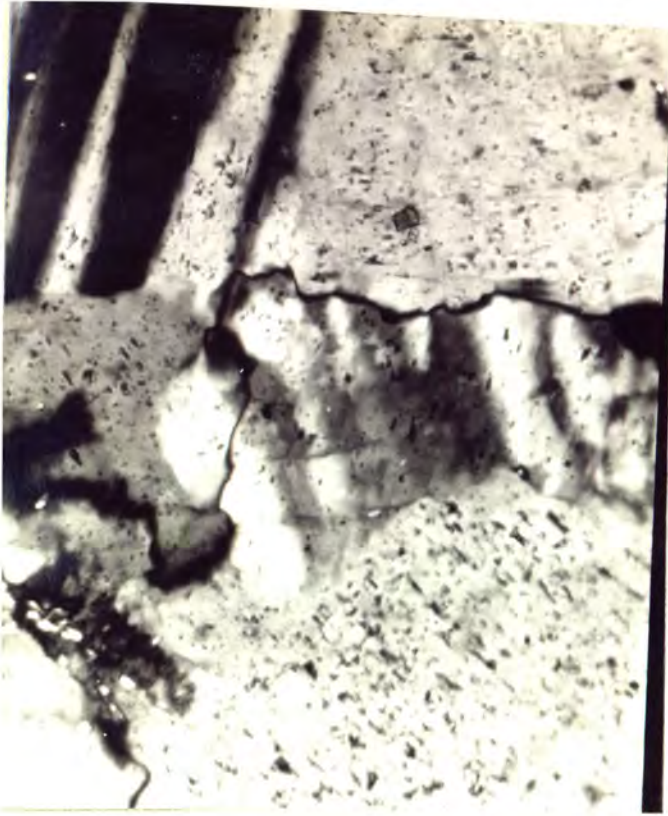
Simple-Haloed Pockets

The mature simple pockets had a very sharp halo which was visible on a macroscopic scale. Three types were examined microscopically, a simple rose-coloured halo, a simple chalcopyrite halo, and a simple cassiterite halo. As in other pockets, microscopically the halo boundaries appeared very sharp. There was virtually no gradation from one rock type to another.

The simple rose-haloed pocket consisted of orthoclase densely speckled (Fig.423). The speckling appeared to be due to limonite and rutile. The result was a red halo with white arkosite either side. The arkosite and the halo showed an allotriomorphic granular texture with grain size less than 1 mm and of an aphanitic texture. In some pockets the quartz content in the white zone was about 10 per cent higher than found in the country rock which made it look like a quartzite (Fig.45c). Less spectacular haloes were found such as red haloes in pink arkosite; they were suspected of being stages in the formation of the red halo in white arkosite. However these trends were difficult to establish. The transition from the arkosite to the bleached halo is illustrated in Fig.43D.

The most common simple-haloed pockets were those with rose-coloured haloes and tourmaline haloes. Less than ten simple pyrite pockets were recorded on Rooiberg and fewer than a hundred simple cassiterite pockets.

The rose-haloed pockets seemed more common with depth, and were observed by the writer at a depth of 135 m.



1. A study of grain boundaries of crystals. It also shows the inclusions which give a clouding effect in orthoclase and plagioclase (x 100, crossed nicols). B. The textural nature of the arkosite (x 60, crossed nicols). C. The recrystallised arkosite with considerable interpenetration near pocket haloes (x 60, crossed nicols). D. Arkosite in the bottom left becomes more quartzitic in the bleached halo area, top right (x 15 crossed nicols).

Figure 43

The pyrite in the simple-haloed pyrite pockets was massive and the halo consisted of more than 90 per cent pyrite and chalcopyrite. In many cases it was 100 per cent chalcopyrite. No intermediate stages were found. The bonding was so strong between crystal faces that pockets fractured across their crystals in a brittle fashion.

Simple cassiterite pockets, when fractured, broke along the crystal faces revealing the crystalline structure clearly. The crystals were very often euhedral and in some cases subhedral. The haloes consisted of 100 per cent cassiterite, and the cores of the pockets were of sericite, or sericite with pyrite specks. Their development was deduced from other pockets which consisted of disseminated cassiterite with sericite in the altered country rock. These pockets are believed to be an intermediate stage before the simple-haloed pocket is formed.

5.31 Complex-Haloed Pockets

Where pockets have repetitive haloes there is little difference between the inner haloes or the outer haloes of the same mineral. In some cases the inner halo is better developed than the outer halo; in other cases it is vice versa.

Disarranged-haloed pockets are where haloes are not concentric and there is cross-cutting emplacement. Often the evidence is marked as in Fig.39. Fragments of crystals of earlier mineralisation are seen as inclusions in later mineralisation, and earlier structures are often sharply truncated.

TABLE III

ANALYSES OF POCKET CORE MINERALS

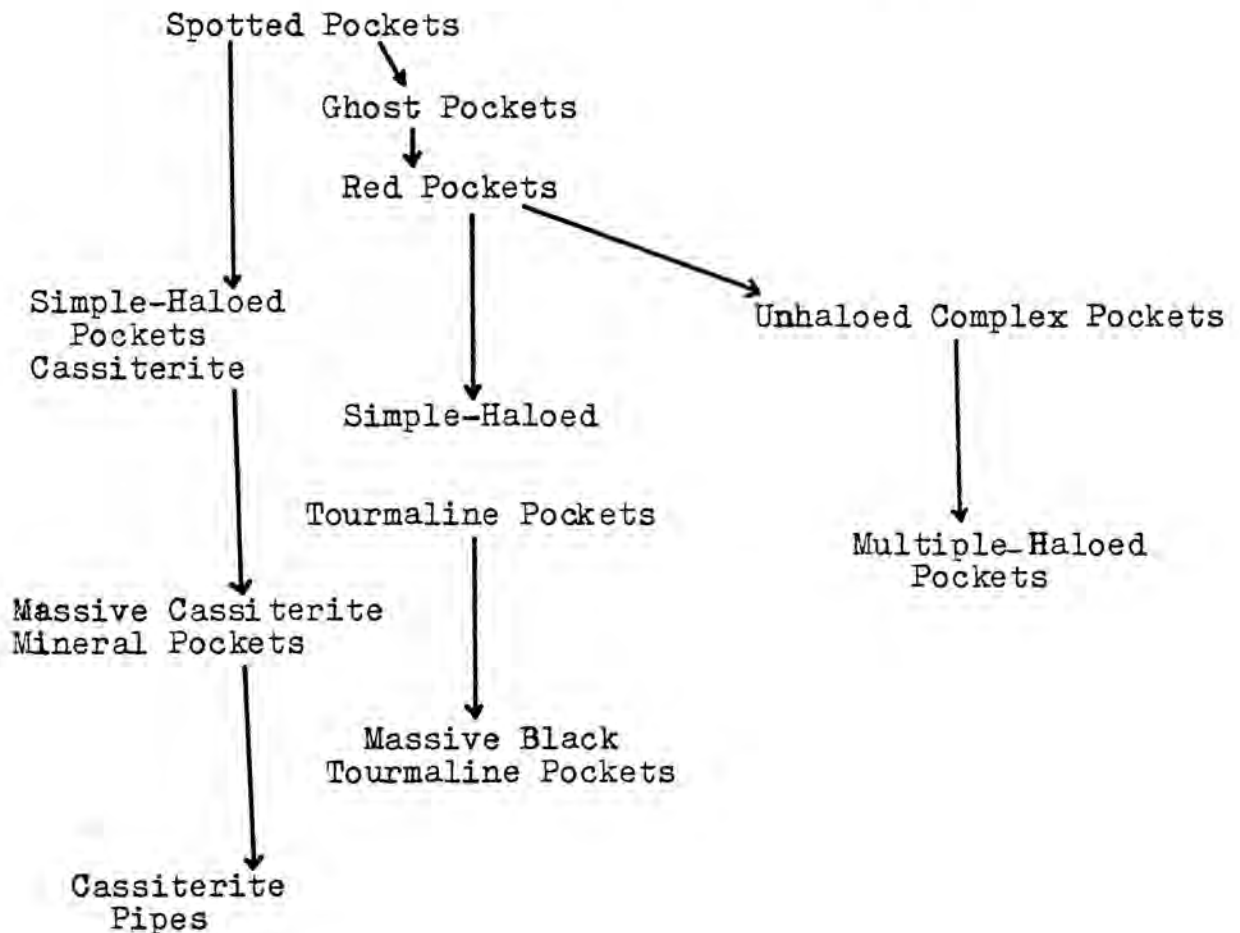
Pocket Core	Quantity of Mineral Present Per Cent				
	Ankerite	Orthoclase	Plagioclase	Tourmaline	Sericite
A	40	30	20	8	2
B	Ankerite	Quartz	Accessory Minerals		
	85	10	5	-	-
C	Ankerite		Accessory Minerals		
	40	10	5	-	45
D		Quartz			
	-	5	-	20	75

Intermediary stages were found between core types A, B, C and D.

TRENDS IN POCKET TYPES

The trends suggested by the pocket types with their intermediate stages are represented diagrammatically below.

CHART SHOWING DIFFERENT STAGES OF POCKET DEVELOPMENT
OBSERVED WITH INCREASING MINERALISATION.



The trends are deduced from the increasing developments of spots and new mineral. As well as a trend to an established order of zones of particular minerals the trends are towards the particular types indicated which suggested these are the result of the completion of the process of alteration and hence have reached "maturity".

5.32 Pocket Cores

The less well-developed cores of multiple-haloed pockets contain partially replaced feldspar and quartz from the original sedimentary rock. The coarsely crystalline cores of multiple-haloed pockets revealed the original sediments to have been totally replaced by massive anhedral lumps of sericite which occasionally contained broken-up needles of tourmaline. Ankerite often occurred in lumps of crystals of subhedral or even euhedral nature. Quartz, where it occurred, replaced sericite and ankerite, and was found in some areas as aggregates of euhedral crystals 30 mm long. Fluorite occurred very rarely. In one case galena made up 20 per cent of the pocket core, although it usually occurred as an accessory mineral. Scheelite also is usually just an accessory mineral. Galena was found as euhedral crystals replacing tourmaline and ankerite; scheelite was usually in anhedral masses.

Cores of multiple-haloed pockets analysed by modal analyses showed considerable variation from pocket to pocket. Most of the pockets were in the range of core analyses shown in Table III.

There were trends visible in the pocket cores, but these were not related to the haloes. Pockets with Type A core were more common in shallower areas of the mine away from major fissures progressing to pockets of Type D core which were more common in deeper areas of the mine or close to major fissures. Most cores had a subhedral to euhedral fabric and varied from very fine to coarse.

Chemical Analyses of Rocks and Minerals of Rooiberg Mine

Wall Rocks

5.33. In order to verify any trends in alteration of rock adjacent to the cassiterite area, four samples were selected for analysis, on strike of the strata. Samples were obtained along a sidewall section on a stope in the ION and W2 areas in the mine. These samples were labelled 1A, 2A, 3A, and 4A and the results of the analyses are shown in Table IV

Sample 1A is from a visible white quartzite halo which was characteristic of most pockets. Samples 2A and 3A are from the typical quartzite which surrounds the pocket area often up to 10 m or more. Sample 4A was taken 15 m away from the pocket area and considered typical of the country rock.

Microscopic study of a sample of the bleached white halo revealed an increase in quartz and a decrease in feldspar. This was verified by the analysis for SiO_2 (which showed an increase), and for Al_2O_3 , MgO , CaO , Na_2O , K_2O , (which had all decreased proportionally). There is also a significant decrease in Fe_2O_3 and TiO_2 which can account for the loss in colour of the rock. Much of the TiO_2 remaining was probably contained in the occasional grains of sphene which were detected during microscopic observation. A striking fact is that sample 4A was redder than 2A and 3A although 2A had more Fe and Ti. The Ti in 2A and 3A was largely in sphene and not in rutile as in sample 4A; hence the lack of strong colour.

The wall rock is the rock adjacent to fissures and this can be affected by migrating fluids while the country rock is the rock surrounding areas of wall rock alteration.

TABLE IV

Comparative Table of Wall-Rock Alteration

SAMPLE	1A White Halo	2A Wall Rock Adjacent to pockets	3A Wall Rock 10 m away from pockets	4A Country Rock
Analyses of	per cent	per cent	per cent	per cent
SiO ₂	89.3	73.9	76.4	76.6
Al ₂ O ₃	6.3	12.1	12.21	12.61
Fe ₂ O ₃	0.43	1.20	0.74	0.75
MgO	0.09	0.83	0.64	0.22
CaO	0.20	1.62	1.47	0.47
Na ₂ O	2.69	4.22	3.87	3.12
K ₂ O	0.78	3.05	2.75	4.23
TiO ₂	0.11	0.26*	0.37*	0.15
P ₂ O ₅	0.03	0.05	0.04	0.03
F	n.d.	0.03	-	-
MnO	-	-	0.04	0.02
TOTAL	99.93	97.26	98.53	98.2

p.p.m. TRACE ELEMENT ANALYSIS

Ba	250	681
Sr	29	30
V	38	33
Y	6	8
Zr	209	59

TABLE V.

