ALTERATION AND MINERALISATION IN THE MT. READ VOLCANICS, WESTERN TASMANIA

A report to Getty Oil Development Company Ltd., Electrolytic Zinc Co. of Australasia Ltd. and Mt. Lyell Mining and Railway Co. Ltd. on a study funded by those companies on their various joint venture exploration leases, and undertaken in co-operation with the University of Tasmania.

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Contents

C 002

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Figures

Alteration and Mineralisation in the Mt. Read Volcanics, Western Tasmania

Introduction

Current models for the formation of massive sulphide ore deposits (e.g. Solomon and Walshe, 1979) envisage the convective circulation of hot water through large volumes of rock beneath the sea-floor, and the deposition of sulphides where the water emerges. In the common situation of deposits hosted by calc-alkaline volcanic rocks, the circulation of seawater is thought to be driven by heat from shallow-level granitic intrusions. Volcanic activity commonly continues after ore deposition. In this situation it might be possible to distinguish pre-ore rocks from post-ore rocks according to alteration style. Furthermore, chemical and thermal gradients around zones of emergence should be high. These gradients should be preserved in the alteration assemblages.

A question of importance both to exploration and to testing the theoretical model, then, is whether alteration can be used to map the volcanics, effectively to determine stratigraphy where mappable lithological units are characteristically impersistent along strike, and once this is done, whether fossil gradients can be detected in pre-mineralisation rocks.

A comprehensive investigation of alteration in the Mt. Read Volcanics had not been attempted at regional scale. At deposit scale, the close association between phyllosilicate-rich assemblages and ore deposits was well-established. There are also marked differences in alteration style among rocks not so closely associated with known mineralisation, and these were not understood.

In the context of a regional compilation of data relevant to mineral exploration (being undertaken by the joint venture exploration partners) and of the theoretical considerations mentioned above, the study was begun in 1980. The aims were:

(i) to classify alteration styles, and determine significant differnces between them.

(ii) to investigate, at regional scale, the relationship between mineralisation and alteration.

(iii) to determine whether alteration style can be used as a criterion in mineral exploration.

In addition, as an investigation of the known mineralisation, a sulphur isotope study has been undertaken encompassing most sulphide and sulphate occurrences in the region.

The region investigated stretches from Bulgobac to South Darwin Peak, and includes all known mineralisation in this part of the volcanics except for Chester, Pinnacles and Mt. Block. Fig. 1 is a locality map giving place-names cited in the report.

The bulk of the report is a detailed account of the project. Because this is of considerable length, a section stating briefly the principal conclusions and their relevance to exploration is added at the end.

The Geology of the Mt. Read Volcanics

1. Summary of foregoing work

Recent publications on the geology of the Mt. Read Volcanics include those of Corbett (1981) and Corbett et al. (1974). The brief summary which follows is derived from those sources.

Corbett recognises three major subdivisions of the volcanics:

a) Central Sequence, a belt of lavas, and pyroclastics largely of rhyolitic to dacitic composition, comprising the bulk of the volcanics and hosting most of the known mineralisation. Granites intrude these rocks at Mt Darwin and Mt Murchison. Sediments form a very small component. These rocks form an almost continuous (in places obscured) belt extending throughout the study area.

b) Western Sequence, a belt of non-fossiliferous marine sediments with interbedded tuffs and lavas and tabular quartz-feldspar prophyry intrusives. These extend along the entire western margin of the study area.

c) Tyndall Group and correlates (also previously termed Eastern Sequence), in the Queenstown area a series of tuffs and agglomerates with minor lavas and sediments in the lower part and volcaniclastic conglomerate in the upper part. South of Lake Selina, this sequence occurs discontinuously to the east of the Central Sequence, and similar rocks overlie the Central Sequence in a discontinuous belt west of the West Coast Range between the Henty Fault and Mt. Owen.

The Tyndall Group and correlates clearly overlie the Central Sequence unconformably. The Darwin Granite is truncated by a Tyndall correlate on South Darwin Peak. The Owen formation (conglomerate and basal volvaniclastic breccia) in turn overlies the Tyndall Group, in places conformably, in others unconformably. Both the Tyndall Group and the Owen formation may have accumulated in small rift systems developed (in the area of study) south of the Henty Fault only.

The relationship of the Western Sequence to the Central Sequence is less easily established. Corbett favours the view that the Western Sequence is the older in the Queenstown area, but states that relationships may be different to the north. (In the present study - Eastoe, 1981 - it has been confirmed that Western Sequence sediments overlie volcanics at the Pinnacles Ridge, but the affinities of the volcanics are not clear). White (1975; his Clark Volcanics correspond to the Western Sequence) considers the Western Sequence rocks to be younger than Central Sequence rocks in the Jukes-Darwin area.

In the Queenstown area, Corbett distinguishes Central Sequence rocks from volcanics of the other units by the absence or rarity in Central Sequence rocks of quartz phenocrysts. Such a distinction has been found in this study not to hold good further north, particularly in the Murchison Gorge and Lake Selina areas.

Because they host most of the mineralisation, the Central Sequence volcanics have been the main concern of this study and will be considered separately from Western Sequence and Tyndall Group rocks.

2. Furthur comments based on the present study

The field geological aspects of this study have been reported elsewhere (Eastoe, 1980;1981). It will suffice to summarise the main points, and add new comments as appropriate.

a) Detailed work was undertaken in the Rosebery area because that area seemed suitable as a control example for relating alteration style to known mineralisation. It appears to be possible to relate all known syngenetic sulphide lenses to one mineralised horizon extending from the Pieman River south to Howards Road. The horizon is exposed as many as four times across the belt, the repetitions being due to folding.

b) On the Lyell side of the Henty Fault, it is suggested (on the basis of a much less detailed investigation than in the case of Rosebery) that a single horizon contains all significant syngenetic mineralisation (with the possible, and very minor, exception of the small pyrite-chert body on Mt. Huxley). Pink rhyolites, veined by magnetite and sulphides, are characteristic of the footwall of this horizon. The horizon is exposed only twice across the belt in the limbs of a syncline of northerly axial trend.

c) It is not possible to correlate mineralising events across the Henty Fault.

d) In the Murchison Gorge, a full section from sulphide-bearing sediments through altered, mineralised volcanics to granite (which may have provided heat for driving the hydrothermal circulation) may be present. Polya (1981) has investigated the area in detail as an honours project.

e) Another, unlocated, repetition of the host horizon on the Lyell side of the Henty Fault was postulated (Eastoe 1981 fig. 11) to account for the pyritic mineralisation at Lake Selina, then thought to be of shallow footwall style.

A new drill-core has revealed granitic intrusions in close proximity to this mineralisation, and a magnetite-pyrite assemblage similar to that found near the Murchison Granite. Therefore it is concluded that the Lake Selina mineralisation is deep-seated and that there is no likelihood of an east-facing repetition of the host horizon to the east of Lake Selina. A similar situation may obtain east of Mt. Sedgwick.

e) North of the Pieman River, a massive sulphide host horizon is known at Que River, and may extend southwest through the Mt. Charter and Mt. Block barite deposits. Another outcrop of a host horizon may occur at Pinnacles. The Chester deposit is apparently enclosed in pyroclastics younger than the Rosebery mineralisation. The evaluation of this area by examination of alteration assemblages will be discussed in this report.

f) South of the King River, no massive sulphide host horizon is known to crop out. The area has been re-evaluated according to alteration styles, and this will be discussed below.

g) The Dora Conglomerate (east of the Tyndall Range) is mineralised and altered, but is lithologically and structurally akin to the Tyndall Group. M. Hutton (pers. comm.) has mapped several small intrusions in and near the mineralised zone.

h) There is evidence for significant folding and erosion of the Central Sequence volcanic rocks prior to the deposition of the Tyndall Group and correlates. Both the Murchison and Darwin Granites were exposed (the Murchison Granite prior to the deposition of the Owen formation). Beneath the Tyndall Range, the inferred synclinal structure of the Central Sequence is out of harmony with the structure of the overlying Owen Conglomerate. The folding was probably coaxial with a later Devonian phase of northerly axial trend so that Cambrian cleavage and mesoscopic folds cannot be distinguished. Devonian deformation may only have tightened pre-existing Cambrian folds, slightly overturning certain limbs in the Rosebery area.

3. Spacing of Deposits

There is probably a hierarchy of north-south spacings between massive sulphide deposits in the Mt. Read Volcanics. Between Rosebery and Hercules, small deposits occur about every kilometre. This might also apply at Mt. Lyell (Blow to Crown Lyell to Comstock). The Rosebery to Hercules spacing (7 to 8 km) corresponds roughly with the spacing between small deposits in other areas (Farrell to Sterling Valley to Red Hills; Henty Fault Zone to Howards Anomaly; Rosebery to Chester to Pinnacles; for Red Hills to Itat Creek, the spacing is about twice this unit). For large deposits, the spacing may be 30 km (Rosebery to Mt. Lyell) or 15 km (East Darwin to Mt. Lyell).

The east-west component of spacing is more difficult to estimate because there is no continuous east-west outcrop of the host horizon(s). In any case, the tightness of folding varies. A question of interest is whether the deposits occurred in lines or in two-dimensional arrays. Is it fortuitous, for instance, that the six centres of syngenetic mineralisation from Rosebery to Hercules appear to compose a single line of deposits cropping out in different fold limbs?

Alteration Study

Introduction

The present mineralogies and fabrics of the Mt. Read Volcanics represent the response of the original fresh volcanics to a variety of processes. The fresh volcanics themselves are considered to have varied in composition; rhyolitic to dacitic rocks were apparently the most common, but significant andesite and minor basalt occur locally. Subsequent processes have included:

a) Submarine weathering in the case of rocks erupted on the sea-floor. This would devitrify all glass, and in the extreme replace all mafic and feldspar phenocrysts by clays. Whether the Mt. Read Volcanics were submarine or not is debated. Certainly, the formation of massive sulphide deposits is a submarine process requiring a considerable depth of water. But at Rosebery, the volcanics above and below the host horizon contain abundant bent and flattened pumice. Corbett (1981) has interpreted this as the texture of terrestrial ash-flow tuff. Green (1981), however, considered this flattening and bending to be due to compaction in submarine density flow deposits and compared the effect to "a weak foliation" of pumice in submarine pyroclastics from Japan. If Green's view is correct, much of the Central Sequence may have undergone submarine weathering, but evidently not to the extent of altering plagioclase to clay, or destroying all hornblende and glass structures. This relative freshness, the presence of what might be considered a strong primary foliation in some cases, and the very massive nature of most hangingwall rocks suggest that submarine weathering may not have been important, at least in hangingwall rocks. A terrestrial origin cannot yet be dismissed.

b) Hydrothermal circulation associated with massive sulphide deposition during the Cambrian. The circulation would be expected to affect a large volume of footwall rocks around a deposit. Given one mineralising event, volcanic rocks deposited after sulphide deposition should undergo only minor effects of this kind (in the immediate hangingwall of a deposit, as hydrothermal circulation in the footwall wanes) or none at all.

c) Cambrian hot spring activity associated with volcanism might affect any part of the volcanic pile locally. While the effects might be entirely overprinted by process (b) in the footwall, they may persist as local inhomogeneities in hangingwall rocks.

d) Cambrian contact metamorphism particularly in the contacts of granites, and possibly including the effects of magmatic hydrothermal fluids.

e) Devonian metamorphism. The entire region has undergone lower greenschist grade metamorphism during the Devonian. Variations in assemblage and composition represent either variation in metamorphic grade (discussed below) or pre-metamorphic differences in composition. The metamorphism probably generally took place in the presence of relatively unimportant quantities of introduced fluid. Locally, fluid may have increased in quantity, bringing about intense alteration and hydrothermal veining.

f) Deformation, both Cambrian and Devonian. The development of cleavage is almost universal, but the degree of development and of modification of earlier fabrics is extremely variable. It appears largely to be related to the amount of phyllosilicate developed in the rock prior to deformation.

An important concern in a study of alteration is the differentiation of the more widespread effects (particularly b and c above) from primary compositional differences. It has been argued (Eastoe, 1981) that in certain areas at least, alteration style correlates with stratigraphic position and that this principally reflects Cambrian hyrothermal activity. This will be examined below for other parts of the study area. First, the nature of the fresh rocks will be reviewed.

Fresh Rocks

It is convenient to classify the Mt. Read Volcanics as rhyolites, rhyodacites, dacites etc. although no entirely primary mineral assemblage survives anywhere and distinctions are blurred (difficulties recognised in the past by the use of keratophyre and spilite terminology).

Primary mineralogy: This is best preserved in rocks of intermediate composition, for example at Sterling Saddle between Rosebery and Tullah. There, phenocrysts of hornblende, plagioclase, ilmenite and magnetite (primary?) survive in an altered groundmass. From these and other occurrences, it can be deduced that the primary components of the volcanics comprised-

Phenocrysts		Groundmass
Plagioclase	Biotite	Glass
Quartz	Ilmenite	Apatite
(?) K-feldspar	Magnetite	Zircon
Hornblende	Apatite	
Clinopyroxene		

These do not all occur in every rock type; the ferromagnesian phenocrysts in particular are limited to the more mafic rocks. Clinopyroxene was not definitely identified in any specimen prepared for this study, but is reported by Cox (1981) and Corbett (1981). No glass persists, but vitroclastic structures and devitrification textures are abundantly preserved.

Primary textures: Almost all of the volcanics are porphyritic, phenocrysts being sparse in a few cases and commoner in others, but in most no more than 50% by volume. Vesicles are preserved in a few cases. Flow textures are preserved at outcrop scale as banding and rarely at microscopic scale as pilotaxitic texture; these indicate lavas. Certain coarsely fragmental volcanics may be autobrecciated lavas or vent breccias.

Pyroclastic rocks preserve a variety of clastic textures depending on their mode of deposition and the amount of subsequent reworking. Pumice is abundant (the significance of flattened and bent varieties has been discussed above), and shards are less abundant.

Perlitic cracks are preserved in a few originally-glassy rocks, probably lavas.

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Devitrification textures: Almost all of the lavas and non-reworked pyroclastics contained glass which has devitrified mainly to quartz and feldspar with a variety of textures:

Granular: An intergrowth consisting largly of quartz and feldspar grains, irregular both in size and shape. The feldspar is commonly albite (where it is coarse-grained enough to be identified) and in some cases makes up almost the entire groundmass. In specimens with perlitic cracks, the distribution pattern of grains is controlled by the cracks.

Axiolitic: This texture - the radial arrangement of quartz or feldspar grains about the axes of elongate pieces of glass - is rarely preserved explicitly in the Mt. Read Volcanics. It is probably implicit, however, in the preservation of shards and flattened pumice as recognisable entities.

Spherulitic: A spherical cluster of quartz or feldspar crystals about a point nucleus in originally isotropic glass. These are uncommon in the Mt. Read Volcanics.

Snowflake: A family of similar textures, the common feature of which is the development of areas of micropoikilitic, optically continuous quartz. The microinclusions were originally plagioclase and are commonly sericitised in the Mt. Read Volcanics. Variants differ according to the degree of development of snowflakes, the amount of radial structure they exhibit, whether they have nuclei (which are optically continuous with the snowflake where present). An extreme case is the development of annealed, polygonal snowflakes without radial structure throughout the entire rock. On weathered

017 surfaces, snowflake texture if well developed is revealed as abundant round granules.

Eutectoid: Graphic intergrowth of quartz and feldspar. This may be a primary crystallisation texture, but White (1978) suggests that the growth of snowflake nuclei at the expense of snowflakes produces the same result.

Miarolitic: A texture of irregular cavities formed when volatiles are released from devitrifying glass. It is not present in any specimen from this study, but was recorded by Eastoe (1973) in association with snowflake devitrification.

The diagnostic significance of snowflake texture is of great interest because the texture is very common in the Mt. Read Volcanics, and becauce the topic has been debated in the literature. Anderson (1969) considered snowflake texture to occur only in densley-welded ash-flow tuffs in his study area. White (1975) considered the texture to be characteristic of lavas in the Juke-Darwin area. The findings of this study confirm White's view. As a general rule, divitrification style should reflect the structure of the precursor glass. For example, pumice should develop axiolitic or granular devitrification controlled by the form of the pieces of glass. Structureless glass might be expected to devitrify on one of the more isotropic styles - snowflakes, spherulitic or eutectoid. The anisotropy of structured glass may well inhibit isotropic devitrification. Structureless glass is to be expected in lavas (except those with pilotaxitic texture) and densely-welded ash-flow tuffs. Snowflake texture is known in lavas of the Mt. Read Volcanics, and also in massive rocks which cannot be classified on other textural grounds. It is

C16 possible that very dense welding could not be distinguished in these deformed rocks, but all such are tentatively classed as lavas in this study.

Examples of the textures cited above are included in the photographic atlas accompanying this report.

The destruction of early textures

Progressive alteration of the volcanic rocks correlates with progressive destruction of primary fabrics and devitrification textures, largely because the pressure of phyllosilicates facilitates the formation of cleavage. As a general rule, therefore, the fresher rocks have a blocky appearance, and the more altered rocks a schistose appearance. This is not true in every case, however - e.g. specimens RL1 and BD6 are massive, but have undergone an advanced degree of mineralogical alteration.

Not all early textures at microscopic scale are readily destroyed by the formation of phyllosilicates and cleavage. Pumice fragments are clearly recognisable in sheared quartz-mica assemblages from the Hercules footwall (HF 4 et al). Quartz and plagioclase phenocrysts survive much shearing provided the plagioclases themselves are altered mainly to albite and bear minimal sericite. Snowflake texture is relatively easily destroyed, converting by degrees to schistose texture, but it survives as well in footwall rocks (e.g.ND2, JP 11) as in hangingwall rocks (e.g. CS2, RD2).

The progressive destruction of early textures, then, is useful only as a general guide to degree of alteration. The many exceptions preclude a reliable criterion in this case.

<u>Secondary mineral assemblages</u>

019 The following are found as secondary minerals in the Mt. Read Volcanics.

<u>Widespread</u> major	<u>Widespread</u> minor	<u>Local</u>
Quartz	K-feldspar	Apatite
Albite	Biotite	Allanite
Chlorite	Sphene	Tourmaline
Sericite	Pyrite	Barite
Calcite	Hematite	Calcic garnet
Epidote	Magnetite	Monazite
	Rutile/Leucoxene	

Clays and goethite are also widespread, but are considered to be weathering products and will not be included in this discussion.

Considering only major components, the number of assemblages appears to be small.

1. quartz + albite + sericite ± chlorite
2. quartz + albite + chlorite + epidote
3. quartz + albite + chlorite + calcite

These are classic lower greenschist facies assemblages (Turner and Verhoogen, 1960). If biotite is also considered, two further assemblages arise:

1A. quartz + albite + chlorite + biotite

2A. quartz + albite + chlorite + epidote + biotite

These are present to a relatively minor extent, but indicate that conditions locally may have just attained those of the quartz-albite-epidote-biotite subfacies. The quartz-albite-epidote-almandine subfacies is not represented. Garnet is extremely rare; calcic garnet is reported only at Mt. Lyell (Cox, 1981) and manganiferous garnet has been identified in the Rosebery orebody (Green et al 1981). At the lower-

- temperature end of the scale, zeolitic and prehnite - pumpellyite assemblages are also unknown in the Mt. Read Volcanics.

These five assemblages differ in ways that reflect two major effects, namely:

(i) The presence or absence of significant calcium, differentiating 1 and 1A from the others.

(ii) The mineralogy of potassium silicates, distinguishing 1 and 2 from 1A and 2A.

Calcic and Non-Calcic Assemblages

All of the volcanic rocks should have originally contained a little calcium. Modern fresh rhyolites from New Zealand and New Britain contain 1.2 to 1.6% CaO, dacites around 4% and andesites about 8% (Carmichael et al, 1974). This increase in calcium content corresponds with an increase in the amount of plagioclase relative to quartz, the amount of Ca in the plagioclase and the amount of hornblende as a function of increasing mafic character. Calcic plagioclase is almost unknown in the Mt. Read Volcanics, both as phenocrysts and as devitrification products. Analyses of plagioclase in phenocrysts generally show Ab99-100 compositions; the exceptions (ST4, ST10) may be mixtures. Their Ca:Na:K molecular ratios, 6:92:2, 5:91:4 and 7:90:3 indicate amounts of K which should be unstable in plagioclase under greenschist conditions. If the plagioclase compositions are re-adjusted after the removal of potassium, they lie between the characteristic range (An 0-7) of greenschist albites and that of the amphibolite facies (An 15-30) (Turner and Verhoogen, 1960). Therefore the calcium in the analyses may also have been contributed by microimpurities.

Calcium, then, characteristically occurs as the secondary minerals calcite, epidote (including clinozoisite) and sphene in the Mt. Read Volcanics. The calcium minerals commonly dot plagioclase phenocrysts in which the surviving plagioclase is albitic. The phenocrysts presumably contained calcium when they were fresh. The present mineralogy would thus represent the re-adjustment of volcanic plagioclase (and glass) compositions to stable greenschist assemblages, the calcic phenocrysts or glass having survived until the metamorphic event.

Absolutely non-calcic rocks should not have been present among the fresh volcanics (by modern analogy) so that the presence of non-calcic assemblages implies the subsequent removal of calcium.

Further complications arise. Calcic assemblages could be the result of adding calcium to volcanics depleted in calcium. Furthermore, there is evidence of short distance redistribution of calcium in certain outcrops (e.g. PR8, where secondary, albitic, chloritic and epidote-rich patches up to 5 cm across are differentiated). This might be possible on a larger scale.

Whether calcium takes the form of epidote, calcite or sphene depends partly on the availability of the other chemical components involved. Sphene requires a source of titanium and calcite a source of carbon dioxide. In the case of calcite metamorphic fluids probably transported sufficient carbon dioxide from elsewhere, because sources within the volcanics would have been very small. Epidote and calcite occur together in some cases (e.g. RA2, which also bears sphene) but commonly only one is observed.

In biotite - bearing calcic assemblages the characteristic mineral is epidote (although calcite also occurs in ST 5). Epidote is most abundant in the general vicinity of biotite occurrences near Rosebery and near the Murchison and Darwin granites. Thus epidote may have formed where metamorphic temperatures were higher than in other parts of the volcanics.

Potassium silicates

At least a little potassium silicate of one form or another occurs in every specimen. A little sericite generally flecks plagioclase phenocrysts and lines grain boundaries even in the "non-sericitic" assemblages. This might be explained as a product of retrogression. A little potassium is expected in every specimen, but the stable form with assemblages 2 and 3 may be feldspar. K-feldspar may be much more widely spread than suspected; in fine-grained form it is difficult to distinguish from quartz and albite without detailed microprobe work.

K-feldspar is a prominent secondary mineral in two situations. In the first, it replaces phenocrysts (other feldsar?) in the vicinity of massive sulphide deposits. This form of K-feldspar has a characteristic mottled, almost cross-hatched appearance. It characteristically occurs with calcite and chlorite (in which case it belongs with assemblage 3) but in one case (KJ 13) occurs with biotite and chlorite (assemblage 1A). In the second it occurs as deformed veins (MR 11A) or in recrystallised groundmass (MS2) in the pink rhyolites from the Murchison Gorge. The pink rhyolites were probably more potassic than other volcanics in the area.

023 Volcanics bearing secondary biotite are of limited extent, and probably evidence relatively high temperatures during the Devonian. The grade of metamorphism cannot be considered to have truly entered the quartz-albite-epidote-biotite subfacies in the Rosebery area; although biotite is widespread, it is abundant at thin section scale in only two cases (RL1,KJ13) and is probably not uniformly scattered over any large area. It does not seem possible to draw an isograd within which only assemblages 1A or 2A occur.

Presence or absence of Mg and Fe

Rocks which consist of assemblage 1 vary widely in the amounts of Mg and Fe they contain. Chlorite is in many cases absent or insignificant. It is evident that such compositional variation is characteristic of the footwall zones of massive sulphide deposits (especially visible at Hercules). Other means of separating Mg and Fe from Na appear to operate, however, as in the case of PR8, the mottled rock cited in connection with epidote segregation, and HA20 where epidote, albite and chlorite-rich varieties have developed. Large quantities of fluid do not appear to be implicated in the case of PR8, because a little primary hornblende has survived.

Extreme cases of development of this type of assemblage are quartz-sericite rocks (e.g. Rosebery footwall schist) and albite-quartz rocks (e.g. BG1, BP5). The albite-quartz assemblage may arise by the action of the unknown mechanism responsible for the mottling in PR8.

Relationship of minor minerals to the major assemblages

Titanium in secondary form occurs as rutile, leucoxene and sphene and to a minor extent in biotite. It appears that sphene occurs in otherwise calcic assemblages, and rutile or leucoxene in non-calcic assemblages. Much detailed microprobe work would be necessary to demonstrate this beyond doubt. Rutile or leucoxene may also occur with calcic assemblages. Sphene and rutile are difficult to distinguish when finely divided. Intimate mixtures of sphene, rutile and quartz may occur in some cases (indicated by semiquantitative microprobe analyses). Sphene occurs in a variety of habits; for example, in occurs as large, pale-brown, clear crystals of high relief, but in STP 221 it occurs as brown, turbid, wormlike bodies enclosed in chlorite.

Iron oxides and pyrite Magnetite appears to be primary where it occurs as euhedral crystals of phenocryst size. Much secondary magnetite is encountered in close association with pyrite and chalcopyrite mineralisation.

Hematite is widespread as secondary mineral, particularly near unconformities where it occurs in specular form in veins and in fine-grained form distributed within the volcanics to which it imparts a purplish colour. The fine-grained form is the product of metamorphism of limonite. This can clearly be seen near the Jukes Pty. workings. The strongly chloritised volcanics at Jukes Pty. have developed a bright red-orange colour through recent weathering (to limonite). But where the zone is truncated by the unconformity at the base of the Jukes

025 Breccia it is purple. There, Cambrian weathering had produced limonite prior to metamorphism. The origin of hematite in the Blow at Mt. Lyell is probably similar but early (pre-sulphide) hematite is also known in the Prince Lyell deposit (Walshe and Solomon, 1981).

Pyrite is a minor but widespread alteration product in certain areas of the volcanics, even away from significant mineralisation - for example in the Pieman Road section where it occurs with assemblages 1, 2, 3 and 2A, commonly associated with chlorite. In BP5, however, pyrite is relatively abundant in a quartz-albite assemblage. The pyrite - or the sulphur it contains - may be primary or associated with late volcanic phenomena such as fumaroles.

Other minerals The rarer alteration minerals fall beyond the scope of this study which does not seek to encompass the complexities of hydrothermal alteration zones such as those at Mt. Lyell and beneath Rosebery. Apatite and monazite occur mainly at Mt. Lyell (Hendry, 1981) and are mentioned in company with allanite (Lake Dora, DS 8; Murchison Gorge, CH 345) because they indicate that Cambrian hydrothermal processes brought about strong redistribution of the rare earth elements.

Tourmaline occurs an alteration product in association with iron oxides at Prince Darwin (PD3) and Jukes Pty. (JP7, JP10).

Alteration and geology - relationships, in the Central Sequence

Traverses between Rosebery and Hercules and in the Murchison Gorge were chosen as control examples in which alteration assemblages could be related to known massive sulphide mineralisation. As has been stated in earlier reports (Eastoe 1980, 1981) the geology of the Rosebery - Hercules area was soon found to require reinterpretation. As a result of this and an extension of the study northwards and southwards, certain systematic relations between alteration and the proposed single host horizon have been detected. The Rosebery - Hercules area has the disadvantage that no traverse penetrates more than a few hundred metres into footwall rock. Nor, probably, does any traverse on the Rosebery side of the Henty Fault. On the Lyell side, the Murchison Gorge provides what may be a complete section from host horizon to granite of a Cambrian hydrothermal system associated with massive sulphide formation. This, too was examined in this study and in greater detail by Polya (1981).

The distribution of alteration assemblages is shown in fig 2. for the whole study area.

Calcic and Non-Calcic Assemblages:Pieman River to Howards Road

In the area between the Pieman River and Howards Road, calcic assemblages (not including carbonate mineralisation associated with the various massive sulphide bodies) are found in three areas:

(i) A broad band to the east of Rosebery, including Mt. Black, the summit of Mt. Read and the road junction just north of the Henty Camp.

(ii) A band stretching south of Koonya towards Howards Road, bounded westward by the Jupiter-Williamsford - Hercules line of deposits and eastward by the Grand Centre - Dallwitz - South Dallwitz line of deposits/sediment lenses.

(iii) A small area north of Koonya (near the large bend on the Mt. Read Road in this area).

Sedimentary facings, structural considerations and the well-exposed sections in the Rosebery and Hercules areas suggest that the volcanics with calcic assemblages are younger than a single mineralisation event which rationalises all syngenetic deposits in the area.

Non-calcic assemblages occur invariably in volcanics older than the massive sulphide host horizon, and in places in those younger than the host horizon. In the older volcanics, quartz-sericite schist is commonly developed, and can be traced as more-or-less continuous bands from the Koonya deposit between the Jupiter deposits to about 1 km south of Hercules, and south of the Mt. Read Road, west of Lake

Johnston. Similar alteration persists into the hangingwall at Hercules and Jupiter Cu, passing gradationally into calcic assemblages and massive, blocky outcrop. At Rosebery, however, the transition is sharp and no quartz-sericite alteration occurs above the host horizon. Other non-calcic volcanics of massive, blocky appearance are interspersed with calcic volcanics in the hangingwall. Yet another type of occurrence of non-calcic assemblages occurs along the linear zone of mineralisation through the East Hercules workings in the Hercules hangingwall.

There are probably insufficient hangingwall volcanics along the western faulted margin of the Mt. Read Volcanics in this area for a recurrence of calcic assemblages on that side. Volcanics along that margin are strongly silicified.

Polya (1981) has delineated another zone of calcic alteration in deep-seated footwall rocks in the Murchison Gorge. Both calcite and epidote occur in veins and patches near the granite contact (including volcanics near the westernmost intrusions). Calcium minerals are absent from the alteration assemblages in the 300 - 400 m section of volcanics in the footwall of the Farrell Slates. There is apparently no hangingwall preserved in situ west of the Farrell Slates.

Calcic assemblages, then, appear to occur in the hangingwall rocks and in deep footwall rocks relative to host horizons in the Rosebery and Murchison Gorge areas.

029 It was possible to test part of this assertion in the Mt. Read area (see Eastoe, 1981). Around Rosebery, the eastermost repetition of the host horizon sediments is consistently east-facing and is succeeded eastwards by volcanics with calcic assemblage. At Mt. Read, the easternmost known sediments (the South Dallwitz lens) were west-facing. The volcanics on the summit of Mt. Read and eastwards are calcic. By analogy with the control section, a repetition of the host horizon was predicted to lie between the South Dallwitz sediments and the summit of Mt. Read. A thin lens of sediments was subsequently located, with quartz-sericite alteration to the west (as far as the South Dallwitz sediments) and a gradational change into massive, calcic volcanics to the east. The suggested relationship of alteration and the host horizon in the Rosebery-Hercules area apparently has some predictive value within that area. From the point of view of exploration, it is of fundamental interest to know whether the same distribution of alteration assemblages applies elsewhere in the Mt. Read Volcanics, especially in areas remote from known mineralisation.

Calcic and Non-Calcic Assemblages: Other Areas

In no area on the Lyell side of the Henty Fault is it apparently possible to move far along strike from known syngenetic mineralisation. On the traverses studied, the distribution of calcic assemblages is as follows (in Central Sequence rocks only):

(1) Jukes - Darwin: Calcite and epidote are prominnent in the volcanics near the western contact of the Darwin Granite (see fig 10 in Appendix 1) A little calcite occurs in JP4, an intensely mineralised sample from Jukes Proprietary.

(ii) Mt. Huxley: A trace of calcite occurs in HX4, which is on the inferred hangingwall side of a shale lens, but probably within a broader group of host sediments and pyroclastics.

(iii) Mt. Lyell: Cox (1981) reports epidote and calcite in his units E and F which overlie Mine Sequence pyroclastics. He also reports calcite replacing plagioclase in his unit A, dacitic volcanics 200 m and more below significant footwall mineralisation, and possibly 800 - 1000 m below the original (largely removed) host horizon.

(iv) Mt. Sedgwick: Calcic assemblages occur in volcanics younger than the Itat Creek black shale (SE 1, SE 6). Older volcanics have non-calcic assemblages.

(v) Howards Anomaly - Basin Lake: Andesites in the footwall of the mineralised horizons are calcic and show no sign of pre-metamorphic hydrothermal alteration. Insignificant hangingwall is preserved.

(vi) Lake Selina: Minor calcite occurs in DDH LS5, in what is thought to be deep-seated mineralisation associated with granitic intrusions.

(vii) Red Hills: A trace of epidote occurs in a vein in one footwall sample, RH2. In hangingwall pyroclastics there is a significant amount of a finely-divided high-relief mineral of rhombic to lenticular section; this may be sphene.

031

With one exception, observations seem consistent with irregular occurrence of calcic assemblages in hangingwall rocks, their absence in footwall immediatley below host horizons and their eventual reappearance at depth.

The exception is the Howards Anomaly - Basin Lake area. The andesites exposed in a road section and drillcore are remarkably fresh. In Basin Lake drillcore they are seen to be extrusive. In that area, we may be far from a mineralising centre, and mineralisation may be distal. Alternatively, the andesites may not become altered in the same way as more acid rocks. This is suggested by the fact that andesites beneath the Que River deposit are similarly unaltered (S.F. Cox, pers. comm). There must be fluid pathways through the andesites; presumably these are narrow and unlikely to be found in field exposure, while the rest of the andesite remains impermeable.

<u>North of the Pieman River</u> In this area, there is a relatively large section of the volcanics with no significant mineralisation. The Chester and Pinnacles deposits occur against the western margin of the volcanics, and Que River to the north east. The Que River horizon may extend south-west through the Mt. Charter and Mt. Block barite deposits. Here, then it might be possible to use or test the assertions based on observations to the south. Lack of geological control, however, precludes an investigation of the alteration of footwall rocks far along strike from known mineralisation; we must first find the continuation of the host horizon. Calcic assemblages occur throughout most of the area. Eastoe (1981) noted that a zone of non-calcic alteration is intersected by the Pieman Road. The zone is on the southward extension of

032 the Que River - Mt. Charter - Mt. Block line, which intersects the Murchison Highway near the Farm Creek bridge. Samples were taken along the highway, and were found to be calcic except for MH2 near Farm Creek. That specimen is from a cutting 100-200 m long in volcanic rock of massive habit, but more readily weathered than the surrounding calcic rocks. Other non-calcic volcanics occur along the Burns Peak track, but these are more massive and preserve glassy textures. It can be concluded that a distinctive linear zone exists, defined to the north by sulphide and barite deposits and to the south by differences in alteration style.

Potassium Silicates

Biotite: The probable significance of secondary biotite in terms of metamorphic conditions has already been discussed. It remains to relate the occurrence of biotite to other geological features. Fig. 3 compares secondary biotite occurrences with features thought to be associated with Devonian and Cambrian granites.

Secondary biotite occurrences in the Rosebery area, tourmaline and axinite occurrences (indicating fluids rich in boron), and Sn, As and pyrrhotite occurrences form a broad band which joins the High Tor pluton to the southern end of the Heemskirk pluton. The Pine Hill granodiorite and the pluton underlying the Renison deposit fall in this band, which may broaden west of Renison. The only known secondary biotite occurrences outside this band are at PR8 on the Pieman Road or far to the south (Lake Dora; Darwin Granite). In the Rosebery area, sampling north and south of the band has covered most of the country (compare fig. 2); the pattern is not an artifact of

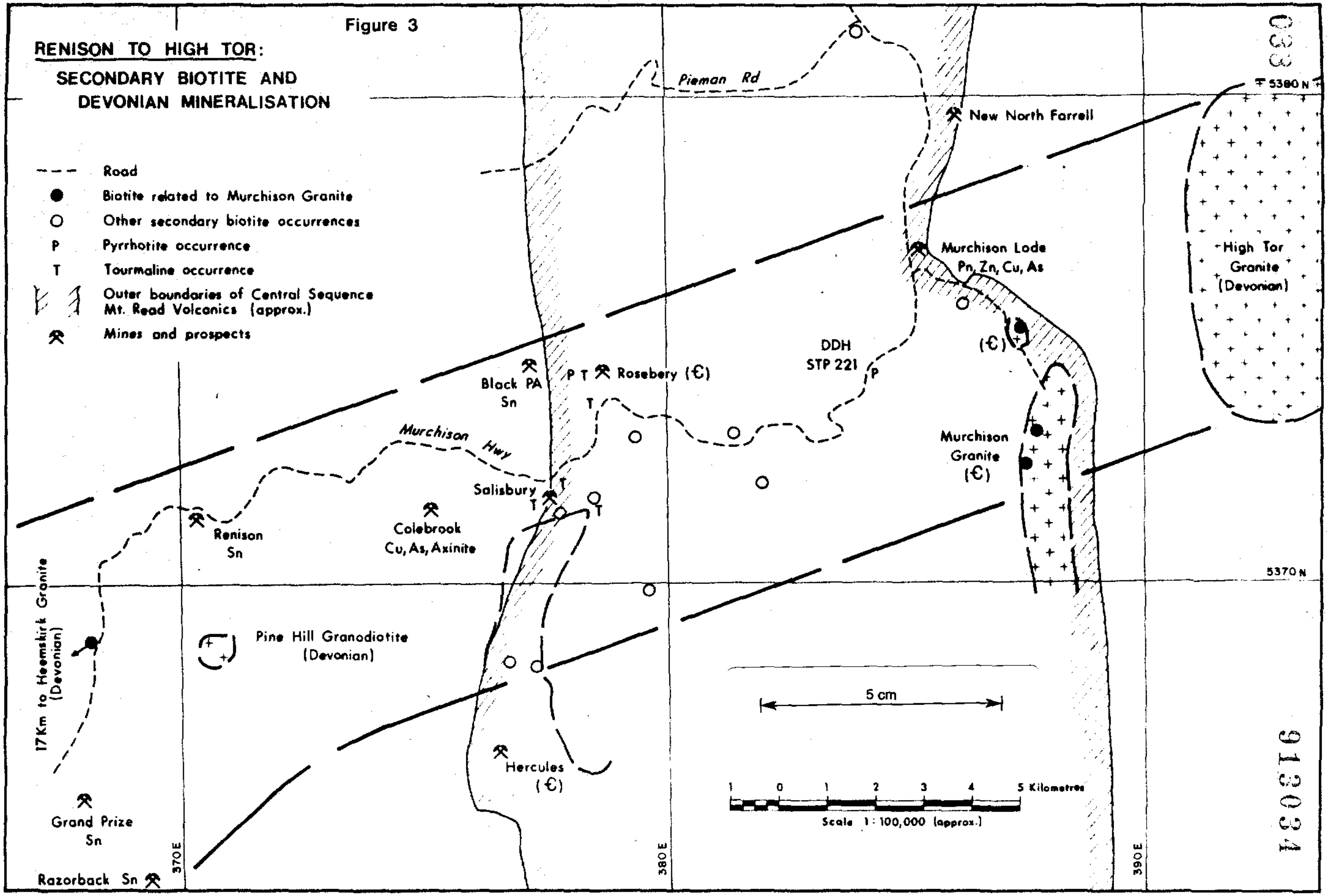


Figure 3
RENISON TO HIGH TOR:
SECONDARY BIOTITE AND
DEVONIAN MINERALISATION
Road
Biotite related to Murchison Granite
Other secondary biotite occurrences
Pyrrhotite occurrence
Tourmaline occurrence
Outer boundaries of Central Sequence Mt. Read Volcanics (approx.)
Mines and prospects
Pieman Rd
New North Farrell
Murchison Lode
Pn, Zn, Cu, As
High Tor Granite (Devonian)
DDH STP 221
Black PA Sn
Rosebery (Є)
Murchison Hwy
Murchison Granite (Є)
Salisbury
Renison Sn
Colebrook Cu, As, Axinite
17 Km to Heemskirk Granite (Devonian)
Pine Hill Granodiotite (Devonian)
5 cm
Hercules (Є)
Grand Prize Sn
Razorback Sn
1 0 1 2 3 4 5 Kilometres
Scale 1 : 100,000 (approx.)
5380 N
5370 N
370 E
380 E
390 E

91 30 34

sampling. The coincidence of secondary biotite occurrences near the Murchison Granite (Cambrian) with the band may be fortuitous; those are probably a product of contact metamorphism.

The pattern of biotite occurrence, with or without the occurrences near the Murchison Granite, suggests that Devonian granitic intrusion and biotite formation were related. The non-pervasive nature of the biotite suggests patchy hydrothermal zones (rather than contact metamorphism) above a granite which may be relatively high beneath the Rosebery to Hercules area.

The single biotite occurrence at Lake Dora is in a pressure shadow, and was confirmed by electron microprobe. It is probably of Devonian metamorphic origin, but cannot be related to any geological features. Allanite occurs in the same specimen in sheared chlorite.

The secondary biotite at Prince Darwin in clearly related to the contact of the Darwin Granite. Specimen SD12 is a biotite-quartz schist 200 m from the contact. PD1 and specimens from the Mt. Lyell collection contain deformed biotite in veins.

Note that biotie is very variable in colour in the Mt. Read Volcanics. Red-brown biotites occur is phenocrysts in rhyolite (Clark Valley, Murchison Gorge - Polya, 1981) and to a minor extent in SD 12. Most of the biotite in SD12 is very pale brown. Bright green biotites are found in the Murchison Granite and PD1 at Prince Darwin. The biotites in the

Rosebery area are green in some cases and brown in others. The distinction of green biotites from highly birefrigent (?) chlorites is dealt with in the next section.

<u>K-feldspar</u>: Occurrences of the type of K-feldspar which has a characteristic mottled texture near extinction and replaces phenocrysts are shown in fig 2. There is a strong association with massive sulphide deposits, at Rosebery, Herculos, Red Hills and Mt. Sedgwick, the K-feldspar defining a broad aureole relative to the size of the deposits. This type of feldspar has not been identified elsewhere.

Alteration in the Western Sequence

Thin sections were prepared from a few specimens of Western Sequence rocks from Howards Rd, Bradshaws Rd, the Lake Margaret Road and Yolande Gorge area, and from the King River gorge. Calcic assemblages are scattered throughout: HR6 bears a little epidote, LM6 calcite and BR7B calcite. These are lavas and (?) ash-flow tuffs. The other specimens, including reworked pyroclastics, consist of assemblage 1 minerals. Massive sulphide mineralisation is known to occur in this sequence (at White Spur and along the Lake Margaret Tramway) so that it is possible that a situation similar to that in the Central Sequence obtains, i.e. calcic assemblages survive in post-mineralisation volcanics. The Western Sequence has not been studied sufficiently to determine if this is so. It is known that the structure is locally very complex (Eastoe, 1981) so that such a study might be difficult. The environment of these rocks is undoubtedly submarine, so that submarine weathering or post-depositional reaction with seawater trapped in the predominant sediments may be important factors governing present secondary assemblages.

The calcic assemblages preserved in the Western Sequence resemble those of the hangingwall rocks in the Rosebery area rather than those which occur near the granites. There is no sign of granitic intrusion in the Western Sequence, and no example of pyrite-magnetite-chlorite mineralisation. By analogy then, it might be speculated that the Western Sequence rocks are not older than the Central Sequence, but possibly of the same age or younger.

Alteration in the Tyndall Group and correlates

Samples from Red Hills, Howards Anomaly, Lake Dora, the King River, East Darwin and the South Darwin track have been examined in thin section. Calcic assemblages are preserved at Howards Anomaly (epidote, HA20) East Darwin (epidote, ED21) and the King River (calcite, KR1 and 3). Epidote and allanite occur in intensely mineralised samples from Lake Dora. Much of the Dora Conglomerate may bear calcite - an adit at DS14 contains calcite decorations. In other cases from these areas and the others the assemblages are non-calcic. By analogy with Central Sequence Volcanics, the preservation of calcic assemblages is consistent with demonstrated stratigraphic relationships, the Tyndall Group being younger than the Central Sequence. Although non-calcic assemblages exist, the development of phyllosilicates is minor except in the Lake Dora area, and even there the rocks scarcely lose their massive appearance.

03

Properties of Chlorites

Chlorite is a common mineral in the Mt. Read Volcanics, and one whose variable composition might be expected to have responded to the physical and chemical gradients associated with ore deposition. Many electron microprobe analyses have been performed with a view to learning more about the variations in chlorite and their significance.

The optical and chemical data of the chlorites are summarised in Appendix 3. Chlorites from a wide variety of geological situations are represented.

Effect of metamorphism

A discussion of the possible preservation of Cambrian geochemical patterns in chlorites must first consider the effect of Devonian metamorphism. Does this reset chlorite composition?

The preservation of patterns related to Cambrian geology strongly suggests that Devonian recrystallisation (which has certainly occurred) has not been accompanied by regional homogenisation of the chlorites. The variation in chlorite composition in the Hercules footwall (below) and the patterns found by Polya (1981) in the Murchison Gorge are large-scale examples. At microscopic scale, the very close similarity between compositions of chlorites in pressure shadows and the groundmass in HF66 and DS3 suggests that recrystallisation may not have affected chlorite composition. D. C. Green (pers.

comm) reports an exception, in the Williamsford deposit. There a remobilised chlorite in a vein bearing chalcopyrite has a lower Mn content than chlorite from syngenetic chloritepyrite layers.

Variation in composition

A typical chlorite analysis is given in Appendix 4. In addition to the major components (SiO_2, Al_2O_3, FeO, Fe_2O_3, MgO, H_2O) most chlorites from the Mt. Read Volcanics contain at least a little MnO. In Appendix 3, the data are simplified as follows:

(i) An "Al-number", or Al/Al+Si%, which varies little around 50%.

(ii) An Mg-number, or Mg/Mg+Fe%, which varies in the range 12 to 78%.

(iii) Mn-content, which varies from 0 to 0.74 structural formula units (see explanation of table), equivalent approximatley to 0 to 4% MnO.

(iv) A structural formula total (see explanation, and appendix 4) which should give an indication of the amount of Fe^{3+} present but in practice is not accurate or consistent enough to be of use.

(v) Alkalis (and other elements) detected.

Mg-number. Figure 4 is a frequency histogram of Mg-numbers. Each unit represents the average of data for a single type of chlorite in one specimen (i.e. units are based on different numbers of analyses). The data are classified according to stratigraphic position localities, both general and specific.

The main group of data (25 to 56%) are not strongly dependent on locality or stratigraphic position.

The lowest values (12 to 22%) are contributed mainly by vein chlorite from Jukes - Darwin and Lake Dora.

The highest values (58 to 78%) are all but one from the Hercules footwall.

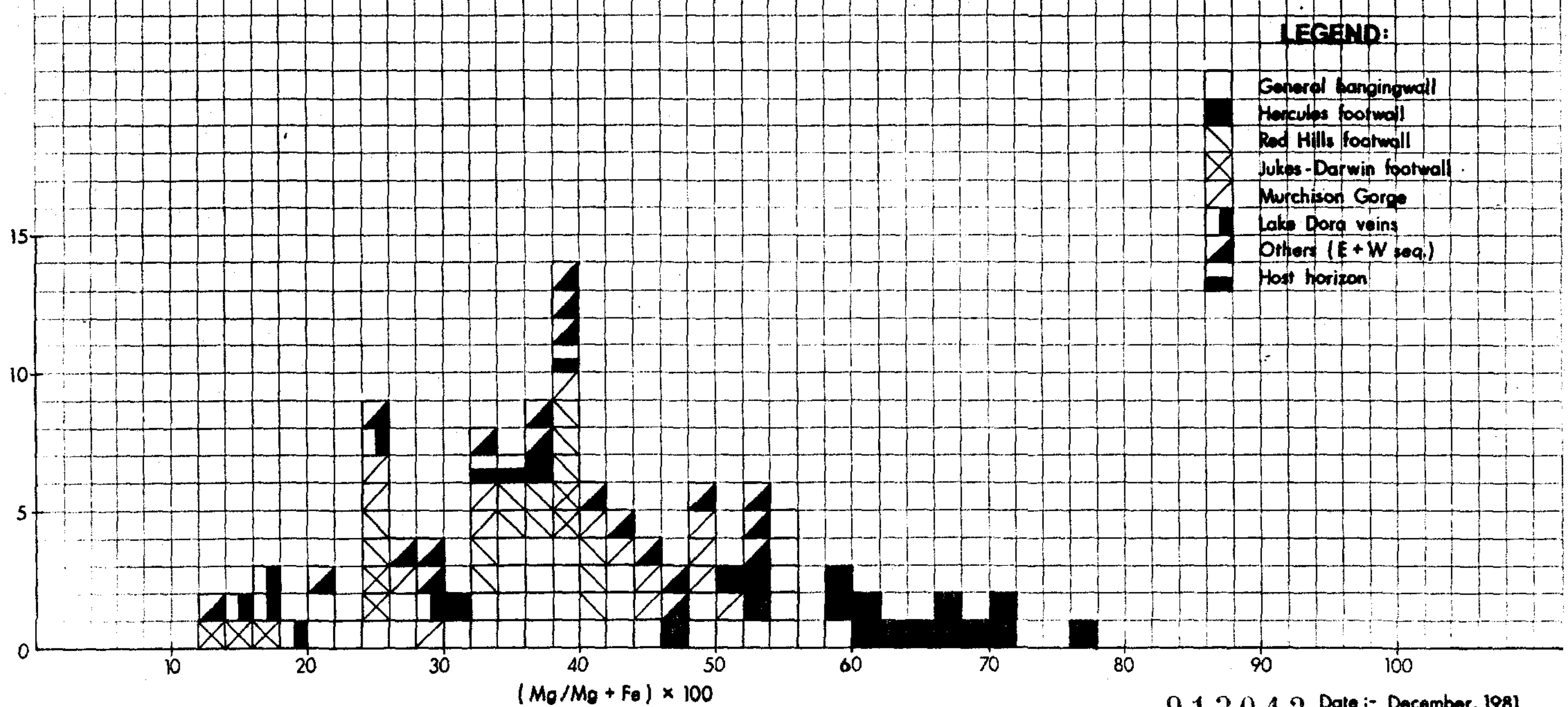
<u>Mn content</u> The histogram (fig. 5) is typical for trace component distribution, being skewed towards low values. Hangingwall chlorites (Central Sequence) and chlorites from non-mineralised Western Sequence and Tyndall Group are characteristically low. The highest bracket (0.52 to 0.74) is defined by chlorites from Lake Dora veins and from the host horizon at Koonya. Another high Mn bracket (0.28 to 0.50) is occupied largely by chlorites from the Hercules footwall. Note, however, that chlorites from the Red Hills footwall are low in Mn (less than 0.10).

<u>Alkalis etc</u> Na is reported in many microprobe analyses, but is in most cases regarded as spurious, an artefact of the microprobie calibration routine (see Appendix 4). K is not uncommon, and is variable within a given grain. If other components are plotted as a function of K_2O content linear relationships are usually found, implying sub-microscopic mixing of a chlorite (whose composition is found by extrapolating to $K_2O = 0$) and a potassic phyllosilicate (biotite, sericite, clay). A little Ti accompanies K in some cases, but TiO_2 seldom varies linearly with K_2O, suggesting that minute rutile inclusions may be present. Such chlorites probably replace titaniferous biotite or hornblende. Ca is uncommon, and does not appear to be related to K_2O content.

CHLORITE Mg/Mg + Fe

FREQUENCY HISTOGRAM

FIG. 4



913042 Date :- December, 1981

Rare components include Cr (specimen F3) and Cl (specimens Rh4, 5, 19).

Variation in optical properties

Chlorites from the Mt. Read volcanics vary considerably in colour, birefringence and interference colour. Data are summarised in Appendix 3.

Colour Pleochroism varies between colourless to pale green and yellow to intense green, the greens varying in degree of yellowness and blueness. Because these qualitites are difficult to classify, and the classification is difficult to communicate, colour is not considered to a useful criterion. Certain correlations with composition have emerged, however:

(i) Mn-rich chlorites are generally very pale green to colourless in the Rosebery - Hercules area.

(ii) Cr-bearing chlorites from Findons are an intense yellow-green. But other chlorites are intensely coloured yet non-chromian.

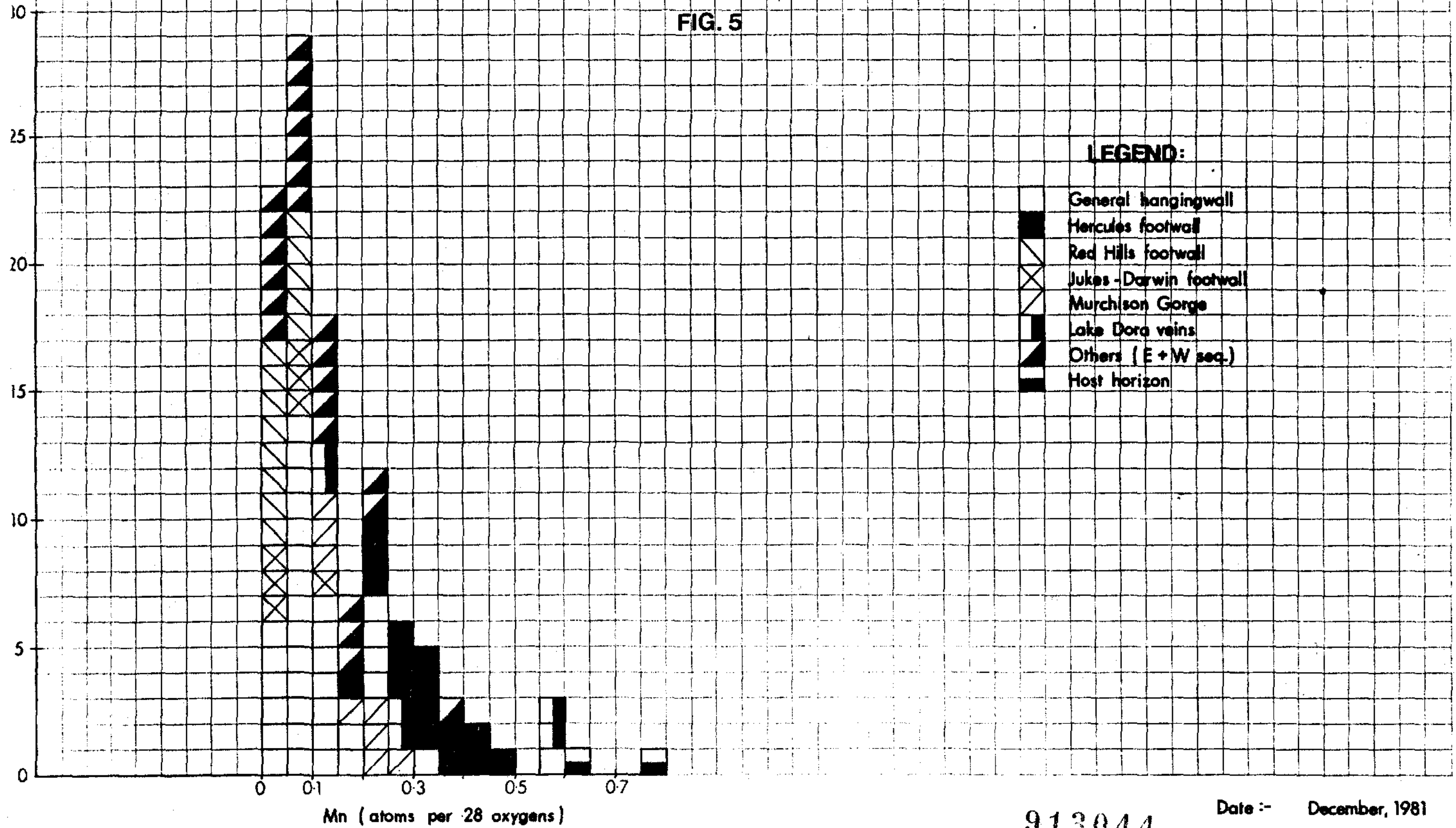
Fe^{3+} content is probably important in determining colour. Mg - number does not necessarily appear to be so, because the wide variation in Mg-number in the Hercules chlorites (fig 4) does not correspond to colour differences.

Birefringence Most chlorites show first-order colours, but a significant number have second-order colours. High birefringence is documented in chlorites of a limited range of composition (Deer et al, 1966). Most of the high-birefringent chlorites can probably be explained by weathering, particularly those which have a yellowed or orange-tinted appearance. This applies to the high-birefringent chlorites from the

CHLORITE = Mn CONTENT

FREQUENCY HISTOGRAM

FIG. 5



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C4

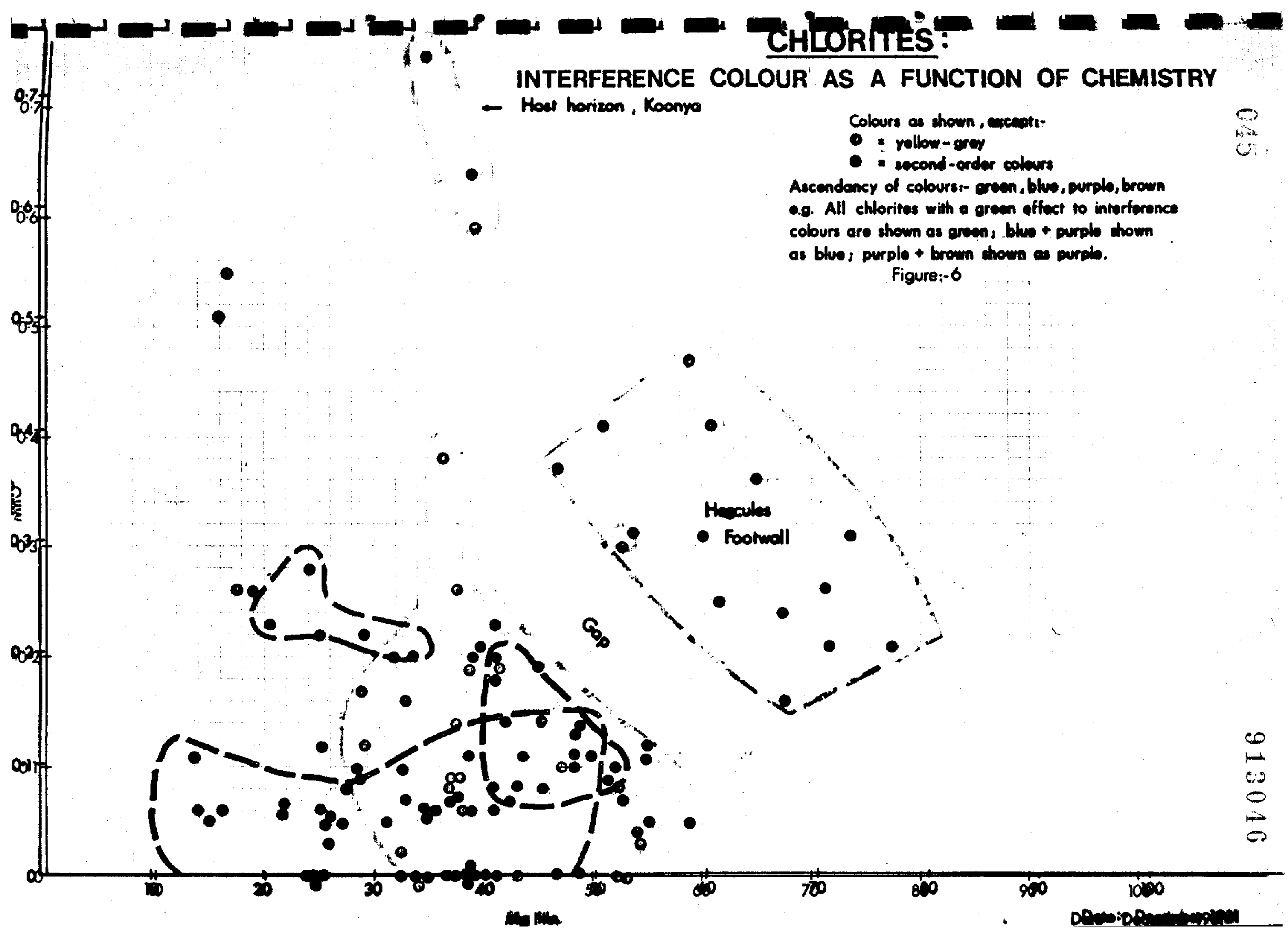
Rosebery to Hercules area, where microprobe analyses (DJ3) have shown high water content, of the order of 20%, and variable K_2O content, probably indicating some clay component. Similarly, the mineral in BP12 may be a clay.

Certain high-birefringent chlorites cannot be so dismissed. Those in specimens RH4, 5 and 19 do not appear to be weathered, and are of a distinct, earlier, more deformed generation than "normal" chlorites. The high-birefringent minerals have low total MgO + FeO, less than 30%, as opposed to 35 - 42% for the "normal" chlorites in the same specimens. In RH5, the high-birefringent mineral contains appreciable Cl whereas the "normal" chlorite does not; in RH19 the opposite is true.

It is difficult to tell such minerals from green biotite without a microprobe analysis.

Interference Colours Low-birefringent chlorites may display a variety of anomalous and masked interference colours e.g. purple, blue, brown, salmon and green. Because these are easier to classify and to communicate, an attempt has been made to relate these to Mn content and Mg - number. Fig 6 is a plot of Mg - number versus Mn content, the points being colour-coded for interference colour. In practice, two or more colours can occur in a single chlorite, and for simplicity a hierarchy of "dominance" has been adopted, as explained on the figure.

The relationships are not random. Purple-only chlorites have a limited field; blue ones a rather larger field, and green-masked chlorites even larger. But none of these overlap with


CHLORITES:
INTERFERENCE COLOUR AS A FUNCTION OF CHEMISTRY
Host horizon, Koonya
Colours as shown, except:-
= yellow-grey
= second-order colours
Ascendancy of colours:- green, blue, purple, brown
e.g. All chlorites with a green effect to interference colours are shown as green; blue + purple shown as blue; purple + brown shown as purple.
Figure:-6
Hercules Footwall
Gap
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
10
20
30
40
50
60
70
80
90
100
Mg No.

913046

the Hercules footwall chlorites, which occupy a characteristic field and have brownish or non-anomalous interference colours. The more manganiferous Koonya chlorites have a characteristic pale blue anomalous interference colour.

It has been noted that "purple" chlorites characteristically occur with epidote.

From these considerations, a bright anomalous interference colour in a chlorite is probably a negative indicator in the search for chlorites similar to those in the Hercules footwall.

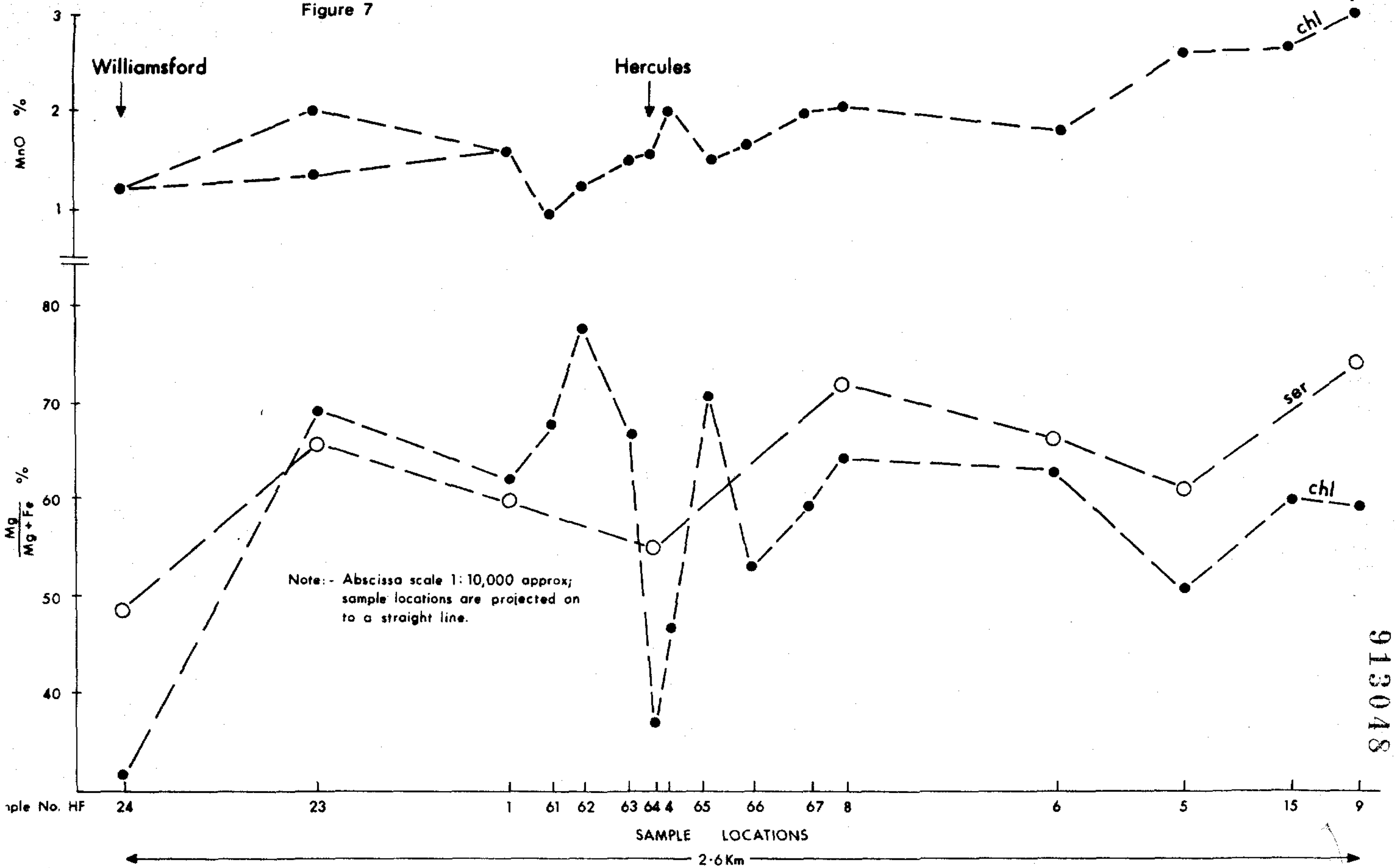
This very preliminary look at interference colours should encourage further investigation of the topic, particularly if ever reliable Fe^{3+} determinations become feasible for finely divided chlorite.

The Hercules Footwall

It is possible to trace footwall rocks 1.6 km south of the Hercules, and 1.0 km north (with some difficulties around the 500 m mark - see Eastoe, 1981 for a discussion of the geological difficulties). These were sampled for chlorite at 16 points along a line more-or-less parallel to the host horizon. The Mg-numbers and MnO contents of the chlorites are plotted as a function of position in fig 7.

The MnO contents diminish northwards. This does not necessarily reflect a similar trend in whole-rock MnO content, because chlorite varies greatly in abundance; HF4 is much more

VARIATION IN CHLORITE COMPOSITION
IN THE HERCULES FOOTWALL
Figure 7



chloritic than HF9 or HF24. The trend is unexplained. As seen above, all of the chlorites are rich in Mn in the regional context.

Values of Mg/Mg+Fe form a more complicated pattern. Beneath the centre of the Hercules deposit, and in HF24 (which may be centrally placed beneath the Williamsford deposit) the values are relatively low, i.e. the chlorite is Fe-enriched. Presumably these mark feeders, zones of intensified upward tranpsort of hot water. Around the Hercules feeder is a zone some hundreds of metres wide in which Mg is enriched (Mg-numbers of 60% or greater). In the regional context, this is the anomaly; such high Mg-numbers are not known from any other geological situation in the Mt. Read Volcanics.

Mg-numbers of sericites were determined in eight specimens. A correlation with chlorite Mg-numbers exists but is imperfect (contrast the results of Hendry, 1981, for Prince Lyell). The chlorites give a larger range and also, apparently, better polished surfaces for analysis. Therefore the study of sericites was not pursued further.

Alteration similar to that in the Hercules footwall could probably be detected by the Mn and Mg-number anomalies at a distance of several hundred metres from a feeder zone. One other test case with sufficient geological control exists: the footwall zone below the small Red Hills massive sulphide deposit.

The Red Hills Footwall

Chlorite analyses from pyrite and chalcopyrite - bearing veins in the pink rhyolites at Red Hills, and along-strike about one km to the south of the apparent centre, fail to give the patterns like those from Hercules.

Mn is all but absent from all chlorites in the area. (The syngenetic deposit contains no significant Mn carbonates).

Chlorite Mg-numbers are largely confined to the narrow range 32 to 42% and there is no recognisable trend.

The presence of K-feldspar replacing phenocrysts is the only distinctive feature common to both footwalls.

Other manganiferous chlorites

Chlorites with anomalous Mn contents have been found in the sulphide deposit at Koonya (KJ8), in the Williamsford orebody (D. C. Green, pers. comm.), and in the Hercules hangingwall (RD7). A correlation between high Mn and the host horizon is indicated. One other example, RD5, is also rich in Mn and was unexplained until the discovery of the lens of sediments near Lake Johnston (see section, above, on Calcic and Non-Calcic Assemblages and their relationship to geology). Specimen RD5 lies approximately along-strike from the newly-discovered lens.

Sulphur Isotope Study

Introduction:

Past sulphur isotope studies in the Mt. Read Volcanics have centred on the major deposits, e.g. Mt. Lyell (Solomon et al, 1969; Walshe and Solomon, 1981), Rosebery (Solomon et al 1969; Green et al, 1981), New North Farrell and adjacent sulphide occurrences (Solomon et al, 1969) and Chester (Collins, 1981). Polya (1981) has assembled a new set of data for sulphides from the Murchison Gorge. In this study, samples have been collected from most other sulphide and sulphate occurrences in the Mt. Read Volcanics and from the Colebrook Mine.

The $\delta^{34}S$ values for this study have been determined in the Stable Isotope Laboratory of the Geology Department, University of Tasmania. Mr. P. Robinson, Mrs. R. Nickel and Ms. C. Hall-Jones performed most of the gas separations and much of the mass spectrometry. The help and expertise of these people, and of Dr. D. C. Green of the Mines Department, are gratefully acknowledged.

Results:

The data are presented in table form (Appx. 6), as histograms (fig 8) and as a map depicting all available S-isotope data from the Mt. Read Volcanics. (fig 9)

Processes:

If we accept that a system forming massive sulphide deposits consists of seawater circulating through volcanic rock, the circulation driven by magnetic heat (from a granite?), then the following may be sources of sulphur, each with its characteristic isotopic composition.

1. Seawater sulphate, $\delta^{34}S$ = +30‰ (in the Cambrian).
2. Sulphur in volcanic rocks.
3. Magmatic sulphur, borne in magmatic fluids.

The last two might be expected to lie in the range 0 ± 3‰. This is the average isotopic composition of acid igneous rocks, although ranges as high as 10 ± 5‰ have been suggested. (see discussion by Ohmoto and Rye, 1979).

There is no indication as to whether this is so in the case of the volcanic rocks. Polya (1981) has determined $\delta^{34}S$ on pyrite disseminated in granite from the centre of the Murchison Granite (+10.1‰), and on a pyrite vein in altered granite at the top of the intrusion (+ 9,0‰). If the disseminated pyrite represents magmatic sulphide, then the Mt. Read Volcanics may be atypical in sulphur isotope composition. Conversely, the sulphur in the granite may itself be introduced from outside.

Various processes may affect the distribution of sulphur isotopes in such a circulating system. These include:

1. Reduction of seawater sulphate by Fe^{2+} in volcanic rock. Complete reduction would give a sulphide species with $\delta^{34}S$=30‰. Partial reduction would lead to a variety of possibilities. For example, 10% reduction to H_2S at equilibrium at 300°C, where $\Delta SO_4 - H_2S$ = 22‰, would give sulphide at 10.2‰ and sulphate at 32.2‰. Disequilibrium could produce different results depending on reaction kinetics.

2. Partial oxidation of sulphide species in volcanic rock. This would produce lighter sulphide and lighter sulphate to add to the above.

3. Decomposition of magmatic sulphur species. SO_2 may predominate, or may become predominant, over H_2S during the expulsion of magmatic volatiles, and SO_2 is thought to decompose to sulphate and sulphide species on cooling to 400°C. These may be added to convecting waters above a pluton.

4. Precipitation of sulphides. The $\delta^{34}S$ value of sulphide - sulphur in convecting waters would be slightly diminished.

5. Boiling in zones of upward circulation would affect the distribution of sulphide species, both through pH change and through fractionation between liquid and vapour.

6. Oxidation or reduction at or below the point of emergence of hot water on the sea floor. The emergent hot waters may partially reduce seawater sulphate, in which case sulphate becomes enriched in ^{34}S. Sulphide so formed might be lighter or heavier than emergent sulphide. In another situation, sulphide-sulphur might be oxidised on emergence. This would lighten remaining sulphide, but have a negligible effect on sulphate which would be dominated by seawater sulphate.

The relative quantitative effects of the above might vary, so that predictions are extremely difficult.

Discussion of Data

Granite: Within the Darwin Granite, and in veins and replacements near the contact, 6 pyrite samples lie in the range 8.7 to 11.3‰, and ore vein in the western contact has $\delta^{34}S$ = 13.5‰.

In the Murchison Granite, pyrite lies in the range 8 to 10‰, but in mineralised contact is 12‰. Late Pb-Zn sulphide veins contain heavier sulphur (Polya,1981).

The pyrite at Lake Selina appears to be associated with dyke-like intrusions of granite, and 4 determinations fall between 9.8 and 10.9‰.

Most granite associated values cluster around 10‰, but values may increase in the volcanics above the granite.

Footwall: The Jukes-Darwin sulphides are placed in this category, and have a range 10.5 to 17.0‰. Jukes Propriety (deep-seated?) where there is an association of sulphides with massive magnetite and tourmaline replacement has a range of 10.5 to 12.3‰. Findons, associated with patches of chlorite alteration with disseminated magnetite (of higher level than Jukes Pty?) has $\delta^{34}S$ in the range 13.6 to 15.8‰. East Darwin, where chlorite and sericite form an extensive alteration zone (subsurface?) the range is 13.5 to 15.7‰. The Lake Jukes bornite is +17‰. Sulphides from the barite vein at Taylour's Reward are exceptional, 4.9-5.6‰. Those sulphides have equilibrated with sulphate in a sulphate-dominated system, and hence have low $\delta^{34}S$ values. In gross, there may be an upward increase in $\delta^{34}S$

In the Murchison Gorge, a sample of chalcopyrite from rhyolites beneath the Farrell Slates gave +12.7‰. This is slightly heavier than pyrite deposited near the granite contact (see above). (Polya, 1981).

At Red Hills, shallow-level footwall sulphides gave 10.8 to 13.0‰. These can be compared with the Lake Selina pyrites (above) which may be deeper-seated sulphides from the same system.

At Hercules, two shallow-level footwall pyrites gave 14.5, 15.3‰.

At Rosebery, pyrite from the footwall schist has a range 10.9 to 14.9‰. (Green et al, 1981; Solomon et al, 1969).

In general, $\delta^{34}S$ appears to increase upwards between granite (+10‰) and host horizon (+15‰ in the subsurface). There is, however, a major exception:

At Mt. Lyell, footwall sulphides (shallow level) lie in the range -10 to +10‰. (Walshe et al, 1981; Solomon et al, 1969).

Host Horizon relative to Footwall

At Red Hills, the sulphur becomes heavier, 11.4 to 17.8‰.
At Hercules, the sulphur becomes a little lighter on average, pyrites ranging from 12.5 to 14.5‰. A heavy galena, 19‰, occurs in the Williams workings.
At Rosebery, both lighter and heavier sulphur is found, 8 to 19‰ (Green et al, 1981; Solomon et al, 1969).
At New North Farrell, the sulphur in heavier, 13 to 17‰, than that in the Murchison Gorge. But the Murchison Lode bears lighter sulphur, 8 to 10‰ (Solomon et al, 1969). This lighter sulphur may be derived partly from the same source as a nearby ?Devonian pyrrhotite vein (see below).

At Mt. Lyell, the Blow, Comstock and Tasman and Crown Extended massive sulphide lenses lie in the range 5 to 10‰. This is the same as for Prince Lyell footwall sulphide, but heavier than the Comstock footwall pyrite (Solomon et al, 1969; Walshe and Solomon, 1981).

Massive sulphide lenses

Other massive sulphide lenses span a broad range, from -9 to + 18‰. In most cases, individual deposits have much narrower ranges.

Deposits bearing Cu, Pb and Zn sulphides occupy the upper end of the range, higher than 5‰. The lower end of the range, -9 to + 5‰, is occupied only by barren pyritic deposits, or by barren pyritic sections of deposits.

The isotopically light, pyritic deposits differ among themselves in character. Chester is a large body of slumped, interbedded pyrite and chert. The very small occurrence at Huxley Saddle is similar. The pyrite at Basin Lake prospect occurs in bedded, carbonate-bearing shales and tuffs. At Howards Anomaly, it occurs with bedded tuffs, one zone of which includes prominent hematitic bands and beds of carbonate, chert and barite. The Ring River occurrence is a bed less than 5mm thick in a flysch sequence of conglomerates (some bearing clasts of pyrite), sandstones and siltstones. At Dunn's Blocks light pyrite occurs 1 km south along strike from the Hercules deposit. The Lake Margaret Tramway pyrite lens is relatively light (6‰) but overlaps isotopically with some of the lighter Pb-Zn and Cu bearing ores.

The Howards Anomaly occurrence warrants detailed description because the isotopic distribution appears to be complex. There are three successive mineralised units, described in order downwards, (i) Tuff in which pyrite occurs in association with carbonates, hematite, magnetite, chert and barite. Values of $\delta^{34}S$ are - 5.4‰ (pyrite from a hematitic carbonate bed); + 6.0‰ (pyrite band from a carbonate-bearing tuff).

(ii) In the underlying tuffs, mixed sulphide from a sphalerite - galena lens, possibly slumped into its present position, + 8.3‰.

(iii) In andesitic tuffs underlying unit (ii), disseminated pyrite, + 16.8‰ and - 8.3‰. P. Komyshan (pers. comm.) considers this unit to be the same as the pyritic unit intersected in DDH BL4.

Empirically, there is an association of light sulphur and the deposition of barren pyrite. This could be a useful exploration criterion. It is not, however, fully understood at present. The correlation is imperfect: Pb-Zn bearing and barren sulphide lenses overlap isotopically in the range +5 to +6‰, and heavy sulphur (+16.8‰) is found in one pyrite sample from Howards Anomaly. Oxidation of emergent waters on the sea floor may produce light sulphide-sulphur and prevent the formation of Pb and Zn sulphides. This hypothesis appears reasonable in the case of Howards Anomaly, where hematite was a primary exhalative deposit - i.e. conditions were more oxidised than usual. Such conditions might vary rapidly with time and over short distances, giving the large range of $\delta^{34}S$ values apparent at Howards Anomaly.

No primary hematite is found in the other isotopically light pyritic deposits. There is thus no indication of oxidation state (although it could have been high; iron oxide need not form if there is sufficient sulphur available). Alternatively there may be some other process for depleting the sulphur in ^{34}S and removing Pb and Zn. The Que River sulphides complicate the situation even further. They are relatively light (5 to 6‰) but are composed mainly of galena and sphalerite.

Barites

North and west of the Henty Fault, the six stratiform barite bodies for which data are available have a $\delta^{34}S$ range of 35 to 47‰. The enrichment in ^{34}S is probably the result of partial reduction of seawater sulphate (+30‰) by emergent waters. This process should be exclusive of the process (discussed above) for producing light sulphide by oxidation of hydrothermal sulphide as it emerges on the sea floor.

No light sulphide is known in association with barite in the deposits concerned (at Que River, $\delta^{34}S$ values of galena-sphalerite ore are as low as 5‰, but barite occurs 1000m long strike).

Barite is reported from Chester, where sulphide is very light, but none was found on the dumps. It would be extremely interesting to determine $\delta^{34}S$ on Chester barite, if it exists.

Stratiform barite occurs south and east of the Henty Fault (Lyell-side) at the Blow, at Howards Anomaly and possibly in the Lyell Tharsis area and at Tullah. The Blow barite is similar to Rosebery-side barites, and associated sulphides range from 5 to 10‰. At Howards Anomaly, where an oxidising environment is demonstrable, sulphide associated with barite is very light, and barite has a $\delta^{34}S$ of 33‰, near seawater value, possible slightly enriched in ^{34}S (which enrichment if significant would not accord with the oxidation-reduction model). If the Lyell Tharsis barite is stratiform, its environment of deposition may have been oxidising (it occurs with banded hematite). The $\delta^{34}S$ values are 23 to 28‰, close to Cambrian seawater or depleted in ^{34}S. The Tullah barite is remobilised and recrystallised and has $\delta^{34}S$ = 23.2‰.

Other barite occurrences are veins, most of them obviously deformed and probably of Cambrian age. All such veins gave results in the range 26 to 34‰, which may be considered coincident with Cambrian seawater. At Mt. Lyell, however, certain vein/footwall barites have $\delta^{34}S$ values of 19 to 20‰ (Solomon et al, 1969).

In a strongly oxidising environment, sulphate derived by partial oxidation of hydrothermal sulphide might account for low $\delta^{34}S$ values in barites.

Walshe and Solomon (1981) have suggested that sulphate in equilibrium with the light footwall sulphides in the North Lyell - Crown Lyell area could account for the light barites there. On emergence at the sea floor, this sulphate would be insignificant in quantity relative to seawater sulphate, and should not be detected in stratiform barite.