Comparative Table of Pocket Areas to study the
Change that has taken place in Wall-Rock

SAMPLE	1B Rose Halo	2B Red Pocket	3B Massive Tourmaline Pocket	4B Sericite Core	4A Country Rock
Analyses by wt.of	per cent	per cent	per cent	per cent	per cent
SiO ₂	82.18	55.77	34.61	17.16	76.6
Al ₂ O ₃	8.67	11.1	30.69	8.75	12.61
Fe ₂ O ₃ (Total)	0.59	3.31	7.75	19.03	0.75
MgO	0.34	2.6	8.67	9.21	0.22
CaO	0.88	5.17	2.2	11.74	0.47
Na ₂ O	3.37	0.23	2.03	0.45	3.12
K ₂ O	2.46	7.91	0.27	1.32	4.23
TiO ₂	1.09	0.03	0.45	0.58	0.15
P ₂ O ₅	0.01	0.1	0.17	0.19	0.03
MnO	0.03	0.12	0.04	0.47	0.02
Loss on Ign. * (at 900°C)	1.3	8.44	2.1	26.96	
TOTAL	100.9	94.73	88.98	95.86	98.2

p.p.m. TRACE ELEMENT ANALYSIS

Ba	293	630	19	137	681
Sr	23	115	197	184	30
V	13	32	877	183	33
Y	31	6	24	18	8
Zr	737	70	103	406	59

* Includes losses due to CO₂

Changes in Country Rock with Pocket Development

5.34 From microscopic observations on the cassiterite halo and pyrite halo it was possible to establish their origin by replacement of the country rock. However in order to compare the chemical changes which have taken place by the formation of other haloes and the cores, with the composition of the country rock, four more analyses were made, the results of which are compared in Table V. Sample 4A Table IV was considered to be a sample of the average country rock in the area chosen for study.

The rose-coloured halo of the rose-coloured-haloed pockets shows orthoclase and quartz crystals under the microscope with minute pink and red inclusions which give the halo its colour; the analysis of this halo was thus significant. The increase in Fe_2O_3 from the original sediment was very small; however there is a major increase in TiO_2 from an 0,15 per cent to 1,09 per cent which would add significantly to the colour. The specks are considered most likely to be rutile. The increase in Ca from the country rock is thought to be due to the feldspar (Deer, Howie & Zussman 1966, p.136). Ankerite and sericite were not present. Another outstanding feature of the rose-coloured-haloed pocket was its high Zr content; occasional zircon was observed. This suggests that some Zr was introduced.

The analysis of the primary red pocket confirms its feldspathic nature, (Table V, No.23). Its decrease in SiO_2 and increase in K_2O , CaO are marked. It also shows an increase in Ba content. The colour is probably due to an increase in Fe_2O_3 which is observed microscopically as haematite flakes.

The irregularity in Ba results suggests migration of Ba was taking place.

In the development from country rock to haloed pockets and core material, four major trends are obvious from Table IV - IA and Table V, - the increase in Fe_2O_3 and MgO , P_2O_5 and Sr.

Other changes in the content of the country rock in the formation of pockets are the increase in TiO_2 in tourmaline pockets and core material. The TiO_2 in core material is probably in sphene as rutile is not visible.

A feature of interest is also the high content of V in the tourmaline pocket and sericite core; however from the results of V no trend is obvious.

5.35^a Tourmaline

Observation on polyascendant haloed pockets often showed inner and outer tourmaline haloes. For comparison tourmaline from an inner halo and an outer halo was analysed for Mg and Fe. The tourmaline was largely schorlita. However the inner halo (later halo) was found to have a significantly higher proportion of Fe. Thus in the outer halo another element has taken the place of Fe, which is probably Mn.

This indicates two periods of mineralising fluids of different composition.

TABLE VI
Tourmaline Analyses of Concentric Haloes

	Inner Halo	Outer Halo
Mg	3.6	3.4
Fe	10.5	4.4

5.35^b. Ankerite

An associated feature of the polyascendant period of mineralisation is the two periods of ankerite. The first ankerite is brown, and the later ankerite is white and was observed to cut across the brown ankerite. Both were

analysed. The first was found to be low in Ca and rich in Fe while the later one was rich in Ca and low in Fe.

TABLE VII

Carbonate Analyses

	White Carbonate	Brown Carbonate
Ca	17.3	1.57
Mg	7.71	5.55
Fe	10.4	32.3
Mn	0.32	0.81

5.35c. Plagioclase Feldspar in the Tin Horizon

In several cases plagioclase boundaries faded into orthoclase (Fig.43A) though in most cases the boundaries were distinct (Fig.43B). There were only rare instances of perthite development.

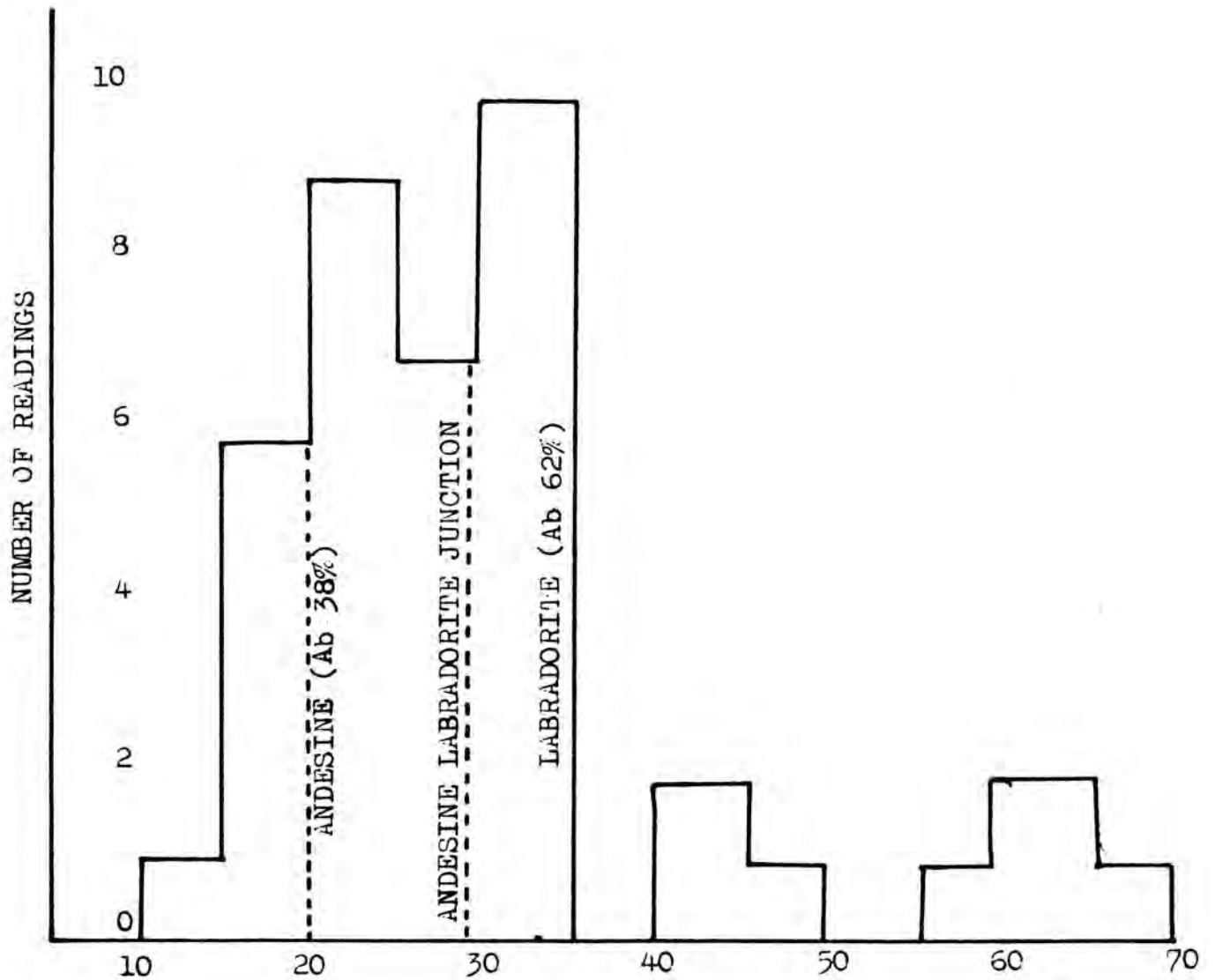
The presence of Carlsbad-Albite twinning allowed the anorthite content of the twinned feldspar to be determined. Extinction angles showed it to be on the Andesine-Labradorite boundary, i.e. An. 50. Numerous albite twins made it possible to determine the anorthite composition by Michel Levy's method (Kerr 1959).

Although there was a variation in the maximum extinction angle (Table VIII) the plagioclase was shown to be largely andesine-labradorite in the altered arkosite country rock.

5.35d. Cassiterite

Massive cassiterite was looked at under the electron microscope for the presence of other trace elements. Although the quantities were not measured, traces of chromium and nickel were found using the Edax system.

TABLE VIII
DISTRIBUTION OF
MAXIMUM EXTINCTION ANGLE
OF ALBITE TWINS DETERMINED
FROM THE ARKOSITE



Maximum Extinction Angles
Histogram

5.36. The Distribution of Pocket Types

Pockets of different types often occur in specific zones (Fig.44).

The commonest outer halo of haloed pockets is the bleached white-looking quartzite halo. It is common with all pocket types; however it is not around every pocket; other haloes vary and are found to have a relation to the major fissure

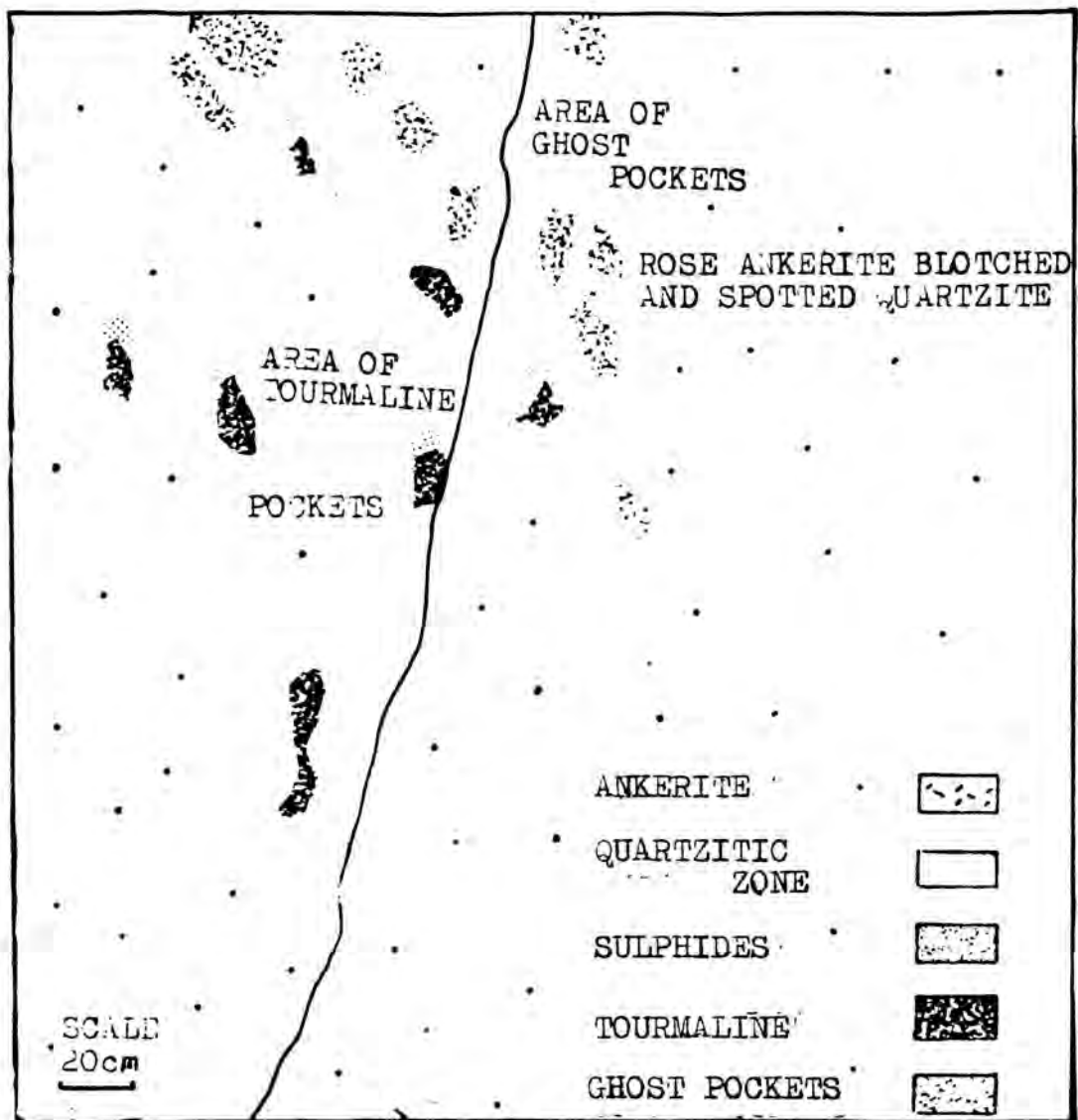
In ideal circumstances, when tracing pockets laterally, from minor fissures towards a major fissure, there is a sequence in mineralogy of pocket types. A similar sequence exists when tracing pockets in depth along one fissure. The sequence is not always complete, however, in ideal circumstances a pattern was observed and is represented diagrammatically in Fig.61.

The pockets found furthest away from major fissures or at the extremity of the pocket horizons are often the medium grained granitic-looking pockets.

Next in sequence are the red pockets and simple rose-coloured-haloed pockets.

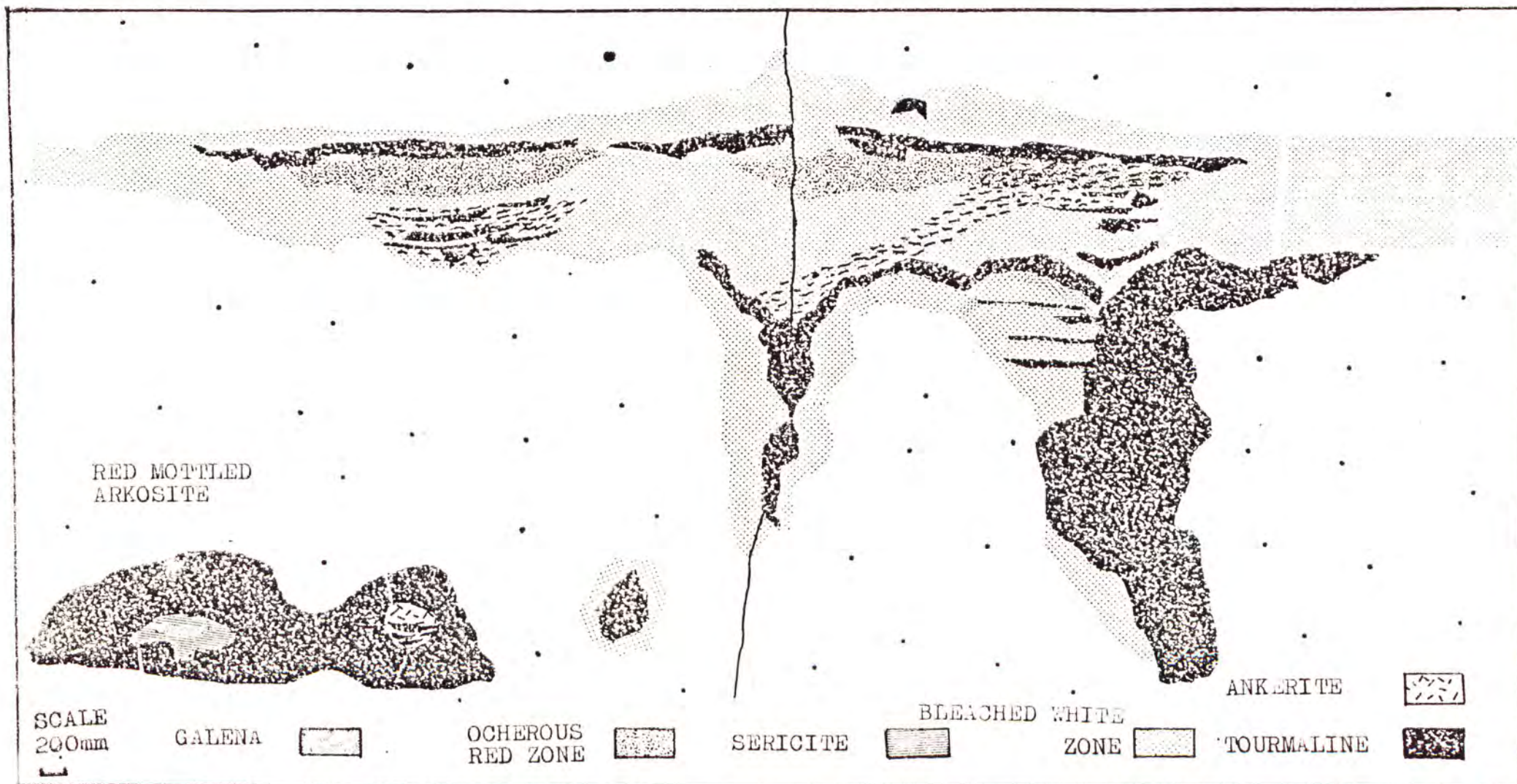
In normal circumstances, closer to the main fissure, massive tourmaline pockets and simple, tourmaline-ringed pockets are very common. The tourmaline may be fine-grained with grains less than 1 mm or with large rosettes of needle-like crystals of up to 20 mm in diameter, sometimes with galena cores (Figs.45 & 56C).

Tourmaline pockets are often followed by mixed tourmaline, pyrite and chalcoppyrite pockets. It is only



A zone of small massive tourmaline pockets grading into a zone of ghost pockets above. The sudden change in pocket feature is indicative of the sensitive conditions of metasomatism.

Figure 44




105

Fractures carrying metasomatic fluids upwards are strongly influenced by bedding plane partings. The effect is well illustrated by this example where arkosite alteration is seen spreading out in a horizontal plane.

Figure 45



Scale 100mm 

A thin-ringed tourmaline pocket with a core of altered feldspar and a characteristic tourmaline halo. The outer bleached halo shows areas where the selective tourmaline replacement has accentuated cross-bedding structures.

Figure 46

very rarely that simple chalcopyrite pockets or simple pyrite pockets occur. The former were only frequent at Blaauwbank. The tourmaline-chalcopyrite pockets defined as multiple-haloed pockets are in varying stages from well mixed pyrite, chalcopyrite and tourmaline pockets (defined as unhaloed complex pockets), thus establishing a trend. Pyrite crystals can be up to 10 mm in size and as well-formed pentagon-dodecahedrons. Sometimes they are discrete, surrounded by tourmaline; at other times they form an aggregate. The trend is towards an aggregate tourmaline-pyrite inner halo with a massive tourmaline outer halo. (Fig.5A).

Cassiterite pockets occur nearest to the main fissures and on the main fissures themselves. There is often a mineralogical trend observable in these pockets. In a fully preserved sequence, outermost there are tourmaline-pyrite-cassiterite pockets. These progress to tourmaline-cassiterite type pockets. Then next in sequence are the massive cassiterite pockets. Again, the multiple mineral pockets, termed 'unhaloed complex pockets', can have the same structural variation from areas where cassiterite, tourmaline and sulphides are mixed, to a well-developed halo stage defined as multiple-haloed pockets. The cassiterite is coarse-grained and usually found in aggregate form. Pockets in the transition stage are common. (Fig.47).



Scale 100mm

A. transition from a red pocket to a multiple-haloed pocket. The core was in the process of developing. Golden-coloured pyrite has become concentrated. It is a transition via an unhaloed complex mineral pocket. The haloes are just beginning to form.

Figure 47

5.37 The Relationship Between Less Prominent Metallic Minerals

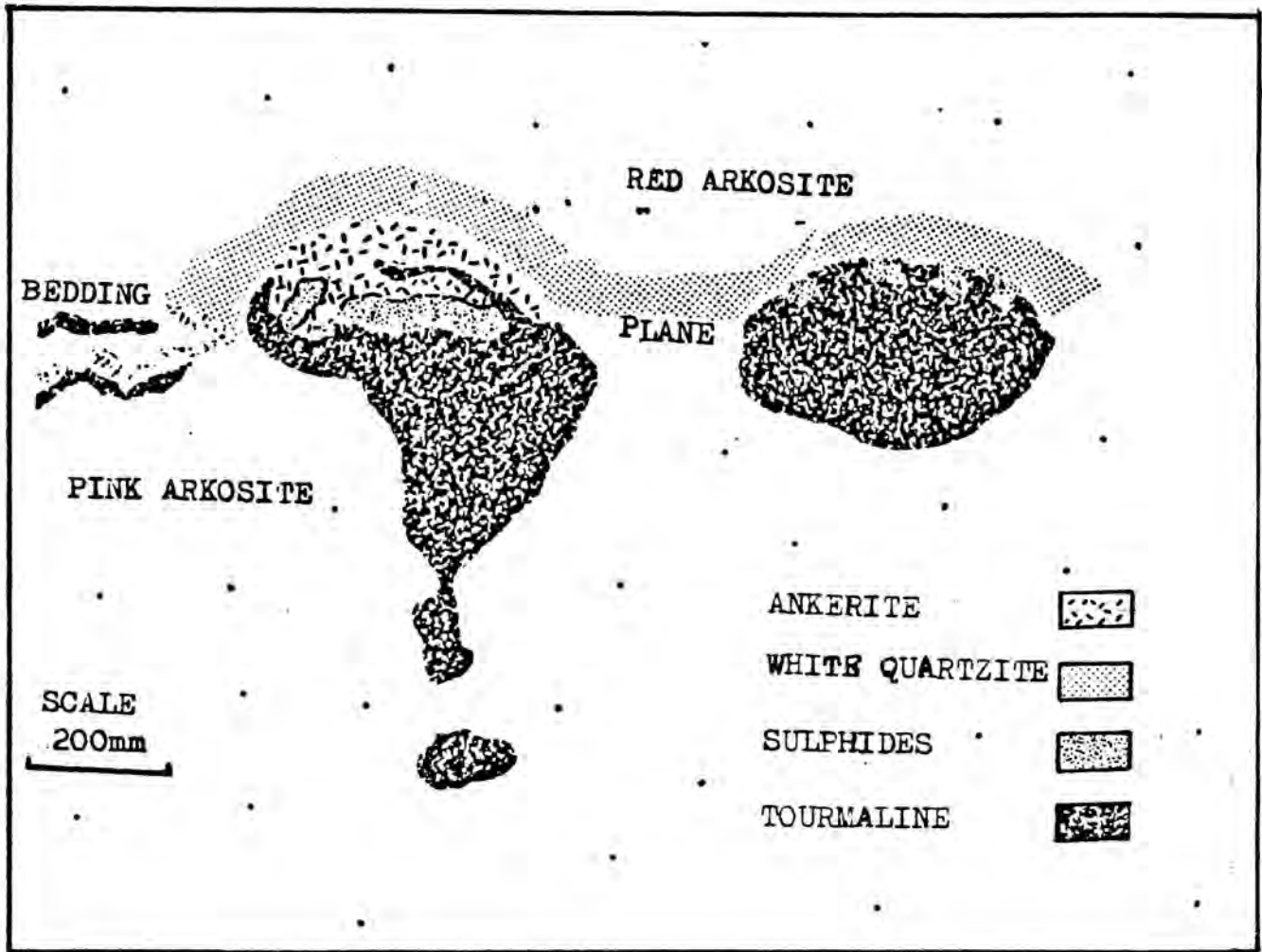
Along some fissures there is a recognisable sequence in the variety of metalliferous minerals in the pockets. Pockets with specularite exist further away from major fissures than those with galena (Fig.61).

Cassiterite pockets follow next in sequence, then those of scheelite. Sometimes a transition can be seen where pockets can have both specularite and galena or both cassiterite and scheelite.

Galena as a core mineral has been seen along fissures up to 10 m away from cassiterite bearing fissures, whilst specular haematite has been seen 5 m away. It is possible to establish zones in which pockets of a particular mineralogy can be expected (Fig.61).

From the writer's work galena, specularite, and scheelite pockets do not appear to be common. Scheelite pockets were most common in the A3 and A7 shaft area at Rooiberg Mine while specularite pockets were found most readily in the 10 North and West 2 area, and galena in the 19 North area at the same mine.

The separation between sericite and ankerite has been shown to resemble the other metallic minerals in having preferential zones in the main fissures. There are also very occasional cases where there is an inter-relation between ankerite and pyrite (Fig.48).



Massive tourmaline pockets showing late ankerite and sulphide development and white quartzite area influenced by a bedding plane parting.