Black shales

All black shale pyrites have positive $\delta^{34}S$ values, the range being 2 to 43‰. This is consistent with bacterial reduction of sulphate subject to kinetic controls in a system closed to $SO_4{=}$ (i.e. sulphate is reduced faster than it can be supplied), for example in semi-enclosed shallow marine or brackish basins (Ohmoto and Rye, 1979) or perhaps during the diagenesis of a mud to which seawater no longer has free access.

In such basins, the $\delta^{34}S$ value of seawater is an upper limit to the $\delta^{34}S$ of pyrite if the system is closed to H_2S (i.e. there is relatively little formation of sulphide). If sulphide forms as fast as it is produced, pyrite so formed may be heavier than seawater sulphate, and the system is open to H_2S. Only the pyrites from the Que River black shale exceed a $\delta^{34}S$ value of 30‰, and that system can therefore be considered open to H_2S. At Rosebery and Red Hills, where values from 2 to 26‰ are known, the systems may have been closed to H_2S.

Devonian mineralisation in the Rosebery area

Devonian hydrothermal activity is thought to be responsible for:

1. The pyrrhotite-axinite-amphibole replacement deposit at Colebrook Hill, $\delta^{34}S$ = 4 to 6‰.
2. Pyrrhotite alteration of the massive sulphide ore at Rosebery ($\delta^{34}S$ = 15 to 16‰; Green et al, 1981).
3. Tourmaline and sulphide bearing veins at Salisbury and Rosebery Lodes ($\delta^{34}S$ = +16.0, +18.6‰).
4. (Probably) the pyrrhotite-pyrite veins intersected in DDH STP 221, Sterling Valley ($\delta^{34}S$ =+8.7‰; Polya, 1981).
5. The Murchison Lode, arsenopyrite - bearing veins ($\delta^{34}S$ = 8 to 10‰). The possible role of Devonian hydrothermal activity in the formation of the Farrell ores is much debated (see Polya, 1981, for a summary). These ores give a $\delta^{34}S$ range of 13 to 17‰.

There is no characteristic isotopic composition for the sulphur in the occurrences above. Colebrook Hill sulphur resembles that at Renison (Patterson et al, 1981). The other occurrences contain heavier sulphur, in most cases resembling the sulphur of Cambrian mineralisation. It may be concluded that on reaching the Mt. Read Volcanics, the Devonian hydrothermal fluids had become poor in sulphur, and that most of the sulphur in the observed vein and replacement sulphides came from the volcanics.

Miscellaneous Sulphur in the Lake Dora, Burns Peak, Langdons and East Hercules veins, and in (?) secondary Pb-Zn bearing veins from the Murchison Dam area lie in the range 8 to 19‰, and is not distinguishable from sulphur in stratiform occurrences.

Sulphur Isotope Thermometry

Attempts at calculating temperatures from various sulphide and sulphate pairs are summarised in Appx. ..6. The temperatures were calculated using data from Ohmoto and Rye (1979). Only in the case of the Taylour's Reward barite were they both consistent and reasonable. A temperature near 280°C is indicated.

Summary

The sulphur isotope study has demonstrated the complexity of the massive sulphide forming systems in the Mt. Read Volcanics, particularly those which deposited the larger orebodies. Various explanations of the data have been suggested, but without independent constraints, particularly on temperature, these cannot be regarded as final solutions to the problems posed by the data. Indeed, it is probably possible to explain any conceivable variation in $\delta^{34}S$ with a suitable combination of temperature, oxidation state and sulphide to begin with. It can safely be concluded only that many different possibilities were realised, possibly as variations of a single, simple process.

From the point of view of exploration, we have the empirical finding that light sulphur and barren pyritic stratiform lenses appear to correlate. Any new discoveries should be tested to see if this holds good.

From the academic point of view, we have indications of a consistent upward increase in $\delta^{34}S$ between granite and seafloor, and of a variety of processes in and near the ore horizon.

In addition to more detailed treatment of some of the occurrences dealt with here (particularly Howards Anomaly, which appears complex), I recommend the following $\delta^{34}S$ determinations to complete the study.

(i) Sulphides from the pink rhyolites east of Little Farrell and on a southern spur of Mt. Sedgwick.
(ii) Barite from Mt. Block, from a prospect on the north slope of Mt. Murchison and, if they exist, from Chester, Red Hills and the Henty Fault Zone sulphide lens. These last three are reported in Company literature, but could not be found by this author and may have been misidentified.
(iii) Pb-Zn sulphides from Chester
(iv) Sulphides from the area between Great Lyell and Little Owen.

Conclusions, and implications for exploration

Within the framework of the three aims set out in the Introduction, the conclusions of the study are as follows:

(i) Five assemblages (in terms of major minerals) appear to be present.

1. quartz + albite + sericite ± chlorite
1A. quartz + albite + chlorite + biotite
2. quartz + albite + chlorite + epidote
2A. quartz + albite + chlorite + epidote + biotite
3. quartz + albite + chlorite + calcite

The significant differences between these are the presence or absence of calcium minerals and the nature of potassium silicates.

(ii) Certain relationships between alteration and mineralisation appear to hold. In the Rosebery and Murchison Gorge areas, calcic assemblages occur in hangingwall rocks (relative to the massive sulphide host horizon) and in deeper footwall rocks, near granite. Calcic assemblages are not found in the immediate footwall of the host horizon. The same appears to apply elsewhere, one major exception being the andesites in the footwall of the Howards Anomaly - Basin Lake mineralisation.

A characteristic K-feldspar replaces phenocrysts in an aureole in both hangingwall and footwall and along strike from four known massive sulphide deposits.

Biotite as an alteration product occurs near granite contacts and in a zone near Rosebery thought to have been affected by a Devonian granite high beneath the volcanics.

A broad and distinctive halo of Mn-enriched chlorite in the footwall of the Hercules orebody, and Mn-rich chlorite also occurs in the Hercules hangingwall. Mn-rich chlorites are characteristic of the host horizon at Koonya, Williamsford and an unmineralised section near the summit of Mt. Read. At Hercules, a less extensive halo of Mg-enrichment in the same chlorites is present. Not every deposit footwall has such characteristics, however, as in the case of Red Hills.

(iii) Alteration as an exploration criterion.
Alteration appears to be a guide to stratigraphy in the areas investigated. As such, it should be of use in the location of host horizons on across-strike sections. It has not been possible to test the usefulness of the calcic/non-calcic distinction for mapping in areas remote from mineralisation because the only such area available lacks sufficient geological control. It can only be suggested that alteration be considered in such areas; if distinct zones are discovered, proximity to a mineralised area may be indicated. It is stressed that alteration studies must be carried out over large areas and in conjunction with other techniques. Indications from small areas must be treated with caution. Because the mechanisms proposed rely on the permeation by waters of certain rocks and not of others, deviations from gross tendencies are not impossible.

Once a part of volcanic sequence has been identified as being near a host horizon, alteration can be tested for similarity with known mineralised areas. The presence of the distinctive K-feldspar is characteristic of footwall and hangingwall in four known cases of syngenetic mineralisation. Mn-enrichment in chlorite is characteristic of the footwall and the hangingwall at Hercules and host horizon chlorites in nearby small deposits. Mg-enrichment in chlorite is characteristic of the Hercules footwall. Neither Mn nor Mg is enriched at Red Hills, however, so that these criteria may be regarded a positive indication but their absence may not be regarded as a negative indication.

The sulphur-isotope study has produced an empirical result of interest to exploration. Syngenetic pyrite deposits which are effectively barren contain isotopically light sulphur. Deposits containing significant Pb, Zn, Cu are heavier. The two ranges overlap in the $\delta^{34}S$ range 5 to 6‰.

Specific implications for the Mt. Read Volcanics

The likelihood of further discoveries of syngenetic mineralisation in the Mt. Read Volcanics is as follows.

(i) In the Tyndall Group and correlates: unlikely. None is known, and alteration does not suggest the existence of a host horizon.

(ii) In the Western Sequence: possible. Syngenetic pyrite is known in two cases, but both are barren. If there is a host horizon, it cannot be traced at present.

(iii) In the Central Sequence: probably along the lines indicated in Eastoe (1981) figs. 2, 3 and 11. (except for the postulated line in the Lake Dora - Lake Selina area; no repetition of the host horizon is now postulated to the east of Red Hills, Mt. Tyndall and Mt. Sedgwick), and possibly in the Pinnacles area. No other possible repetitions of host horizon are indicated by the evidence available. Where absent in an east-west section the host horizon has been either eroded away or concealed by younger formations. In some areas, the line of the host horizon is inferred but has not been located in outcrop (e.g. Henty Fault Zone to Howards Anomaly).

Following on from this study, then, it is recommended that the host horizon be located exactly in those areas where its position is only approximately known. The footwall side should be examined for distinctive areas of alteration, and these could be tested for similarity with the Hercules footwall.

The chief areas of interest are:

(i) Howards Anomaly and environs. This is probably at te right spacing (about 15 km) from Mt. Lyell, and many indications of mineralisation are already known. Some are interpreted as unfavourable - the light sulphur in certain pyrites and the abundance of hematite, for example - but not all are so. Lead-zinc mineralisation is present, and not all pyrites are light. This is a complex piece of mineralisation, not yet well understood. It would make a good honours project.

(ii) The southward extension of the Que River horizon. Most of this lies on other leases. Any geophysical and geochemical anomalies in the area should be carefully considered.

(iii) Huxley Saddle to Whip Spur, where on interval of probably host horizon has been postulated. The $\delta^{34}S$ value of pyrite from the small pyrite-chert body on Mt. Huxley is a negative indicator, however.

The eastern margin of the Central Sequence, form the Murchison River to Lake Beatrice, is not likely to yield syngenetic mineralisation. The pyrite-magnetite mineralisation may yield precious metals, and all examples not assayed to date should be done. If results are negative, the ground could be relinquished. The same applies to the Jukes-Darwin area.

At Prince Darwin and Jukes Pty., the tourmaline - bearing iron oxide bodies should be assayed for tin. The tin potential of the Rosebery area is already under investigation. The area of interest there may extend south towards Hercules and east to the Murchison Gorge.

Fig. 10 is an attempt at classifying alteration styles in the Central Sequence based on the results of this study.

Applicability of this study elsewhere

Whether or not the findings of this study on the distinction of pre-ore rocks from post-ore rocks can be applied in other massive sulphide provinces depends on factors such as -

(i) the number of mineralising events in a given area
(ii) the metamorphic facies
(iii) the original composition of the enclosing rocks

This study should be applicable in other parts of the Mt. Read Volcanics outside present leases.

In south-east New South Wales there are indications of more than one mineralising event in the area around Cooma, for example. Furthermore, limestones are widespread in the host sequences and this may affect the geochemistry of calcium. At higher metamorphic grades, (e.g. possibly in the Peelwood area, where metamorphism is of amphibolite facies) calcium would remain in or be concentrated in plagioclase so that the distinction between calcic and non-calcic would, if preserved, be more difficult to detect by petrography.

At the Fukuzawa mine, Hokuroka Basin, Japan, the ratio $(K_2O + MgO)/(Na_2O + K_2O + MgO + CaO)$ is used to discriminate between pre-ore and post-ore rocks (Date et al, 1979, who cite other Japanese work). Variations in the ratio reflect the removal of Na_2O and CaO and the addition of K_2O and MgO in footwall rocks. This corresponds to what is observed in the Mt Read Volcanics, except that clays are characteristic phyllosilicates in the relatively unmetamorphosed Japanese terrain.

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Characteristic textures of calc-alkaline volcanic rocks from the Mt. Read Volcanics, Western Tasmania.

C. J. Eastoe

A collection of photographs to accompany the report "Alteration and Mineralisation in the Mt. Read Volcanics, Western Tasmania."

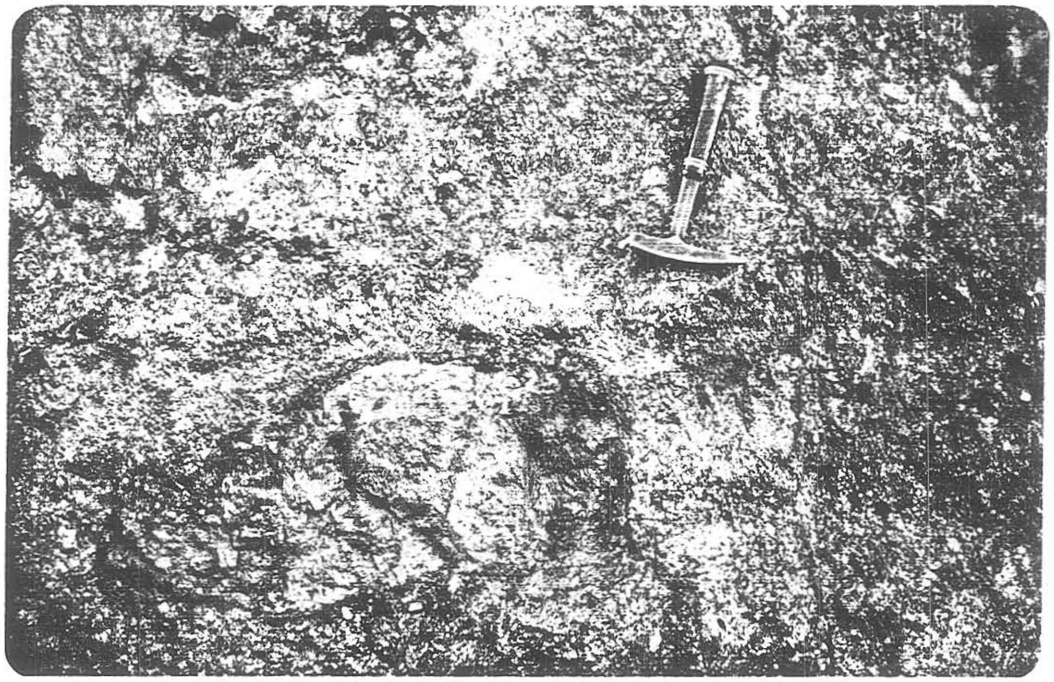
Contents

OUTCROP PHOTOGRAPHS

1. Lahar, Comstock Tuff, Queenstown (near the Mt. Lyell offices). A chaotic gravelly mixture of poorly sorted boulders and pebbles in a gritty groundmass.

2. Blocky lava or ash-flow tuff, locality PR4, Boco Creek, Pieman Road. Note the light-coloured (baked?) margins of the blocks. The blocks are matrix supported despite the large proportion of blocks, suggesting that the matrix was originally a viscous liquid. Divitrification is of snowflake-style in part.

1.



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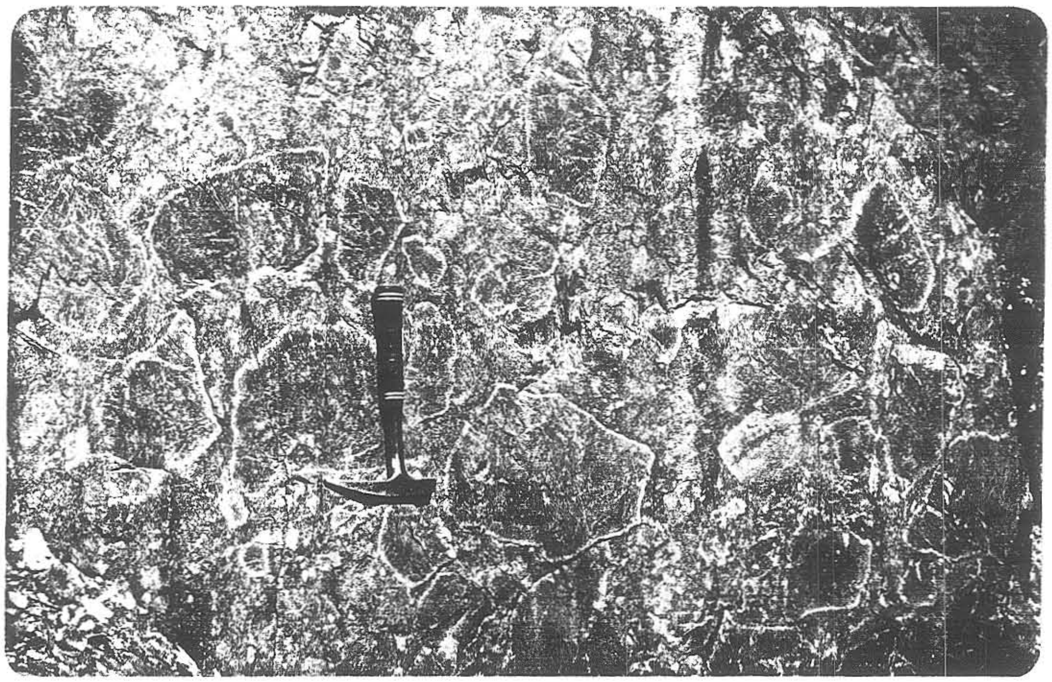

3. Pyroclastic rock of submarine origin, White Spur Track, Mt. Read. Clasts of grey shale are set in a matrix rich in moderately well-sorted quartz and feldspar crystals. (The outcrop is obscured by gravel towards the extremities of the photograph).

4. Flow-banded rhyolite, Intercolonial Spur. The banding is contorted and truncated by later lava.

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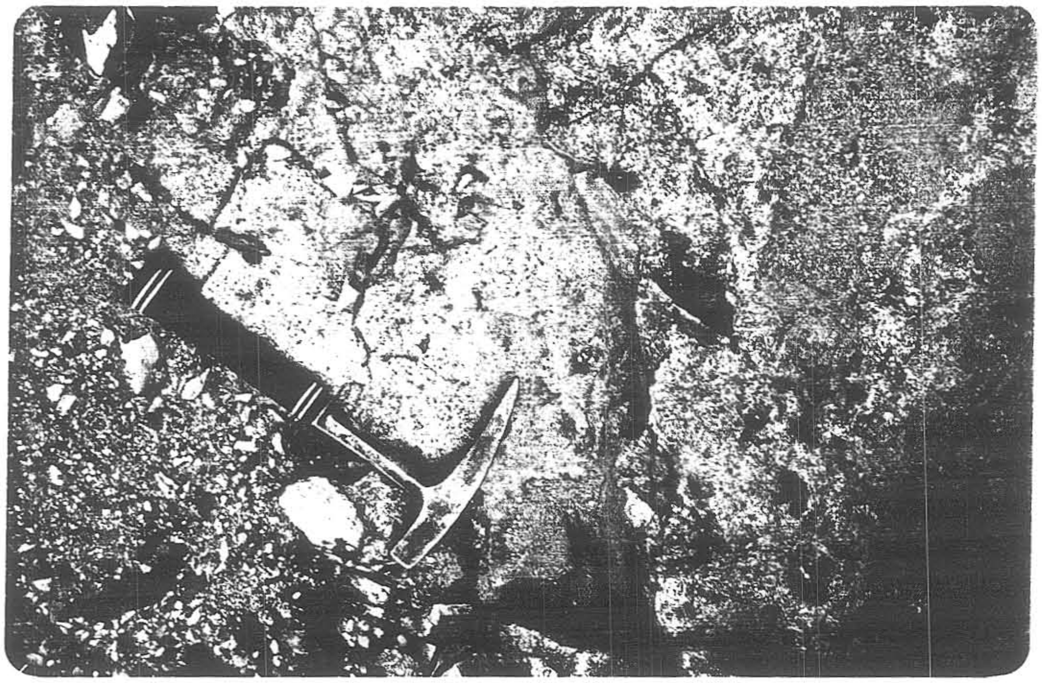

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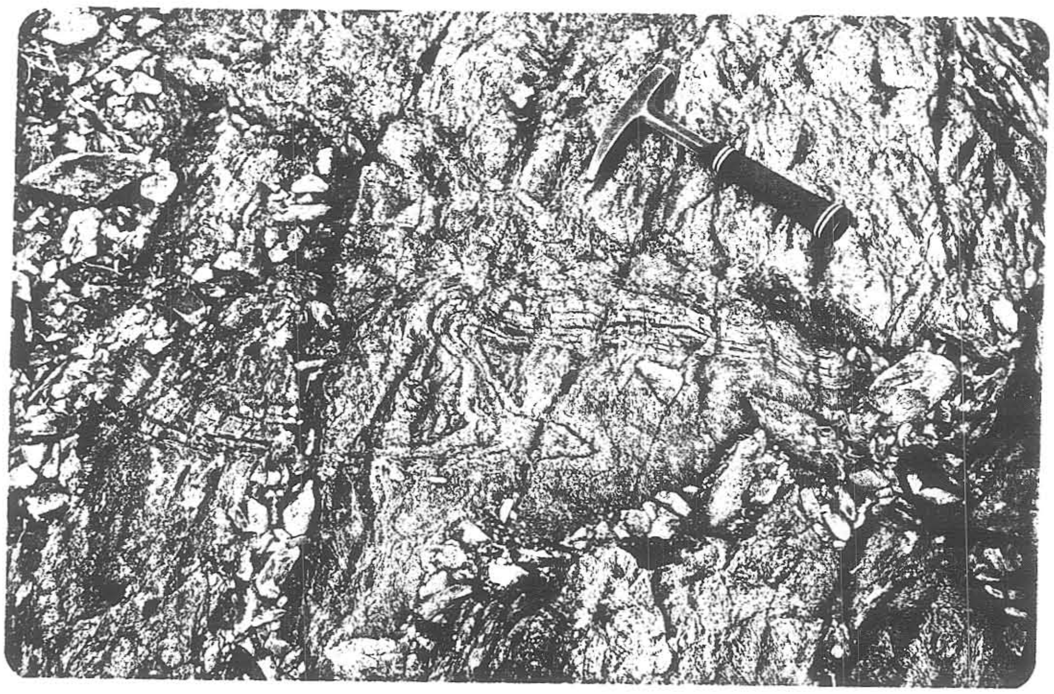
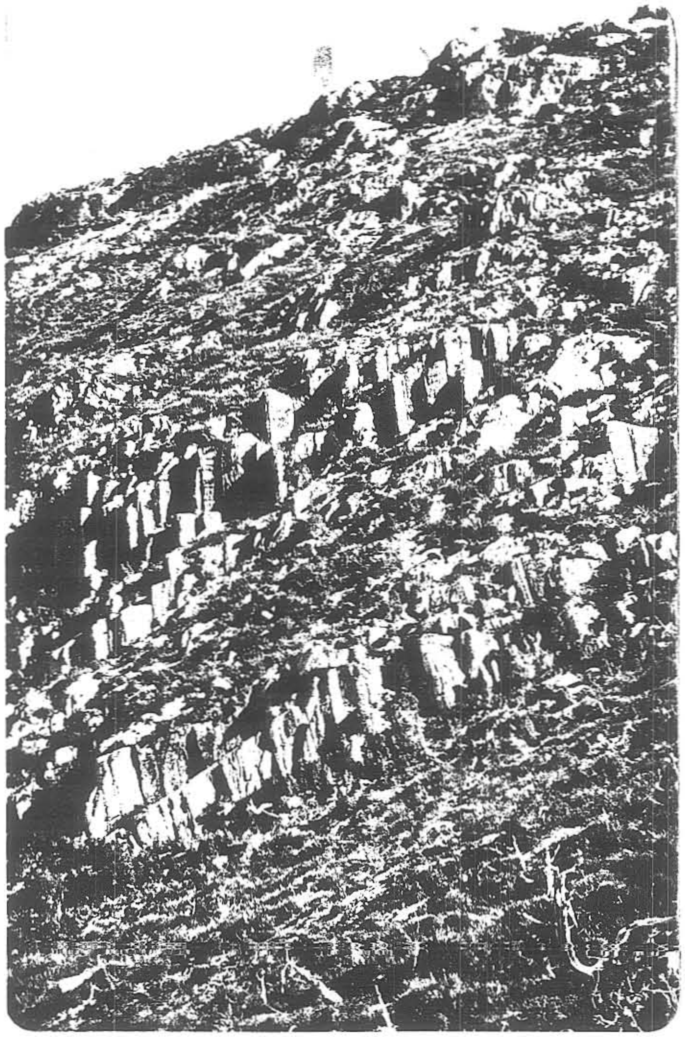


5. Flow-banded rhyolite, Intercolonial Spur.

6. Columnar jointing in rhyolite/dacite, eastern spur of Mt. Read (location RD3). The joints have been folded.



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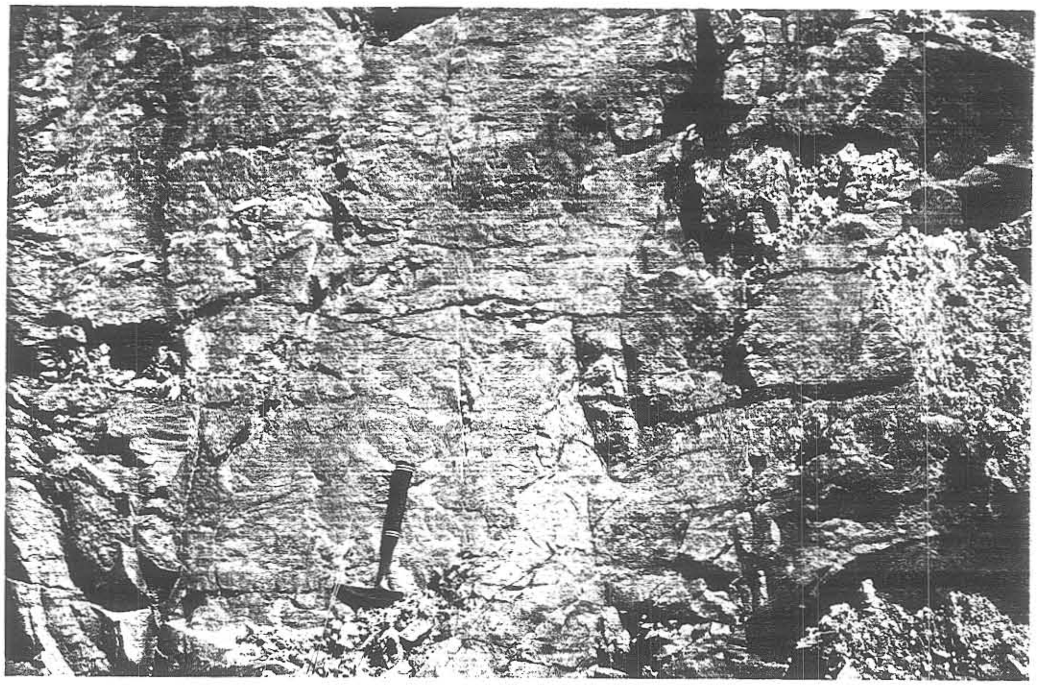
7. Flattened pumice fragments (sub-horizontal streaks) defining a primary foliation in a tuff (ash-flow?), Boco Creek, Pieman Road.

8. Mottled vitric-crystal tuff, Pieman Road between Farm Creek and the Murchison Highway (location PR8). The mottling is irregular and is not a primary texture. The pink areas are rich in albite, the dark green areas in chlorite and the light green in epidote. See thin section description PR8.

7.



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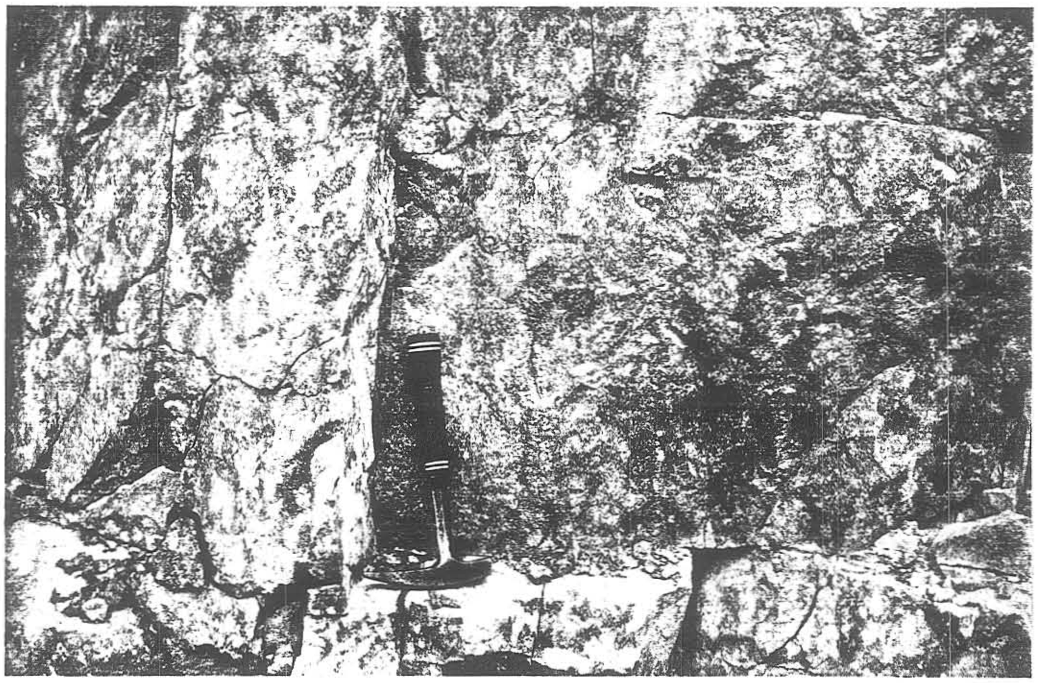

MICROSCOPIC TEXTURES - PRIMARY

9. Specimen BG1. Deeply embayed quartz phenocrysts and turbid plagioclase phenocrysts. The groundmass grainsize is unusually coarse; this may be due to metamorphic recrystallisation or an intrusive origin. Crossed nicols; long side=9mm.

10. Specimen STP 221. Flow or pilotaxitic texture in andesite. Chloritised plagioclase phenocrysts are set in a dark fine-grained groundmass in which the subparallel aligned forms of former plagioclase microlites can be distinguished. Plane-polarised light, long side = 6 mm.

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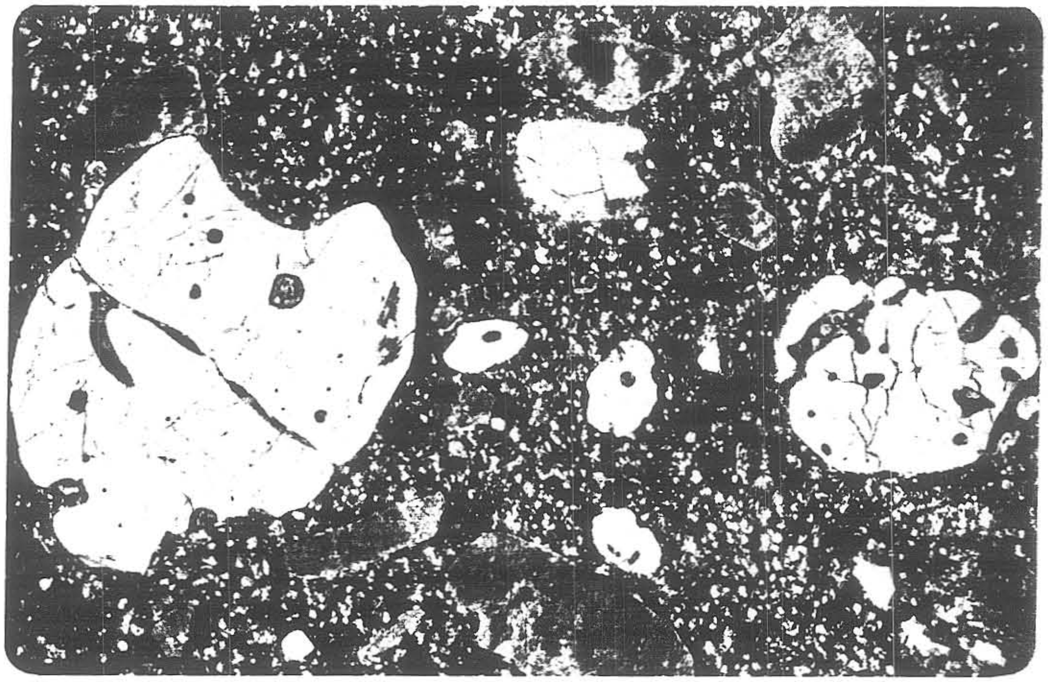

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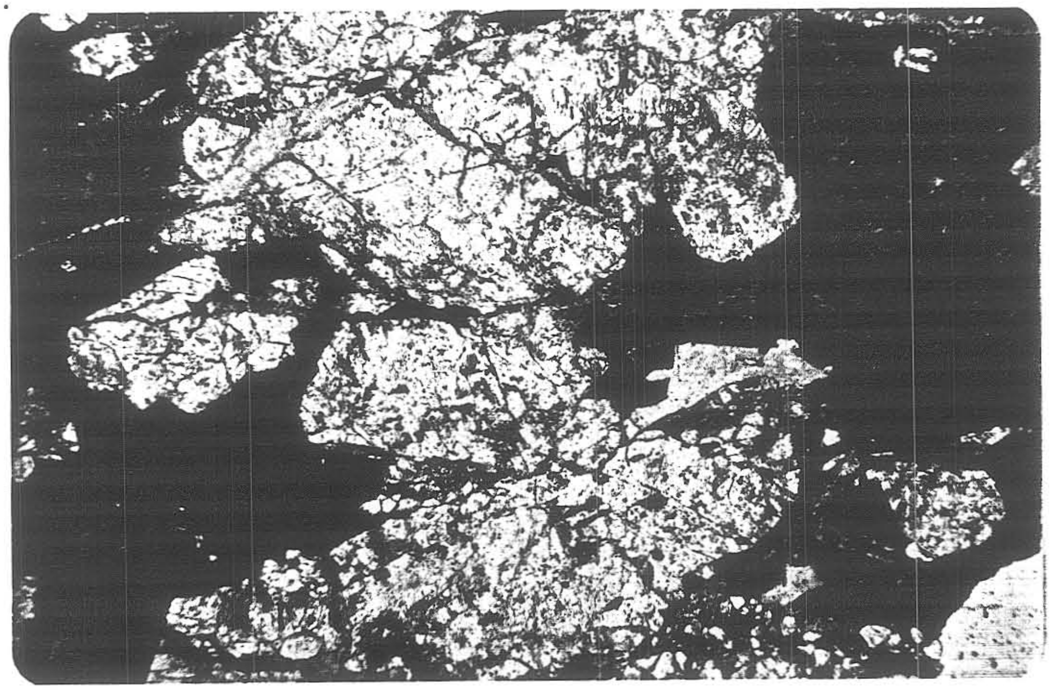
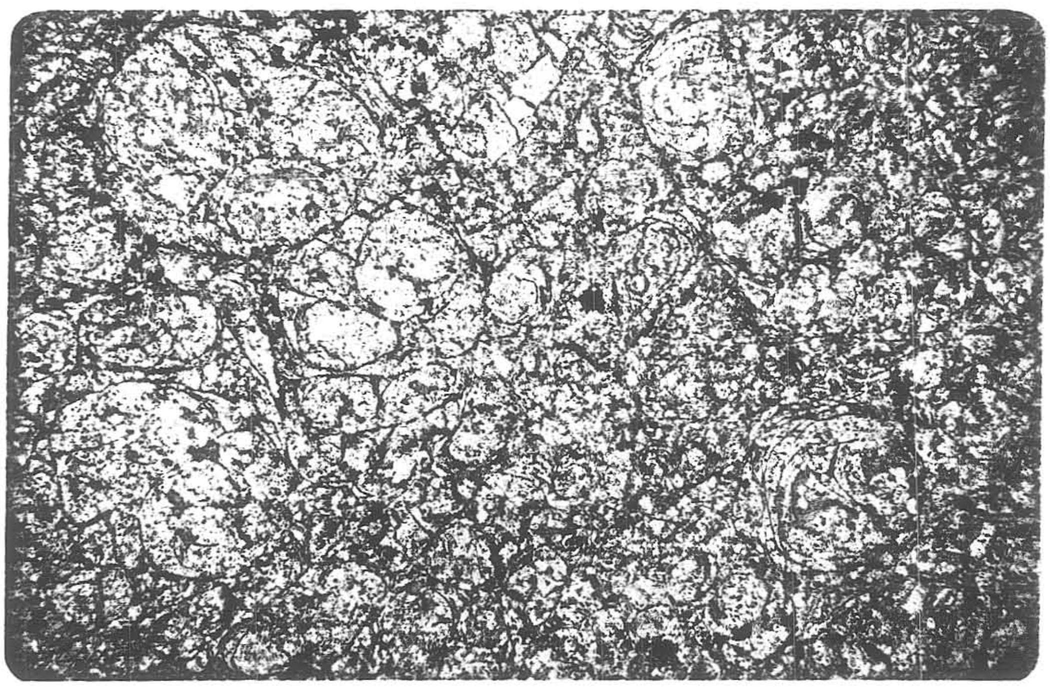


11. Specimen ST5. Plagioclase phenocrysts (altered partly to epidote) set in an altered pilotaxitic groundmass with chloritic areas. Plane-polarised light; long side = 4.5 mm.

12. Specimen BL6. Perlitic cracks are preserved in a rock which consisted entirely of glass. Subsequent devitrification and alteration have produced a quartz-albite-sericite assemblage. Plane-polarised light; long side 6 mm.

11.

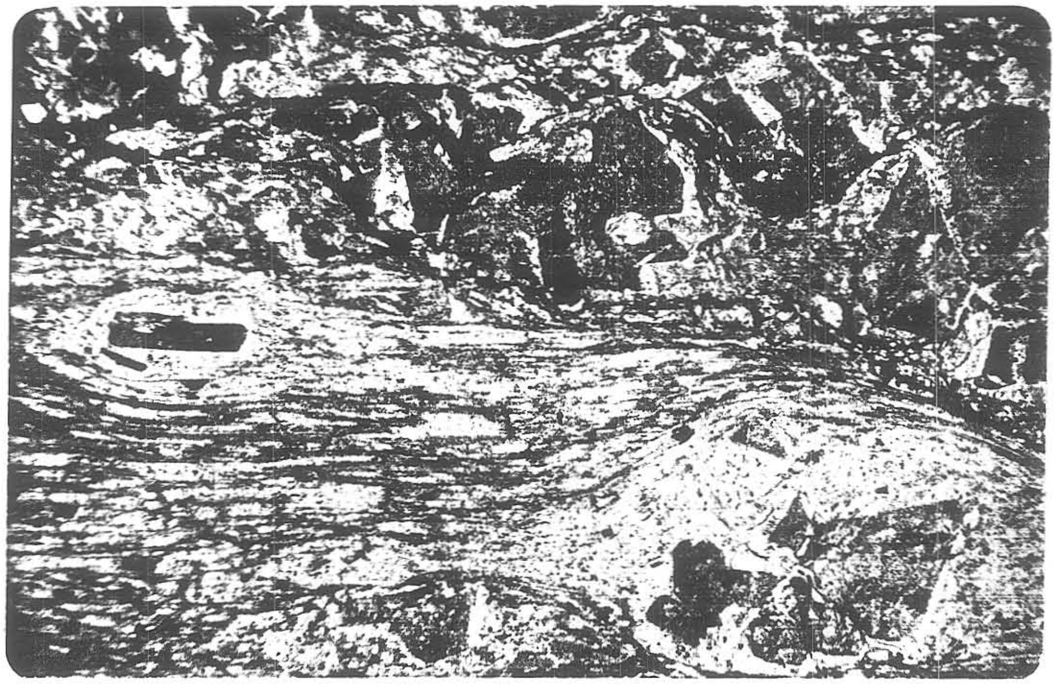
12.



13. Specimen RL1. Collapsed pumice. This is thought to be a well-preserved ash-flow tuff, retaining the texture of flattened pumice. The pumice is bent around plagioclase phenocrysts. Around one phenocrysts, the pumice is not collapsed, and retains round shapes suggesting vesicles.
Plane-polarised light; long side - 9 mm.

14. Specimen HF63. A chloritic fiamma is enclosed in a quartz-sericite-chlorite-pyrite matrix of somewhat eutaxitic texture. The irregular white areas are gaps in the specimen, artefacts of polishing. In this example, primary glass textures survive hydrothermal alteration in the footwall of the Hercules deposit.
Plane-polarised light; long side = 8 mm.

13.



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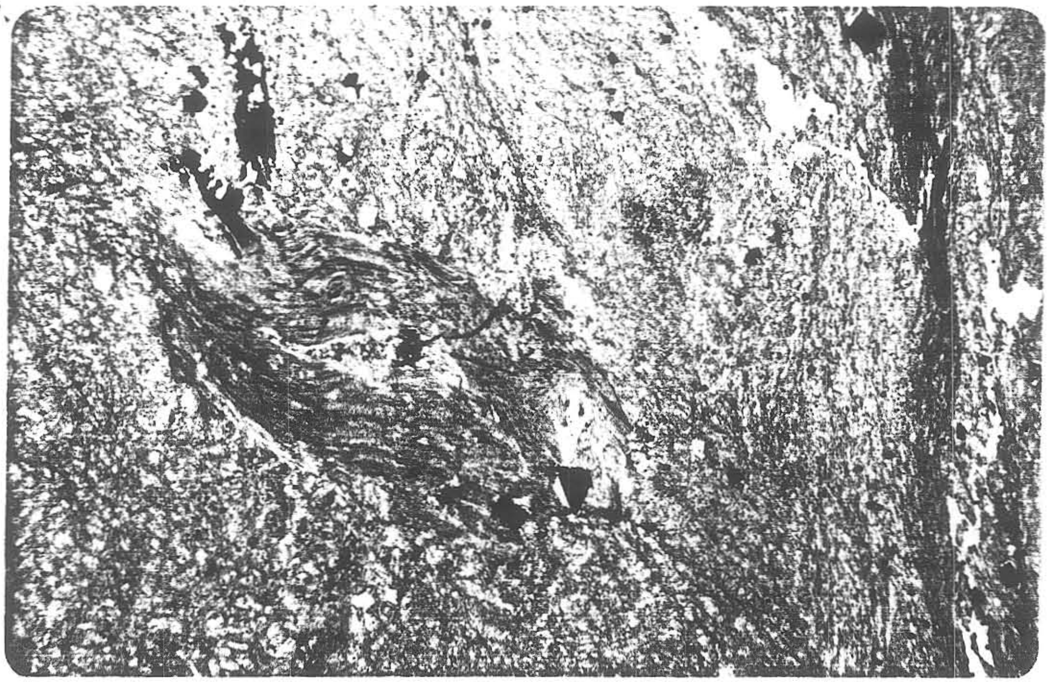
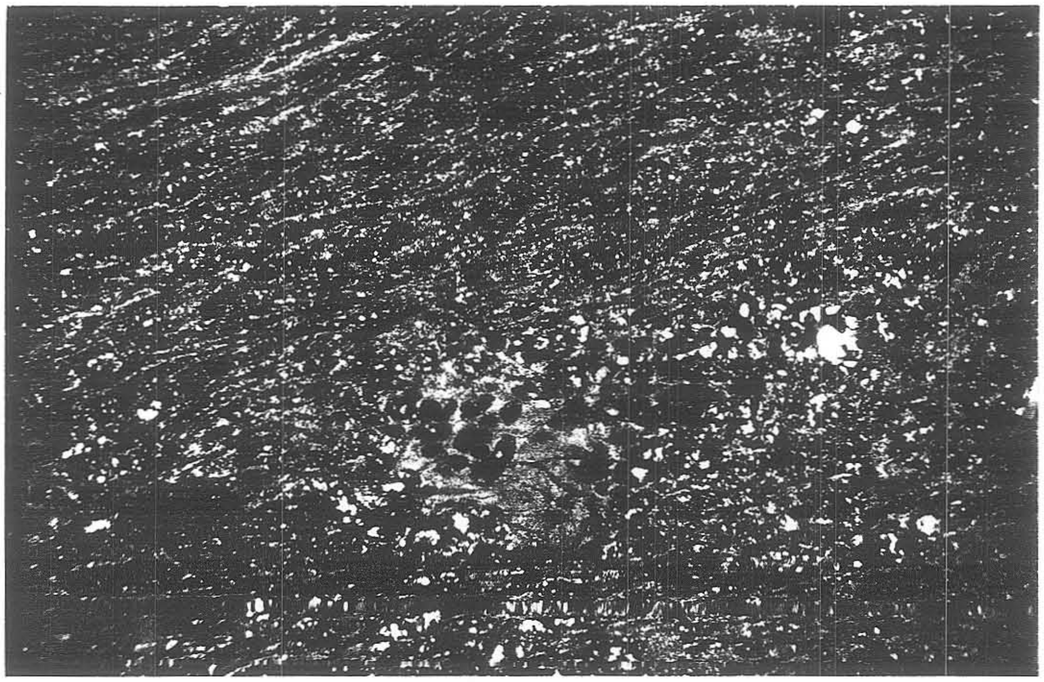


15. Specimen HF67. Round vesicles, now filled with quartz, are preserved in a piece of non-collapsed, sericitised pumice. The groundmass consists of flattened pumice altered to quartz/feldspar and sericite.
Crossed nicols; long side = 5 mm. Yellow colour due to omission of blue filter.

16. Specimen BR9. Abundant shards and feldspar phenocrysts in a vitric-crystal ash-fall tuff. The fine-grained matrix has been weathered.
Plane-polarised light; long side = 6.5 mm.

15.



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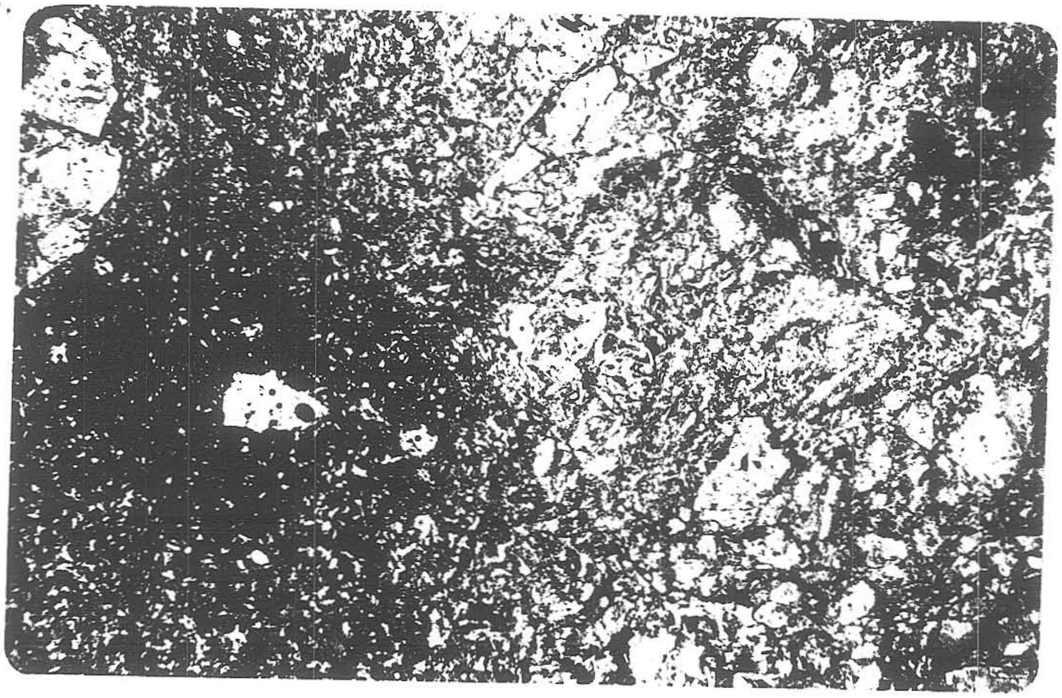
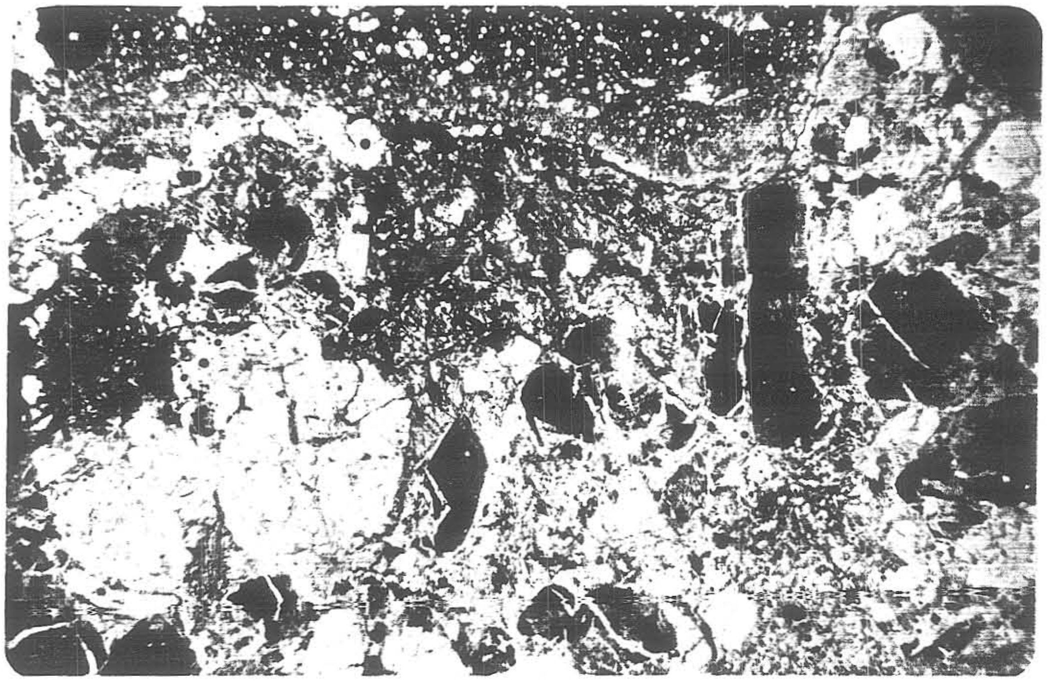


17. Specimen RA2. Ash-fall tuff. Crystals of quartz and turbid crystals of plagioclase, some of each broken, and a large lithic fragment are set in a subordinate matrix of albite, chlorite clino-ziosite, calcite and sphene (weathered chlorite can be distinguished). Sorting is very poor and the arrangement chaotic.
Plane-polarised light; long side 7 mm.

18. Specimen HA15. A plagioclase and quartz-bearing tuff composed almost entirely of crystals. The quartz crystals are broken; the turbid plagioclases are less so, but appear to have been deformed during compaction. Opaques and chlorite form a very minor matrix. This rock is probably of ash-fall origin, reworked since deposition. Plane-polarised light; long side = 9 mm.

17.



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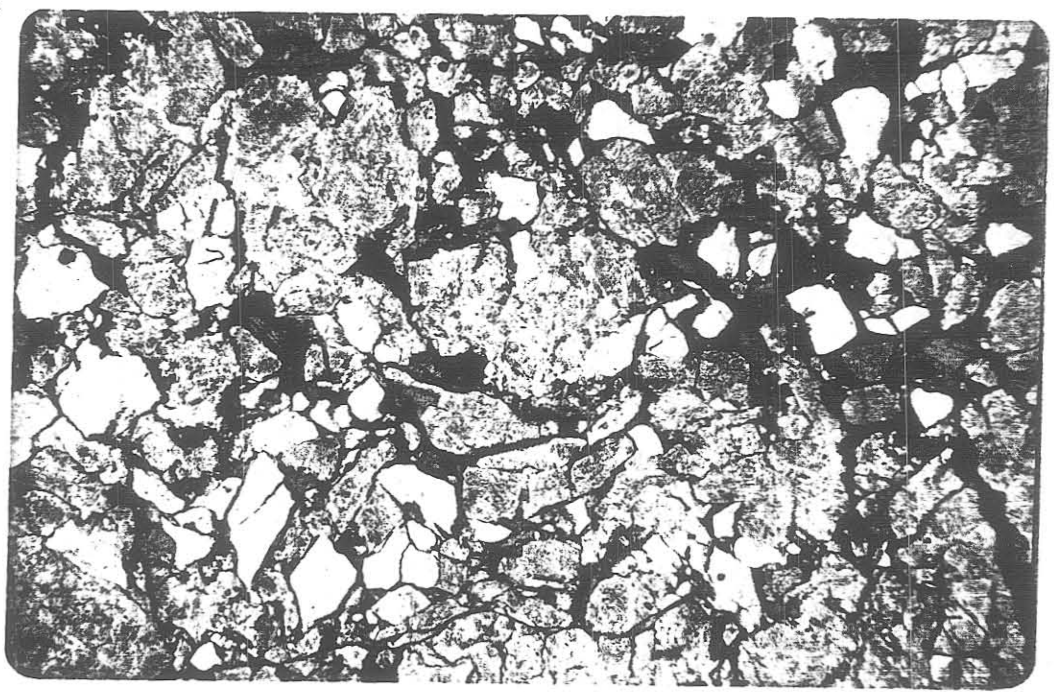
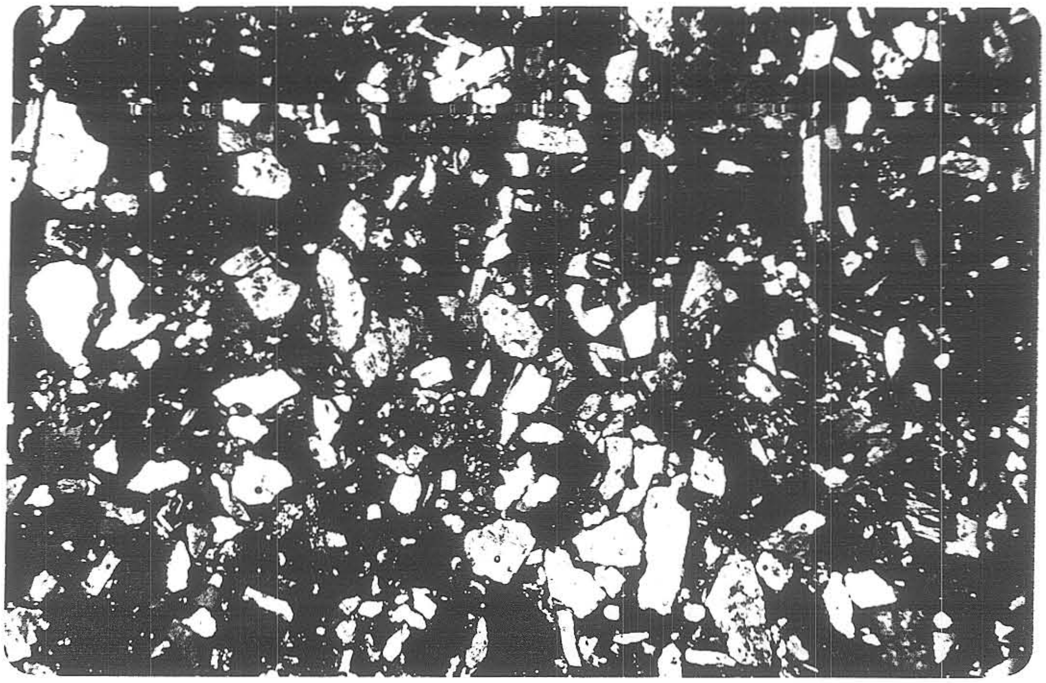


19. Specimen RR9A. A tuffaceous sandstone. Poorly sorted, angular grains of quartz, plagioclase and pre-existing rock occur in a turbid matrix. This represents a more advanced stage of reworking than that in HR7.
Crossed nicols; long side = 9 mm.

20. Specimen HR7. Reworked tuffaceous material composed of abundant shale and siltstone fragments (dark objects) and crystals of quartz and feldspar (now replaced, but outlined by albite rims and veins) set in a turbid, subordinate matrix.
Crossed nicols; long side 9 mm.

19.



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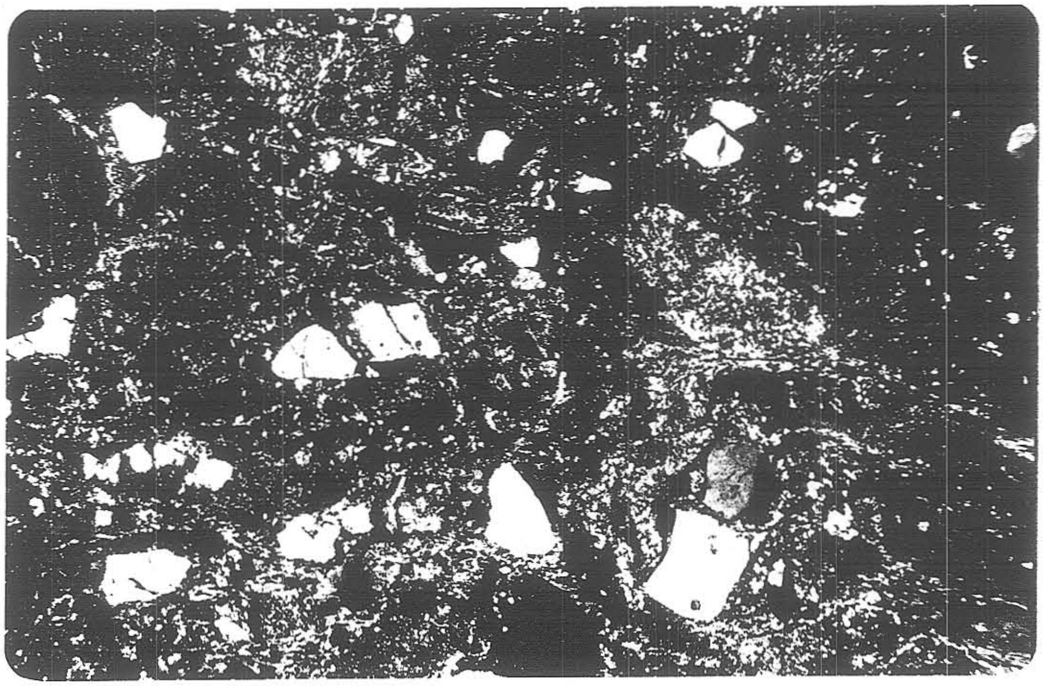
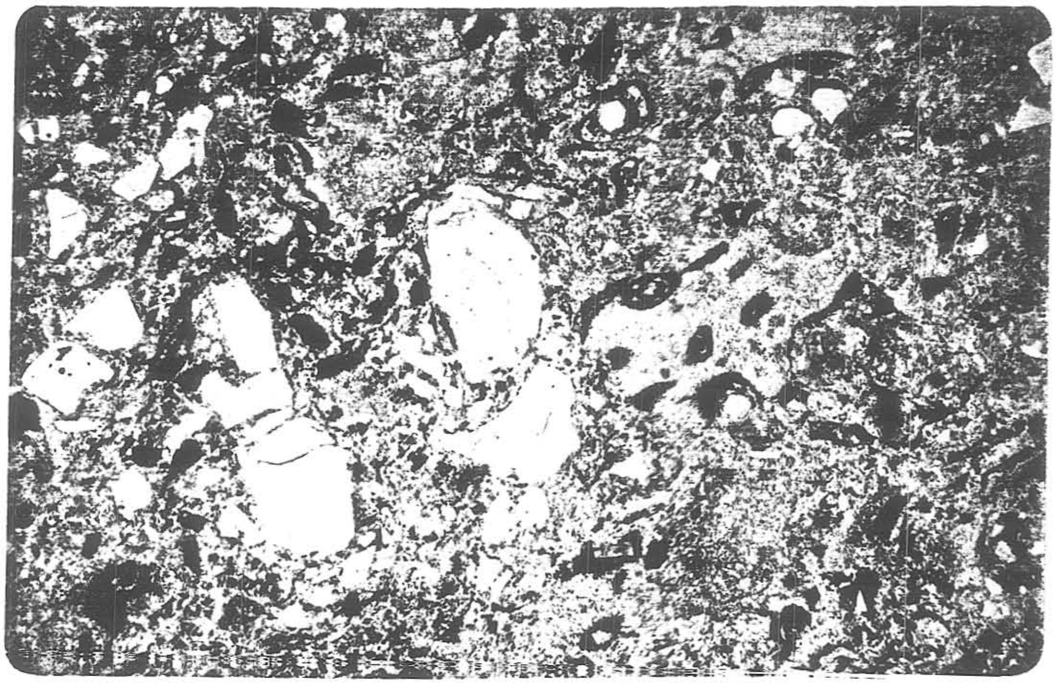


21. Specimen HF16. Probable glass texture. Plagioclase phenocrysts are set in a fine-grained groundmass in which dark swirls and loops (chlorite and rutile) and visible. The loops in some cases enclose phenocrysts, and in others are concentric. This is apparently not a pumice texture.

Plane-polarised light; long side 7 mm.

21.

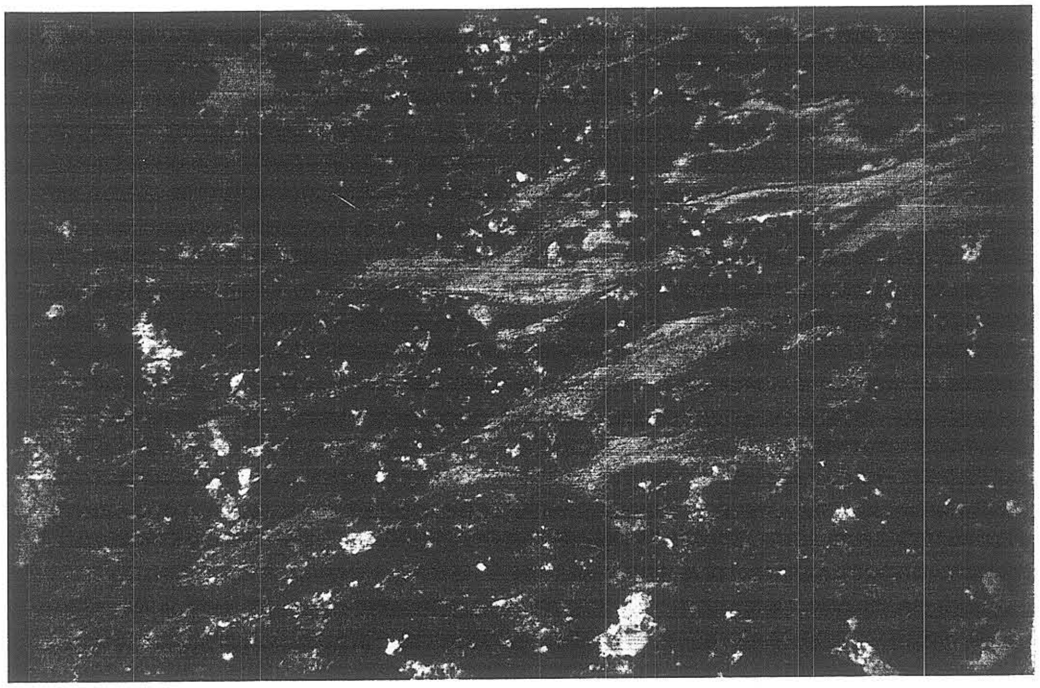


MICROSCOPIC FEATURES - DEVITRIFICATION

22. Specimen RD2. Deformed quartz spherulites and axiolites are set in fine-grained sericite. Crossed nicols; long side = 2.5 mm. (yellow colour due to omission of blue filter).

23. Specimen BR7B. Snowflake texture. A sericitised plagioclase phenocryst is set in a devitrified groundmass which consists of coalesced snowflakes, each an optically-continuous micro-poikilitic quartz crystal. The microlites consist of sericite after plagioclase.
Crossed nicols; long side = 5.5 mm.

22.



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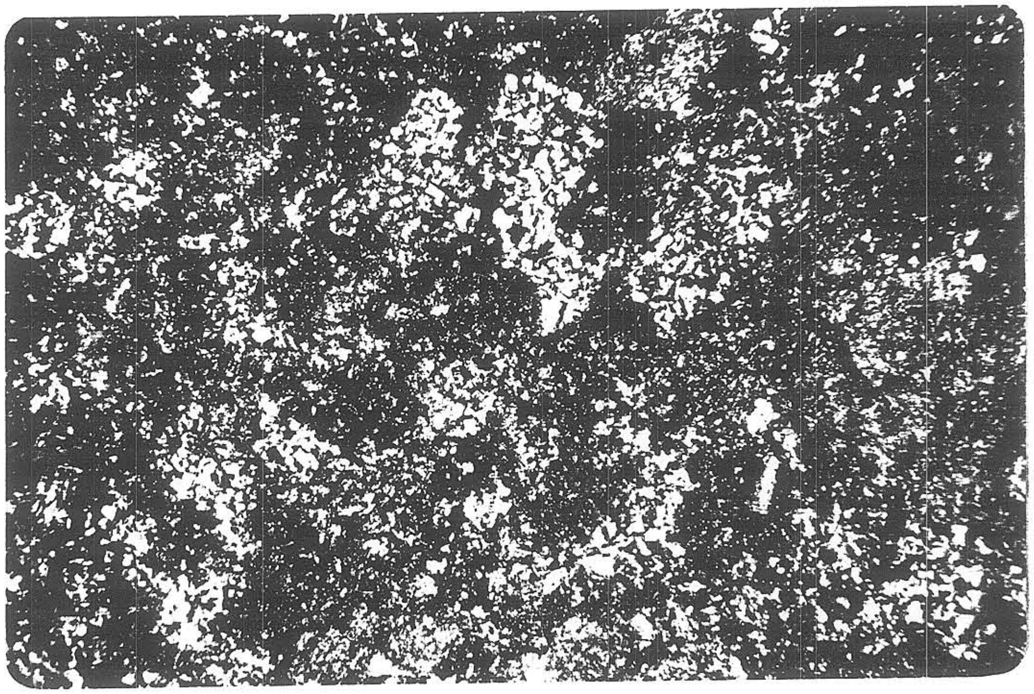
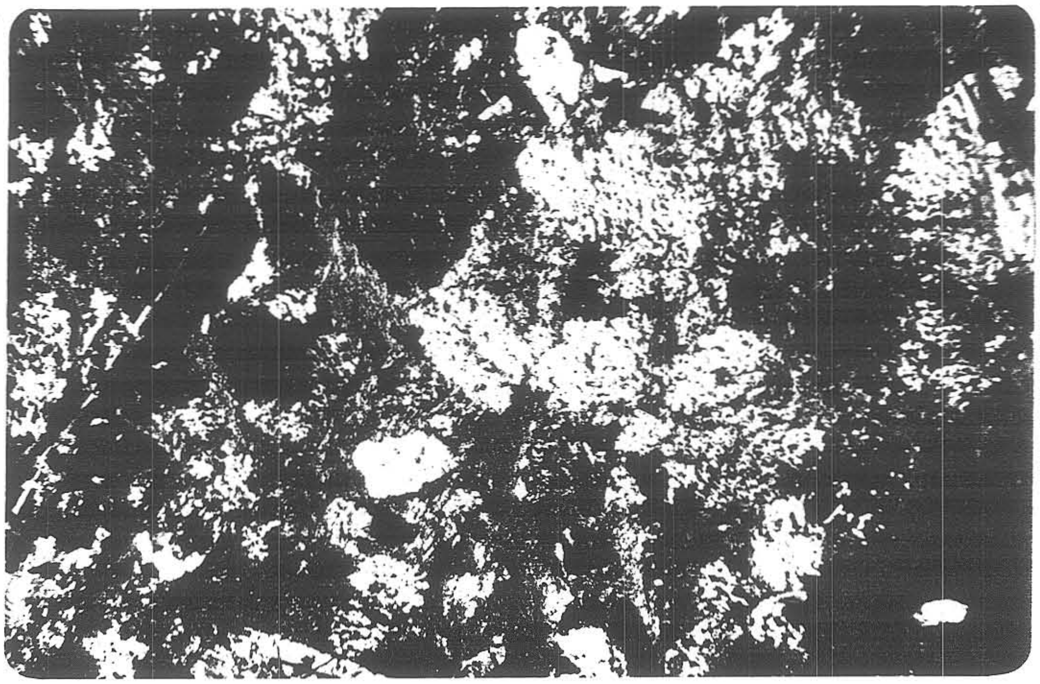


24. Specimen RD2. Snowflake texture. Plagioclase phenocrysts partly replaced by calcite are set in a groundmass which has devitrified to give well-formed micropoikilitic areas of quartz. These appear to have been brecciated and invaded by sericite.

25. Specimen ND2. Snowflake texture. Sericitised feldspar phenocrysts and dark areas of hematite after magnetite are set in a groundmass of coalescing areas of micropoikilitic quartz. The elongate forms of randomly-oriented feldspar microlites (now sericites) are clearly preserved. Certain snowflakes have clear quartz centres with which they are in optical continuity. Some such nuclei have the appearance of embayed microphenocrysts, but White (1975) has suggested that they represent an advanced stage of snowflake devitrification, the nucleus developing at the expense of the snowflake.
Crossed nicols; long side = 6 mm (Yellow colour du omission of blue filter).

24.



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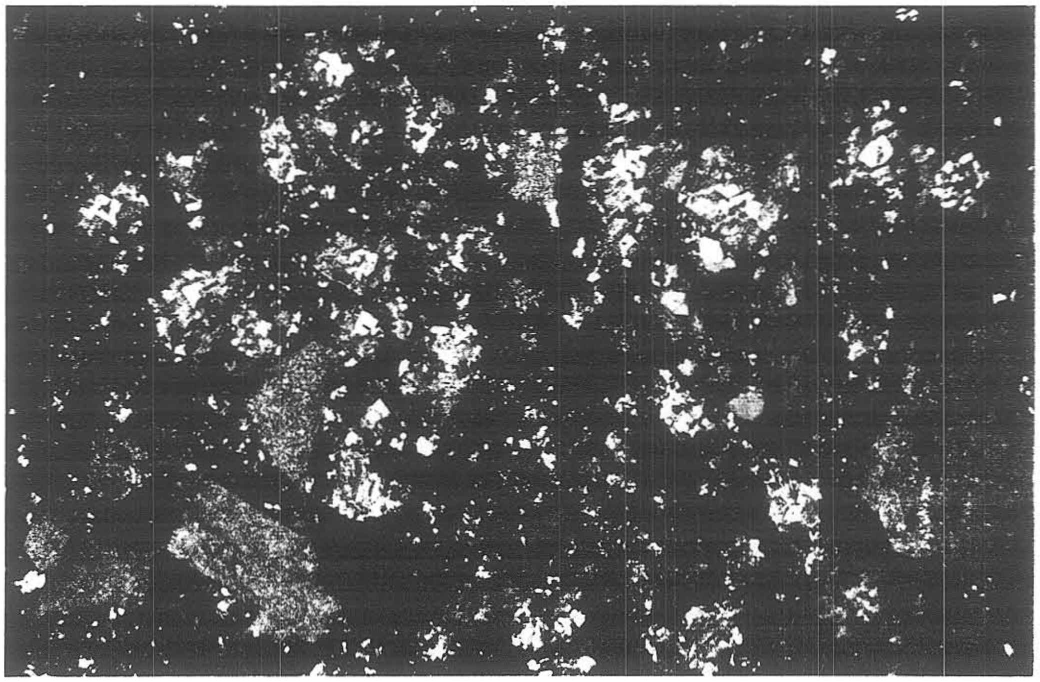
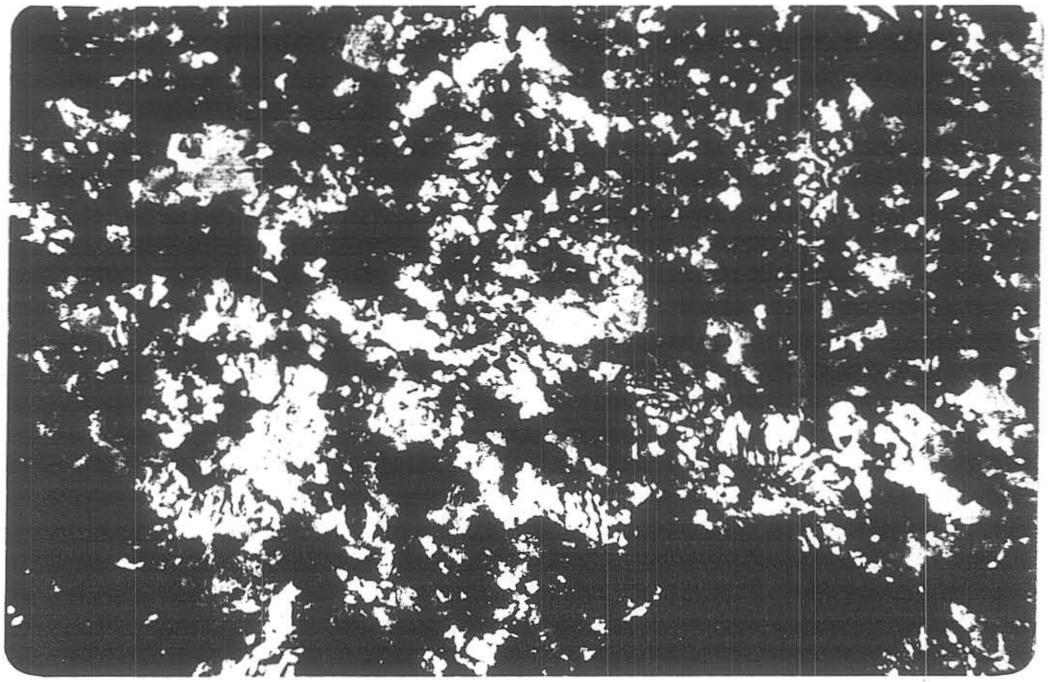


26. Specimen ST2. Eutectoid texture (primary texture or divitrification?). The groundmass consists in part of eutectoid intergrowths of quartz and feldspar.
Crossed nicols; long side = 2 mm.

26.

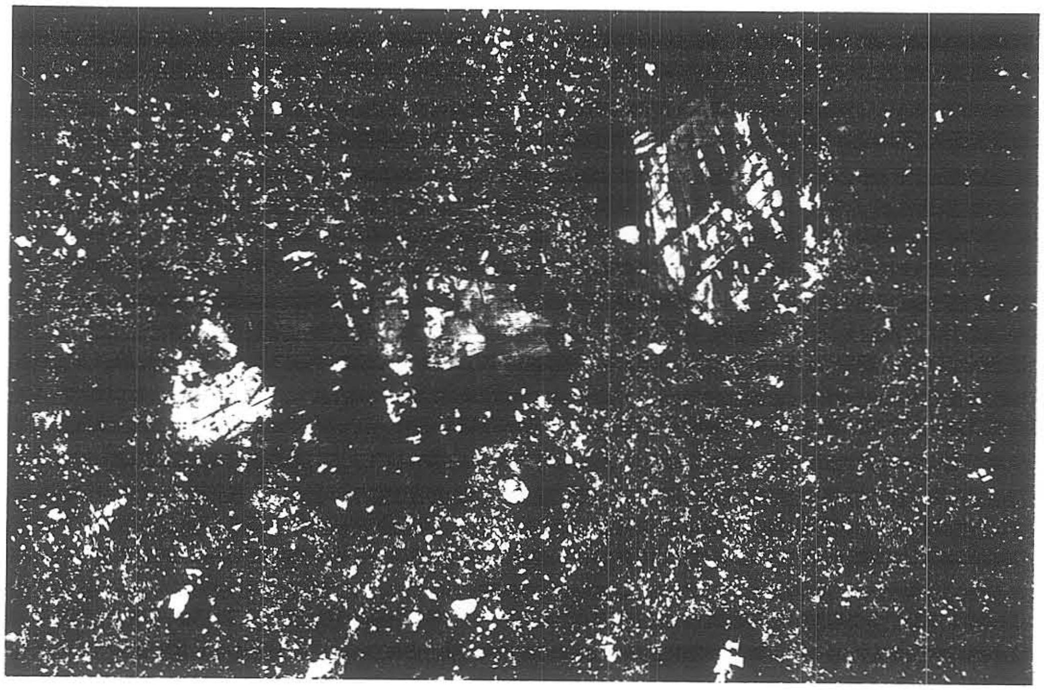


MICROSCOPIC FEATURES - ALTERATION

27. Specimen RD6. K-feldspar after phenocrysts. The feldspar has an unusual mottled texture near extinction. (It is associated with calcite and chlorite in other cases). The groundmass consist of quartz, sericite; chlorite and opaques and is eutaxitic.
Crossed nicols; long side = 7 mm. (yellow colour is due to omission of blue filter)

28. Specimen PR4. Plagioclase phenocrysts altered to albite and calcite. The groundmass consist of weakly foliated quartz/feldspar, sericite, chlorite and calcite.
Crossed nicols; long side = 6 mm.

27.



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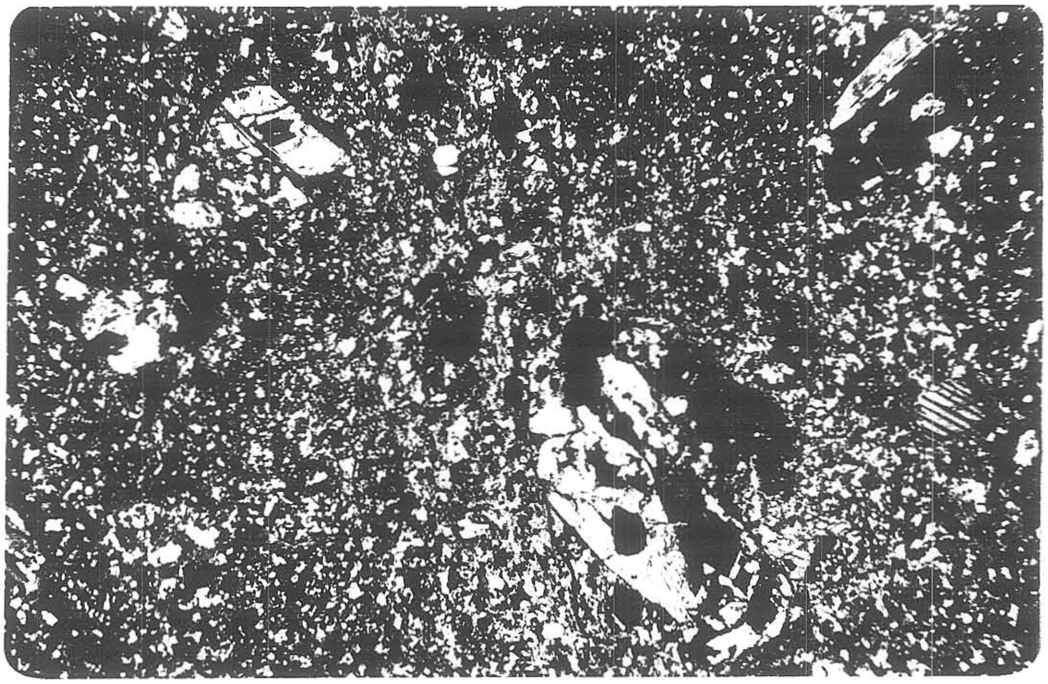
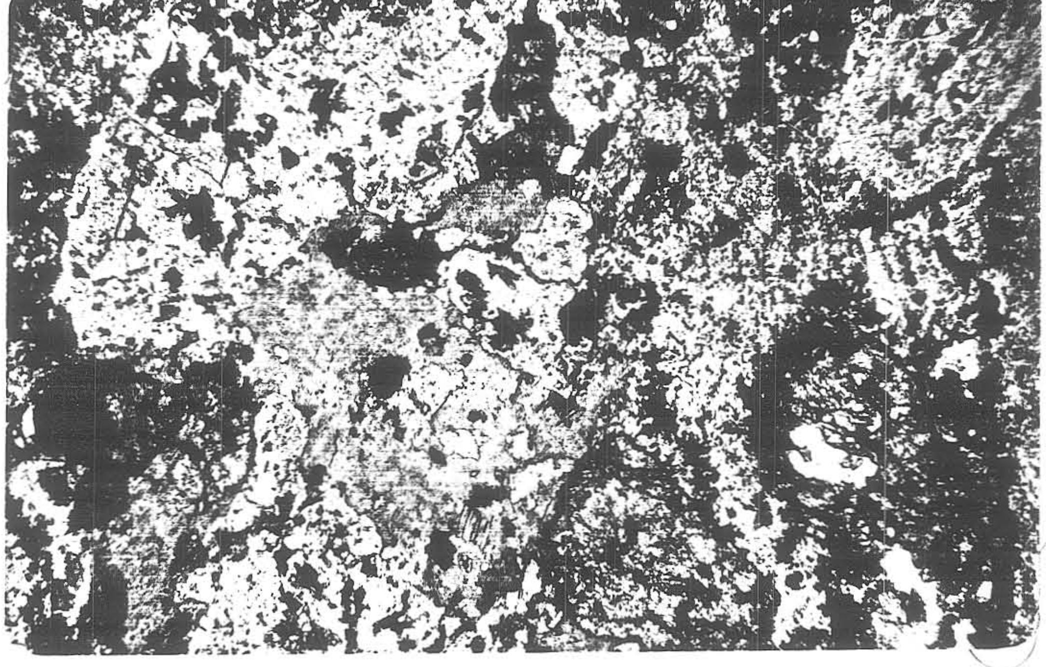


29. Specimen KJ1. Plagioclase phenocrysts (white) are partly replaced by epidote (high-relief, brownish) and are set in a groundmass extensively replaced by chlorite, epidote and minor biotite. The biotite (brownish flakes with cleavage enclosed in chlorite) is definitely secondary. Plane polarised light; long side = 4 mm.

30. Specimen ST5. Phenocrysts of hornblende (altered partly to chlorite), plagioclase (with albitic rims, and with centres partly altered to epidote) and ilmenite (certain dark areas) in dacitic-andesitic lava.
Crossed nicols; long side = 6.5 mm.