Figure 48



▲ typical texture of a green band made up of sericite grey and very fine grains of feldspar (white). There is a slight lineation to the grains which suggests movement.

Cross nicols (x 30)

Figure 49



A Scale 100mm —
A typical green band, green with sericite and yellow ankerite, grades up into typical arkosite. It can be seen to be above the bedding plane parting which is a well-defined boundary line at the base.



B Scale 100mm —
A green band p has spread out along a bedding plane parting with ochreous red haematite on both sides and tourmaline on the perimeter which is seen as a thin black line giving a sandwich effect. This green band p can be seen to be of the same origin as the pocket q from which it diverges.

Figure 50



A Scale 100mm —
Evidence for the hydrothermal origin of green bands is shown by these rectangular patches of early stage green band material a and b surrounded by a rectangular tourmaline halo. Their rectangular nature bears out that these have little relation to the sediments.



B Scale 100mm —
A bedding plane pocket can be seen to be conclusively related to a green band a - b. The green band dies out away from the pocket towards the right and ends abruptly with the end of the pocket on the left. The green band a - b is 20mm thick pure green sericite.

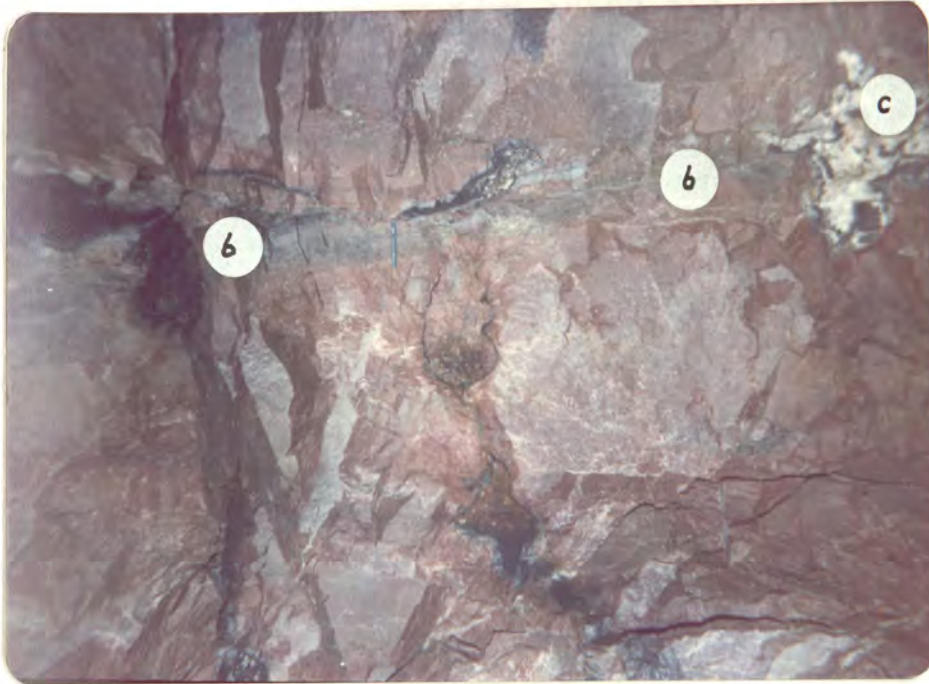
Here the ankerite is deposited in a pocket which is nearer to the main fissure than the pocket containing pyrite, thereby suggesting that ankerite is the less mobile of the two.


5.38. Green Bands

In pocket zones there occur features known as green bands. They are distinct from shale bands which can also be green in colour. Green bands can be seen to be zones of alteration of the sediment. They can also be zoned in many stages and grade into the longitudinal pockets. The simplest form of green band is a thin greenish replacement of feldspar (Figs.49 & 50A).

The replacement can be seen in all stages up to a wholly green massive sericite band. The boundaries are in the initial stages transitional and, in the areas of complete replacement, very sharp. They are almost always associated with structural features, usually bedding-plane partings. Green bands of a more complex nature show a red haematite-enriched zone on either side; others show a red zone, then a black tourmaline zone making a sandwich-like structure. They can be seen to be related to pocket formation (Fig.50B & 52).

As the stages progress green bands develop into pocket cores with pocket zones on either side (Figs.19A & 51B).



Scale 100mm 

A red pocket developed below a green band b. The green band can be seen to be a product of sericitisation of the arkosite. A white ankerite pocket c cuts the green band on the right hand side.

Figure 52

The first stage of alteration of bands appears to be a red band (Fig.63). Then other forms are found with a greenish-tinge suggesting a sequence of formation like pockets.

Two very unusual green band forms are illustrated in Fig.51A where small joint blocks have undergone green-band alteration with tourmaline surrounding them. They thus resemble rectangular pockets.

Green bands in some cases have been intersected by later mineralisation (Fig.25) and thus can be related to periods of emplacement of pockets.

Along some green bands there has been later activity and faulting and they are partially kaolinised. This is probably due to percolating ground water.

5.39. The Location of Pockets

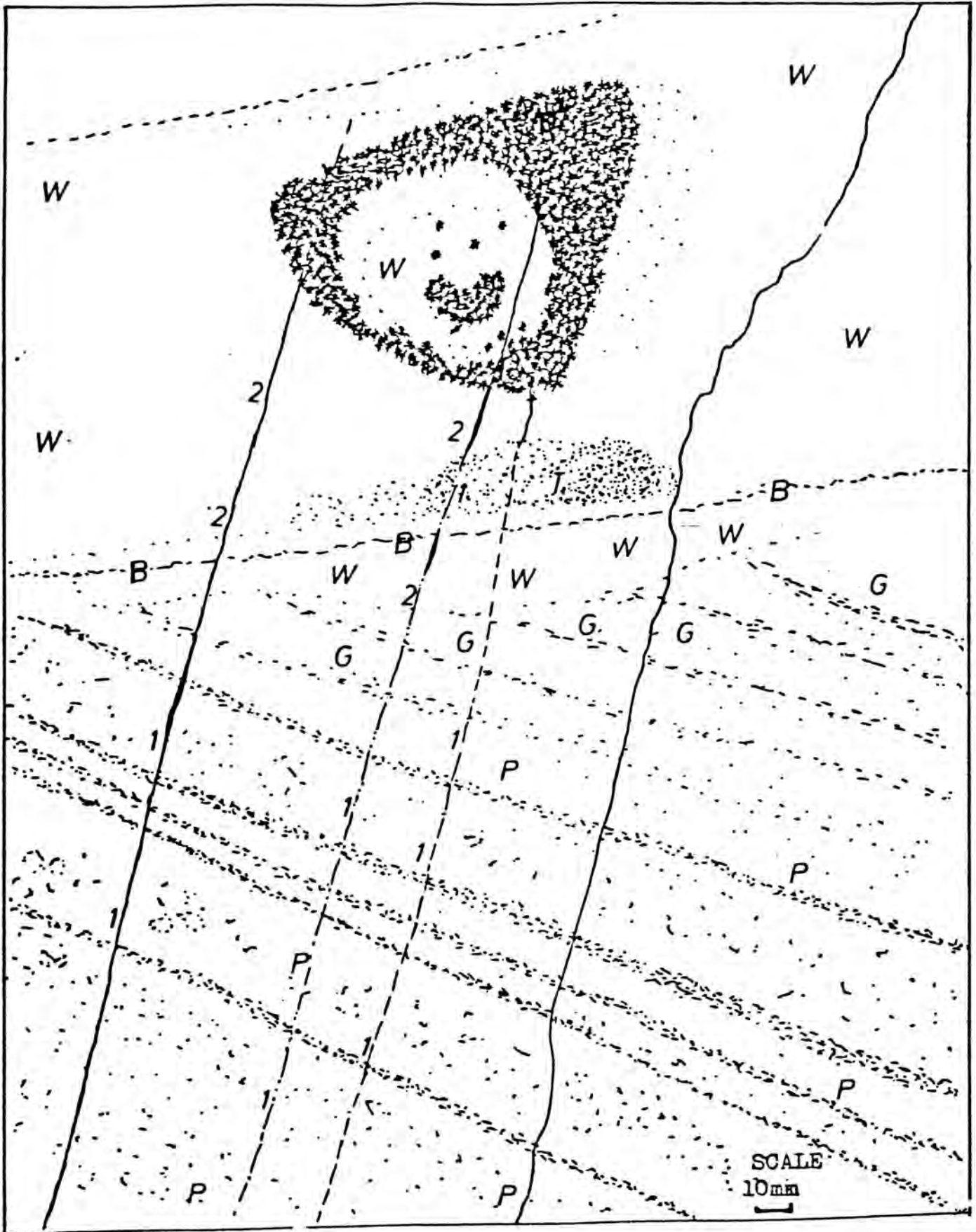
The point where pockets form can usually be related to some structural irregularity. A very common point is at the intersection of joints. Other irregularities such as joints and stylolites are also common. Often the irregularities are not immediately obvious. The part stylolites play can only be observed under a microscope. Typical traps for hydrothermal fluids are microfractures intersecting stylolites (Fig.17C) and the accentuated peaks on stylolites (Figs.17D & 183). Often the area of intersection of stylolites has been a place of nucleation (Figs.18A & 18D). Some stylolites themselves

have sudden changes of direction forming steps. These steps appear to act as centres of reaction (Fig.18C). They were probably traps for migrating fluids.

For pockets to develop not only must the sediments be suitable for replacement, but the physical controls must be right (e.g. ion concentration and temperature). Because there have been two periods of emplacement of mineralising fluids it is possible to draw comparisons. In some areas the second period of mineralisation has failed to form pockets. There are occasional examples where fissures carrying mineralising fluids have cut pockets of an earlier generation and have shown no trace of forming a pocket (Fig.5B). It is probable that intrusion was too rapid, or there was insufficient time for a concentration of ions to build up before cooling.

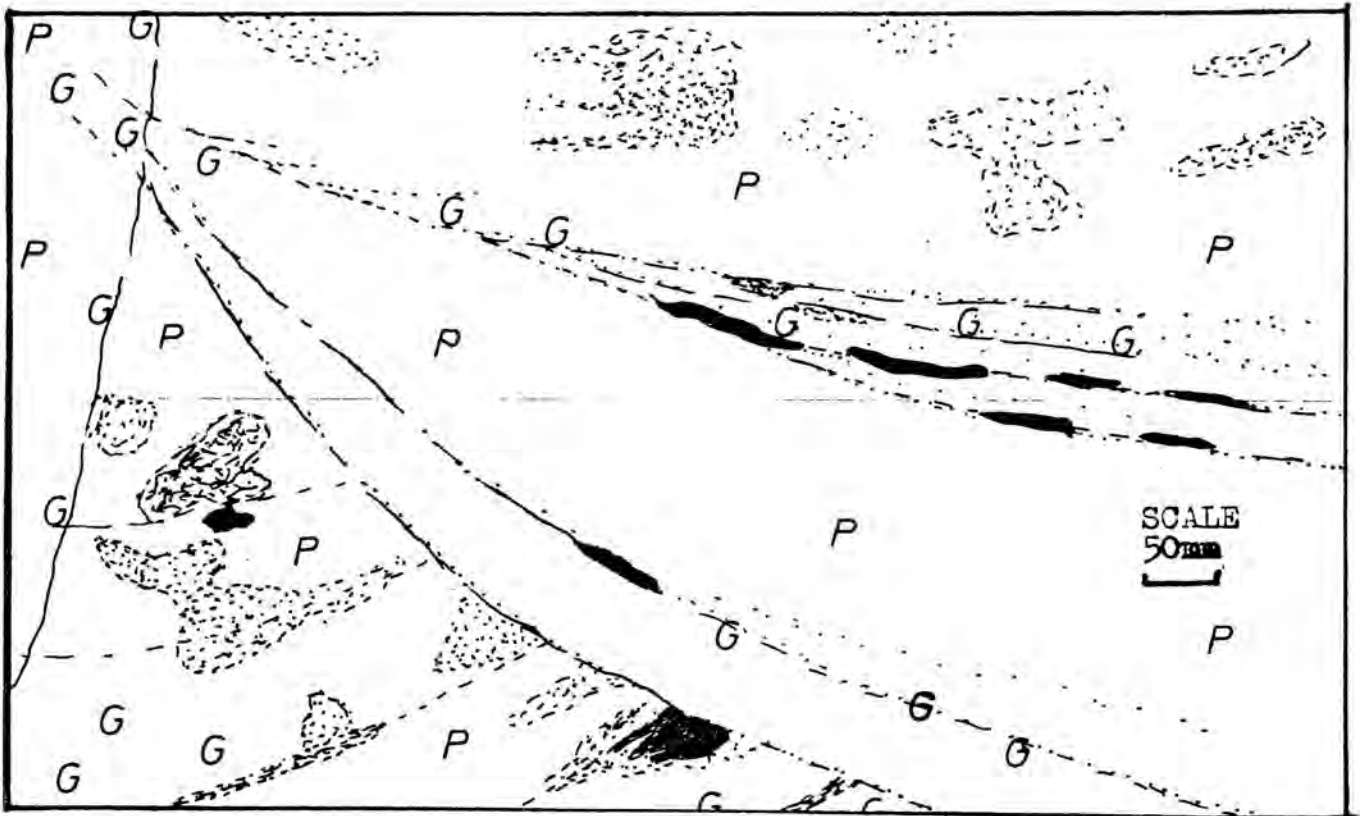
Sometimes a front of reaction can be observed as in Fig.16C where alteration has advanced from left to right causing the observable front. In Fig.16C the main areas of change are adjacent to the stylolites, suggesting mineralisation has spread from the stylolites as the solution migrates from left to right. Large spots of tourmaline often form around a stylolite (Fig.16D). Internal sedimentary structures also can be seen to play a part in the development and the shaping of nuclei (Fig.54).

Sometimes joints and fractures appeared to have acted as a stop to mineralisation giving the truncated tops to some pockets (Fig.55A). In other places irregular fractures are the centres of tourmaline mineralisation and tourmaline rosettes (Figs.53 & 56A).



Black indicates tourmaline. A black rosette pocket is in a bleached zone W, bedding plane partings B. G represents a green zone of sericitisation above the pink arkosite P. 1 and 2 indicate thin fractures.

Figure 53



Alteration of the sediments depicted above illustrates how selective replacement proceeded and ghost spots develop.

G green areas of sericitisation, P unaltered pink arkosite, and black tourmaline, show the accentuation of sedimentary structure in the process of alteration.

Figure 54

5.40 Minerals observed at Rooiberg and their Paragenesis

5.40A Ankerite


Ankerite occurs both as the calcium magnesium-rich and iron-rich variety; the former is white and the latter is brownish and can thus be distinguished by the unaided eye. In many areas two periods of ankerite formation can be seen. The first to occur is usually of the brown iron-rich variety and this is seen to be cut across by veins of a late formation of white ankerite. In some areas it is emplaced (Figs.55B & 19B) and in other areas it appears to be the result of a change from feldspar (Fig.41).

It is a common mineral in pocket cores, and ankerite crystals up to 10 mm in size have developed. It replaces tourmaline in the core, and feldspar in the arkosite. Feldspar and tourmaline are found as occasional inclusions in ankerite. The latter is, in turn, replaced by tourmaline in the areas of the tourmaline halo. The second period of ankerite post-dates the main period of mineralisation as veins are often found cross-cutting pockets.


5.40B Apatite

Apatite is not very common in Rooiberg Mine. It does sometimes occur as a pocket-core mineral, (Fig.56D), where it occurs as well-developed hexagonal crystals; its formation is later than ankerite which it seems to replace.



Scale 100mm 



Scale 100mm 

A. Typical flat-topped pocket as described by Stumpf. The flat top in this case is controlled by a sedimentary structure, a bedding plane parting.
B. A later period of ankerite (white) has not completely followed the earlier fracture system, so that not all pockets are affected by the later ankerite.

Figure 55

5.40C

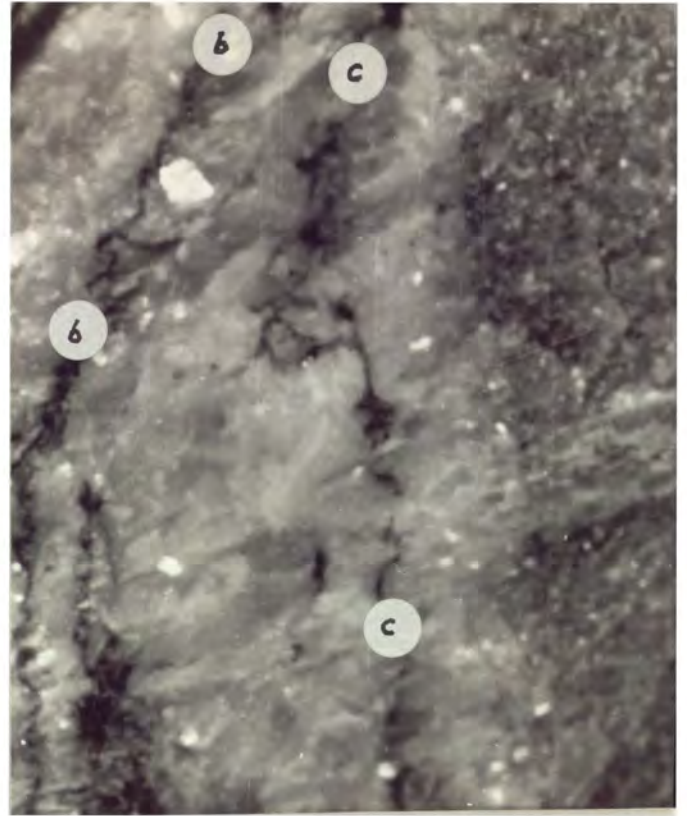
Cassiterite

Cassiterite is often found massive in pockets and also as very fine, discrete, well-developed crystals 3 mm in size intermixed with tourmaline in the halo boundaries. Very fine-grained cassiterite is also found in the sediments replacing orthoclase, plagioclase and quartz (Fig.57B). It is sometimes sufficiently concentrated near fissures and bedding partings to form a low-grade ore. There are two distinct phases of metasomatic emplacements. Fine-grained cassiterite was often seen encrusting earlier cassiterite. Cassiterite occasionally shows inclusions of tourmaline. It often crosscuts rosettes and tourmaline crystals, indicating it to be later.

5.40D

Fluorite

Fluorite at Rooiberg is not a major constituent of the gangue material. It is more commonly found in high levels in the mine and at a distance from the major fissure. It occurs as a fine crystal mat on the side-walls of fissures. In the middle of these fissures there may be either open cavities or a filling of later ankerite. Two periods of fluorite formation can be seen. The earliest deposit is a clear fluorite, and the later one is dark blue. However, in many areas only one period of fluorite formation can be traced, suggesting that in some cases the same channels were not open for the two periods of fluoritization. The fluorite in open cavities must be late and post-date

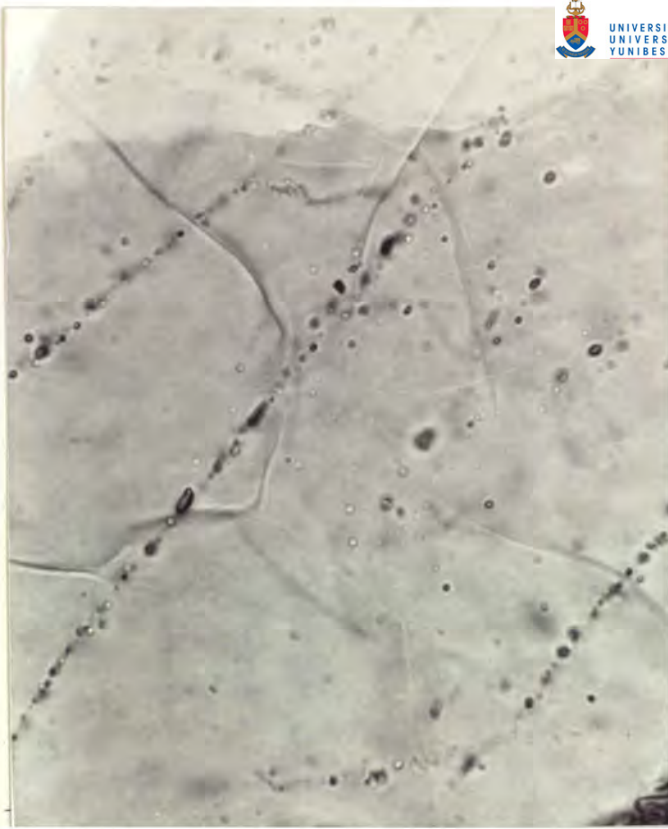


C

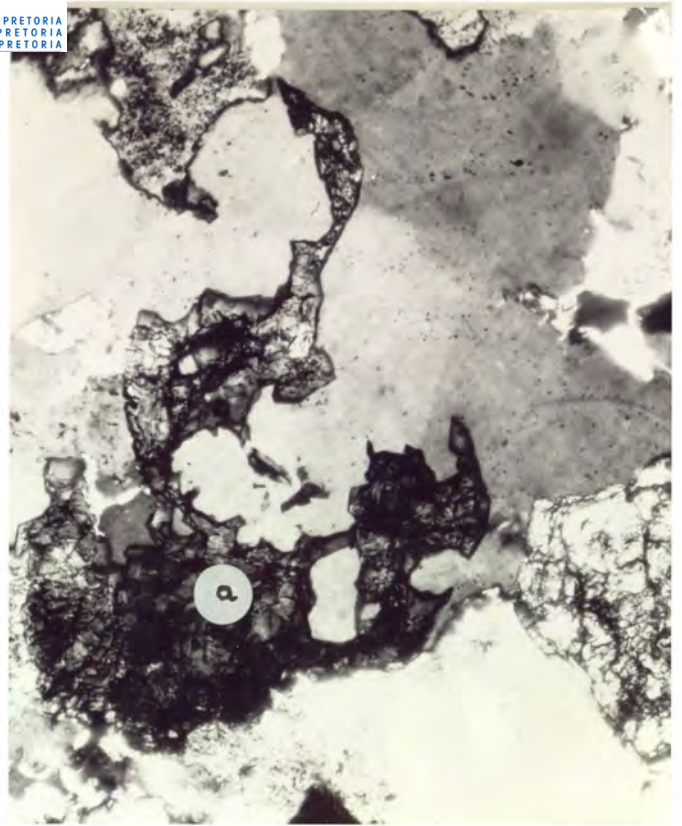
D

A Tourmaline rosettes along a fracture a. B Stylolitic fractures b and c in ankerite. C Galena of a pocket core. D Apatite e found as a core mineral. (All mag.x 5).

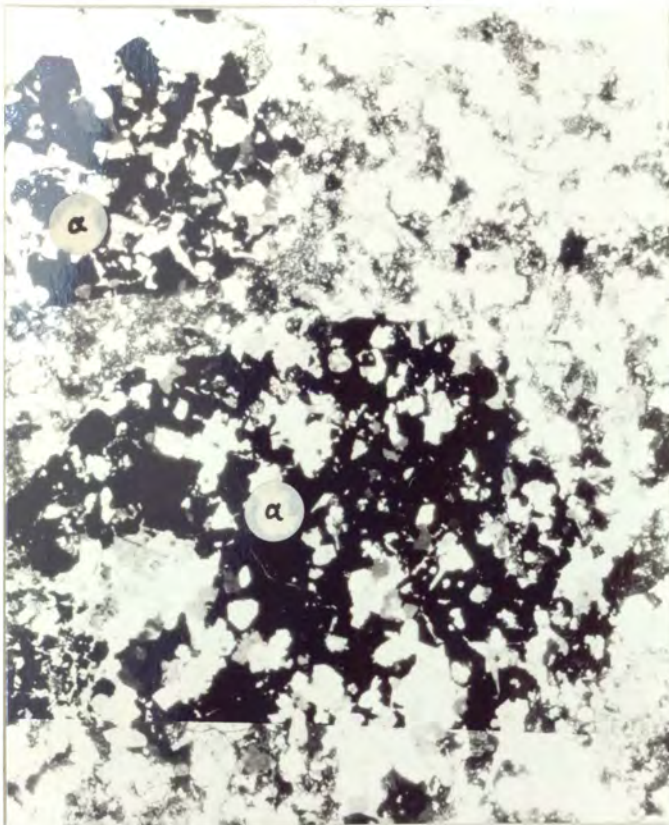
Figure 56



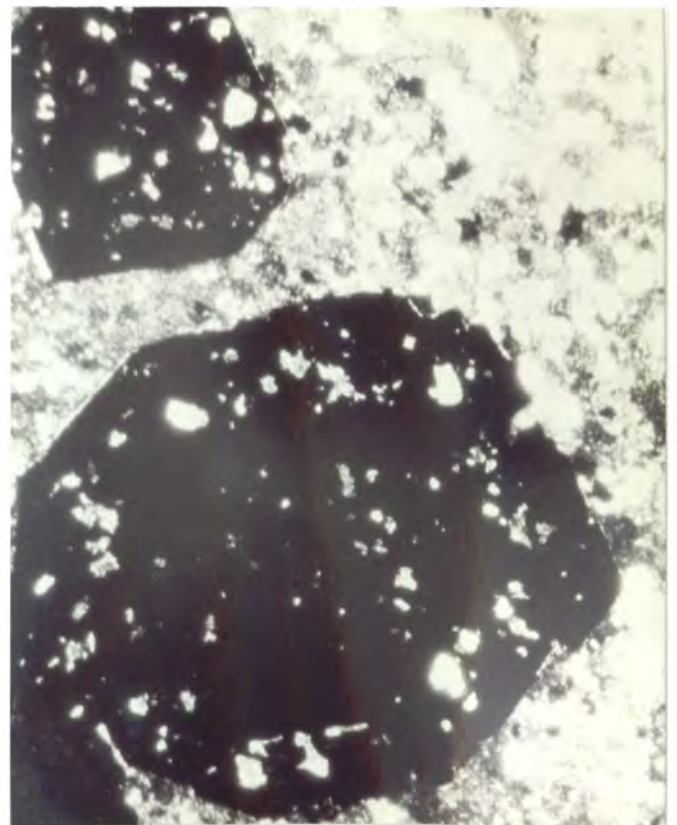
A



B



C



D

A. Lines of inclusions (small specks some of which are rutile) in a recrystallised orthoclase crystal preserve the old cross-bedding structure (x 600).
 B. Cassiterite very dark (a) replacing orthoclase and quartz from an interstitial position (x 300). C. Two pyrite crystals black (a) in a stage of growth in the arkosite (x 200). D. Pyrite crystals black showing inclusions (x 200).

the main mineralization period. An earlier fluorite is occasionally seen trapped in pockets and is suspected to be earlier than the main mineralisation.