29.



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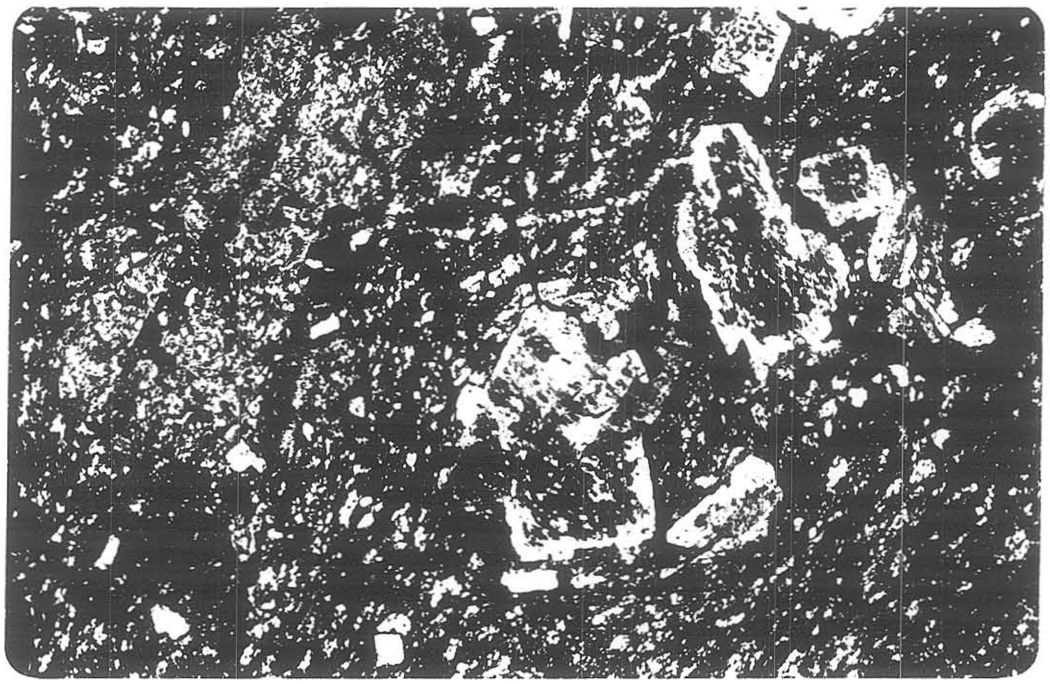
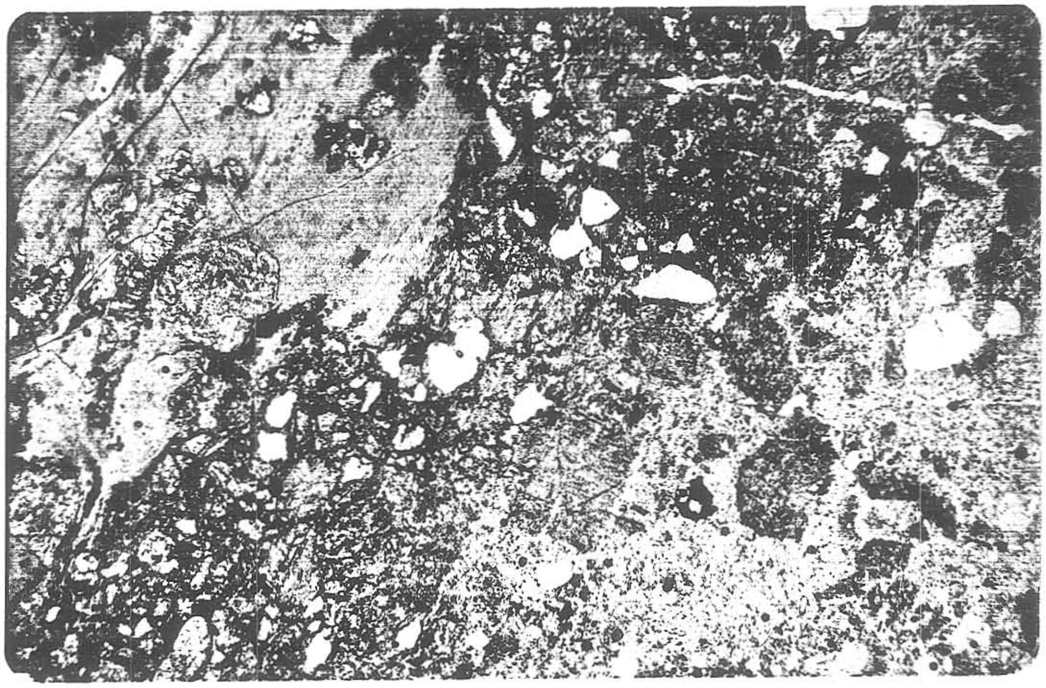


31. Specimen HA20. Selective chloritisation and albitisation. Quartz and plagioclase of phenocrysts origin are set in a dominant groundmass (cf. HA15, which is from the same unit). Some of the groundmass has been chloritised entirely, and the plagioclase phenocrysts in this area are partly replaced by chlorite and sericite. At the other extreme of the photograph, the groundmass is albitised and the phenocrysts lightly flecked with fine-grained sericite. The area between is intermediate in alteration style, and also in deformation style. In hand specimen, the effect is of pink and green mottling, with no obvious primary control. cf. plate 8.
Plane polarised light; long side = 7 mm.

32. Specimen MS2. Laths of K-feldspar are intergrown with quartz to give an uncommon bladed texture, probably the result of recrystallisation. The rock is a potassic rhyolite (cf. Jukes--Darwin pink rhyolites). It contains quartz phenocrysts and patches of highly-birefringent chlorite; the latter may be a weathering product of normal chlorite.
Crossed nicols; long side = 6 mm. (Yellow colour is due to omission of blue filter).

31.



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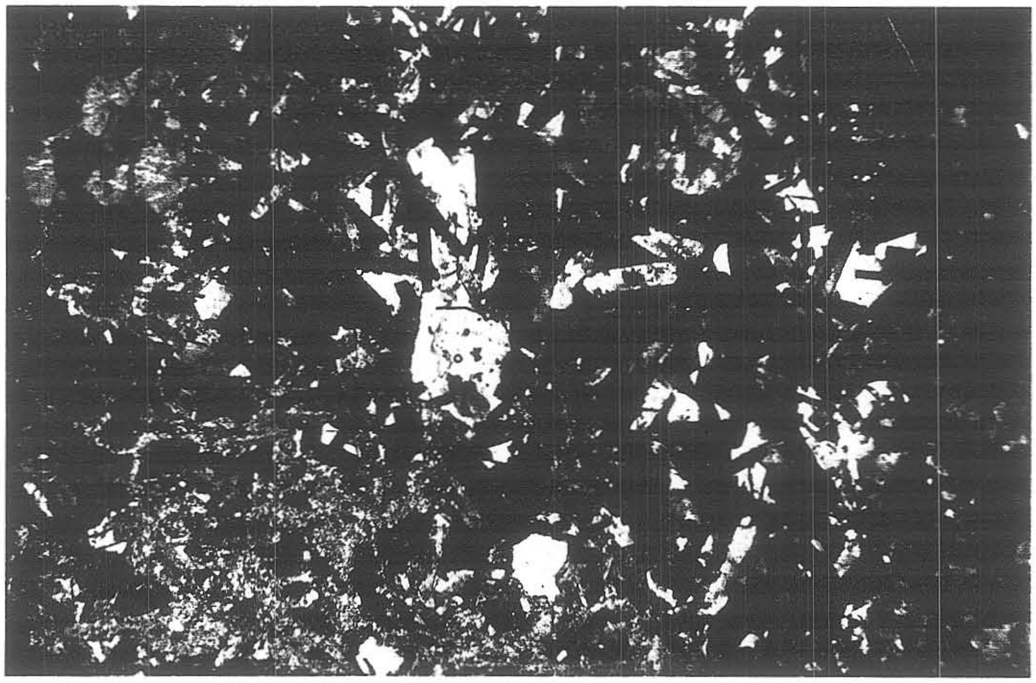
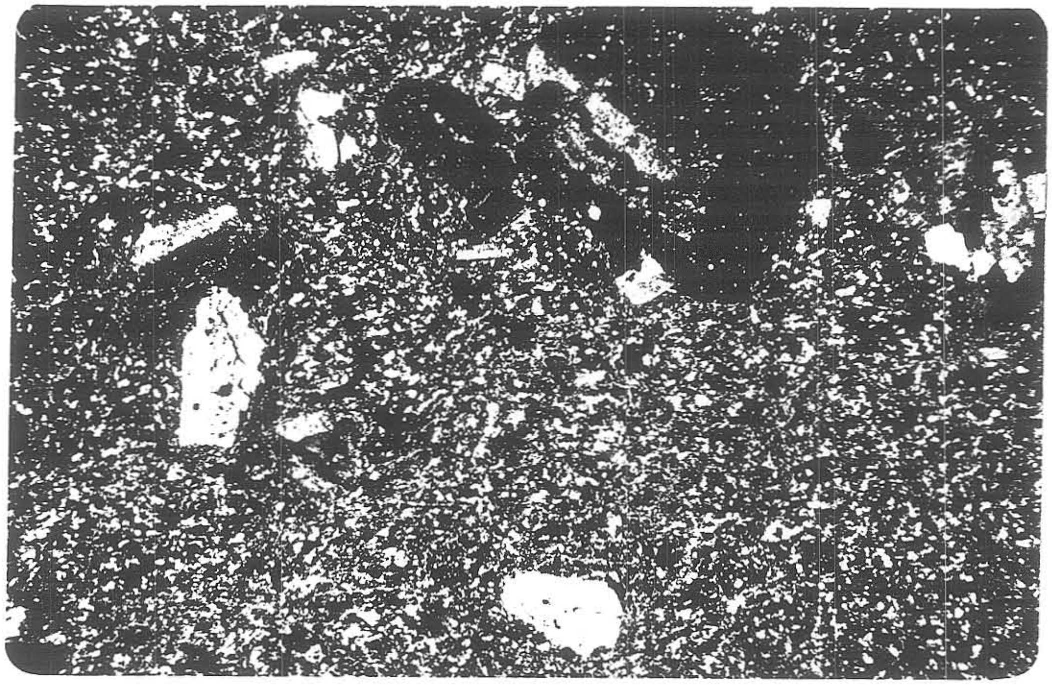


The following five illustrations depict increasing degrees of alteration of plagioclase-phyric volcanics, in particular the development of sericitic assemblages.

33. Specimen MH3. Plagioclase phenocrysts, albitised and lightly flecked with fine-grained sericite. The groundmass is only weakly foliated, and consists of quartz/feldspar, sericite and chlorite.
Crossed nicols; long side = 5 mm.

34. Speciman ST9. Plagioclase phenocrysts, albitised and heavily riddled with fine-grained sericite (note that two phenocrysts are extinct). The groundmass consists of foliated quartz/feldspar and sericite.
Crossed nicols; long side = 4 mm.

33.



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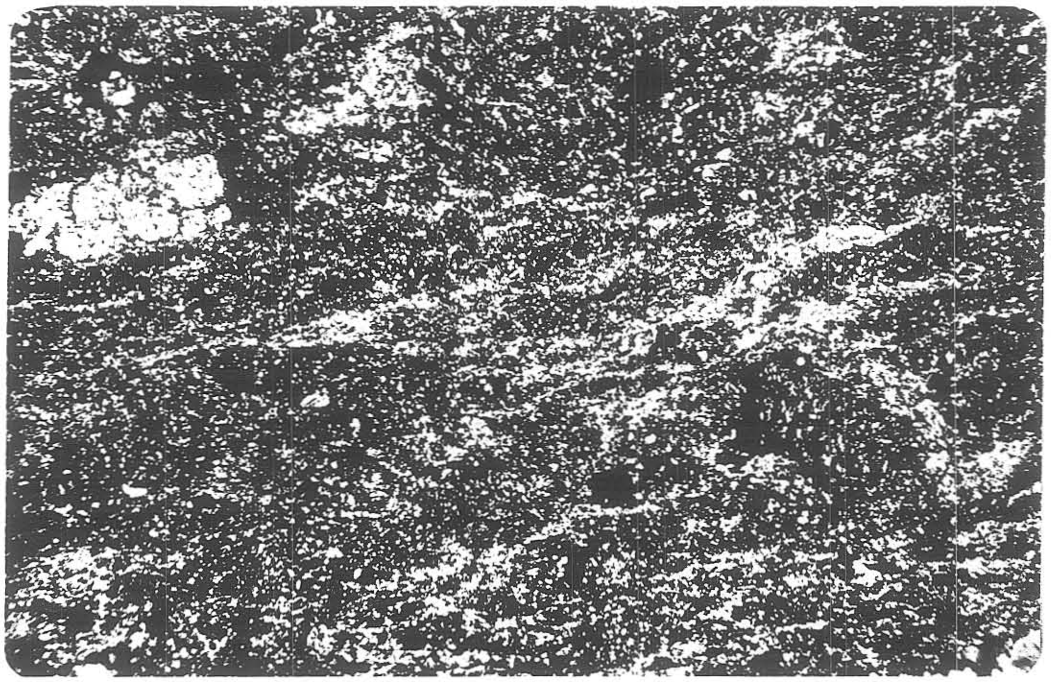
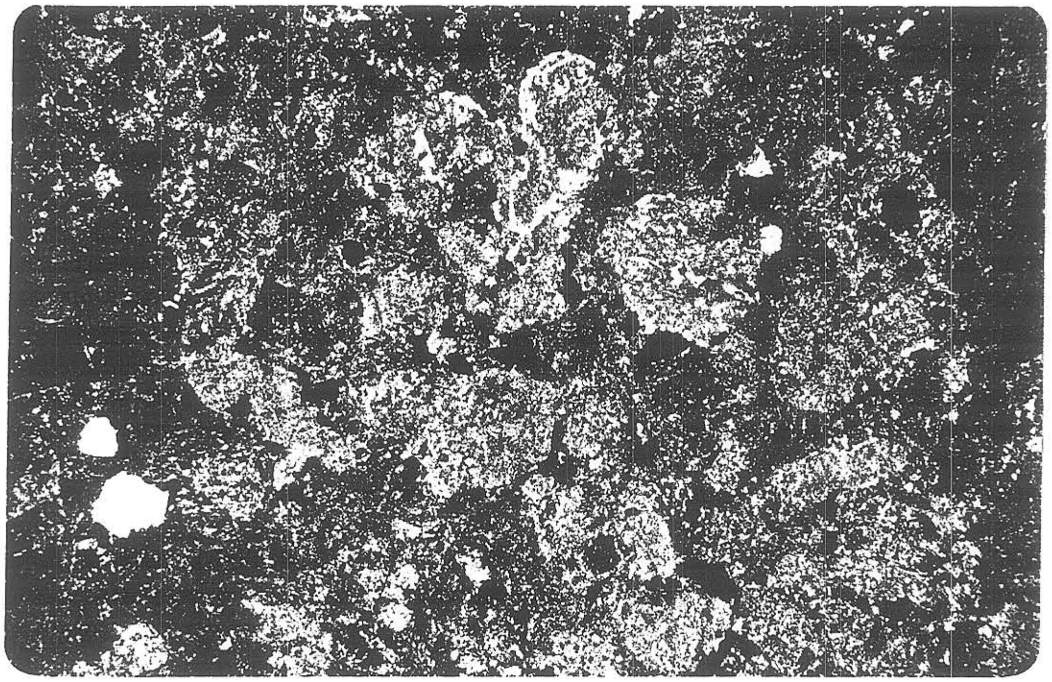


35. Specimen BD6. Advanced sericitisation of plagioclase. The phenocrysts are entirely replaced; only secondary rims and veinlets of albite remain. The light grains are quartz phenocrysts and the black areas are opaque grains and holes. Crossed nicols; long side = 8 mm.

36. Speciman SEO. Quartz-sericite-chlorite rock, after a volcanic rock? The chloritic patches may be replaced phenocrysts.
Crossed nicols; long side = 8 mm.

913107

35.



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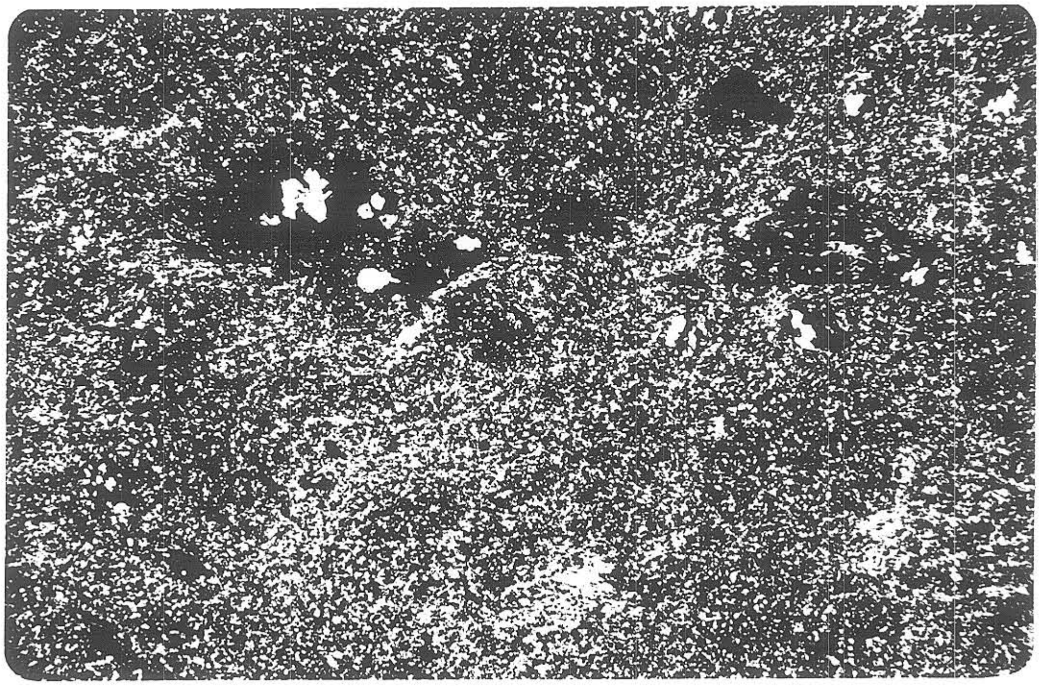
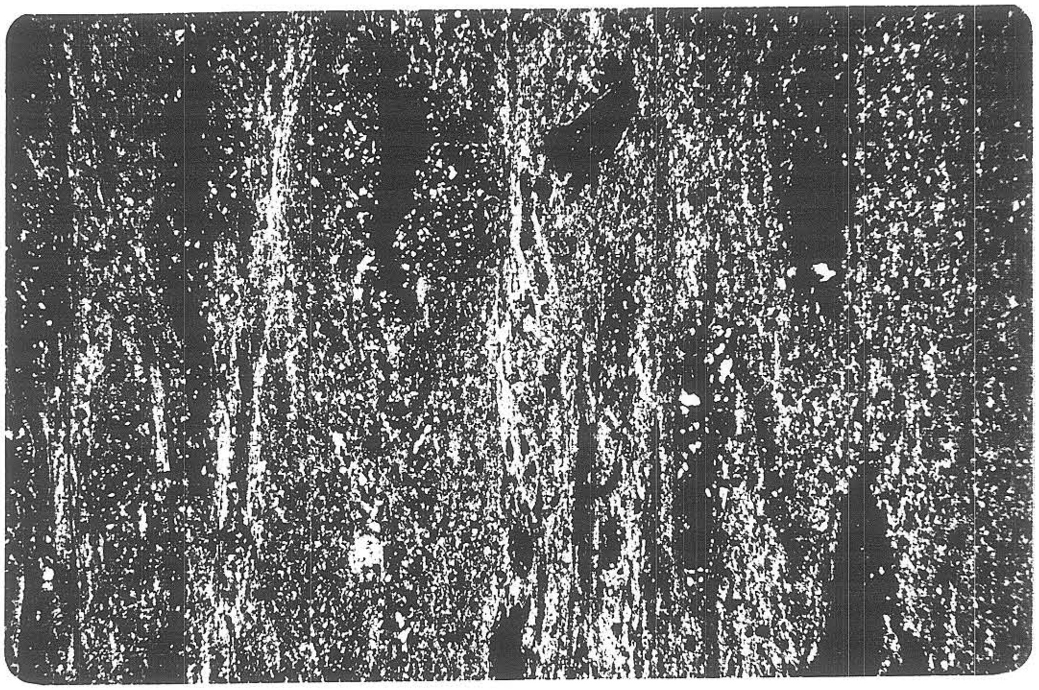


37. Specimen LJ1. Quartz-sericite schist, the product of strong alteration of a volcanic rock. One small plagioclase crystal survives. The dark areas are holes in the section.
Crossed nicols; long side = 6 mm.

37.



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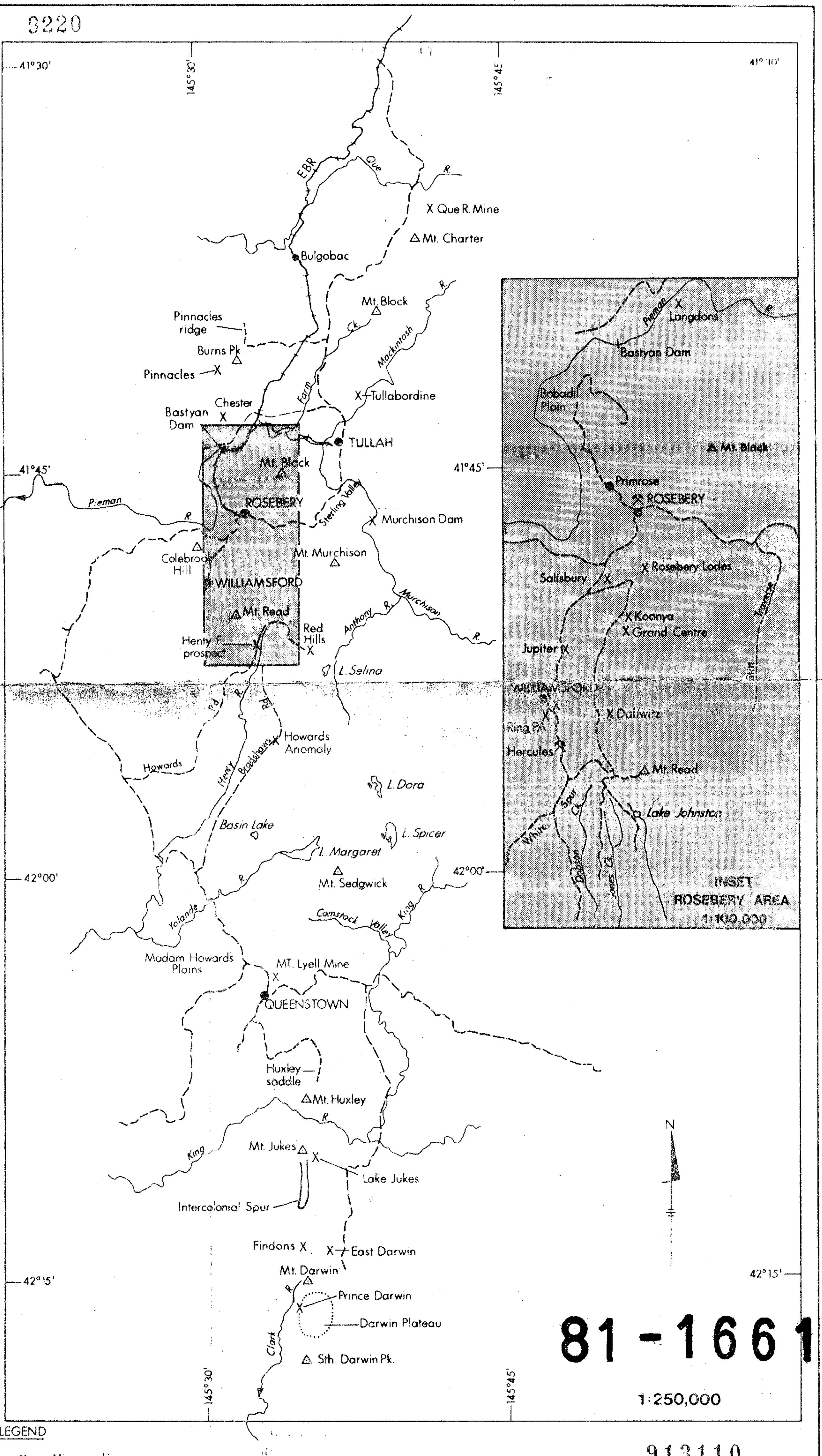

81-1661.

913110

LEGEND

X Mine workings

△ Mountains

Rivers

Roads

● Towns

5 cm

0 5 10 15kms

1:250,000

0 1 2 4 6kms

1:100,000

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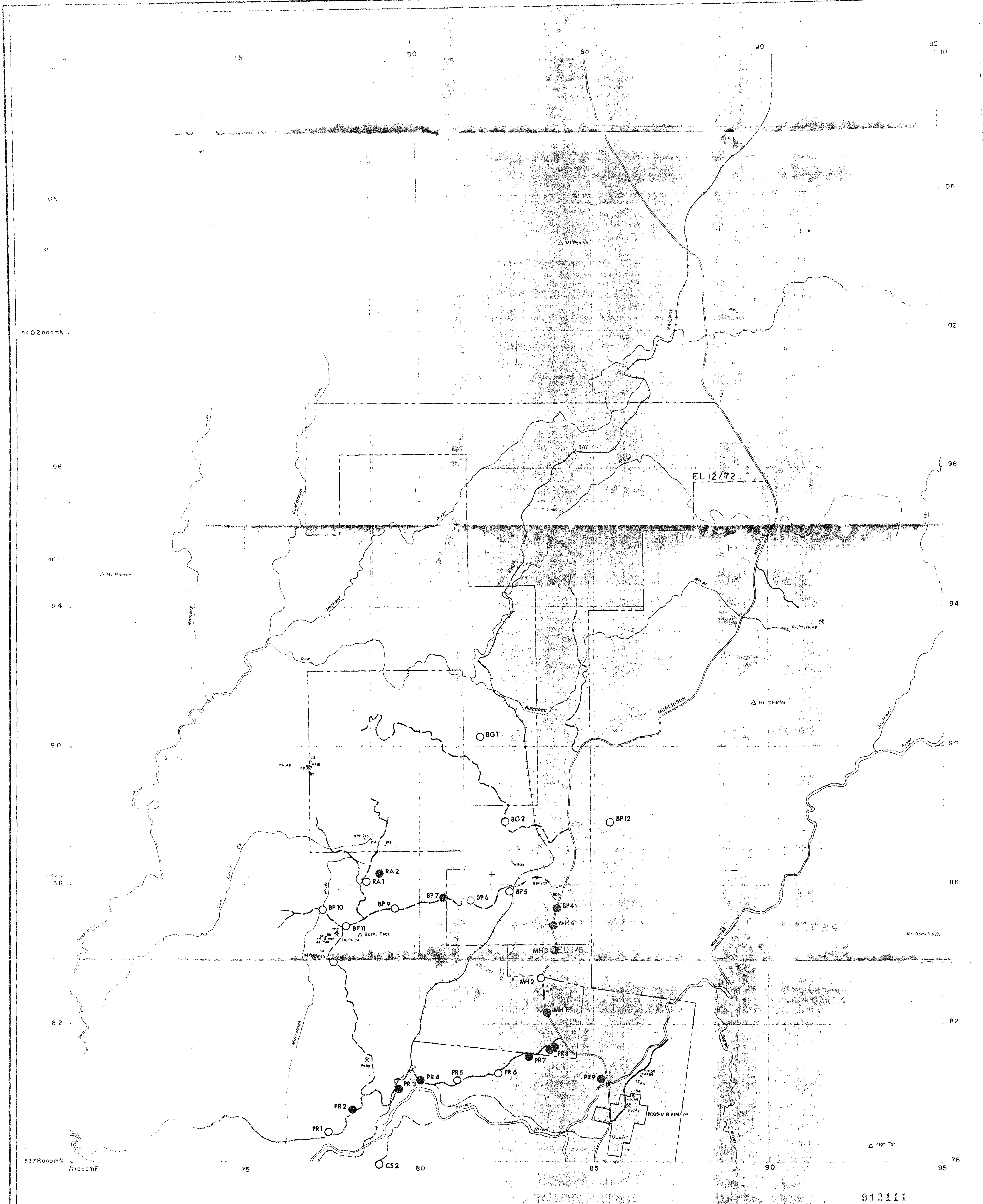
TASMANIA

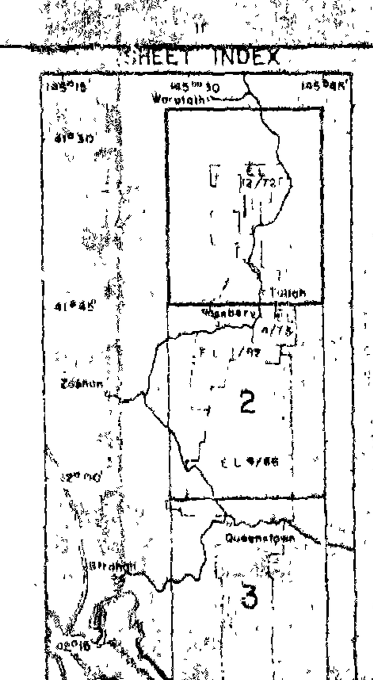
LOCALITY MAP

Author:	C. Eastoe	Scale:	As shown
Drawn:	K. Turner	Date:	Dec. 1981
Revised:		FIGURE No.	1

9221



913111



Notes:- **81-1661**

Scale

0 1 2 3 km

LEGEND

Main Road	Major Mine Working (Hercules Pb Zn Ag Au)	Calcic
Vehicular Track	Major Mine Abandoned	(Calcic from other studies)
River, Creek	Old Workings, Mineral Occurrence	Non – calcic
Railway (abandoned)	Alluvial Workings	Biotite – bearing
Boundary	Diamond Drill Hole	Mottled K - feldspar occurrences
Boundary	Exploration Camp	
Prominent Peak		

5 cm

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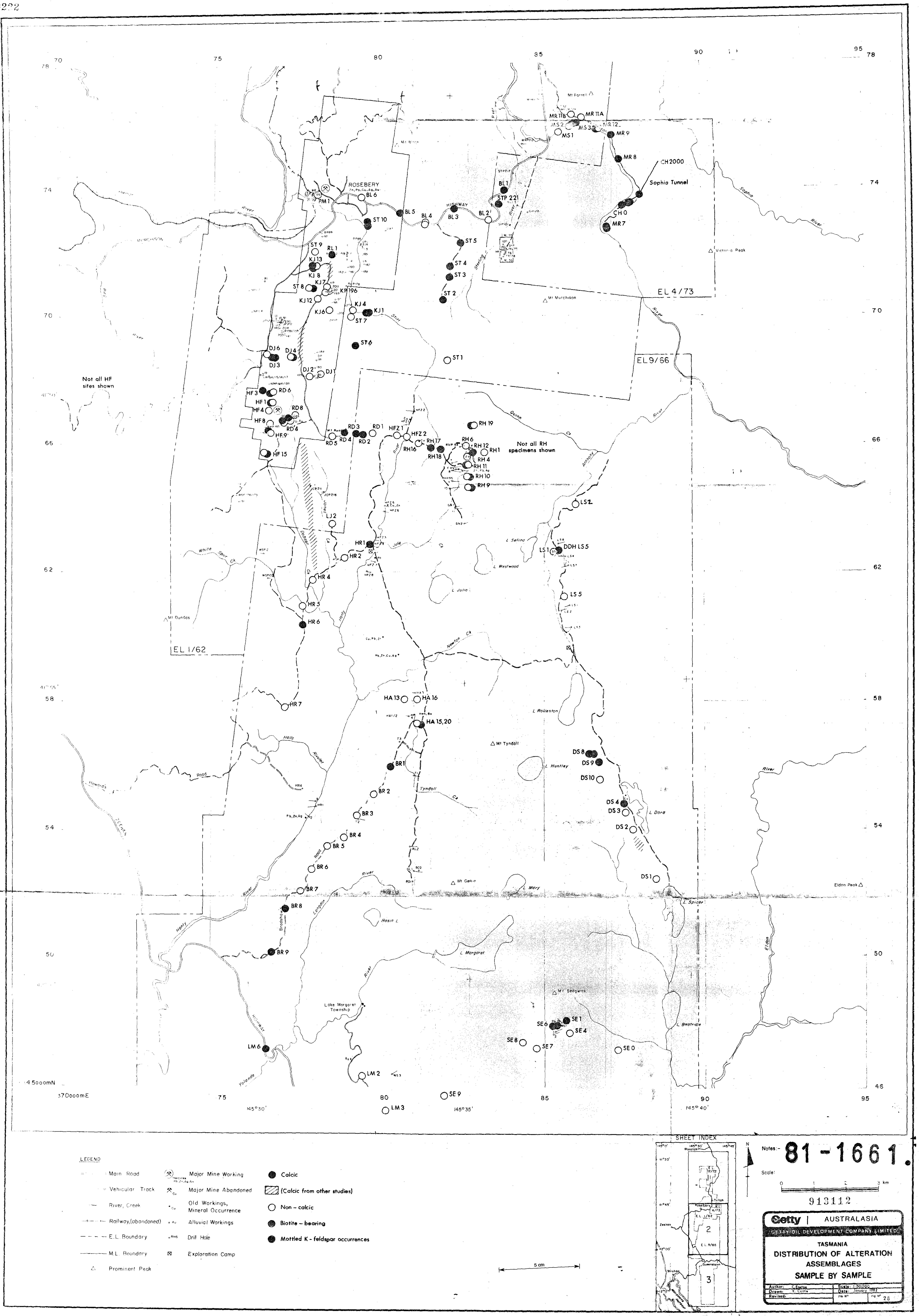
TASMANIA

DISTRIBUTION OF ALTERATION ASSEMBAGES

SAMPLE BY SAMPLE

Author: C. Eastoe	Scale
Drawn: K. Cattle	Date: January 1982
Revised:	File No. / Fig. No. 2A

9222


ROSEBERY
Sophia Tunnel
CH2000
EL 4/73
EL 9/66
EL 1/62
Not all HF sites shown
Not all RH specimens shown
Mt Farrell
Mt Murchison
Victoria Peak
Mt Dundas
Mt Tyndall
Mt Geikie
Mt Sedgwick
Eldon Peak
L. Selina
L. Westwood
L. Julia
L. Rolleston
L. Huntley
L. Dora
L. Mary
L. Spicer
L. Margaret
Basin L.
L. Beatrice
Lake Margaret Township
MR 11B
MR 11A
MS2
MS3
MR12
MS1
MR 9
MR 8
CH 0
MR 7
BL 1
STP 221
BL 6
PM 1
ST 10
BL 5
BL 4
BL 3
BL 2
ST 5
ST 4
ST 3
ST 2
ST 9
RL 1
KJ 13
KJ 8
ST 8
KJ 7
KP 196
KJ 12
KJ 4
KJ 6
ST 7
KJ 1
ST 6
ST 1
DJ 6
DJ 4
DJ 3
DJ 2
DJ 1
HF 3
RD 6
HF 1
HF 4
RD 8
HF 8
RD 4
HF 9
HF 15
RD 3
RD 1
RD 5
RD 2
HFZ 1
HFZ 2
RH 16
RH 17
RH 18
RH 19
RH 6
RH 12
RH 1
RH 4
RH 11
RH 10
RH 9
LS 2
LS 1
DDH LS 5
LS 5
LJ 2
HR 1
HR 2
HR 4
HR 5
HR 6
HR 7
HA 13
HA 16
HA 15,20
BR 1
BR 2
BR 3
BR 4
BR 5
BR 6
BR 7
BR 8
BR 9
DS 8
DS 9
DS 10
DS 4
DS 3
DS 2
DS 1
SE 1
SE 6
SE 4
SE 8
SE 7
SE 0
SE 9
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LM 2
LM 3
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370000mE
145°30'
145°35'
145°40'
LEGEND
Main Road
Vehicular Track
River, Creek
Railway (abandoned)
E.L. Boundary
M.L. Boundary
Prominent Peak
Major Mine Working
Major Mine Abandoned
Old Workings, Mineral Occurrence
Alluvial Workings
Drill Hole
Exploration Camp
Calcic
(Calcic from other studies)
Non - calcic
Biotite - bearing
Mottled K - feldspar occurrences
5 cm
SHEET INDEX
Notes:- 81 - 1661.
Scale
0 1 2 3 km
913112
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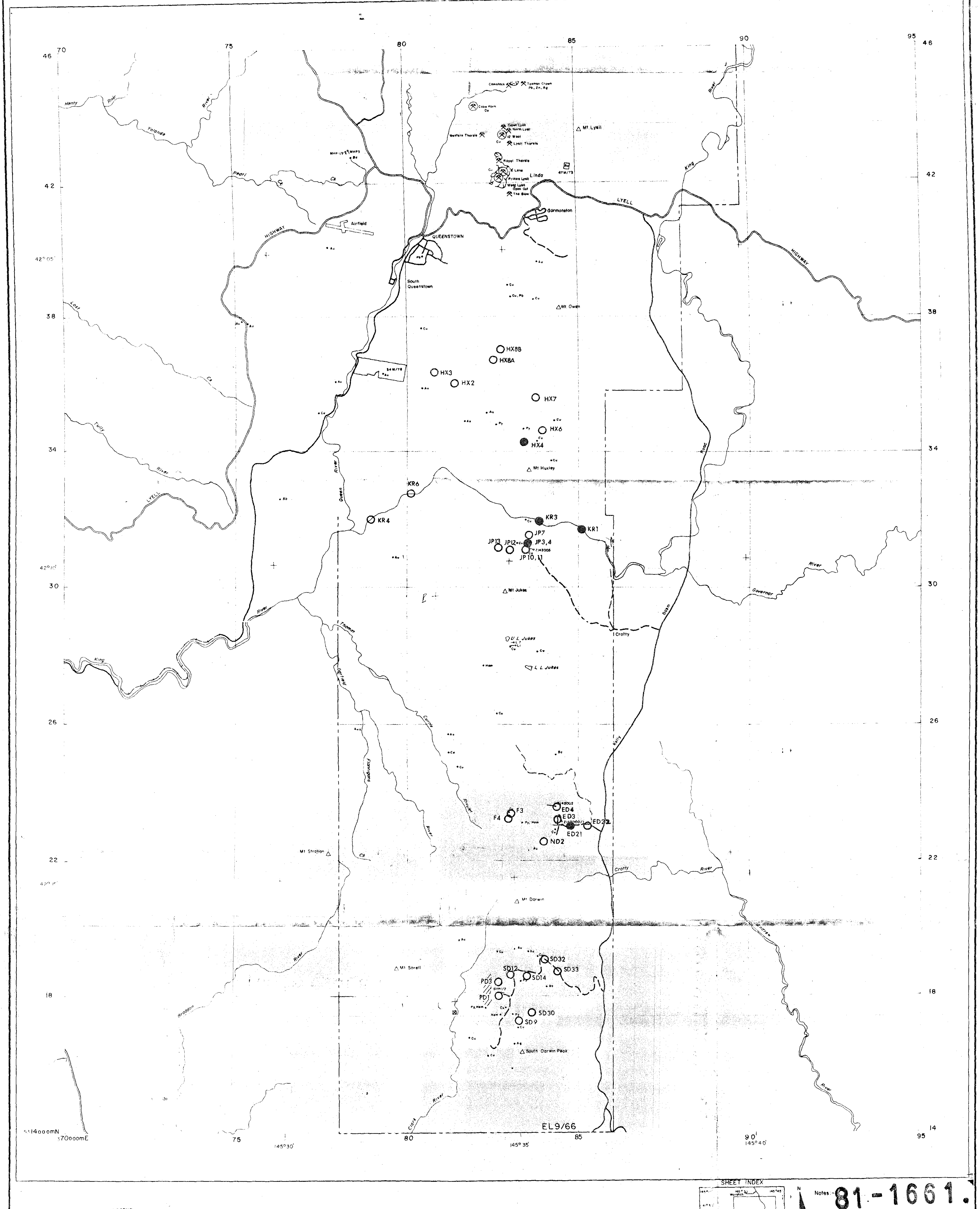
GETTY OIL DEVELOPMENT COMPANY LIMITED
TASMANIA
DISTRIBUTION OF ALTERATION ASSEMBLAGES
SAMPLE BY SAMPLE
Author: C. Eastoe
Drawn: Y. Cottle
Scale: 1:50,000
Date: January 1982

9223



LEGEND

Main Road	Major Mine Working	Calcic
Vehicular Track	Major Mine Abandoned	(Calcic from other studies)
River, Creek	Old Workings, Mineral Occurrence	Non - calcic
Railway,(abandoned)	Alluvial Workings	Biotite - bearing
E.L. Boundary	Drill Hole	Mottled K-feldspars occurrences
M.L. Boundary	Exploration Camp	
Prominent Peak		

5 cm

SHEET INDEX

Notes:- 81-1661.

Scale: 0 1 2 3 km

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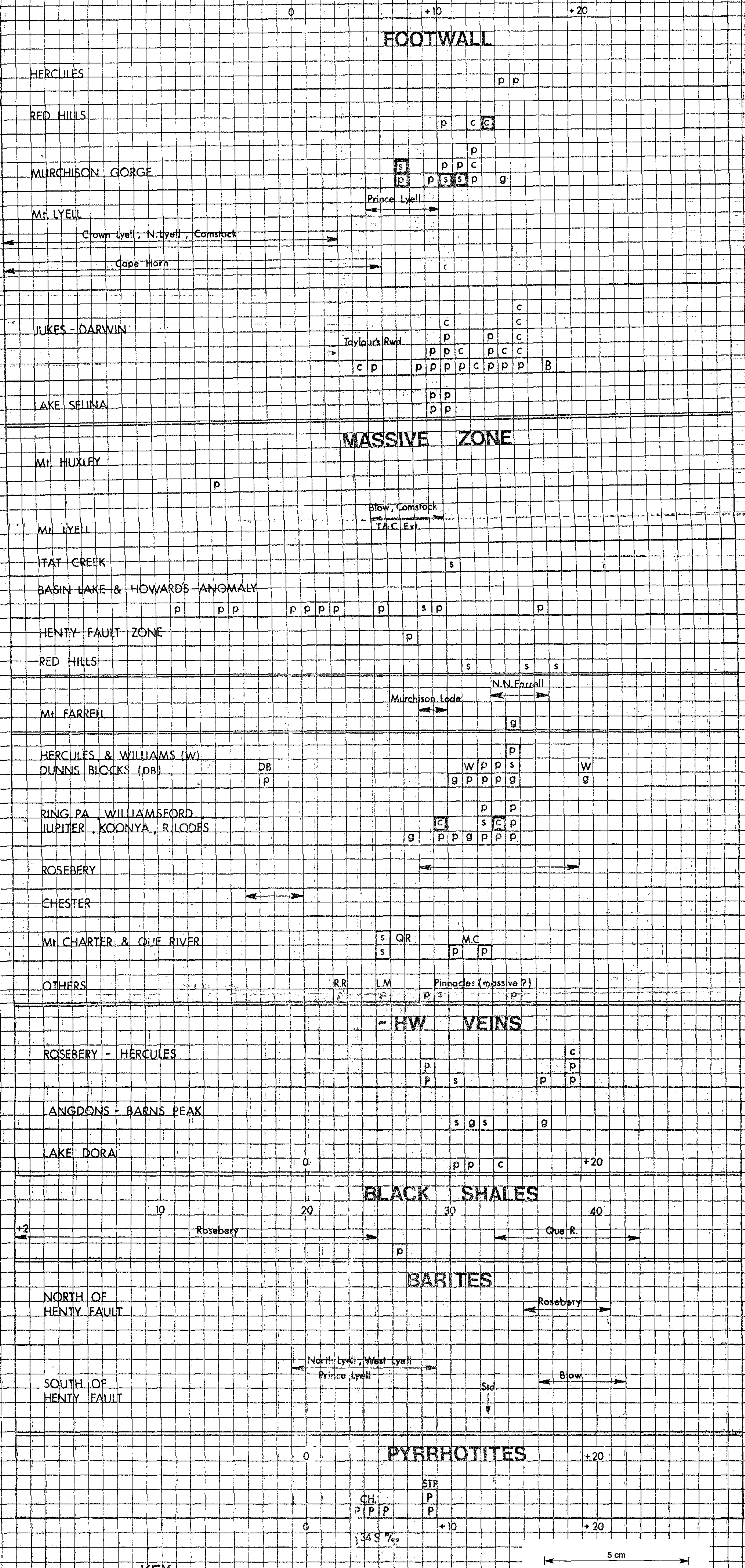
TASMANIA

DISTRIBUTION OF ALTERATION ASSEMBLAGES SAMPLE BY SAMPLE

Author: C. Eastoe	Scale: 1:50,000
Drawn: K. Cottle	Date: January 1982
Revised:	File No. / Fig No. 2C



KEY:

☐	= 1 measurement from this study
p	pyrite
s	sphalerite
g	galena
c	chalcopyrite
B	bornite
P	pyrrhotite
■	remobilised

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GETTY OIL DEVELOPMENT COMPANY LIMITED
TASMANIA

SULPHUR ISOTOPE RESULTS
FREQUENCY HISTOGRAM

Author: C. EASTOE
Drawn: K. TURNER
Revised:
Scale: AS SHOWN
Date: DECEMBER, 1981
Fig Nº 8

9225

81-1661.

913115

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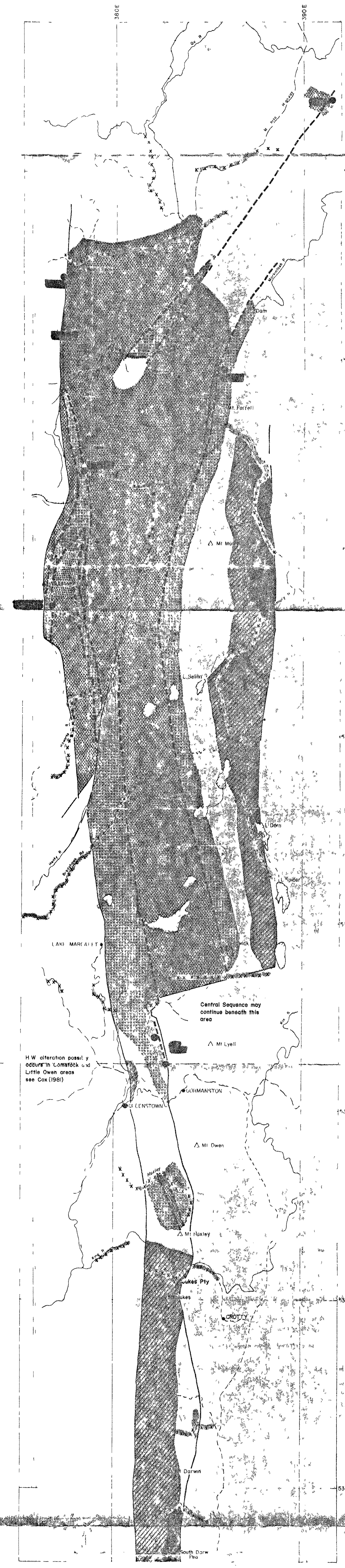
TASMANIA

Mt. READ VOLCANICS

SULPHUR ISOTOPE DATA

Author: C. Eastoe	Scale: 1:100,000
Drawn: K. Cottle	Date: December 1981
Revised:	FIGURE No. 9



81 - 1601

GEOLOGICAL

LEGEND

- Geological boundary Observed
- Geological boundary inferred
- Outcrop Scree or float
- Strike dip of bedding measured
- vertical
- Anticline Overturned
- Syncline Overturned
- Plunge of minor fold
- Unconformity
- Fault
- Shear zone
- Strike dip of joint
- foliation
- cleavage
- Gossan
- Minor mineral occurrence
- Mine prospect
- Costean
- Specimen location
- Diamond drill hole
- Percussion drill hole

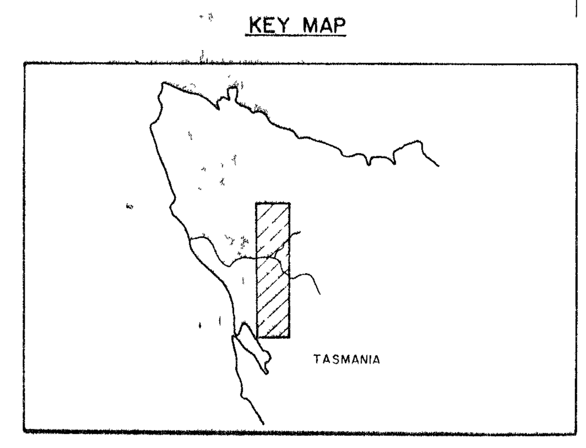
TOPOGRAPHICAL

- Trig station elevation m
- 2WD road
- 4WD road
- Track
- Fence
- Homestead
- Stream
- Railway
- Dam
- Bore
- Lake

GEOPHYSICAL GEOCHEMICAL

- Traverses sampled
- Boundary of Central Sequence
- Host horizon
- Hangingwall
- Shallow footwall
- Deep footwall
- Granite

KEY MAP



Notes – sheet 8013 8014

SCALE

0 5000 10000 metres

5 cm

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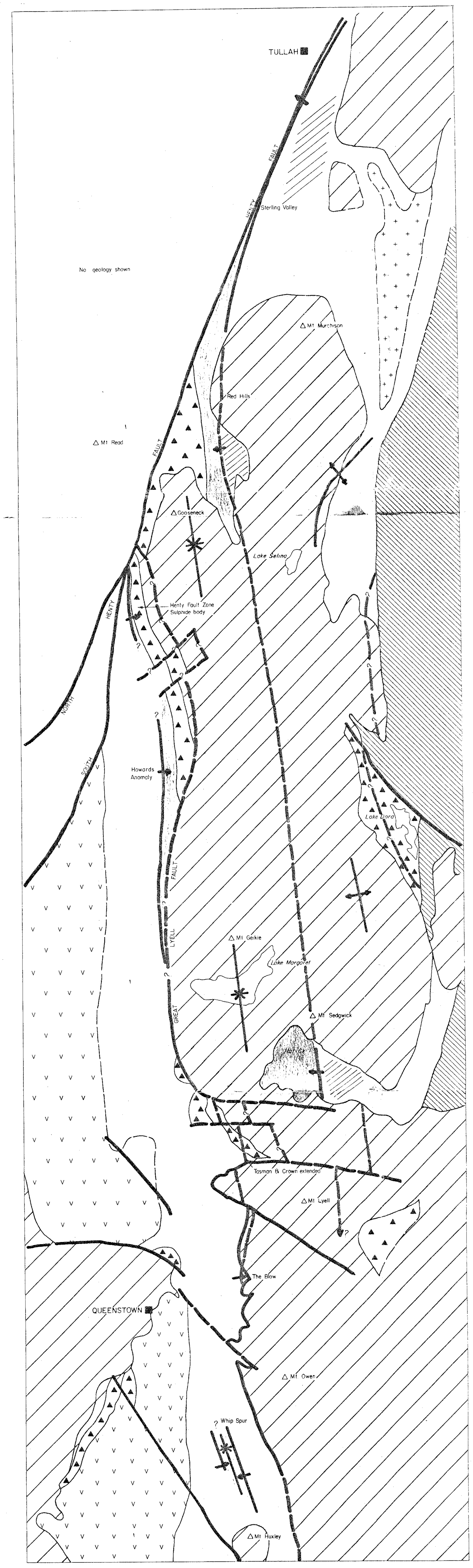
GETTY OIL DEVELOPMENT COMPANY LIMITED

MT LYELL

SKETCH MAP
ATTEMPT AT CLASSIFICATION OF ALTERATION STYLES IN THE CENTRAL SEQUENCE COVER REMOVED (OWEN FM TYNDALL GROUP)

Author C Eastoe	Scale 1 100000
Drawn K Cattle	Date January 1982
Revised	File No. / Fig No. 10

913116



81-1661.

GEOLOGICAL

- Owen Conglomerate (including basal Jukes Breccia) and younger formations
- Comstock Tuff, Dora Conglomerate and correlates
- Western Sequence
- Central Sequence, post mineralisation
- Central Sequence, pre mineralisation ("Darwin type" rhyolites hatched)
- Granite
- Host horizon, with facing
- Host horizon, inferred buried
- Fold axis, inferred in Central Sequence (not in Owen Conglomerate)
- Significant faults
- Formations older than Mt Read Volcanics

LEGEND

- Geological boundary. Observed
- Geological boundary. Inferred
- Outcrop. Scree or float
- Strike, dip of bedding, measured (60°); vertical
- Anticline. Overturned
- Syncline. Overturned
- Plunge of minor fold (20°)
- Unconformity (Younger rocks / Older rocks)
- Fault (F — F)
- Shear zone
- Strike, dip of joint (20°); foliation (30°); cleavage (40°)
- Gossan
- Minor mineral occurrence (• Cu)
- Mine, prospect
- Costean
- Specimen location (X No.)
- Diamond drill hole (D.D. No.)
- Percussion drill hole (P.D. No.)

TOPOGRAPHICAL

- Trig station, elevation m. (△ 150)
- Road
- Vehicle track
- Track
- Fence
- Homestead
- Stream
- Railway
- Dam
- Bore

GEOPHYSICAL GEOCHEMICAL

5 cm

N

Notes:– After Corbett et al [illegible] 1981 with additions

SCALE

KEY MAP

913117

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GETTY OIL DEVELOPMENT COMPANY LIMITED

POSSIBLE STRUCTURE
CENTRAL SEQUENCE
MT. READ VOLCANICS

Author: C Eastoe	**Scale:** 1 63,360
Drawn: K Turner	**Date:** June 1981
Revised:	**File No.** 4400/36 — **Fig. No.** 11

ALTERATION AND MINERALISATION IN THE MT. READ VOLCANICS WESTERN TASMANIA

C.J. EASTOE

Appendices 1-6

VOLUME II

E.L. 9/66

Appendix 1: Petrographic Descriptions

Contents

The descriptions are arranged area by area, from north to south.

Explanation: Petrographic observations are divided as far as possible into primary and secondary features, the latter including devitrification phenomena.

Quartz and feldspar, where fine-grained in the groundmass, are commonly difficult to distinguish. In such cases, the groundmass mineral or minerals are recorded as quartz/feldspar. Similar considerations apply for rutile and sphene.

BULGOBAC AREA

BG1. Outcrop: Pink to brown, massive feldspar and quartz prophyry.

Thin section:

Primary features: Large phenocrysts of plagioclase (predominating) and deeply embayed quartz are set in a groundmass of fine to medium grain. One plagioclase phenocryst has a prominently marked outer zone. There is accessory zircon and apatite, some included in plagioclase phenocrysts.

Secondary features: The plagioclase phenocrysts are albitic, and are flecked with minute crystals of sericite. Several bear small patches of clinozoisitic epidote. The groundmass texture may be secondary. Quartz of medium grainsize and subtesselate texture is set in a fine-grained mixture of quartz/feldspar, sericite, rutile and Fe-oxide (the last imparting a brownish turbidity). Hemitite or goethite replaces what may have been primary grains of magnetite.

Identification and discussion: a rhyolitic porphyry of indeterminate origin. An intrusive origin has been suggested, but cannot be confirmed on the basis of textures in this specimen.

BG2. Outcrop: Pink volcanic rock interbedded with laminated sandstones, sillstones and shales.

Thin section: Primary features: Small, rather ragged phenocrysts of feldspar and subordinate quartz are set in an originally-glassy groundmass with accessory zircon.

Secondary features: The plagioclase phenocrysts are lightly flecked with fine-grained sericite. The groundmass bears sparse spherulitic devitrification centres in a fine-grained intergrowth of albite (and quartz?) grains of irregular shape, size and extinction. There is a little rutile, and veins of an orange-weathered material cut the specimen.

Identification: a rhyolitic to dacitic volcanic rock, possibly a lava.

113

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BURNS PEAK ROAD

Order east to west

RA1, 2 / E BP12, 4, 5, 6, 7, 9, 11, 10 \ BP2

BP2. Outcrop: Pinkish volcanic rock with chloritic patches.

Thin section: Primary features: Plagioclase phenocrysts and glomerocrysts, commonly broken, are abundant in a eutaxitic groundmass with much bent and flattened pumice and accessory zircon.

Secondary features: The plagioclase phenocrysts bear radial clusters of chlorite crystals, and minor sericite as veinlets and a few, scattered, separate, small crystals. The groundmass consists largely of fine - grained quartz/feldspar. The grain is coarser in those areas where pumice-structure is preserved. The primary foliation of the pumice is marked by sericite. Chlorite and fine-grained rutile are scattered throughout. The chlorite has P:green to light yellow; AIC purple to blue.

Identification: a plagioclase-phyric ash-flow tuff.

BP4. Outcrop: Hard, light green volcanic rock, (?)siliceous with sericite and chlorite fragments (fiamme?) and minor disseminated pyrite.

Thin section: Primary features: Phenocrysts of plagioclase and angular grains of quartz, which may be broken phenocrysts are set in a fine-grained groundmass with accessory apatite and vague shard-shapes. Clasts of volcanic rock, plagioclase porphyry, are present. The coarser-grained opaques - weathered magnetite? - may be primary.

Secondary features: The plagioclase phenocrysts are riddled with fine-grained sericite crystals, and are veined with recrystallised albite. A few bear crystals of clinozoisite. The groundmass consists of irregular relatively coarse-grained intergrowths of albite, clinozoisite, rutile, (pyrite and quartz, with local fine-grained patches of quartz/feldspar with or without sericite. Opaques seem abundant in transmitted light, and make the section turbid, but in reflected light only scattered grains of pyrite, rutile and magnetite are observed. Patches of sericite have a yellowish, oxidised colour.

Identification: a quartz - and plagioclase - phyric lithic crystal vitric tuff.

BP5. Outcrop: Fine-grained pink to brown, massive volcanic rock with abundant fine-grained pyrite.

Thin section: Primary features: Plagioclase phenocrysts and glomerocrysts occur in a fine-grained groundmass, probably once glassy, with accessory zircon.

Secondary features: The plagioclase phenocrysts bear pyrite euhedra and rutile/sphene, and are extensively altered to sericite where pyrite occurs. Otherwise, fine-grained sericite and recrystallised albite are the alteration products of the phenocrysts. In the groundmass, quartz/feldspar occurs as ragged intergrown crystals. Sericite ranges from a minor component along grain boundaries to the chief component of certain patches. Pyrite and rutile are scattered throughout, and most of the groundmass pyrite is not associated with sericite. Coarser-grained patches of quartz and albite are scattered irregularly through the groundmass, and appear to be associated with pyrite. One small flake of chlorite was observed replacing plagioclase in a phenocryst. Veins of quartz, albite and sericite and one vein of albite only cut the specimen.

Identification: a plagioclase-phyric volcanic rock, possibly a lava.

BP6. Outcrop: A hard, massive, volcanic rock consisting of pink blocks (?) in a green matrix.

Thin section: Primary features: A few plagioclase phenocrysts and accessory zircon occur in a fine-grained groundmass with a superimposed cellular texture, probably the result of perlitic cracking. The cracks are even in distribution and the resulting cells are of much the same size, but the cracks are rarely branched or concentric.

Secondary features: The plagioclase phenocrysts are riddled with fine-grained sericite. The groundmass consists largely of intergrown quartz/feldspar crystals within the cells, and sericite marking the cracks. In some cells, or band of feldspar lines the inside of the crack and surrounds a polycrystalline intergrowth without structure. Chlorite and rutile also occur in the groundmass. Abundant fine-grained high-relief crystals imparting a turbidity may be rutile. The chlorite has P:green to pale yellow; AIC: yellow-grey, weathered.

Identification: a plagioclase-phyric, originally glassy rhyolitic to dacitic lava.

BP7. Outcrop: Massive, hard, light-grey feldspar-phyric volcanic rock with disseminated pyrite.

Thin section: Primary features: Plagioclase phenocrysts are abundant in a vesicular, finer-grained groundmass with a cellular texture probably due to perlitic cracking (cf BP6, BL6). Accessory apatite and zircon occur as inclusions within phenocrysts. Large Fe-oxide grains are probably primary.

Secondary features: The plagioclase phenocrysts are riddled with fine-grained sericite and also bear epidote. The vesicles are filled with quartz in radial array with microinclusions of sericite at the centres. The Fe-oxide grains now consist apparently of fine-grained goethite. The groundmass consists of an intergrowth of ragged grains of quartz/feldspar with abundant epidote, sericite (marking the perlitic cracks), rutile, (?) Fe oxides and minor chlorite and pyrite. There are scattered large grains of rutile. The finer-grained rutile and (?) Fe - oxides impart a turbidity in some areas. The chlorite has P:pale greens, AIC: yellowish-greys (weathered ?).

Identification: a plagioclase-phyric, vesicular, originally glassy rhyolitic to dacitic lava.

BP9. Outcrop: Felspar-phyric, grey-green agglomerate, enclosing a partly-disrupted lens of shale.

Thin section: Primary features: The larger primary clasts include rounded quartz grains, large, heavily altered plagioclase feldspars (some within lithic clasts) and sharply-rounded clasts of sandstone. The matrix contains abundant small, spherical quartz grains, and much finer-grained material.

Secondary features: Most of the large quartz grains and some of the smaller ones have overgrowths of quartz not in optical continuity with the nuclei. The material between discrete grains includes sericite (which marks the cleavage), quartz of very irregular extinction and sheaves of low-birefringent crystals (clay on chlorite ? - the section is too thin). A few of the primary grains may include small pyrite crystals. Grains of rutile are attached to some primary quartz grains.

Identification: A lithic agglomerate with an impure quartz sandstone matrix; some tuffaceous input.

BP10. Outcrop: a light green, quartz-feldspar-phyric rock with chloritic patches and fragments resembling fiamme.

Thin section: Primary features: Abundant plagioclase phenocrysts and broken, embayed phenocrysts of quartz occur in a fine-grained groundmass. Accessory zircon occurs as groups of small crystals. Patches of weathered phyllosilicate with rutile and zircon may represent phenocrysts of other varieties.

Secondary features: The plagioclase phenocrysts are sparsely dusted with fine sericite. Other replacement minerals include minor chlorite and recrystallised albite. The groundmass consists of fine-grained quartz-feldspar, sericite, oxidised chlorite (P:brownish colours; AIC:orange) and much fine-grained rutile. It is not heavily sheared. Recrystallised albite occurs as discontinuous veinlets and relatively coarse-grained patches also containing yellow, weather phyllosilicate in the groundmass, and as pressure shadows to plagioclase phenocrysts. Clusters of larger rutile crystals, and a large area of chlorite and rutile are also present in the groundmass. The chlorite in that patch is less weathered, and has P:light greens; AIC yellow-greys.

Identification: a plagioclase - and quartz-phyric (?) rhyolite , of indeterminate origin.

BP11. Outcrop: Light grey-green, fine-grained quartz-sericite rock with disseminated pyrite.

Thin section: Primary features: A few grains of monocrystalline quartz (phenocrysts?) and rounded bodies of polycrystalline quartz, subradial in arrangement, some bearing muscovite also, are scattered sparsely across the section. The polycrystalline bodies may be filled vesicles. The groundmass is very fine-grained.

Secondary features: The groundmass consists mainly of fine-grained/ feldspar, sericite and groups of rutile crystals. It is stained with goethite. One quartz grain may include a crystal of pyrite. The cleavage is poorly developed, and is marked by sericite.

Identification: a much-altered vesicular lava?

BP12. Outcrop: Hard, light pink volcanic rock with small (?) feldspar phenocrysts and small chloritic patches. Weathered.

Thin section: Primary features: Phenocrysts of embayed quartz and feldspar (mostly replaced or entireley polished out) are set in a fine-grained groundmass which may have been glassy.

Secondary features: The feldspar phenocrysts (where one can see) are partly replaced by sericite. The groundmass is very turbid, and consists of quartz/feldspar, scattered grains of sericite, many minute crystals of high relief (rutile?) and a Fe-oxide which is probably responsible for the turbidity. The ragged, equidimensional grains of quartz/feldspar may be devitrification products. Patches of coarser-grained quartz contain two-phase (liquid + gas) fluid inclusions and are associated with a mineral of acicular or micaceous habit. The mineral is pleochroic, colourless to yellow-green or brownish, has straight extinction and high second-order interference colours. It occurs in yellowish (oxidised) patches possibly replacing phenocrysts. (microprobe analyses indicate a composition higher in silica than most chlorites in the volcanics. This may be a clay.

Identification: a quartz - and feldspar-phyric volcanic rock, possibly a lava.

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RA1. Outcrop: Massive, light-brown (?) lava with dark green spots (after ferromagnesian phenocrysts?) and vague flow-banding.

Thin section: Primary features: Plagioclase phenocrysts and (?) hornblende phenocrysts pseudomorphs are set in a fine-grained groundmass with no microscopic primary texture.

Secondary features: Plagioclase phenocrysts bear relatively unaltered overgrowths of albite in optical continuity. One zone of the phenocrysts is characteristically altered to yellow to orange weathered phyllosilicate. Otherwise, sericite and the weathered phyllosilicate (clays after chlorite) occur as scattered grains riddling the phenocrysts. The (?) hornblende pseudomorphs consist of radial growths of sericite and chlorite at the centre, rimmed by orange, weathered phyllosilicate (clay after chlorite?) and this in turn is rimmed by fine-grained sericite. The groundmass consists of fine-grained, equant, irregular quartz/feldspar with yellow, weathered phyllosilicates and scattered rutile/sphene. There are abundant spherical bodies of radial structure, micropoikilitic, with irregular extinction and in some cases enclosed within a single crystal of quartz. These are probably centres of divitrification. A coarse-grained patch of quartz, rutile/sphere and yellow phyllosilicate occurs in the groundmass.
The chlorite at the centres of the hornblende pseudomorphs has P:bluish green to colourless; AIC none (grey).

Identification: a plagioclase - and hornblende-phyric (?) lava.

RA2. Outcrop: a course-grained crystal lithic tuff consisting of abundant white feldspar and quartz crystals and large blocks of white (?) lava and black pumice.

Thin section: Primary features: Abundant phenocrysts of plagioclase and quartz, and lithic fragments including tuffaceous sandstone, lava or intrusive equivalent and pumice, occur in a fine-grained groundmass with accessory zircon. The quartz phenocrysts are embayed and broken. The feldspars are turbid so that twinning is not easy to distinguish. Some show twinning characteristic of plagioclase. Others may be only simply twinned. The pumice fragments are deformed, apparently by compaction between other grains.

119

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Secondary features: The plagioclase phenocrysts are riddled with fine-grained sericite, and veined and rimmed with recrystallised albite. Clinozoisite occurs as a minor alteration product of the phenocrysts. Some of the pumice fragments are chloritised. The groundmass is in part recrystallised and consists of albite, chlorite, clinozoisite (as sheaves and individual equant crystals), sphene and locally, calcite in coarse-grained patches. Elsewhere, it consists of fine-grained quartz/feldspar.
The chlorite is not strongly pleochroic, having P:pale greens; AIC: bluish-grey.

Identification: a crystal-lithic ash-fall tuff.

MURCHISON HIGHWAY

(Pieman Road to
Burns Peak Road)

MH1. Outcrop: Massive, splintery, dark green, feldspar-phyric lava with pink bands and large angular pink clasts of volcanic rock. There is minor pyrite.

Thin section: Primary features: In the pink clast intersected, plagioclase phenocrysts and glomerocrysts, and scattered grains of pyrite (primary?) occur in a fine-grained, predominant groundmass. In the matrix portion of the section, plagioclase phenocrysts occur in a fine-grained, predominant groundmass.

Secondary features: In the pink clast, the plagioclase phenocrysts bear calcite and chlorite as alteration products. The groundmass consists of very fine-grained, irregular, intergrown quartz/feldspar with a few small patches of calcite and scattered fine-grained rutile and chlorite. One large pyrite crystal may bear a little chalcopyrite.
The groundmass is similar, except in showing some relatively coarse snowflake texture and containing more chlorite and larger opaques. The opaques are mainly rutile and magnetite, and there is only a little very fine-grained pyrite. One grain has an opaque rim and centre with an intervening zone of silicates.
The chlorite has P:bright green to yellowish; AIC:greenish-grey. The chlorite in the matrix is mostly browner than that in the clast, and has interference colours up to low second-order. This is probably due to weathering.

Identification: a blocky, plagioclase-phyric (?) lava.

MH2. Outcrop: Massive, somewhat weathered, light-green volcanic rock with pink to white feldspar phenocrysts. Some minor varieties contain dark green wisps.

Thin section: Primary features: Feldspar phenocrysts, mostly polished away, are set in a fine-grained groundmass with accessory zircon. Abundant, relatively large grains of rutile may also be primary.

Secondary features: A little plagioclase (presumably albite) remains from some phenocrysts, and sericite is the only alteration product present. There is no sign of calcium minerals. In the groundmass, there are irregular bodies of polycrystalline quartz set in fine-grained quartz/feldspar with sericite and rutile. Some parts of the groundmass have a texture suggesting snowflake devitrification. this appears to surround some of the bodies of quartz. Sericite occurs as a network of irregular veinlets. Some yellow phyllosilicate material may be weathered chlorite.

Identification and discussion: A plagioclase-phyric volcanic rock, possibly a lava. The quartz bodies, being surrounded by devitrification textures, could be primary but do not otherwise resemble primary bodies. They may be due to secondary silicification.

MH3. Outcrop: Massive pink-and-green feldspar-phyric volcanic rock with chloritic spots, streaks and (?) vesicles. Some (?) vesicles are filled with silica.

Thin section: Primary features: Phenocrysts and glomerocrysts of plagioclase are abundant in a fine-grained groundmass with a cellular texture probably due to perlitic cracking. A possible lithic fragment, large magnetite grains, some chloritic bodies (possibly after ferromagnesian phenocrysts) and accessory apatite and zircon are present.

Secondary features: Alteration products of the plagioclase phenocrysts include epidote (probably clinozoisitic), opaques, chlorite and sericite, the last as veinlets and fine-grained crystals. The groundmass consists of quartz/feldspar, chlorite, edidote, sericite, rutile and rare pyrite, all forming a fine-grained, irregular intergrowth possibly after glass. Rutile occurs locally in groups of grains, and some patches of groundmass are relatively rich in chlorite. Sericite occurs also as veinlets. There is no obvious foliation.
The chlorite has P:bright green to pale yellow; AIC:bluish to purplish grey.

Identification: A feldspar-phyric volcanic rock, possibly a lava.

MH4. Outcrop: A coarse fragmental volcanic rock with pink and white blocks in massive, hard, green feldspar-phyric groundmass.

Thin section: Primary features: Phenocrysts of plagioclase and large fragments of devitrified volcanic rock occur in a fine-grained matrix/groundmass. The texture of the groundmass differs from the textures of the lithic fragments. Some large pyrite grains may be primary.

Secondary features: The plagioclase phenocrysts bear a little sericite and very little calcite as alteration products, and are somewhat turbid. The plagioclase is albitic, and some of the albite is recrystallised. The groundmass is an intergrowth, irregular in grain-size and grain-shape, of quartz/feldspar with sericite, chlorite, calcite and rutile. Patches relatively rich in chlorite, sericite, calcite and albite occur locally. Most of the sericite is very fine-grained, occurring on the grain boundaries of quartz/feldspar crystals; there are also scattered larger crystals and veinlets. Shearing is slight.
The chlorite has P:green to pale yellow: AIC:bluish-grey.

Identification: A feldspar-phyric volcanic agglomerate on blocky lava.

PIEMAN ROAD

PR 1B. Outcrop: a green, heavily-sheared volcanic rock with local traces of original feldspar phenocrysts. The rock is pyritic, and is veined with quartz and chlorite. There are vague wispy chloritic patches.

Thin section:

Primary features: A possible embayed quartz phenocryst and minor zircons are set in a fine-grained groundmass.

Secondary features: The rock consists largely of quartz, sericite chlorite, pyrite and rutile/sphene. The phyllosilicates mark the foliation and are wrapped around equigranular poikilitic grains of quartz. This "equigranular poikilitic" texture may be the product of deformation of snowflake devitrification texture. The grains of quartz are polycrystalline; some consist of a poikilitic over growth on an angular fragment. Some quartz grains have chloritic beards. Sericite is more abundant than chlorite. Both occur in association with veins (which pre-date the foliation) as does pyrite. The pyrite crystals have beards of quartz and chlorite. A quartz vein cuts a chlorite-bearing vein. Many fine-grained opaque crystals have not been identified.
Only one variety of chlorite is distinguished on optical properties. Pale-green to yellow-green, AIC:blue-grey.

Identification: possibly a vitric-crystal ash-flow rhyolitic tuff.

PR 2A. Outcrop: A sheared pink volcanic rock, with chloritic patches (the remains of original fragments?). Sulphides are associated with small chloritic blebs. Elsewhere, coarse pink fragments of volcanic rock are visible. Basic dykes intrude the volcanics in this area.

Thin section: (slightly too thick).

Primary features: Plagioclase phenocrysts are set in a fine-grained, foliated groundmass. Some of the foliation is probably due to bent, flattened pumice.

Secondary features: The phenocrysts are patchily altered to chlorite and calcite. Remaining plagioclase is albitic. Sericite veins cut some phenocrysts, and most have rims of fine sericite crystals. The groundmass consists mainly of fine-grained quartz/feldspar, sericite and lesser calcite (as rhombs) and chlorite. A large patch of calcite and chlorite may represent a completely replaced phenocryst. It is veined by sericite, which therefore belongs to a later stage of alteration.
There is one variety of chlorite, P:bright green; AIC:green to purple-grey.

Identification: vitric-crystal ash-flow tuff/agglomerate.

R 3. Outcrop: A coarse-grained fragmental rock of green, quartz-feldspar phyric blocks in a dominant, darker-green, quartz-feldspar phyric groundmass. The groundmass may have a primary foliation. One weathered rock face shows a wispy pattern suggestive of an ash-flow origin.

Thin section: (matrix or fragment?).

Primary features: Plagioclase phenocrysts and glomerocrysts and quarts grains generally smaller that the plagioclase occur in a fine-grained groundmass. The number, small size and angular shapes of some of the quartz grains suggest that they may be broken phenocrysts.

Secondary features: The plagioclase phenocrysts are albitic where plagioclase remains, but have commonly been replaced up to 100% by calcite, chlorite and sericite. Commonly, the calcite is rimmed by chlorite, and the chlorite (and any exposed albite) by sericite. The groundmass consists of fine, poikilitic quartz (and feldspar?) with sericite, calcite and minor chlorite. Pyrite and rutile/sphene occur as abundant small crystals and intergrowths, and one not associated with any alteration mineral in particular. There is one variety of chlorite. P:green to yellowish, AIC:blue-grey-green.

Identification: quartz-and feldspar-phyric rhyolitic volcanic, whether an ash-flow tuff/agglomerate or an autobrecciated lava is uncertain.

PR 4. Outcrop: A massive, hard, grey-green, unsheared agglomerate. Matrix-supported, rounded blocks of volcanic rock have pink, altered margins. The matrix contains chloritic objects like fiamme.

Thin section:

Primary features: The centre of the one block intersected consists of micropoikilitic aggregates of quartz (the microlites presumably being feldspar) - i.e. snowflake devitrification texture. The margins are finely crystalline (quartz + feldspar mixtures?). The matrix of the agglomerate consists of abundant plagioclase and less abundant, smaller, broken quartz phenocrysts and a few small lithic fragments set in a groundmass with well-preserved snowflake texture. Hints of bent shards and flattened pumice survive in the groundmass.

Secondary features: No phyllosilicates have developed in the margins of the block. The plagioclase phenocrysts of the matrix are albitised, and less than 10% replaced by other minerals (commonly calcite, but sericite as veinlets and rutile/sphene also occur. In the matrix groundmass, sericite forms networks around fine-grained quartz/feldspar patches, the whole suggesting the texture of pumice. Grains and patches of calcite are abundant. Chlorite occurs as occasional swarms of sheaves in the groundmass and rarely replaces plagioclase phenocrysts. Scattered, fine-grained pyrite is abundant, and shows an association with chlorite. Rutile/sphene occurs as small grains in the groundmass.
There is one variety of chlorite. P:green-yellowish; AIC:blue-grey-green.

Identification: a quartz- and plagioclase-phyric, rhyolitic ash-flow agglomerate, densely welded, or a blocky lava.

PR 5. Outcrop: Light grey-green, altered, feldspar-phyric volcanic rock of indeterminate origin. Some is coarsely fragmental. Basic dykes intrude the volcanics in the area.

Thin section:

Primary features: Large (2-3mm) plagioclase phenocrysts and glomerocrysts lie in a groundmass lacking primary textures.

Secondary features: The plagioclase phenocrysts are albitised, but show only very minor replacement by sericite and rutile/sphene. The groundmass consists of micropoikilitic quartz (recrystallised snowflake texture ?) and microphenocrysts of plagioclase much altered to sericite. Chlorite is very minor, occurring only in the groundmass. Rutile grains, and possibly one grain of pyrite, occur in the groundmass.
There is one variety of chlorite, P:green-yellowish; AIC:grey-green.

Identification: A rhyolitic or dacitic volcanic rock, probably a vitric pyroclastic or autobrecciated lava.

PR 6B. Outcrop: A massive, grey, relatively unsheared, feldspar phyric rock with patches and veins of chlorite, (?) calcite and pyrite.

Thin section:

Primary features: Plagioclase phenocrysts, and minor quartz phenocrysts and lithic fragments lie in a groundmass without primary textures.

Secondary features: The plagioclase phenocrysts are albitised and otherwise not very altered; a little chlorite, sericite, rutile and an opaque mineral replace less that 2% of some. The groundmass is a fine-grained mixture of quartz, feldspar and abundant sericite.

One variety of chlorite is present. P:green to yellowish; AIC: grey-green.

Identification: A rhyolitic to dacitic volcanic rock of indeterminate origin.

127

PR 7A. Outcrop: A massive grey, feldspar-phyric rock with disseminated pyrite and scattered vuggy patches. The vugs are lined with chlorite. Some parts may contain magnetite.

Thin section: Primary features: There are plagioclase phenocrysts and glomerocrysts, and the groundmass has abundant vitroclastic textures: shards and bent, collapsed pumice.

Secondary features: The plagioclase phenocrysts are albitised, and are 40-50% replaced by other minerals, mainly by calcite and in some cases by chlorite. Scattered veins and small crystals of sericite and minor rutile also replace plagioclase phenocrysts. Axiolitic devitrification of the groundmass has taken place where vitroclastic textures are preserved, but other areas consist of a mesh-like array of sericite and lesser chlorite around small patches of quartz/feldspar. This texture may be after pumice. Sheaves of chlorite are scattered throughout the groundmass, and calcite is also present. Rutile and pyrite, in some cases intergrown, are disseminated in the groundmass. An association between pyrite chlorite and calcite is evident locally.
One variety of chlorite occurs. P:green- pale yellow; AIC:blue-purple.

Identification: The rock is a rhyolitic to dacitic vitric-crystal ash-flow tuff.

PR 8B. Outcrop: A hard, massive feldspar-phyric rock coarsely and irregularly mottled in pink, chlorite-green and epidote-green. Pyrite is a minor, but widespread, component.

Thin section:

Primary features: Plagioclase phenocrysts and glomerocrysts are abundant. In pink areas, no other primary texture remains. In green areas, shard-shapes are well-preserved. The shards do not appear to be flattened. Two phenocrysts of brown hornblende are partly preserved in a green area.

Secondary features: There is a strong contrast between the pink and green areas. The pink areas consist of plagioclase phenocrysts, albitised, in a fine-grained groundmass of albite/quartz. The pink colour is attributed to albite. The phenocrysts are replaced (< 5%) by epidote, chlorite and rutile/sphene, and by recrystallised albite as veins and rims. In the green areas the plagioclase phenocrysts are as much as 60% replaced by epidote with rims of chlorite. Remaining plagioclase is albite. The hornblende phenocrysts are partially replaced by chlorite. The groundmass consists of chlorite, epidote, rutile/sphene and ? albite, irregularly distributed so that there are, epidote-rich and, chlorite-rich patches. One such patch contains crystals of biotite of secondary origin, intergrown with the chlorite. Pyrite occurs as two euhedral crystals enclosed by a plagioclase phenocryst, and may be of primary origin.
There is one variety of chlorite, P:green-pale yellow; AIC:purple.

Identification: (?) Dacitic vitric-cryatsl (?) ash-fall tuff.

Discussion: This rock is distinctive in several respects. (i) A primary ferromagnesian mineral is preserved. (ii) Secondary biotite is present (iii) The mineralogical differentiation into pink and green areas is spectacular (it is encountered in various stages of development in rocks with similar alteration assemblages elsewhere in the Mt. Read Volcanics).
It is suggested that the rock remained fairly fresh until it was metamorphosed, retaining hornblende and calcic plagioclase, and that the metamorphic temperature was hotter than elsewhere in this section (hence the biotite). The same event probably produced the chlorite, epidote and albite and Na-rich and Cu, Mg, Fe, Ti - rich areas.

PR 9. Outcrop: A massive (slightly sheared)brown-grey feldspar-phyric rock. Some is vuggy, the cavities containing limonite and ? chalcedony. The outcrop is somewhat weathered.

Thin section:

Primary features: Plagioclase phenocrysts are set in a fine-grained groundmass with textures suggesting shards.