5.40E

Galena

Galena occurs in some places in the core of the pockets with other core minerals. It has been found in the core of a tourmaline pocket as a thin lens and in cubic form occurring with ankerite. It is, however not common. The majority of pockets with galena were found in the A3 and 19 North area of the mine, but always at some distance away from cassiterite pockets. Galena occurred before the specularite as specularite was found in one area pseudomorphing galena.

Cubic crystals of galena have been found up to a size of 5 mm, and its occurrence as a pocket core mineral is illustrated in Fig.56C.

5.40F

Gold

Using an electron microscope traces of gold were detected in pyrite.

5.40G

Haematite

(a) Red Earthy

Haematite is the mineral which caused the red-colouring of the arkose and often leaves faint pinkish haloes. In many areas where tourmaline had formed, the red-colouring had decreased in the sediment. Thus in the areas of tourmalinisation faint pink or in some cases white haloes were developed; probably the haematite has contributed to form the tourmaline.

Where there is a re-introduction of haematite into red pockets its effect often appears as a halo.

(b) Specularite

Specularite has been found occasionally in the tourmaline halo where it occurs irregularly as small patches. It has never been found in quantity at Rooiberg and the patches of specularite seen are rarely over 20 mm in size.

5.40H

Microline

Microline has been found in pocket haloes. It is exceptionally rare and occurs as scattered grains.

5.40I

Magnetite

Grains of magnetite were occasionally found in Rooiberg Mine; they have been observed trapped in stylolites. The usual maximum grain size is of the order of 0,3 mm. However, near pockets, magnetite grains appear to have been locked together. At a considerable distance away from the pocket they were also seen to replace orthoclase and quartz.

5.40J

Nickeliferous Pyrite

Traces of nickel were found associated with pyrite in an area in the mine called 'the pyrite workings'. These traces were detected using an electron-microscope.

5.40k

Orthoclase

Orthoclase is an inherent mineral in the country rock, and is often replaced by ankerite. The average crystal grain size is about 0,1 mm. Sericite is found as a replacement of orthoclase as well as

ankerite, tourmaline, pyrite and cassiterite.

Perthitic inclusions occur within the crystals as elongated dashes. Other inclusions in orthoclase are common. Suggestions of the recrystallisation of orthoclase were found where grains actually contain lines of inclusions of rutile (Fig.57A).

5.40L

Plagioclase

The plagioclase is found as a primary mineral of the arkosite. Plagioclase has also been found as a secondary mineral replacing tourmaline in the process of albitisation. Plagioclase itself is often replaced by cassiterite. Also pyrite, in turn, replaces both orthoclase and plagioclase.

5.40M

Pyrite and Chalcopyrite

Pyrite occurs as scattered crystals in the sediment and, as mentioned above, replaces orthoclase and plagioclase, showing it to be an introduced mineral. Closer to the fissure it forms nucleations as in pocket haloes in the pocket zone. Pyrite and chalcopyrite usually occur together and associated with tourmaline. However, there are occasional pockets with chalcopyrite rings only. The chalcopyrite replaces quartz in the chalcopyrite haloed pockets, and replaces tourmaline in the multiple haloed pockets. Later pyrite introduction is evident in complex-haloed pockets.(Figs.57C & 57D).

5.40N

Quartz

Quartz is liberated from the breakdown of feldspar. It does not seem to be very mobile as it tends to remain, in situ, whereas the calcium migrates away to leave a silica enriched-zone around pockets in the bleached haloes. Quartz is not common as a core mineral. However, when it does occur it is of a late stage in mineral formation. Quartz in pocket cores is seen to envelop galena, apatite, and specular haematite, which suggests a low temperature origin.

5.40 O.

Rutile

Rutile is common throughout the sediments. It has a considerable resemblance to cassiterite in granular forms. It also has a similar colour and high R.D. which makes it nearly impossible to distinguish between them in panning. In areas of wall-rock alteration rutile can usually be seen to be replaced by sphene (Fig.13C). As it occurs in inclusions in quartz and orthoclase it is thought to be earlier (Fig.57A).

Rutile occurs in rose-haloes pockets. Where these haloes start to appear in a tin-mining area, they give an indication of an immediate reduction of tin content in the ore. The grain size is often about 0,015 mm.

5.40P

Sericite

Sericite replaces the feldspar in the country rock; it less readily replaces quartz leaving some pocket cores with granular inclusions of quartz. However, complete replacement does occur, and some cores are pure sericite. Sericite often replaces tourmaline in the inner haloes. The former is more commonly formed in pockets of higher temperature minerals, whereas ankerite is found in those of lower temperature. (Sericite pocket-core minerals are illustrated in Figs.51A & 51B).

5.40Q

Scheelite

Scheelite has only been seen in pocket cores next to fissures, where it occurs in a massive form, often surrounded by ankerite. Its proximity to the fissure suggest it is late in the paragenetic sequence as it has not travelled far from the fissure source.

5.40R

Sphene

Sphene replaces rutile in the sediments, especially in the metasomatic zones. Large grains occur near some of the fractures and pockets. The largest size observed was 0,25 mm. (Fig.13D).

5.40S

Tourmaline

Tourmaline replaces orthoclase, plagioclase and quartz readily (Fig.58). It is often found a long distance away from the main fissures. However when it occurs near the fissures it completely replaces the sediments. It is very early in the paragenetic sequence.

5.40T

Zircon

Zircon has a grain size of less than .03 mm and is randomly distributed in the sediments at Rooiberg. However concentrations in stylolites and in increase in concentration deduced by chemical analysis of wall rock and sericite core suggest more penetrated from fissure fluids.

TABLE IX

SCHEMATIC DIAGRAM SHOWING THE SUGGESTED PARAGENETIC SEQUENCE OF THE PRINCIPAL MINERALS DEDUCED FROM OBSERVATIONS AT ROOIBERG MINE

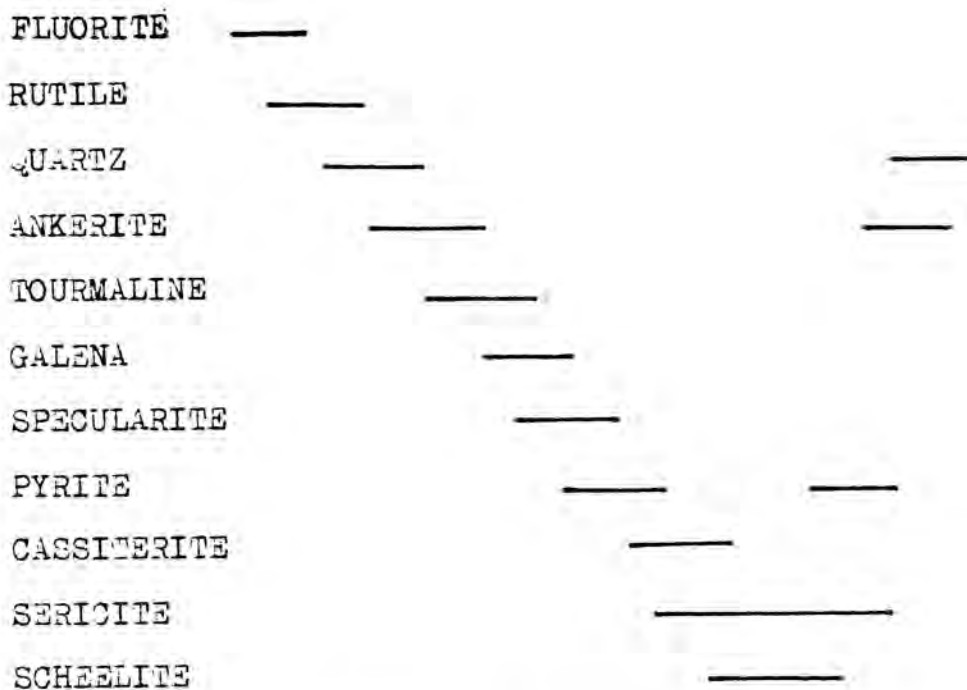


Diagram shows a single phase.

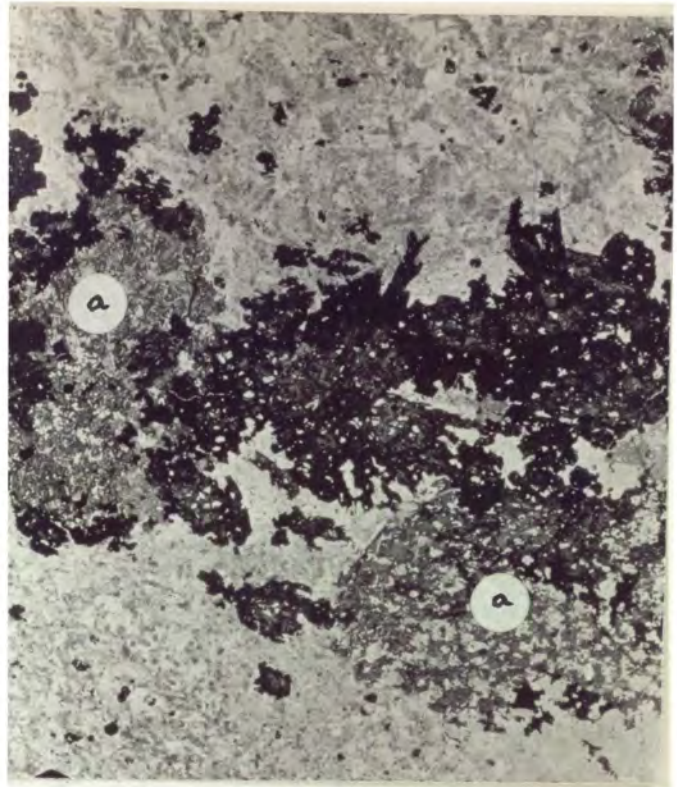
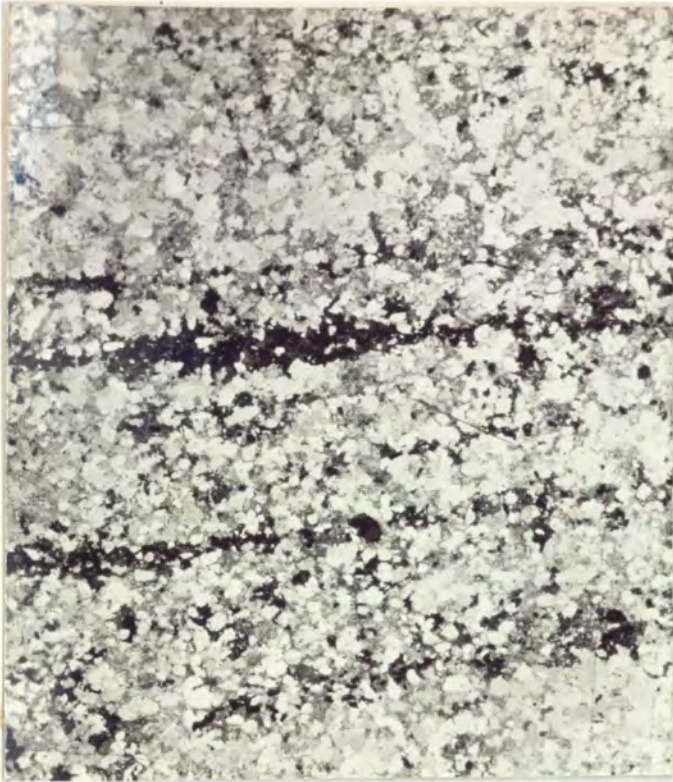
The sequence is for the first period of mineralisation.