Secondary features: Some phenocrysts appear to have been completely replaced by aggregates of irregular quartz crystals or of chlorite, these preserving the original shape. Others are 5-10% replaced, mainly by chlorite and rutile/sphene, but there is also a dusting of small sericite crystals and minor (?) epidote. The groundmass is varied; some is of a dark-coloured mixture of chlorite, sericite and quartz/feldspar, fine-grained and foliated. A mesh-like array of chlorite veinlets enveloping areas of quartz/feldspar may represent a sheared snowflake devitrification testure. There are scattered patches of coarser quartz/feldspar and chlorite. Disseminated rutile occurs throughout, and there is abundant hematite pseudomorphing magnetite.

There are two varieties of chlorite, differing only in interference colour. P:bright green - yellowish; AIC:green - blue or purple.

Identification: a rhyolitic to dacitic vitric-crystal (?) ash-flow tuff.

MURCHISON GORGE

MR7 Outcrop: A grey, quartz-phyric volcanic rock with dark green spots. It occurs near the contact of the Murchison Granite.

Thin section:

Primary features: Embayed quartz phenocrysts and a few lithic clasts occur in a fine-grained, turbid groundmass without primary textures.

Secondary features: Patches of chlorite, biotite and epidote may represent ferromagnesian or feldspar phenocrysts, but no original mineral is left. In some cases, the patches are zoned with chlorite and biotite intergrown at the centre and epidote surrounding them. The epidote is therefore later than the chlorite and biotite. Biotite appears to rim chlorite in one case. Chlorite and biotite are also intergrown and surrounded by epidote in a vein. The groundmass is almost impossible to resolve. It may contain epidote and biotite, and does contain an opaque mineral, anisotropic with brown internal reflections, (?)sphene.

There is one variety of chlorite. P: green to pale yellow; AIC: blue-grey.

Identification: a (?)hornfelsed rhyolitic volcanic rock.

MR8A Outcrop: An epidote-calcite-chlorite vein from massive, hard, dark-green, quartz-phyric volcanic rock with disseminated pyrite.

Thin Section:

Primary features of wallrock: The wallrock (of which only a small portion is represented) is a coarse-grained intergrowth of quartz, albite and (?)K-feldspar.

Secondary features: The wallrock feldspars are partly altered to fine-grained chlorite and a little epidote. The vein consists of coarsely crystalline calcite, epidote, quartz and minor chlorite and disseminated pyrite. These minerals are undeformed. The quartz contains many fluid inclusions, possibly primary, each of which contains a crystal of halite. A visual estimate of phase-proportions suggests a homogenisation temperature of 300°C (minimum estimate of formation temperature) and a salinity near 30% NaCl.

There is one variety of chlorite, P: bright green to yellow; AIC: purple.

Identification: The wallrock is probably from a minor intrusion (granitic?) within the quartz porphyry described above.

MR9B Outcrop: A dark grey-green, massive, quartz-phyric rock with disseminated and banded magnetite and pyrite scattered sparsely throughout.

Thin section:

Primary features: There are abundant embayed quartz phenocrysts, many of them broken. No feldspar phenocrysts were observed. A lithic fragment and one apatite crystal enclosed by quartz are present.

Secondary features: The groundmass consists of many small quartz/feldspar grains enveloped in sericite and subordinate chlorite, and also contains many small magnetite crystals. Pyrite is also present, and some grains of magnetite include pyrite.Patches of chlorite may be replacements of phenocrysts (plagioclase?). A pale-green variety of epidote in sheaves is a minor groundmass constituent. It may be replaced by chlorite. Several varieties of veins cut this specimen: (a) chlorite (+quartz?), (b) quartz, boudinaged, with chlorite and calcite between the boudins, (c) sericite, (d) calcite as irregular veins and patches, some rimmed by chlorite. Sericite predates chlorite which in turn predates calcite.

All chlorites have similar optical properties (P: green to yellowish; AIC: grey-green). Five habits have been distinguished: (a) veins, (b) rims to calcite, (c) replacement of phenocrysts, (d) surrounding epidote, (e) groundmass.

Identification: altered rhyolitic volcanic rock, probably pyroclastic (broken quartz).

MR11A Outcrop: A sheared, grey-green, feldspar-phyric rock bearing chalcopyrite locally. There is a compositional banding in phenocrysts.

Thin section:

Primary features: Plagioclase phenocrysts, most almost completely replaced, are set in a fine-grained groundmass. No other primary features - except possibly a rutile-zircon intergrowth - remain.

Secondary features: A little albite remains in one plagioclase phenocryst. Others are replaced by chlorite, and to a lesser extent by sericite and rutile/sphene.

The groundmass is strongly foliated and consists of four main elements: phyllosilicates, poikilitic quartz grains, veinlets of K-feldspar and opaque minerals. The phyllosilicates are sericite and chlorite which occur in association throughout the groundmass and mark the cleavage. The poikilitic quartz (the inclusions are difficult to identify) may be the deformed equivalent of snowflake devitrification texture. The K-feldspar in the veinlets is very fine-grained. The pattern of extinction is not random, but suggests deformation. The form of the veinlets themselves suggests isoclinal folding at microscopic scale. The feldspar is colourless to flesh pink and pleochroic, the colour being patchy and commonly associated with vein-margins. (Microprobe analysis was necessary to identify the vein mineral, and showed also that the feldspar bears detectable barium. Barium and titanium peaks interfere in X-ray fluorescence methods, and the print-out of the analysis shows Ba as TiO_2.) Opaque minerals occur with relatively coarse-grained sericite, the grains being distributed along the foliation. Some opaque grains are associated with quartz and these areas may represent deformed quartz-sulphide veins. Chalcopyrite is the predominant opaque mineral, and pyrite is subordinate. There is a small amount of scattered rutile/sphene, some intergrown with zircon.

There is one variety of chlorite, P: green to yellowish; AIC: grey to yellow-grey.

Identification: A much-altered and much-deformed rhyolitic or dacitic volcanic rock, possibly originally a crystal-vitric tuff. It has been hydrothermally veined and mineralised.

MR11B Outcrop: Strongly foliated quartz-sericite schist.

Thin section:

Primary features: none definite.

Secondary features: Sericite marks the cleavage, and envelops grains of polycrystalline quartz. There are rare poikilitic feldspar grains. The section is veined by quartz. Rutile/sphene and possible magnetite occur as rare, scattered grains. There is no chlorite.

Identification: A quartz-sericite schist with no intrinsic indication as to origin. The enclosing units are feldspar-phyric volcanics, probably pyroclastics.

MR12 Outcrop: Pink, quartz-phyric rhyolite associated with minor intrusions of granite.

Thin section:

Primary features: Quartz and less abundant apatite phenocrysts are fresh. There are also ragged remnants of feldspar phenocrysts, some showing simple twinning, (K-feldspar?) and others polysynthetic (plagioclase). The groundmass texture (described below) might be primary..

Secondary features: The feldspar phenocrysts are extensively altered to sericite. Coarse-grained chlorite occurs in patches and may be the alteration product of ferromagnesian phenocrysts.

The groundmass is largely tesselate in texture, a mosaic of quartz and feldspar grains with interstitial sericite and minor chlorite, opaques and zircon. The feldspars are not twinned, but optic sign and 2V determinations indicate the presence of two different feldspars: sanidine and albite. Elsewhere in the groundmass, aggregates of coarse-grained chlorite occur. Many of the laths of chlorite contain rutile/sphene and zircon inclusions. Where zircon is abundant, the chlorite is metamict and isotropic. Magnetite, a little altered to hematite, occurs in the groundmass.

The coarser chlorites (P: brownish-green - pale yellow or isotropic; AIC: purple-grey or none) may be of a generation different from the finer groundmass chlorite (P: blue-green; AIC: none (grey). The coarse chlorites with inclusions probably replace titaniferous biotite, the rutile/sphene resulting from the non-incorporation of Ti into the chlorite structure and the zircons being original inclusions in the biotite.

Identification: A potassic rhyolite, possibly intrusive (hence the coarse grainsize of the groundmass) or extrusive, the country-rock to minor granitic intrusions, hydrothermally altered as in the porphyry copper environment and later recrystallised (hence the biotite and K-feldspar, and the tesselate texture).

MS1 Outcrop: A white-weathering, quartz-phyric, coarsely-fragmental volcanic rock with a crude layering with respect to grainsize.

Thin section:

Primary features: Embayed quartz phenocrysts are abundant and plagioclase phenocrysts subordinate. Small zircons are present. Clasts as seen in outcrop cannot be distinguished in this section.

Secondary features: Plagioclase remaining in phenocrysts is albite; certain phenocrysts are altered partly to sericite. The groundmass consists largely of micropoikilitic quartz, i.e. snowflake devitrification texture. Sericite, marking a non-pronounced foliation, is abundant and grades into an orange-pleochroic phyllosilicate mineral (cf RD5), probably a clay after sericite. There is no chlorite. Small grains of rutile/sphene are scattered sparsely throughout. Thin quartz veins, some with rutile/sphene, cut the specimen.

Identification: a moderately-altered, originally glassy autobrecciated rhyolite lava.

MS2 Outcrop: A pink quartz-phyric volcanic rock with patches of dark green chlorite. In the same outcrop is a small lens of grey rock containing lithic fragments and possible clastic quartz.

Thin section:

Primary features: Embayed quartz phenocrysts and sparse, scattered zircons. One of the groundmass textures may be primary - see below.

Secondary features: The quartz phenocrysts are fractured and polycrystalline.

The groundmass includes two distinct textural types. One consists of an intergrowth of large, anhedral, very irregular crystals of albite and sanidine. Both minerals show very irregular extinction patterns, possibly due to deformed twinning or to a temperature-inversion. The other consists of intergrown laths of quartz and sanidine giving a distinctive "cuneiform" texture. The laths are arranged locally in crude radial groups (suggesting recrystallised or replaced spherulitic or snowflake devitrification?). Most of the laths have uneven extinction, the structure being parallel to the sides. The sanidine crystals include minute crystals of hematite - hence the pink colour of the rock. The groundmass also contains abundant sericite in irregular veins and patches marking the cleavage. Chlorite occurs with sericite, or in separate clots which may be the altered remains of ferromagnesian phenocrysts. One such clot has a quartz overgrowth. Euhedral magnetite crystals are scattered throughout the section. A little biotite is present.

Two varieties of chlorite are present: (i) in the groundmass and in clots with P: green to yellowish; AIC: grey masked by yellow-green. (ii) in clots, P: yellow-green, AIC: colours up to second-order blue masked by yellow-green.

Discussion and identification: The rock is a potassic rhyolite, probably extrusive (outcrop observation) and comparable to the "Darwin-type" potassic rhyolites from the Mt. Read Volcanics south of the King River. The freshness of the groundmass textures suggests that one at least is secondary - probably the "cuneiform" texture.

MS3 Outcrop: A light green fine-grained, altered, feldspar-phyric volcanic rock.

Thin section:

Primary features: Phenocrysts are abundant. Quartz is embayed and broken; plagioclase is also present, but merges with the groundmass because of alteration. K-feldspar phenocrysts are also present, as are scattered, small zircons. Two lithic fragments were noted, one of quartz-sandstone, the other of volcanic rock with snowflake devitrification texture. There are suggestions of vitroclastic texture in the groundmass.

Secondary features: Shearing is intense, and this may have led to the breaking of some of the quartz phenocrysts. Minor calcite replaces certain quartz phenocrysts. Most feldspar phenocrysts are extensively replaced by sericite, but some are replaced by calcite and epidote. The cleavage in the groundmass is marked by fine-grained sericite and subordinate chlorite, and there are local concentrations of epidote and calcite with sericite. Opaques include pyrite rimmed by hematite (which appears to have replaced some grains entirely) and less common grains of rutile/sphene. The pressure shadow of a hematite-rimmed pyrite grain contains quartz, chlorite and biotite.

Two varieties of chlorite occur: (i) in the pressure shadow of the pyrite, P: pale blue-green to yellowish; AIC: yellow-grey. (ii) in the groundmass, P: green-yellowish; AIC: purple.

Identification: An altered rhyolitic ash-fall crystal-lithic -?vitric tuff, possibly somewhat reworked.

Sophia Tunnel, CH345

Outcrop: Green, pyritic, sheared country-rock adjacent to the contact of the Murchison Granite.

Thin section:

Primary features: Few persist. Some objects may have been lithic fragments; others may have been phenocrysts.

Secondary features: The possible primary grains are replaced by quartz and sericite or sericite alone. The rock is compositionally banded, parallel to the foliation, in quartz, sericite, chlorite, opaques and allanite. Quartz-rich bands consist of round, polycrystalline grains enveloped in phyllosilicates which mark the cleavage, a deformation texture. Chlorite-rich bands include minute opaques, and in some cases are intergrown with coarse opaques and allanite. A little (?)rutile/sphene occurs. The opaque assemblage comprises pyrite, subordinate magnetite and a single minute grain of molybdenite.

The chlorites are complex; at least three types are present. (i) In veins and coarse patches, P: green-pale yellow; AIC: purple-grey. (ii) Disseminated in the groundmass, and around veins of (i) P: green-pale yellow; AIC: grey masked by yellow-green. (iii) Scattered, P: green to brown; AIC: brown, in coarse flakes with opaque inclusions, probably after biotite. Brown pleochroic haloes are common. The relationships between the chlorites are ambiguous.

Identification and discussion: The rock is a mineralised chlorite-sericite-quartz schist. The molybdenite is also likely to be associated with the granite. The chlorites may have been superimposed on earlier biotites during later hydrothermal circulation.

Sophia Tunnel CH360

Outcrop: Green, altered granite with areas of prominent large red feldspars, from close to the contact which is marked by a dyke of the red feldspar-bearing material.

Thin section:

Primary features: The red areas consist of quartz, and graphic intergrowths of K-feldspar and quartz, and abundant zircons enclosed in secondary minerals. The green areas are clastic in texture, consisting of broken pieces of graphic granite in a matrix of secondary minerals.

Secondary features: In the red areas, chlorite (presumably after biotite) encloses zircons and has pleochroic haloes. Calcite occurs interstitially between the large grains. In the green areas, the matrix consists of calcite, quartz/feldspar and patches of chlorite. The specimen is cut by a calcite-chlorite-quartz vein in which the chlorite occurs as minute inclusions in the calcite, and as veins between calcite crystals. Magnetite and a little pyrite are scattered throughout, but are more common in the breccia matrix.

There are three varieties of chlorite: (i) After biotite in the graphic granite, P: green to yellow; AIC: brown-purple-blue. (ii) Replacing type (i), P: blue-greens; AIC: grey-green. (iii) In the calcite vein, P: green to yellow; AIC: purple-orange.

Identification and discussion: The rock is an altered, brecciated graphic granite. The granite margin appears to have undergone late intrusion by residual, eutectic silicate liquid and simultaneous brecciation with the result that only the latest dykes of graphic granite remain intact. The mineralisation of the breccia matrix seems similar to that in the country rock at the contact, and brecciation may therefore have been due to an explosive release of magmatic volatiles.

Sophia Tunnel CH855

Outcrop: Grey-green equigranular granite bearing rounded xenoliths, epidote veins and minor pyrite. There is no red feldspar (cf. CH360).

Thin section:

Primary features: The texture of the rock is equigranular and granitic. The grain-boundaries are simple, as though the rock has been annealed. The primary mineralogy is quartz, sanidine with deformed twinning or perthitic structures, zoned plagioclase, green hornblende, green biotite (apparently replaced by the hornblende) and accessory apatite, zircon and (?)muscovite. The large grains of pyrite and magnetite (some of which include pyrite) may be of primary origin. The biotite may enclose small grains of rutile.

Secondary features: Sericite and epidote have replaced plagioclase extensively. Sanidine remains almost unaltered. The ferromagnesian minerals are replaced by epidote and a secondary generation of green biotite. Primary biotite is rimmed and replaced by sphene. There is no chlorite.

Identification and discussion: The rock is an altered hornblende-biotite granite/adamellite. The metamorphic/hydrothermal event which gave rise to the secondary mineralogy occurred at a temperature high enough to form biotite. The sericitisation of plagioclase may have taken place at another stage.

MT. BLACK & ENVIRONS

BD1. Outcrop: Sericitised, grey ash-flow tuff; weathered.

Thin section: Primary features: Phenocrysts of plagioclase and embayed and broken quartz phenocrysts occur in a fine-grained groundmass with accessory apatite and zircon. The groundmass preserves the shapes of abundant shards and some bent pumice, but the texture is not truly eutaxitic.

Secondary features: The plagioclase phenocrysts are up to 50% replaced by sericite/muscovite. The groundmass consists mainly of quartz/feldspar sericite, goethite and orange-stained patches which may be weathering - products of chlorite. (?) Rutile is present as scattered large and small grains. The specimen is cut by veins, now folded, of quartz with or without sericite and goethite.

Identification: a rhyolitic to dacitic, vitric-crystal tuff, probably the non-welded part of an ash-flow.

BD2. Outcrop: Green, massive volcanic rock with chloritic patches.

Thin section: Primary features: Phenocrysts of magnetite are set in an originally-glassy groundmass.

Secondary features: The magnetite is largely replaced by goethite. Goethite of finer grain is scattered throughout the groundmass. The lath-like habit of some grains suggests that the goethite may be a replacement of hematite. The groundmass has a snowflake divitrification texture of largely coalescing quartz areas bearing sericitised microlites and patches of chlorite. Most of the snowflakes have no nuclei, but many are in contact with clear, monocrystalline quartz grains in optical continuity with the snowflake. These quartz grains could be primary. The areas where quartz snowflakes have not developed are occupied by quartz, sericite and chlorite, with a little rutile/sphene. Some such areas are polygonal and may be after phenocrysts.
The chlorite has P:blue-green to yellow; AIC: olive-green on grey, and has been yellowed locally by weathering.

Identification: a magnetite-phyric, (?) rhyolitic to dacitic, originally glassy volcanic rock, possibly a lava.

BD6. Outcrop: Massive, hard, grey, pyritic volcanic rock.

Thin section: Primary features: Plagioclase phenocrysts and subordinate quartz phenocrysts are set in a relatively fine-grained groundmass with accessory apatite and zircon.

Secondary features: The plagioclase phenocrysts are 50-100% replaced by fine-grained sericite and are veined and rimmed by secondary albite. The groundmass consists of quartz/feldspar, sericite, chlorite, rutile, goethite and pyrite. The goethite has apparently replaced primary magnetite grains. Some is associated with rutile and may replace titaniferous magnetite. Rutile occurs elsewhere as clusters of grains. A little pyrite is scattered throughout the specimen.
The chlorite is disseminated evenly or in swarms, and has P:pale green to colourless; AIC:blue-grey.

Identification: a plagioclase - and quartz-phyric volcanic rock of unknown origin.

BL1 Outcrop: Weathered grey-green basic to intermediate volcanic rock with altered feldspar and hornblende phenocrysts.

Thin section:

Primary features: Phenocrysts originally of amphibole, plagioclase and possibly orthopyroxene lie in a groundmass of intergrown laths of plagioclase, amphibole, (?)pyroxene and rutile/sphene. No quartz is visible.

Secondary features: Weathering and alteration have made the rock turbid. Chlorite and (?)epidote replace amphibole. Plagioclase is extremely poikilitic - most alteration products are too small to resolve.

The chlorite has P: pale green, AIC: deep blue.

The specimen is cut by an albite vein with minor hematite and epidote.

Identification and discussion: This is an unusually mafic member of the Mt. Read Volcanics, and may be a basalt.

BL2 Outcrop: Sheared, grey-green volcanic rock with pink feldspar phenocrysts.

Thin section:

Primary features: Plagioclase phenocrysts and scattered accessory zircons are the only surviving primary features.

Secondary features: The phenocrysts are replaced by albite, many small crystals of sericite, and scattered patches of chlorite. The chlorite in some cases is marginal to veins cutting the phenocrysts, and the sericite is earlier than the chlorite.

The groundmass consists largely of micropoikilitic quartz (snowflake texture). There are large grains of rutile/sphene and magnetite, and small grains of pyrite (possibly associated with veins) scattered through the groundmass. Coarse patches of sericite may be replacements of phenocrysts. Near the weathered edge of the section, sericite becomes pleochroic in bright orange. Patches of chlorite-rutile-opaques and sericite-chlorite-opaques-quartz/feldspar are present. The section is veined by sericite-chlorite and quartz-albite. Where a quartz-albite vein intersects or albitised plagioclase phenocryst, the vein-albite is optically continuous with the phenocryst.

There may be two varieties of chlorite, (i) coarser-grained, P: green-yellowish; AIC: purple, (ii) finer-grained, P: pale green, AIC: grey.

Identification: A plagioclase-phyric rhyolitic to dacitic (?)lava.

BL3 Outcrop: A hard, massive, pink volcanic rock with green chloritic patches.

Thin section:

Primary features: Phenocrysts of plagioclase and hornblende (now entirely pseudomorphed) and one of embayed quartz, and accessory apatite are present.

Secondary features: The hornblende phenocrysts are entirely altered to epidote and minor chlorite. Plagioclase is altered to albite and several phenocrysts preserve zoning. Sericite (a fine dusting) and epidote replace plagioclase, and several phenocrysts are rimmed by chlorite. Chlorite also rims patches of epidote. The groundmass is an equigranular array of very irregular quartz/feldspar grains (a devitrification texture?). It contains magnetite and rutile/sphene, the magnetite being associated with chlorite.

There is one variety of chlorite, P: deep green to colourless, AIC: purple.

Identification: An altered plagioclase-hornblende-phyric rhyolitic to dacitic (?)lava.

BL4 Outcrop: Massive, hard, pink volcanic rock with green chloritic patches.

Thin section:

Primary features: Phenocrysts of plagioclase and quartz are set in a groundmass without primary features.

Secondary features: The plagioclase phenocrysts are riddled with minute sericite crystals, and remaining plagioclase is albitised. There is minor development of chlorite and opaques. The groundmass retains a spherulite and other radial textures suggestive of devitrification. It consists largely of a partly-annealed mosaic of interlocking quartz and feldspar grains, and is turbid with microinclusions. Patches of chlorite, and a few veins and patches of clear albite are present. Magnetite and rutile grains are scattered throughout. Two flakes of biotite of green-brown pleochroism are surrounded by chlorite of type (ii), below.

Two types of chlorite are present: (i) flakes scattered through the groundmass, P: blue-green; AIC: blue grey, and (ii) patches in the groundmass, P: yellow-green; AIC: colours to mid second order, masked by yellow-green.

Identification: A plagioclase- and quartz-phyric rhyolitic (?)lava.

PM1 Outcrop: Light grey, massive to sheared (?)pyroclastic rock from west of the contact of the Primrose shale lens.

Thin section:

Primary features: Embayed quartz phenocrysts are present, also a siliceous (?)lithic clast and two untwinned feldspar phenocrysts, possibly sanidine.

Secondary features: The quartz phenocrysts have been recrystallised in some cases. The groundmass includes one area of unsheared micro-poikilitic quartz (snowflake texture). Otherwise the groundmass consists of foliated sericite and quartz with abundant small crystals of pyrite, scattered rutile and rare magnetite. The specimen is veined by bondinaged, recrystallised quartz.

Identification: a quartz- and feldspar-phyric rhyolitic lava or pyroclastic rock.

CS2. Outcrop: Massive, grey-green, (?) lava.

Thin section: Primary features: The rock consisted largely of glass, and contains quartz microphenocrysts and a few small phenocrysts of apatite; and large grains of magnetite which may be primary. Banding now marked by secondary minerals may be flow-banding.

Secondary features: The quartz microphenocrysts are the nuclei of round , optically continuous overgrowths of micropoikilitic quartz, a variety of snowflake devitrification texture. Some such overgrowths have a radial structure. The microlites they contain are too small to identify. Between the snowflakes, the rock consists of monocrystalline quartz grains, magnetite and fine-grained quartz/feldspar, sericite and chlorite. Certain small groups of quartz grains are in optical continuity; these may be parts of single, deeply embayed phenocrysts without overgrowths. Sericite and chlorite mark the banding mentioned above. The section is cut by a quartz vein consisting of several parallel bands separated by wallrock, perfectly parallel but of irregular (non-planar) form. The vein quartz is optically continuous with neighbouring snowflakes.
The chlorite has P:green to yellow; AIC:grey-green.

Identification: a glassy rhyolitic (?) lava with quartz microphenocrysts.

STP221. <u>Thin section</u>: <u>Primary features</u>: Two distinct primary textures are present:

(a) Plagioclase phenocrysts and glomerocrysts set in a fine-grained groundmass with a pilotaxitic texture defined by many microlites of plagioclase. Accessory zircon is present.

(b) Randomly-oriented, interpenetrant, laths of plagioclase (some relatively large, giving porphyritic texture), with fine-grained intersertal material.

<u>Secondary features</u>: Plagioclase in albitic throughout, but is heavily altered to calcite, epidote and minor sericite and chlorite. The intersertal groundmass consists of fine-grained calcite, chlorite, epidote and rutile/sphene. The pilotaxitic groundmass consists of plagioclase, chlorite, rutile/sphene and local calcite. Between these two textural types is a zone of plagioclase phenocrysts set in a groundmass of epidote and chlorite. The epidote-rich areas preserve a banding (presumably after pilotaxitic banding) but plagioclase microlites have not survived. The chlorite-rich areas enclose lenses and folded, worm-like bands of brown sphene. The zone is cut by a disrupted vein of sericite, and by gashes filled with chlorite and lesser calcite and epidote. There are rare, scattered grains of chalcopyrite.

The chlorite has P:green to pale yellow; AIC:purple-blue to salmon-brown (very dark).

<u>Discussion and identification</u>: The section appears to cut the contact of an intrusive rock (intersertal) and a lava (pilotaxitic). The epidote and chlorite rich zone may be a contact effect or associated with nearby pyrrhotite mineralisation. Both rock types appear to be of intermediate to basic composition, andesites or basalts.

STITT TRAVERSE TO BALD HILL

ST 1. Outcrop: (large boulders of float, from flanks of Mt. Murchison close to sample point). Sheared grey quartz- and feldspar - phyric volcanic rock.

Thin section: Primary features: Abundant phenocrysts-derived quartz grains, most of them angular, and fragments of volcanic and metamorphic rock occur in a predominant fine-grained matrix. The volcanic rock fragments include feldspar porphyry and types exhibiting snowflake devitrification texture. The metamorphic rocks are quartzite with different proportions of muscovite. Subordinate clastic components comprise magnetite (angular to rounded grains), grains (now sericitic) which may have been feldspars, rutile and a little zircon. The rock is poorly sorted.

Secondary features: The coarser-grained clasts appear little-altered, except for the sericitised grains which may have been feldspars. The matrix consists of sericite and subordinate quartz/feldspar. It is strongly foliated, the sericite marking the cleavage.

Identification: a lithic wacke with some tuffaceous input.

ST 2. Outcrop: a weathered pink and green feldspar porphyry with spaced shears and quartz-chlorite veins.

Thin section: Primary features: Phenocrysts of plagioclase are set in a medium - to fine-grained groundmass.

Secondary features: The plagioclase phenocrysts are strongly altered to epidote, chlorite, secondary albite and opaques. The epidote is clinozoisitic. The groundmass is a very irregular intergrowth (with respect to size and shape of the grains) of albite and quartz with scattered epidote chlorite and brown turbid bodies which may be chlorite/clay mixed with leucoxene (cf. ST3). The quartz-feldspar intergrowths are commonly eutectic.

The chlorite occurs in veinlets, patches and as scattered crystals, and has P:bluish-green to colourless; AIC:brown,purple and blue, all more or less together.

Identification: a plagioclase-phyric, (?) dacitic intrusive rock.

ST 3. Outcrop: a sheared, grey-green volcanic rock containing pink feldspar phenocrysts and sheared blocks of fine-grained rock.

Thin section: Primary features: Phenocrysts of plagioclase (and one of feldspar, possibly K-feldspar, with cross-hatched twinning) and large, angular fragments of fine-grained volcanic rock occur in a predominant, fine-grained matrix. A large pyrite grain may be primary.

Secondary features: The plagioclase phenocrysts are riddled with minute grains of sericite, and most bear some clinozoisitic epidote. Chlorite and recrystallised albite are found on a few phenocrysts. Areas of goethite may replace primary magnetite grains, and do replace pyrite. The rock fragments consist largely of fine-grained, equant quartz/feldspar with minor epidote and rutile/sphene. The groundmass consists of fine-grained quartz/feldspar, abundant chlorite, a little epidote and scattered grains of brown turbid material, a mixture of chlorite or clay and leucoxene (microprobe analysis).
The chlorite occurs as veinlets, patches and scattered grains. In one veinlet, sericite and chlorite are intergrown, and occur with quartz and albite. The chlorite has P:pale green to colourless; AIC:blue, purple and brown.

Identification: a plagioclase-phyric, (?) dacitic volcanic rock, either a lapilli tuff or a blocky lava.

ST 4. Outcrop: Slightly sheared, grey-green, feldspar-phyric volcanic rock.

Thin section: Primary features: Phenocrysts of plagioclase (some with apatite inclusions) and subordinate phenocrysts of orange hornblende and ilmenite are set in a eutaxitic groundmass in which individual pumice fragments cannot readily be distinguished.

Secondary features: The plagioclase phenocrysts are partly altered to clinozoisitic epidote, and also bear a little chlorite and sericite. The hornblende and ilmenite phenocrysts are not markedly altered. The groundmass is an intergrowth of equant, equigranular quartz/feldspar with sphene, epidote, goethite and a little sericite. The sphene forms bands marking the primary foliation, and a single band of yellowed sericite marks the cleavage. Coarser-grained patches of albite and quartz, and others of chlorite form a subordinate component of the groundmass.
The chlorite has P:pale green to pale yellow; AIC:blue.

Identification: a plagioclase, ilmenite- and hornblende-phyric dacitic to andesitic ash-flow tuff.

ST 5. Outcrop: Sheared, grey-green, pyritic, feldspar-phyric volcanic rock.

Thin section: Primary features: Phenocrysts and large composite glomerocrysts of plagioclase, hornblende and ilmenite are set in a fine-grained groundmass with a pilotaxitic texture.

Secondary features: The plagioclase phenocrysts are partly altered to epidote, or epidote and calcite, with a little chlorite and biotite and in some cases a light dusting of fine-grained sericite. The hornblende phenocrysts are ragged, and altered to biotite and chlorite. Grains of secondary (?) sphene occur in the glomerocrysts. The groundmass consists of fine-grained quartz/feldspar (including relict feldspar microlites which define the flow texture) and epidote, (?) sphene, chlorite and a little sericite in the cleavage. A vague snowflake texture is developed locally. Pyrite (replaced slightly be goethite) occurs as single scattered crystals and in a large cluster where it is associated with biotite and epidote. A quartz veinlet contains also albite, biotite, epidote and some unidentified acicular crystals.

The chlorite has P:pale greens; AIC;blue to brown.

Identification: a plagioclase -, ilmenite- and hornblende-phyric, dacitic to andesitic lava.

ST 6. Outcrop: Green, heavily sheared volcanic rock with pink feldspar phenocrysts.

Thin section: Primary features: Phenocrysts and glomerocrysts of plagioclase are abundant in a fine-grained matrix. There were probably ilmenite phenocrysts, now represented by brown, turbid titaniferous material enclosing ragged residual core of ilmenite and crystals of apatite. There may also have been magnetite phenocrysts.

Secondary features: The plagioclase phenocrysts bear a little clinozoisitic epidote and chlorite, and are riddled with fine-grained sericite. Bodies of quartz are also present, but may be secondary quartz - e.g. boudinaged veins, or folded tension gashes. they contain minor chlorite and pyrite altered to hematite. Areas of (?) goethite may replace primary magnetite. The groundmass consists of fine-grained quartz/feldspar, sericite, chlorite and (?) sphene. Sericite predominates in much of the groundmass, and chlorite-rich patches are common. The chlorite has P:green to yellow; AIC:bluish-purple.

Identification: a plagioclase -, (?) ilmenite- and (?) magnetite -phyric rhyolitic-dacitic volcanic rock of indeterminate origin.

ST 7. Outcrop: Hard, massive, pink-brown, fine-grained, feldspar-phyric volcanic rock with green flecks and veins.

Thin section: Primary features: Plagioclase phencrysts of assorted sizes are set in a fine-grained predominant groundmass. Accessory zircon is present, some as inclusions in plagioclase phenocrysts.

Secondary features: The plagioclase phenocrysts are riddled with fine-grained sericite and bear patches of weathered, orange phyllosilicate, probably clay after chlorite. The groundmass consists of fine-grained quartz/feldspar, sericite, orange (?) clay and goethite. The sericite occurs as disseminated minute grains, veinlets (marking the cleavage) and patches. The (?) clay occurs in irregularly-distributed patches. Relatively large, equant, irregular grains of quartz are scattered throughout the groundmass.

Identification: a plagioclase-phyric, rhyolitic to dacitic volcanic rock of indeterminate origin.

ST 8. Outcrop: Heavily-sheared, grey, feldspar-phyric volcanic rock.

Thin section: Primary features: Phenocrysts and glomerocrysts, presumably originally of plagioclase with inclusions of zircon and (?) apatite, are set in a fine-grained groundmass. Monocrystalline grains of quartz scattered through the groundmass (and larger than groundmass grains) may also be primary.

Secondary features: The feldspar phenocrysts have been replaced completely by K-feldspar and veinlets of sericite. The K-feldspar is of irregular, undulose extinction pattern (cf. HF specimens and RD7). The groundmass consists of fine-grained quartz/feldspar sericite, rutile/sphene and goethite. The quartz/feldspar and sericite are somewhat differentiated into bands marking the cleavage. Folded quartz veins cut the specimen, and polycrystalline bodies of quartz are scattered throughout the groundmass.

Identification: a sheared porphyry, presumably originally plagioclase-phyric, of indeterminate origin.

ST 9. Outcrop: Sheared, grey-green feldspar-phyric volcanic rock with chloritic patches elongate along the cleavage.

Thin section: Primary features: Plagioclase phenocrysts are uncommon in a fine-grained groundmass with vague indications of a eutaxitic texture.

Secondary features: The plagioclase phenocrysts are extensively riddled with fine-grained sericite. The groundmass consists largely of quartz/feldspar and sericite, with a little chlorite and rutile. The sericite marks the cleavage. The chlorite occurs in patches, some relatively coarsely crystalline. The specimen is cut by quartz veinlets bearing minor albite, chlorite and rutile; one is folded.
The chlorite has P:pale green to colourless; AIC:grey-brown.

Identification: a phenocryst - poor ash-flow tuff, of (?) dacitic composition.

T 10. Outcrop: Massive, blocky, grey, feldspar-phyric volcanic rock.

Thin section: Primary features: Phenocrysts and glomerocrysts of minor phenocrysts of limerite and apatite occur in a fine-grained groundmass with accessory zircon. The overall texture is chaotic.

Secondary features: The plagioclase is as much as half-replaced by clinozoisitic epidote. Some phenocrysts bear secondary, recrystallised albite, and a rim of yellow, fibrous (weathered?) mineral occurs in a few cases. The hornblende phenocrysts are ragged, and are altered to chlorite and a little brown biotite and (?) epidote. The groundmass consists of equant, intergrown quartz/feldspar, epidote, sphene, chlorite (abundant) and a little goethite. Areas of yellow, weathered phyllosilicate may include some boitite and may be replacements of phenocrysts. Goethite may replace primary magnetite grains.
The chlorite has P:pale green to colourless; AIC:blue to brown

Identification: a plagioclase-, hornblende-, ilmenite- and apatite-phyric andesite, probably a volcanic, of indeterminate origin.

DALLWITZ-JUPITER-KOONYA AREA

DJ1 Outcrop: Grey-green, feldspar-phyric, flow-banded and autobrecciated lavas. The specimen is from an autobrecciated lava.

Thin section:

Primary features: Large phenocrysts of plagioclase and quartz are set in a foliated groundmass. The plagioclase phenocrysts are deformed and broken; one includes a zircon, and another is attached to a large crystal of muscovite which may also be a primary feature. Other large muscovite crystals, bent and broken, are scattered through the groundmass.

Secondary features: The quartz phenocrysts are rimmed by optically-continuous quartz overgrowths. The plagioclase phenocrysts are albitised, and carry a light dusting of sericite crystals. In the groundmass, sericite marks the foliation and wraps around bodies of fine-grained quartz/feldspar. Chlorite occurs mainly in the pressure shadows of the quartz/feldspar bodies. Rutile/sphene occurs as strings of crystals (after large grains, deformed?) in association with sericite. There are rare hematite grains after magnetite.

There is one variety of chlorite, P: green to yellowish; AIC: grey-green.

Identification: A quartz-feldspar-phyric rhyolitic lava.

DJ2 Outcrop: Greenish, somewhat weathered volcanic rock.

Thin section:

Primary features: Plagioclase phenocrysts occur in a fine-grained groundmass.

Secondary features: The plagioclase phenocrysts are albitic, and are <10% altered to other minerals. Most bear a dusting of fine sericite, and certain phenocrysts have been replaced by high-birefringent chlorite or recrystallised albite. The groundmass is foliated, and consists of phyllosilicates and a mosaic of quartz/feldspar crystals with undulose extinction. The phyllosilicates include sericite and a chlorite-like mineral, but no true chlorite is present. Rutile is abundant, occurring in irregular groups of grains. Hematite or goethite occurs in association with sericite.

The one chlorite-like mineral has P: greenish-yellow; AIC: up to second-order colours masked by yellow. It may be a weathering-product of chlorite.

Identification: an altered, plagioclase-phyric rhyolitic to dacitic volcanic rock.

DJ3 Outcrop: A hard, massive, fine-grained, bright pink rock with dark green chloritic veins and mottles.

Thin section:

Primary features: Plagioclase phenocrysts and a few zircons are set in a groundmass bearing abundant evidence of original vitroclastic components. Certain pieces of pumice may be flattened and bent, and the plagioclase phenocrysts are bent. Vitroclastic textures are preserved in the green areas (cf PR8B).

Secondary features: The plagioclase phenocrysts are albitic and have been replaced by small patches of epidote. The groundmass in the pink areas is a fine-grained mosaic of irregular quartz/feldspar crystals. The green areas consist of colourless to pale green and golden-brown varieties of epidote, chlorite, albite, a trace of green-brown biotite. All of these may occur intergrown together. Rutile grains occur throughout, and in particular in association with a vein of chlorite, epidote, albite and (?)biotite.

The chlorite is of one variety only, P: bluish-green, AIC: purple-brown to dull blue. The biotite-like mineral may have a chloritic component.

Identification: an altered, (?) dacitic, crystal-vitric ash-fall or ash-flow tuff.

DJ4 Outcrop: Brown ash-flow tuff bearing large pieces of pumice, up to 1 m long. Weathered.

Thin section:

Primary features: Feldspar phenocrysts, most relict, and sporadic zircons are set in a groundmass with textures of bent, flattened pumice and shards.

Secondary features: The feldspar phenocrysts are replaced by sericite and minor albite and high-birefringent chlorite; some are marked only by albite rimming the original shape. The groundmass is very fine-grained, and consists of sericite and quartz/feldspar with patches of coarser albite biotite and high-birefringent, yellowed chlorite. Certain pumice structures are replaced by coarser albite and sericite. Rutile is scattered throughout, and there is much orange iron oxide.

Identification: a (?) dacitic ash-flow tuff.

DJ 6 Outcrop: Sheared sericitic schist, some bearing white spots after feldspar phenocrysts.

Thin section:

Primary features: The shapes of phenocrysts, presumably feldspar, are preserved, along with vitroclastic textures in the groundmass.

Secondary features: The groundmass and phenocryst-ghosts consist largely of quartz and sericite. Rutile grains are abundant.

Identification: a (?)rhyolitic to dacitic ash-fall or ash-flow tuff.

KJ1 Outcrop: Coarse-grained pink and green volcanic rock with cavities (miarolitic, or due to weathering?); feldspar phyric, and with chloritic patches.

Thin section:

Primary features: Plagioclase phenocrysts and glomerocrysts and sparse quartz and apatite phenocrysts are set in a groundmass without primary textures.

Secondary features: The plagioclase phenocrysts consist of albite, and most have been less than 5% replaced by epidote and minor chlorite. A few are more completely replaced. The glomerocrysts have developed large patches of chlorite, biotite, epidote, magnetite and rutile/sphene. Similar patches of alteration occur independent of glomerocrysts. The patches consist mainly of fine-grained chlorite studded with crystals of epidote, rutile/sphene and subordinate biotite. Biotite also occurs intergrown with chlorite and sericite in the same areas, as selvages or pressure shadows to phenocrysts, and as veinlets cutting phenocrysts.

The groundmass consists of micropoikilitic quartz/feldspar, but does not show the type of quartz grains characteristic of snowflake texture. Scattered sericite, chlorite and epidote occur throughout.