The Formation of the Pockets and
Zones of Sedimentary Alteration at Rooiberg

In the sedimentary rock, clear zones of alteration exist. There is ankerite alteration which grades into areas of ankerite spots. Sericite shows similar trends of development. In the wall rock nearer to the fissure there are disseminated cassiterite, and tourmaline laths. The new minerals in the country-rock all show definite zones of occurrence. Pocket mineralisation appears to be an extreme phase of the process of alteration.

Pockets represent complete stages of alteration as in medium grained granite-textured pockets, or complete replacement as in tourmaline-haloed pockets. The deposition starts off along grain boundaries (Fig.41B), suggesting migration of mineralising solutions from fissures, with which these zones appear to be always associated. As the process of alteration proceeds spots develop, (Figs.53B & 58C) and they represent the start of nucleation and replacement. The process may be explained by metasomatism. The replacement takes place on a granular scale enabling the original sedimentary structures to be preserved and often very distinct on a microscopic scale (Fig.40).

Pockets themselves seem to be a special case of this mineral replacement. The area of migration and replacement has its source of activity in fissures from which it is believed the introduced fluids have come. The edges of the zone are very well defined and sharp. They



A Tourmaline lenses black (Mag.x5). B A zone of tourmaline laths making up a black spot (cross polars Mag.x10), and two cassiterite crystals (a) with inclusions. C Ghost blotch made up of tourmaline spots running N.E.-S.W. (Mag.x6). D A large tourmaline spot made up of a dense area of smaller spots (Mag.x5).

Figure 58

appear to represent particular limits of alteration, or fronts. Minerals of the inner halo replace those of the outer halo along the boundary. Red pockets and primary complex pockets represent the early stages prior to the development of haloes; they are thus indicative of the conditions before the halo fronts were set up.

The fact that different haloes occur in a pocket and that they usually occur in the same order in different mature pockets indicates that, under the same conditions, different minerals travel different distances from the fissures. The fluids in the fissures will be of a high temperature, and as the fluids emerge from the fissures and penetrate into the wall-rock, they will have a decreasing temperature gradient. This movement of elements, possibly as complex ions in between mineral grains, probably takes place by diffusion.

As the constituents of different minerals travel different distances their diffusion is expected to be related to temperature. Thus the pocket boundaries, outer halo boundaries, and zone boundaries mark the limits where diffusion of the particular element has ceased. Near the source, diffusion will be more rapid because of the higher temperature. Away from the source, the diffusion will eventually cease as the temperature decreases with increasing distance. This results in a halo in which certain elements become concentrated and where the highest degree of replacement takes place.

The fact that different haloes form indicates that different elements or complexes have different diffusion rates. Haematite and specularite haloes form further away from the pocket source than the haloes of pyrite and chalcopyrite. Pyrite and chalcopyrite haloes are usually nearer the source fissures than cassiterite. Tourmaline can be formed long distances away from the source, much further than cassiterite and pyrite. Conversely galena was always found near the major fissures and fractures. It is thus evident that different elements penetrate different distances into the country rock away from the fissures and some, such as galena, hardly at all. It is also evident that minerals formed from elements of lower molecular weight are often found further away than those with elements of higher atomic weight. Diffusion has been used to explain wall-rock alteration in many areas, (Garrels and Dreyer (1949), Haug (1965), Stemrock (1965), Flerov (1970), Fletcher (1972).)

Pockets at different elevations on the same fissure also show trends; in ideal cases pockets at different locations on the source fissure can be compared. This enables the second governing factor of pocket content to be established, that is the result of the fluid composition of the source. This can be determined by the total content of massive pockets and pocket cores.

Furthest away along minor fissures remote from the major fissures, and on the upper extremity of the major fissures, coarse fluorite was found as a core mineral. Fluorite, as a core mineral, is very rare and from the study of the pockets in relation to the fissure it appears

only to occur where the fissure terminates and where there appears to be no escape from any ascending fluids. It can occur in the granitic pocket zone.

The sequence of mineral formation in pockets with decreasing distances from the source appears to be specular haematite pockets, galena pockets, massive cassiterite pockets, and scheelite pockets. Similar trends are to be observed in haloes as described under the distribution of pocket types.

From the study of the mineral content of pockets and their relationship original fluid composition can be deduced at different points along the fissure. This would also govern the formation of pocket haloes.

Furthest away, as mentioned, are the traces of fluorite, and granite-textured pockets. The deposition of fluorite, and the recrystallisation which has taken place in the formation of granite-textured pockets, is expected to be the result of the lowest-temperature ions as these will have travelled furthest along fissures.

Tourmaline, which contains a very highly mobile ion, boron, is also found at great distances from the major fissures and along minor fissures. Galena and specular haematite travel further than cassiterite along fractures. At the extremities of mineralised areas along fractures where galena is found there is rarely any cassiterite.

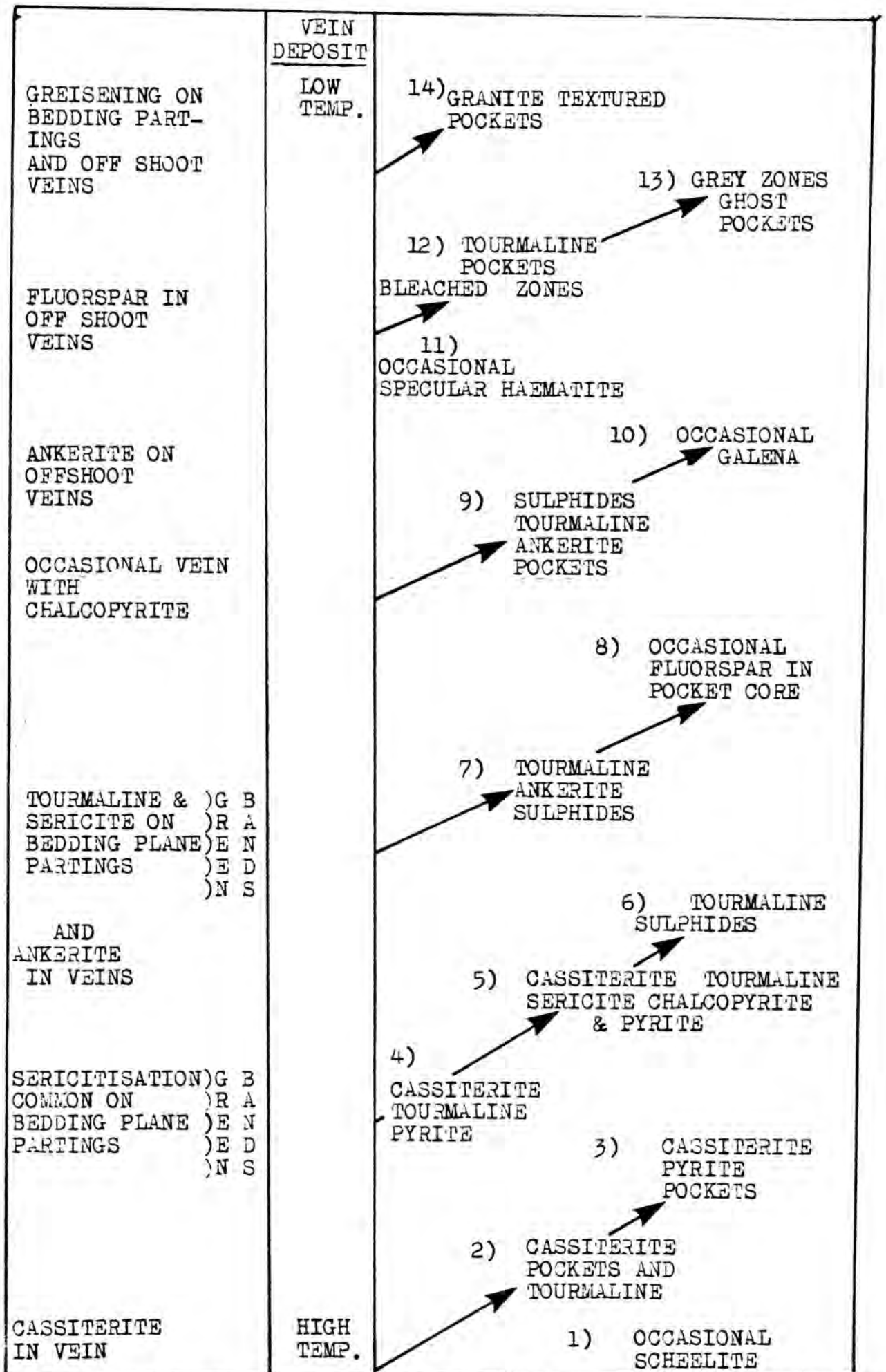
Proceeding along the fissure channels the sequence corresponds to an increasing number of high temperature minerals, thereby confirming the expected temperature gradient. From the mineral distribution a pattern can be deduced, and pocket zones can be distinguished (Fig.61).

Usually the lower-temperature minerals decrease to zero or minute fractions as the high-temperature minerals increase. Exceptions to this may occur in areas where there is a termination of fissuring, and fluids which can travel at low temperatures are trapped at that point. This results in the occurrence of low-temperature minerals with high-temperature minerals. Common traps are at the junction of block faults (Fig.62A). A typical pocket sequence is represented in Fig.59, and the suggested activity which took place in Fig.60.

Other complications do occur when pockets have been formed at the junction of two different fissure channels. The result is suggestive of the fissures-bearing fluids of two different types. They interfere giving complex pocket forms (Figs.25 & 45).

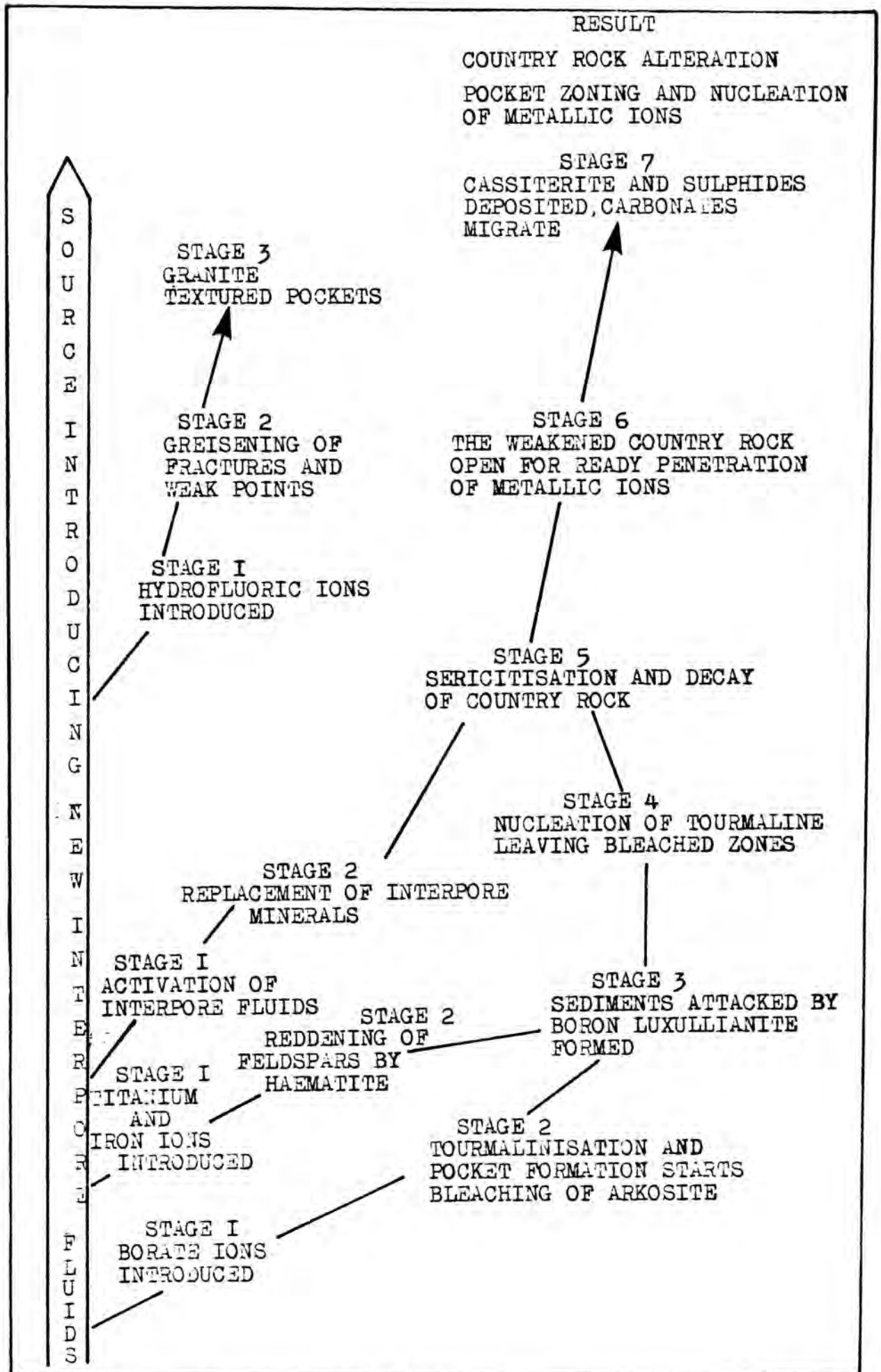
There is always a progressive change of pocket types along fractures. A suggested explanation for this is the temperature change of the migrating fluids as they move along the fissures (Fig.623), and the diffusion from fissures into the wall rock is often represented by tourmaline spots and lines, and a red front as in Fig.36.

It is thus evident that there is a sequence in the localities of pocket types as well as alteration zones as indicated in Figs.59, 60, 61 and 62 which can be useful to a mine geologist.



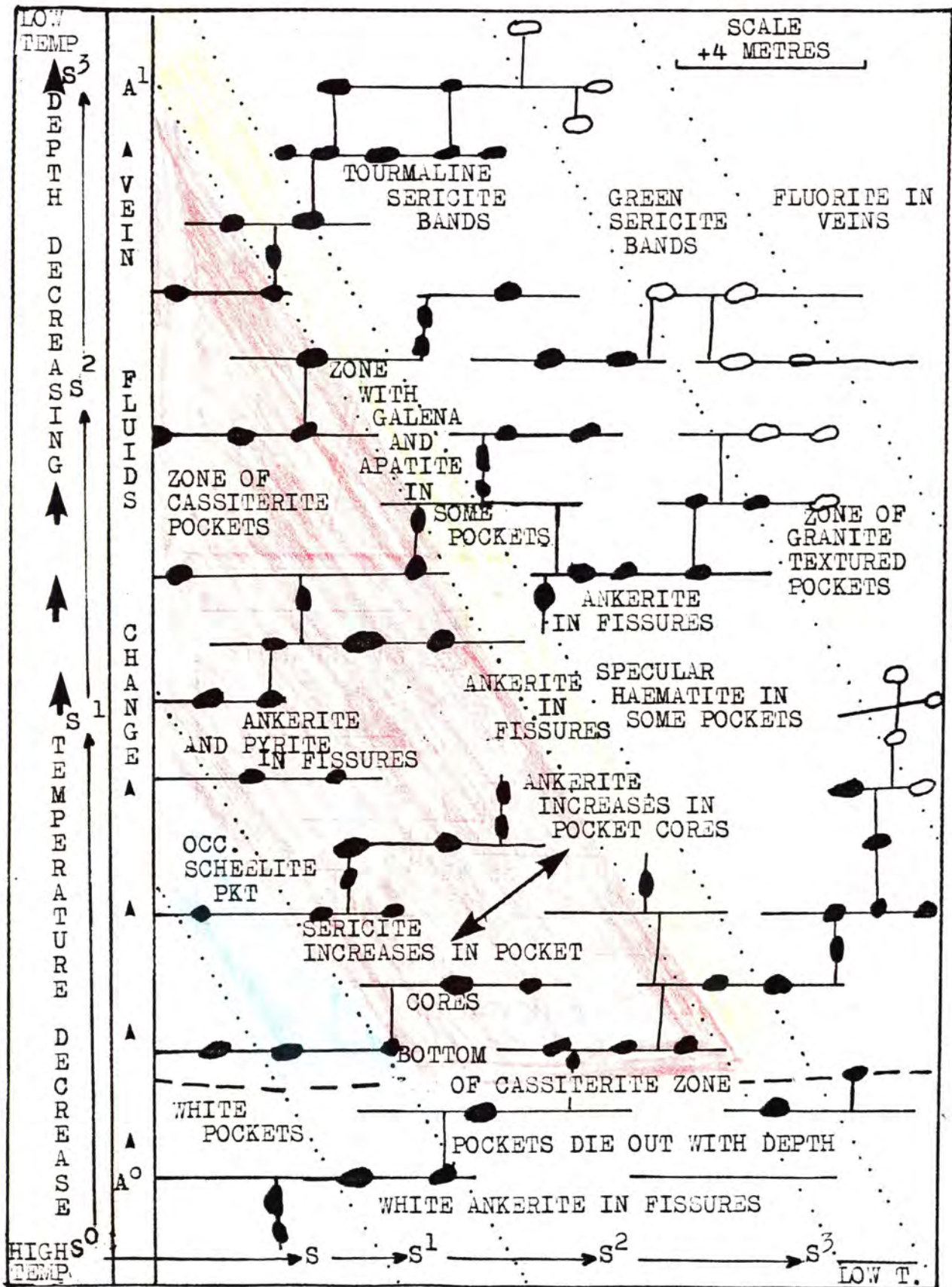
THE SEQUENCE OF CHARACTERISTIC FEATURES EXPECTED TO BE FOUND IN
POCKETS RELATED TO A CASSITERITE ZONE.

Figure 59

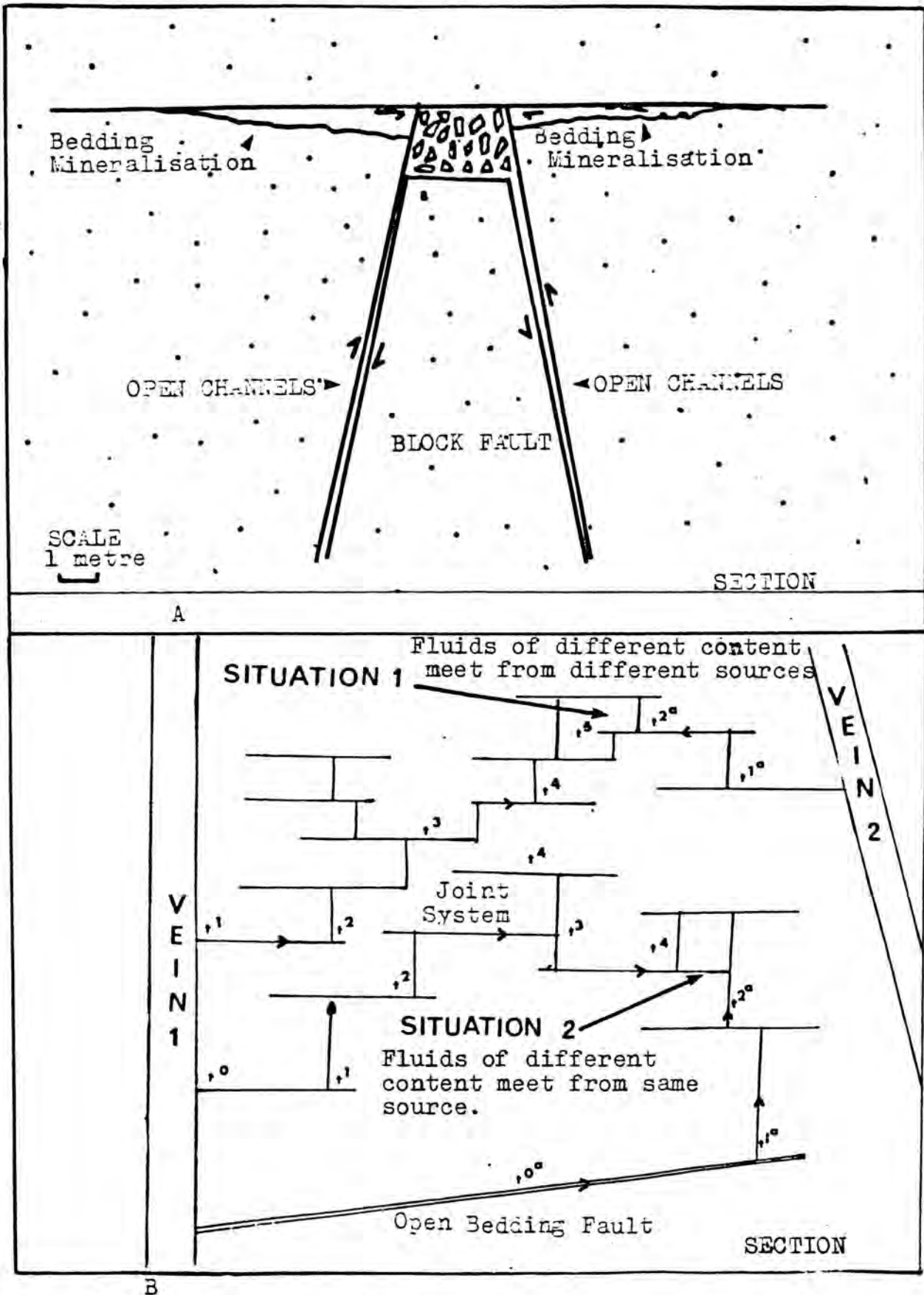


THE SUGGESTED PROCESSES RESULTING IN REPLACEMENT AND POCKET FORMATION

Figure 60



Section shows some aspects of the Tin Zone in the Nineteen North and A7 area and relative distribution of some pocket types. $A^0 - A^1$ represents a typical fissure; $S^0 - S^1 - S^2 - S^3$ represents suggested stages of temperature decrease of migrating fluids along the vein. Black lines with spots diagrammatically represent the joint system. The information was collected from several fissures.



A. Block faulting as visible in the Nineteen North fissure and Water Drive fissure on Rooiberg Mine. The faulted block was filled by gouge and breccia at the top. The sides of the fault block had cassiterite as bedding mineralisation.

B. A diagrammatic representation of the path of fluids from two veins meeting up at different temperatures resulting in fluids meeting with different compositions, Situation 1 and Situation 2; t represents temperature. This can form disarranged haloed pockets.

Figure 62



Scale 100mm 

Ocherous red haematite alteration zone sub-parallel to the bedding with a textural variation of tourmaline lines and dashes in a zone above.

Figure 63

CHAPTER VI

SUMMARY AND CONCLUSIONS

Rooiberg Mine is controlled by a block fault system which shows four periods of movement. A complete joint system is related to the fault system. The cassiterite mineralisation is all related to the complex fracture systems. Apart from cassiterite pockets there are many other types of pockets. They all appear to be related to structural features in the Boshoffsberg quartzite, and are the result of mineral alteration of the sediments, or replacement of sedimentary minerals by introduced hydrothermal minerals.

From the writer's research, several distinctive pocket types were recognised, enabling these pockets to be classified according to their appearance and mineral content. In addition, many stages of change are revealed from embryonic pockets to ghost pockets and intermediate stages of pocket types. From these variations trends were observed which indicated stages of pocket development.

It was found that pocket forms are not only an indication of the various stages in the process of development, but are also indicative of the composition of the source fluids (hydrothermal fluids) present in the area as the latter is the main variable factor to influence pocket development.

The source fluids (hydrothermal fluids) appear to be influenced by cooling in the ascending and radiating veins. The result of the changing composition of the

source fluids is reflected by the distribution of pocket zones and the type of metallic minerals in the pockets at Rooiberg Mine. The pockets which have the lowest-temperature metallic minerals such as galena and specular haematite, were found furthest from the source, and the higher-temperature minerals such as cassiterite and scheelite were found nearer the source. These are the principal characteristics which help to reveal the location of cassiterite in the areas where they occur. Although scheelite is rare, where present, it could be used as a guide for cassiterite.

The pockets themselves also have special characteristics. Their form is firstly dependent on the composition of the fluids at the source. Where many elements are available it was found that different elements penetrate the country rock different distances, forming minerals in distinct cores and haloes such as in multiple haloed pockets. Thus some minerals occur regularly as core minerals near the fractures (sericite, ankerite and galena), while other minerals are found further away from fractures as replacement minerals in the country rock, (chalcopyrite, cassiterite, and tourmaline, normally in that order).

In the study of the replacement process, the simplest form was intergranular. Next, traces of replacement of all grains of the sediments occur, suggesting that a supply of new minerals had been introduced by means of interpore movement of elements. The final stage is complete replacement of the sediments by new minerals forming mature pockets.

In the study of multiple-haloed pockets and mineral zones it is deduced that the elements forming the new minerals of the haloes have different abilities to penetrate the rock. Because of the regular order of the haloes and mineral zones, and because of the inter-pore nature of the movement of elements the process of introduction is presumed to be diffusion.

It was established that where pockets have a sequence along fissures they can be used as local indicators to cassiterite occurrence. The other zones of alteration in the country rock similarly act as indicators of mineralised areas and were found usable in daily practice. Although potential areas can be identified, the quantities of cassiterite cannot be assessed beforehand; the trends only act as a guide-line for future ore.

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