There are two varieties of chlorite, 1. P: green to yellowish; AIC: purple (subordinate, intergrown with epidote) and 2. P: green to yellowish; AIC: greenish blue-grey (broader, fine-grained areas). The difference may be connected with grainsize, because type I includes only relatively large crystals, and type 2 only relatively small.

Identification and discussion: an altered, quartz and plagioclase phyric rhyolite, probably originally a glassy lava. Note that the biotite is definitely secondary.

KJ4 Outcrop: A brown, sheared, feldspar-phyric, banded (?)lava with thin chlorite veinlets.

Thin section:

Primary features: Large phenocrysts of plagioclase occur in a groundmass with no surviving primary textures.

Secondary features: The phenocrysts consist of albite and are turbid, riddled and veined with fine-grained sericite. Parts of the phenocrysts are replaced by "clean" plagioclase in optical continuity along fractures and in patches. Chlorite partly replaces phenocrysts near veins. The groundmass is foliated quartz/feldspar and sericite, with vague indications of an earlier micropoikilitic texture. There are scattered patches of chlorite, and many fine crystals of rutile/sphene. A vein of chlorite-albite-quartz-rutile/sphene cuts the specimen.

There is one variety of chlorite, P: green to pale yellowish; AIC - (grey).

Identification: a plagioclase-phyric, rhyolitic-dacitic volcanic rock, probably a lava.

KJ6 Outcrop: Chloritic schist containing deformed cubes of pyrite.

Thin section:

Primary features: The crystals of pyrite are euhedral and mainly separate in a phyllosilicate matrix, and may be primary (of diagenetic origin in a mud, for example). The specimen is banded according to content of pyrite.

Secondary features: The matrix consists of chlorite (P: green to yellowish; AIC: pale blue-grey, negative optic sign, low 2V;) and minor sericite. Large grains of rutile/sphene occur throughout, but are less abundant than pyrite. Pyrite and rutile/sphene are intergrown in a few cases. The coarsest grained chlorite and pyrite occur together.

Identification: possibly a pyritic mud.

KJ7 Outcrop: Banded, chloritic low-grade ore from the lower Koonya dump.

Thin section:

Primary features: Rounded bodies of polycrystalline quartz occur in the more siliceous bands, and may be clastic. The bands are not continuous across the section, and are probably not a primary feature.

Secondary features: The specimen consists largely of coarse-grained, recrystallised chlorite, quartz and sulphides in areas of contrasting mineralogy. Scattered, coarse-grained crystals of muscovite occur with the coarsest chlorite. Quartz-rich areas have an annealed texture. The sulphides include sphalerite (transparent and yellow, with rare exsolution blebs of chalcopyrite) and subordinate separate crystals of galena and pyrite. Galena rims sphalerite in one band.

There is one variety of chlorite, P: green to colourless; AIC: pale blue-grey.

Identification: probably remobilised massive sulphide ore and gangue.

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161

AIC Outcrop: Banded quartz-chlorite rock with sulphides from the lower Koonya dump.

Thin section:

Primary features: The compositional banding may represent an original banding.

Secondary features: The rock consists of chlorite, quartz, transparent yellow sphalerite, pyrite and minor galena and muscovite. These minerals are coarse-grained and occur to some extent in irregular bands of different composition. Chlorite and sphalerite are intergrown, however, the chlorite occurring as coarse-grained euhedral blades. Chlorite is finer-grained and foliated in areas where it occurs alone. Coarse-grained muscovite is associated with sulphides in certain areas.

The chlorite has P: pale green to colourless; AIC: pale blue-grey to non-anomalous grey (depending on orientation).

Identification: probably remobilised massive sulphide ore and gangue.

KJ12. Outcrop: White, sheared, sericitised volcanic rock.

Thin section:

Primary features: none

Secondary features: The rock consists largely of foliated quartz and sericite. Rutile is a minor component. The specimen is cut by quartz veins bearing swarms of minute, high-relief solid inclusions.

Identification: a quartz-sericite schist of indeterminate origin.

KJ13. Outcrop: Grey, feldspar-phyric volcanic rock with sharp partings, giving regular angular blocks.

Thin section: (too thin).

Primary features: Phenocrysts, probably originally plagioclase, are set in a fine-grained groundmass with accessory zircon.

Secondary features: The phenocrysts are entirely replaced by (?) K-feldspar, biotite, chlorite and rutile. The groundmass is very fine-grained, consisting of quartz/feldspar and sericite/biotite. The biotite is brown. The chlorite has P: pale green to colourless; AIC grey brown (but is polished thin).

Identification: a feldspar porphyry of indeterminate origin.

163 913172

ROSEBERY LODES

RL1. Outcrop: Massive, grey, feldspar-phyric ash-flow tuff with well preserved wispy texture and fiamme.

Thin section: Primary features: Phenocrysts of plagioclase are set in a groundmass consisting largely of pumice. The pumice is flattened and bent to some extent, but round vesicles are preserved around the phenocrysts. Accessory zircon and apatite are present.

Secondary Features: The phenocrysts are rimmed and veined with secondary albite, and are up to 100% replaced by sericite, chlorite, biotite and minor rutile. The biotite is green and also occurs in a quartz veinlet containing chlorite and calcite as solid inclusions in quartz, and large cavities in the quartz, possibly gas-rich fluid inclusions. The groundmass consists mainly of albite/(?)quartz forming an intergrowth of grains irregular in shape and size. Sericite is locally plentiful, marking the primary foliation of pumice. Minor groundmass constituents are chlorite, biotite, rutile and goethite.

The chlorite has P:green to pale yellow; AIC:blue-green on grey.

Identification: A plagioclase-phyric, rhyolitic-dacitic ash-flow tuff. The development of biotite may be associated with a nearby occurrence of quartz-tourmaline-sulphide veins.

KOONYA DRILLCORE

DDH KP196

420ft: Altered volcanic rock from below the Koonya ore-zone.

Thin section: Primary features: Plagioclase phenocrysts and pumice fragments occur in a groundmass preserving shard-shapes and containing accessory zircon. The pumice and shards do not appear to be flattened or welded.

Secondary features: The plagioclase phenocrysts bear rims of quartz/feldspar, and have been ~75% altered to sericite. The groundmass consists of fine-grained quartz, albite, sericite, chlorite and (?) calcite. There are areas of coarser-grained quartz, and clusters of rutile crystals, some associated with chlorite. There may be a little splalerite. The specimen is cut by quartz-calcite veins. The chlorite has P:pale greens; AIC:brown.

Identification: a plagioclase-phyric vitric crystal tuff, possibly from the unwelded part of an ash-flow.

377 ft

Thin section: Primary features: There are no phenocrysts. Pumice fragments, bent and flattened, impart a eutaxitic texture. Polycrystalline patches of clear quartz may represent former phenocrysts.

Secondary features: Most of the section consists of fine-grained quartz/feldspar, sericite and minor opaques and chlorite. There are veins and patches consisting of quartz, chlorite, pyrite, galena, yellow sphalerite and minor muscovite. Pyrite and subordinate rutile are scattered throughout the rest of the section. Two foliations, one possibly primary, are marked by sericite.
The chlorite has pleochroic haloes, some apparently around opaque grains, and has P: pale green to pale yellow; AIC pale bluish-green on grey.

Identification: a pumice-rich ash-flow tuff.

77 ft

Thin Section: Primary features: The texture is eutaxitic, individual pumice fragments being difficult to distinguish unless chloritised. There are no phenocrysts.

Secondary features: Most of the section consists of foliated, fine-grained quartz/feldspar, sericite and chlorite, the phyllosilicates marking the cleavage. Certain chlorite-rich patches appear to be fiamme. Pyrite crystals, the larger ones having pressure-shadows of quartz and chlorite, and fine-grained rutile, are scattered throughout. Pyrite is commonly associated with chlorite, and in a few cases with rutile. Non-planar quartz veins of several parallel bands cut the specimen. The quartz includes swarms of high-relief, highly-birefringent, rhombic crystals which may be sphene.
The chlorite has P:green to pale yellow; AIC: blue-green on grey.

Identification: A pumice-rich ash-flow tuff.

HERCULES FOOTWALL

(and environs)

A large number of specimens from a small area has been examined. Because these are all more or less similar only a selection of the petrographic descriptions are presented here. The samples are from a chloritic zone in ash-flow tuffs underlying the Hercules host horizon. HF1, 4, 6 and 9 are typical of all other specimens except HF23, which may be from hangingwall rocks, and HF2A and 3 which are definitely from hangingwall rocks.

HF1 Outcrop: Sheared, feldspar-phyric, quartz-sericite-altered volcanic rock, locally mottled in dark green. The dark green areas have shapes suggesting fiamme in some cases.

Thin section:

Primary features: Two remaining phenocrysts, relict bent pumice and small patches where shard shapes can be seen and scattered zircons are all that remain in a very altered rock.

Secondary features: The feldspar phenocrysts are altered to K-feldspar (cf RD6). There are also patches of quartz and/or albite which may represent replaced phenocrysts. Most of the rock is a fine-grained, foliated mixture of quartz/feldspar, sericite and opaque minerals. Chlorite occurs only in patches with preserved vitric textures and near opaque grains. The opaque mineralogy comprises abundant scattered rutile/sphene and pyrite grains. One intergrowth of rutile/sphene and sphalerite with chalcopyrite exsolutions are present.

The chlorite has P: pale green to colourless; AIC grey (but the slide may be too thin).

Identification: a rhyolitic-dacitic ash-flow tuff.

HF2A. Outcrop: Sheared, grey-green sericitic rock from the hangingwall side of the Williamsford massive-sulphide body.

Thin section:

Primary features: Vague shard-like shapes are preserved.

Secondary features: The rock consists of foliated, fine-grained quartz/feldspar and sericite with coarser patches of quartz and rutile/sphene. Rutile/sphene also occurs as scattered groups elsewhere, in some cases associated with zircon.

Identification: an altered vitric tuff, probably rhyolitic to dacitic.

HF3 Outcrop: A feldspar-phyric rock with wispy textures and chloritic bodies like fiamme.

Thin section:

Primary features: Phenocrysts of (?)feldspar (now replaced) are set in a fine-grained groundmass preserving vitroclastic textures, including bent, collapsed pumice.

Secondary features: The phenocrysts are entirely replaced by K-feldspar (cf RD6) and (as much as 90%) by chlorite, sericite, rutile/sphene, quartz and a high-birefringent chlorite-like mineral. The groundmass consists largely of quartz/feldspar, sericite and rutile/sphene in a fine-grained mosaic with patches of coarser rutile/sphene and "high-birefringent chlorite".

There are two varieties of chlorite: "normal", replacing phenocrysts, P: blue-green; AIC: grey-green; and "high-birefringent", P: yellow-green; AIC: up to second-order colours masked by yellow.

Identification: a rhyolitic to dacitic ash-flow tuff.

HF4 Outcrop: Chloritic, mottled schist, the mottling in darker and lighter chloritic greens. Locally, the schist bears abundant pyrite. This specimen is from the centre of the chloritic zone beneath the Hercules orebody.

Thin section:

Primary features: Bent and flattened pumice is abundant, one piece having the typical wispy shape of a fiamma.

Secondary features: Patches of relatively coarse quartz and chlorite may represent former phenocrysts. The rest of the rock is a foliated, fine-grained mixture of quartz/feldspar, chlorite, sericite and pyrite. The chlorite marks some of the pumice fragments and is abundant in bands along the cleavage. Abundant pyrite crystals, and less abundant, ragged grains of rutile/sphene are scattered throughout. Chlorite also occurs in pressure shadows of pyrite grains.

There is one variety of chlorite, P: palegreen-yellowish; AIC: blue-grey.

Identification: a rhyolitic to dacitic ash-flow tuff.

HF6 Outcrop: Green, (chloritised) sheared, feldspar-phyric volcanic rock. In the vicinity, pyritic and silicified varieties also occur.

Thin section:

Primary features: The rock is composed of flattened and bent pumice. There are no phenocrysts in the section examined.

Secondary features: The pumice and matrix consist largely of fine-grained quartz/feldspar, sericite and chlorite. Some pumice fragments are predominantly sericitic. Quartz-rich and chlorite-rich patches occur locally; some may be of metamorphic origin. Fine-grained opaques (pyrite?) and a rutile-like mineral are minor components. The specimen is cut by quartz veins.

The chlorite has P: very pale green to pale yellowish; AIC: none (grey).

<u>Identification</u>: a (?)rhyolitic to dacitic ash-flow tuff.

HF9 <u>Outcrop</u>: Heavily sheared, sericitic rock with relict feldspar phenocrysts and quartz augen. Rare chloritic patches, apparently less sheared, occur.

<u>Thin section</u>:

<u>Primary features</u>: Irregular bodies, presumably replaced phenocrysts, are abundant in a matrix of pieces of bent and flattened pumice with accessory zircon.

<u>Secondary features</u>: The presumed phenocrysts have been replaced by K-feldspar showing irregular twinning, in some cases cross-hatched. The feldspar is pink because of minute inclusions of hematite. The phenocrysts also bear sericite at the edges and as veinlets, and minor chlorite. The groundmass consists mainly of fine-grained quartz/feldspar and sericite marking the cleavage. Fine-grained material resembling rutile is widespread but not abundant. Chlorite is a minor constituent.

The chlorite has P: pale yellow-green; AIC: yellowish, and is probably somewhat weathered.

<u>Identification</u>: a (?) feldspar-phyric, (?)rhyolitic to dacitic ash-flow tuff.

HF23 <u>Outcrop</u>: Sheared grey ash-flow tuff with green fiamme, giving a mottled effect on cleavage surfaces.

<u>Thin section</u>:

<u>Primary features</u>: Euhedral areas of secondary minerals, presumably after phenocrysts, are set in a groundmass consisting almost entirely of pieces of bent and flattened pumice. Accessory apatite and zircon are present.

<u>Secondary features</u>: The replaced phenocrysts now consist of calcite, chlorite, a little irregularly-twinned K-feldspar and minor sericite, rutile/sphene and opaques. The pumice now consists of quartz/feld-spar and sericite, chlorite occurs locally. Calcite and fine-grained opaques are minor constituents. The specimen is cut by pre-cleavage veinlets of quartz, chlorite, calcite and rutile/sphene.

The chlorite has P: pale green to very pale yellow; AIC: pale brownish-grey.

<u>Identification</u>: a [illegible] feldspar-phyric (?)rhyolitic to dacitic ash-flow tuff.

171

RING RIVER

RR 4. Outcrop: The section is of a boulder of ?volcanic-derived greywacke from a matrix-dominated conglomerate of very poorly sorted pebbles and boulders including greywacke and laminated siltstones, some pyritic.

Thin Section: Primary Features: Quartz grains, angular to well-rounded and poorly sorted (silt to sand grade) are abundant. There are a few lithic fragments and may have been feldspars. The quartz is clear, with extinction normal to undulose and one grain is embayed. Rare grains of clastic muscovite, zircon and an opaque mineral are present. The matrix is predominant, and is calcareous in parts, elsewhere consisting of secondary phyllosilicates and opaques. The opaque mineralogy is pyrite (mostly fine grained), rutile, magnetite (some rimming pyrite).

Secondary Features: Somewhat regular patches of sericite may psuedomorph original clastic feldspar. The matrix is sericitic, and there is no chlorite.

Identification: An impure and immature quartz sandstone with minor lithic and ?feldspathic components, occuring as a clast in a turbidite.

RR 8. Outcrop: A finely-spotted grey-green massive rock of metamorphic appearance (grading into recognisable limestone at site RR 9). Bears sulphides.

Thin section:

Primary Features: None definite. Large crystals of albite may be secondary (see below). Brown, turbid, fine-grained, presumably calcareous material between the feldspars has the appearance of micrite and may be a primary feature.

Secondary Features: Large, tabular crystals of albite occur singly and in sheaves of all orientations throughout the section. The albite is replaced by calcite (some crystals more than 50%).

172

Between the crystals, as well as the (?) micrite, irregular granules of calcite (and dolomite?), rutile, pyrite and chalcopyrite are found. A single small, transparent, brown grain of very high relief - possible cassiterite - occurs in the matrix.

Identification and Discussion: The rock was originally a limestone. It has subsequently been altered to an albite and sulphide-bearing assemblage, and subsequently to that, the albite appears to have undergone retrograde alteration to calcite.

RR 9A. Outcrop: None, a piece of quartz-feldspathic sandstone from the dump of an excavation in the north bank of the river.

Thin Section - Primary Features: Moderately well-sorted, but very angular, quartz grains, both single crystals and polycrystalline, are present. Some resemble phenocryst-quartz in extinction (undulose). Plagioclase and lithic grains, some of the latter being calc-alkaline porphyry, occur in subordinate amounts. The matrix is fine-grained.

Seconadary Features: Chlorite replaces plagioclase grains. The matrix is chlorite throughout, with local accumulations of rutile grains and a little magnetite. Sericite is minor, if present at all.

Identification: An immature and impure quartz sandstone with feldspathic and lithic components, probably of tuffaceous origin.

RR 9B. Outcrop: None, a piece of fine-grained pink rock of igneous appearance from the dump, as in RR 9A.

Thin Section: Primary Features: Relict euhedral plagioclase phenocrysts and glomerocrysts and lithic fragments are set in a groundmass preserving abundant examples of bent, collapsed pumice and shards.

Secondary Feature: The plagioclase phenocrysts are almost entirely replaced by a fine-grained mass including sericite and locally by chlorite. Chlorite has also developed between phenocrysts and on pumice fragments. The groundmass has recrystallised to give coarser-grained aggregates of quartz/feldspar in patches and in rims to certain phenocrysts.

Identification: A plagioclase-phyric rhyolitic to dacitic ashflow tuff.

R 11. Outcrop: Impure limestone with a visible clastic component, wellbedded and commonly cross-bedded and pyritic.

Thin Section: Primary Features: These are difficult to interpret because of turbidity and shearing. Lithic fragments (some of them volcanic with interlocking feldspars), ill-defined areas of fine-grained turbid material which may be calcareous intraclasts, calcareous fragments with rounded hollows - possibly fossil fragments-and pyrite cubes are among the selection of primary clasts.

Secondary Features: The matrix is in large part calcareous, and includes areas of sparry calcite. The spar has developed prominent rhombs of dolomite, and has locally been silicified. Strings of fine-grained rutile line the cleavage, and rare magnetite and chalcopyrite were also observed.

Identification: A calcarenite, or a sandy limestone.

13. Outcrop: Hard, dark-grey, pyritic quartz-sandstone with prominent micas.

Thin Section: Primary Features: The pre-dominant clastic component is quartz, in moderately well-sorted, angular grains with normal or undulose extinction. No polycrystalline grains are present. Minor clastic components include large flakes of muscovite bent around quartz grains and scattered lithic fragments, rutile and zircon. Some muscovite crystals are aligned end-to-end, suggesting that they could be diagenetic.

Secondary Features: The fine-grained matrix is largely irresolvable but includes quartz and chlorite, the latter occurring also as patches and veins. Sparse, fine-grained rutile is present.

Identification: Micaceous quartz-sandstone.

RR 14. (Slide labelled RR 14A)
Outcrop: Monotonous quartz-rich greywacke.

Thin Section: Primary Feature: Poorly sorted grains of monocrystalline quartz, subrounded to angular, occur with ragged plagioclase grains and lithic grains in an altered matrix. The lithic grains include plagioclase porphyries. There are no deformed or polycrystalline quartz grains. Rare apatite crystals are present. Some of the pyrite and magnetite grains may also be primary. There is minor calcite in the matrix.

Secondary Features: Certain lithic fragments have been altered to sericite. Chlorite occurs in the matrix, marking the foliation.

Identification: A lithic feldspathic quartz sandstone of probable tuffaceous origin.

[illegible] (Slide marked RR 14B)
Outcrop: Sandstone to siltstone, grey, interbedded with minor carbonate.

Thin Section: Primary Features: Quartz grains are monocrystalline or polycrystalline, some are strongly deformed. Some are embayed. Other clasts include rounded fragments of siltstone rich in pyrite, quartzite, flakes and groups of flakes of muscovite, possible feldspars and magnetite grains. The clasts are well-rounded to angular and poorly sorted, and they predominate over the matrix.

Secondary Features: The matrix is foliated, and contains sericite, chlorite and fine-grained pyrite.

Identification: A quartz-lithic wacke, derived from volcanic and PreCambrian sources as well as local sediments.

COMMENTS

1. The metamorphic grade of all samples (except RR 8?) is lower greenschist, the stable assemblage including chlorite, sericite and calcite. Therefore there is no regional zone of high-temperature. The assemblage in RR 8 may represent a local zone of high temperature, and it is associated with copper sulphide mineralisation. It occurs near a known magnetic anomaly.

2. The presence of the block of pink ash-flow tuff on the dump at RR 9 is an anomaly. It may be foreign, and it is certainly difficult to reconcile with the other rock-rypes on the dump, deep-water sediments. The reason for the excavation is not obvious from material examined on the dump. The diggings are near an occurrence of altered limestone similar to RR 8.

MT READ TO WILLIAMSFORD

RD1 Outcrop: Pink, sheared pyroclastic rock containing lithic fragments and feldspar crystals. This unit includes contorted rafts of turbidite-like sediments (graded sands).

Thin section:

Primary features: Variations in groundmass texture probably correspond to lithic clasts. Some areas show non-welded and non-flattened shards. There are plagioclase phenocrysts and quartz grains, the latter irregular, apparently broken and not resembling phenocrysts.

Secondary features: The plagioclase phenocyrsts are albitic and some of the larger ones are veined and rimmed by recrystallised albite. A little sericite rims most phenocrysts. The groundmass consists of sericite, quartz/feldspar and minor chlorite in a foliated mesh texture, possibly deformed snowflake devitrification texture. The amount of sericite varies from clast to clast. Concentrations of coarse-grained chlorite are uncommon in the section. Rutile/sphene and magnetite (mostly replaced by hematite) are scattered throughout.

There is one variety of chlorite, P: green to yellowish; AIC: blue-grey.

Identification and discussion: an altered rhyolitic-dacitic agglomerate of subaqueous origin, probably composed of material reworked in turbidity currents. The glassy components may be individual lithic clasts.

RD2 Outcrop: A brown, much-sheared, lithic, feldspar phyric coarse-grained tuff.

Thin section:

Primary features: Plagioclase phenocrysts, and clasts of quartz which may be broken phenocrysts occur in a groundmass which was probably glassy, but retains only local textural indications of original glass.

Secondary features: Some plagioclase phenocrysts are entirely albitised; others are up to 50% replaced by calcite or by turbid mixtures of fine-grained minerals including rutile/sphène, but otherwise difficult to identify. Albite has developed along rims and cracks. Areas of quartz and calcite form rectangular pseudomorphs, possibly after plagioclase. Shearing of the groundmass is confined to bands between which abundant evidence of devitrification is preserved. Most is in the form of micropoikilitic quartz (snowflake texture), and a few spherulites and minor axiolitic bodies are enclosed in sericite. Sericite is also developed between grains in quartz-rich areas. There is no chlorite. An orange (iron-stained) phyllosilicate has developed locally on sericite. Grains of pyrite, magnetite (altered to hematite), magnetite-pyrite and rutile/sphene are scattered throughout.

Identification: A plagioclase-phyric rhyolitic (?)lava.

RD3 Outcrop: A fine-grained, columnar-jointed, mottled pink and brown volcanic rock.

Thin section:

Primary features: Small plagioclase phenocrysts and broken quartz grains, probably phenocrysts are set in a fine-grained groundmass without primary textures (except perhaps for a local dendritic intergrowth texture).

Secondary features: The plagioclase phenocrysts are completely or partly altered to sericite, any remaining feldspar being albite. The groundmass is a fine-grained intergrowth of quartz and feldspar. There are small areas of micropoikilitic and spherulitic textures. Sericite, altered locally to an orange phyllosilicate, and calcite also occurs in the groundmass. The opaque mineralogy comprises pyrite (rare grains), hematite (after magnetite?) and more abundant, scattered rutile/sphene. There is no chlorite.

Identification: an altered, rhyolitic, quartz- and plagioclase-phyric, originally glassy lava.

RD4 Outcrop: A sheared, feldspar-phyric, pink to grey, sericitic volcanic rock.

Thin section:

Primary features: Plagioclase phenocrysts are set in a fine-grained groundmass with no primary features.

Secondary features: Plagioclase phenocrysts are albitised, and up to 50% replaced by calcite and very minor sericite. The groundmass consists of a fine mosaic of quartz/feldspar crystals with scattered crystals of sericite and calcite where foliation is less developed. The strongly sheared parts consist of lensoid polycrystalline grains of quartz enveloped in sericite which marks the cleavage.
There is also minor calcite. Calcite-rich patches, with more than 50% calcite, are present. There is no chlorite. Rutile is scattered throughout, and there is minor (?)pyrite and Fe-oxide.

Identification: a plagioclase-phyric, rhyolitic to dacitic volcanic rock of indeterminate origin.

N.B. Calcite replacing plagioclase has survived in this specimen despite weathering enhanced by strong shearing and an exposed position at the summit of Mt. Read.

RD5 Outcrop: A sheared, grey-green (?)agglomerate.

Thin section:

Primary features: Sparse plagioclase phenocrysts are set in a fine-grained groundmass retaining no primary textures.

Secondary features: The composition of phenocryst plagioclase could not be determined, but is probably albite. The phenocrysts are up to 10% replaced by sericite in veins. The sheared groundmass consists of sericite, quartz and minor chlorite and opaques. The quartz occurs as rounded bodies with diffuse margins and wavy extinction. Sericite envelops these bodies. Less sheared parts consist of a mosaic of fine-grained quartz/feldspar with sericite and opaques. Rutile is scattered throughout, and crystals of a bladed opaque mineral, possibly hematite, occur near a weathered edge.

There is one variety of chlorite, P: green-yellowish; AIC: grey masked by yellow-green.

Intergrown with chlorite and sericite near the weathered edge, there is another phyllosilicate. Most grains are orange, and the pleochroism varies between yellow and deep red. Extinction is straight, and the interference colours are second- to third-order, strongly masked. The habit is similar to that of the sericite and chlorite. Electron microprobe analyses were very variable in Na_2O (0-4%), MgO (5-7%), Al_2O_3 (16-23%), SiO_2 (20-40%), MnO (1.3-2.1%), FeO (22-30%), reported total (75-88%). Ca, K and Ti are present in small quantities, but not all in each area analysed. The mineral is probably a clay rich in Fe^{3+}.

Identification: a plagioclase-phyric, rhyolitic to dacitic volcanic rock of indeterminate origin.

RD6 Outcrop: a sheared, green volcanic rock with pink feldspar phenocrysts. It contains cavities lined with quartz and Fe-oxides.

Thin section:

Primary features: Numerous làrge phenocrysts (now replaced completely) are set in a groundmass containing abundant relict shards and bent pumice. There are scattered intergrowths of rutile and zircon which may be primary.

Secondary features: The phenocrysts are replaced by K-feldspar of an uneven extinction, and when not extinct, show an irregular, diffuse pattern which may be twinning or perthitic exsolution. Nonetheless, the optics are regular enough to give a low 2V, negative figure. These phenocrysts are corroded at the edges and along cracks by quartz/feldspar, and are as much as 40% replaced (mostly less than 10%). Fe-oxide also replaces the K-feldspar. The groundmass is a fine-grained mixture of quartz/feldspar, sericite and opaques (mainly rutile/sphene). There is no chlorite.

Identification: a rhyolitic to dacitic ash-flow tuff.

RD7 Outcrop: Pinkish schist with chlorite veins and patches of magnetite and pyrite.

Thin section:

Primary features: Replaced phenocrysts (?feldspar) are set in a fine-grained groundmass preserving the forms of shards and bent, collapsed pumice. Euhedral magnetite crystals may be primary.

Secondary features: The phenocrysts have been replaced by K-feldspar with diffuse twinning (cf RD6), which in turn is almost entirely replaced by a mosaic of quartz/feldspar, chlorite and sericite. Magnetite crystals are replaced by hematite unless sheathed in quartz. The groundmass is a fine-grained mass of quartz/feldspar and sericite with scattered chlorite, rutile/sphene and magnetite crystals. A chlorite vein cuts the specimen, and contains also sheaves of a highly birefringent yellowish mineral associated with opaque needles.

There are possibly two varieties of chlorite. 1. In the vein, P: green to yellowish; AIC blue-grey to purplish-grey. 2. In the groundmass, P: green to yellowish; AIC: masked by green.

Identification: a crystal-vitric, rhyolitic to dacitic ash-flow tuff.

RD8 Outcrop: Weathered, white, sheared, feldspar-phyric volcanic rock.

Thin section:

Primary features: Feldspar phenocrysts and glomerocrysts and subordinate quartz phenocrysts are set in a groundmass with textures which may be secondary (see below).

Secondary features: The feldspar phenocrysts are albitised and bear a light dusting of sericite grains and opaque crystals. Some have corroded rims. The groundmass is largely a fine-grained, foliated mixture of quartz/feldspar, sericite and opaque minerals. Patches of sericite alone may represent completely-replaced phenocrysts. Certain areas of the groundmass consist of radial or worm-like overgrowths on both plagioclase and quartz phenocrysts, or radial structures without large nuclei. These may be devitrification textures. Chlorite occurs only as a minor constituent of a quartz-sericite vein. (?)Biotite is also a minor constituent of the vein. Rutile/sphene occurs as scattered, small grains, and there are uncommon grains of martitised magnetite.

The chlorite has P: green to yellowish; AIC: yellowish to bluish-grey.

Identification: a rhyolitic lava, originally glassy.

132

RED HILLS

Arrangement of specimens:

Across-strike (east to west): 1, 2, 11, 14, 15, 18, 17, 16, (HFZ 2).
Along-strike, and samples of mineralisation (north to south):
19, 6a and b, 5, 4, 12, 11, 10, 9a and b.

RH1 Outcrop: A light pink to green, quartz and feldspar-phyric volcanic rock, relatively unsheared (compared with others nearby) and containing sparsely-scattered, rounded lithic fragments. The weathered surface is granular.

Thin section:

Primary features: Angular and rounded grains of quartz of phenocryst origin and subordinate feldspar phenocrysts, lithic fragments and zircons occur in a fine-grained groundmass. The feldspars lack polysynthetic twinning; they are probably K-feldspar. Local variations in texture may be due to the presence of larger, less obvious lithic fragments.

Certain lithic fragments are porphyritic and others not. Some areas of the groundmass preserve shard shapes.

Secondary features: Quartz phenocrysts are recrystallised at the edges. Feldspar phenocrysts are somewhat turbid, and most carry a little chlorite as an alteration product. Patches of intergrown chlorite and sericite may be ghosts of former feldspar phenocrysts. The groundmass consists of a fine-grained mosaic of quartz and feldspar with scattered chlorite and rare opaques (magnetite replaced by hematite, and rutile/sphene). Chlorite-rich areas preserve the vitroclastic textures. The specimen is veined by quartz + chlorite + rutile/sphene, and one weathered vein contains a highly birefringent (?)clay where it cuts a sericitic lithic clast. The alteration mineralogy of the lithic clasts is similar to that of the matrix.

183

Two varieties of chlorite appear to be present: in veins P: green to yellowish; AIC: blue-grey; in the groundmass P: green to yellowish; AIC: yellow-green or grey.

Identification: an altered rhyolitic crystal-vitric-lithic tuff of (?)ash-fall origin.

RH2 Outcrop: Veins containing pyrite and magnetite from chloritised, sheared volcanic rock.

Thin section:

Primary features: Devitrified fragments of volcanic rock can be distinguished.

Secondary features: Quartz, chlorite and subordinate sericite with very abundant, fine-grained magnetite and subordinate pyrite crystals replace the original volcanic rock. There are scattered coarser patches of pyrite + magnetite + chlorite, in some cases associated with late quartz (formed during deformation and metamorphism).

The specimen is veined and replaced by quartz, chlorite, a green mineral of second-order birefringence, sericite (minor) and epidote (very minor), and the veins bear magnetite, pyrite and chalcopyrite rimmed by covellite. Magnetite and pyrite are intergrown, and appear to be associated with the highly-birefringent green mineral (properties described below). This green mineral occurs as deformed grains in areas where late quartz and chlorite have developed. Sericite is associated with pyrite.

The true chlorite has P: green to pale yellow-brown; AIC: grey or yellow-grey. The other green mineral has the appearance of a phyllosilicate, occurring in irregular grains with prominent cleavage. The pleochroism is green to brownish green, the interference colours up to second order blue and green, the extinction straight. The mineral has the uneven appearance of biotite near its extinction positions, but is of lower birefringence than biotite.

Identification and discussion: a much-altered, mineralised volcanic rock bearing lithic fragments. Pyrite + magnetite + green mineral + sericite mineralisation appears to have predated quartz + chlorite + epidote.

RH4 Outcrop: From a costean in volcanic rock altered to chlorite + magnetite and bearing blebs of pyrite.

Thin section:

Primary features: Phenocrysts of (?)K-feldspar are set in a fine-grained groundmass.

Secondary features: The phenocrysts are altered by development of rims and scattered crystals of a green mineral (highly-birefringent, phyllosilicate habit cf. specimen RH2). The groundmass consists of a mosaic of quartz/feldspar, the green mineral (cf. RH2) and true chlorite (generally subordinate to the green mineral). Zones of almost-complete replacement by the green mineral and chlorite have developed, and these grade into veins. Rutile/sphene is scattered throughout. The true chlorite is sparse in the groundmass, and occurs mainly in veins. It has P: bright green to yellowish; AIC: grey to greenish-grey.

Identification and discussion: possibly originally a K-feldspar phyric potassic rhyolite. The high-birefringent green mineral probably predates the true chlorite.

RH5 Outcrop: Volcanic rock altered to chlorite + magnetite + pyrite.

Thin section:

Primary features: Bodies of K-feldspar occur in a fine-grained groundmass; these might be disrupted veins rather than phenocrysts.

Secondary features: The K-feldspar contains swarms of minute hematite inclusions. The rock is extensively replaced or veined with chlorite, a chlorite-like mineral, sericite and magnetite; where not so replaced it consists of a fine-grained mosaic of quartz/feldspar, chlorites, magnetite and minor rutile/sphene. The alteration minerals occur in monomineralic patches. The sericite is fine-grained and equigranular. K-feldspar veinlets in these areas are disrupted, and rounded, elongate areas of polycrystalline quartz may also represent disrupted veinlets. Other veinlets (not disrupted) of quartz and chlorite may be younger.

Several kinds of chlorite (or chlorite-like minerals) have been distinguished.

1. P: brown-greenish, AIC: brown-masked second order colours. This occurs as patches in the groundmass and may be the same as
2. P: yellowish-green-brownish; AIC yellow-green masked colours of upper first order - in an area altered almost entirely to chlorite 3. The difference in birefringence may be due to unevenness of section-thickness.
3. P: colourless-bluish green; AIC: blue to mauvish-grey. This occurs in association with type 2, and cuts certain quartz veins.
4. P: colourless-green; AIC: green. Associated with late quartz.

Identification: The original nature of this specimen cannot be determined.

RH6(a) Outcrop: A thick vein cutting rock altered to chlorite-magnetite-pyrite.

Thin section:

Secondary features: Quartz, chalcopyrite and chlorite are the predominant vein minerals, the quartz enclosing sheaves of chlorite. The chlorite has P: green to yellowish; AIC: blue-grey, in some cases lilac. Chalcopyrite has oxidised superficially to covellite.

Identification: a late, probably metamorphic, quartz-chlorite-chalcopyrite vein.

RH6(b) Outcrop: Pyrite + magnetite + chlorite + quartz rock from IN adit dump.

Thin section:

Primary features: A few patches retain an igneous (?)intrusive texture of interlocking laths of (?)K-feldspar. Another area of quartz + feldspar + chlorite + opaques composing a fine-grained mass suggesting altered snowflake texture may also be a primary feature (a lithic fragment?).

Secondary Features: The areas of interlocking feldspar laths have developed interstitial chlorite and opaques, and fine-grained non-resolvable alteration products which locally form a brown mass with no primary textures. The remainder of the rock consists of vein minerals: slightly deformed quartz, albite bearing hematite inclusions, non-deformed areas of chlorite and chlorite-sericite intergrowths, and opaques. Chalcopyrite, pyrite and magnetite occur separately and intergrown, and chalcopyrite occurs intergrown with chlorite.

There is one variety of chlorite, P: green to yellowish; AIC: blue-grey.

Identification: The host may have been an intrusive potassic rhyolite. The lack of deformation of some of the vein minerals may indicate a late, possibly metamorphic, component.

RH9(a) Outcrop; Fine-grained, pink-brown, massive volcanic rock with green, chloritic spots.

Thin section (too thick in parts):

Primary features: Relict feldspar phenocrysts and a lithic fragment containing rounded quartz grains are set in a groundmass showing bent and flattened pumice and other vitroclastic textures.

Secondary features: The feldspar phenocrysts are replaced by K-feldspar (with irregular extinction, cf. HF6), chlorite and opaques. The groundmass is turbid, consisting of quartz/feldspar, chlorite and opaques where resolvable. The opaques assemblage includes euhedral to anhedral magnetite lightly replaced by hematite and finely-divided, feathery groups of rutile/sphene crystals. The section is cut by a quartz-albite vein.

There is one variety of chlorite, P: green to yellowish; AIC: brown to grey-green.

Identification: (?)rhyolitic, feldspar-phyric ash-flow tuff.

RH9(b) Outcrop: Magnetite veins in a greener, more altered variety of 9(a).

Thin section:

Primary features: One quartz phenocryst, recrystallised at the edges, is set in a fine-grained groundmass.

Secondary features: The groundmass consists of quartz/feldspar, opaques and chlorite. The opaques and chlorite are also concentrated into swarms of crystals and veins. Magnetite occurs as euhedral crystals, and there may also be a very small amount of rutile/sphene. Some crystals of magnetite bear pressure shadows of recrystallised quartz and chlorite. Minor sericite occurs in association with chlorite in veins and groundmass.

Two varieties of chlorite are present: in pressure shadows, P: green to colourless; AIC: none (i.e. grey), and in the groundmass P: green to yellowish; AIC: yellow-grey.

Identification: as 9a, much more altered.

RH10 Outcrop: Pink volcanic rock with green, chloritic patches. The weathered surface is rough, sheared and locally finely-banded.

Thin section:

Primary features: Relict feldspar phenocrysts and a feldspar-phyric lithic fragment are set in a fine-grained groundmass in which vague pumice-like textures are visible.

Secondary features: Relatively fresh feldspar-like bodies are intergrown with opaques in a radial pattern, and may represent a devitrification phenomenon. Each of these has an envelope of fine sericite. Other areas of similar sericite may represent such bodies completely replaced, or replaced feldspar phenocrysts. The feldspar-like bodies also bear chlorite and non-radial opaques as replacements. The groundmass is turbid, and where coarse enough to be resolved, consists of quartz/feldspar, chlorite and sericite. Segregations of euhedral magnetite and fine-grained-rutile/sphene occur throughout. Chlorite, sericite and magnetite are concentrated in the cleavage. A sericite veinlet cuts the specimen.

Two varieties of chlorite may be present: (1) replacing feldspars, P: blue-green to brown-green to colourless; AIC: up to second order blue, masked by green. (2) in groundmass, and also replacing feldspars, P: brown-green to yellow-green, AIC: yellow-green.

Identification: an altered (?) rhyolitic lava or ash-flow.

RH11 Outcrop: Chloritic-green volcanic rock with magnetite veins.

Thin section:

Primary features: Relict phenocrysts (originally feldspar?) and a few zircons are set in a fine-grained groundmass with vague indications of bent pumice fragments.

Secondary features: K-feldspar showing irregular extinction (cf HF6), chlorite and fine-grained (?) sericite replace the phenocrysts. The groundmass consists of fine-grained quartz/feldspar with abundant scattered grains of rutile/sphene. There are irregular patches and veinlets of chlorite and sericite.

Chlorites have P: dark green to yellow; AIC: first order colours up to red, masked by yellow-green. Only the coarser crystals show higher interference colours, and others may be of a different variety.

Identification: rhyolitic ash-flow tuff.

RH12 Outcrop: Massive, chloritic-green volcanic rock with pink, less-altered patches and minor pyrite and chalcopyrite, from the dump of 1W adit.

Thin section:

Primary features: Relict phenocrysts and two possibly-primary quartz grains are set in a fine-grained groundmass. Euhedral magnetite grains, one of which encloses a zircon grain, may be primary.

Secondary features: The phenocrysts are replaced by K-feldspar (lath-like twins, riddled with minute hematite inclusions), chlorite, sericite and magnetite. The groundmass consists of fine-grained, equigranular quartz/feldspar, patches of coarse-grained sericite, chlorite and intergrowths of the two, and euhedral magnetite replaced partly by hematite. Chlorite, sericite and magnetite form linear segregations which appear to mark the cleavage. Minor pyrite, chalcopyrite (partly replaced by covellite) and rutile (intergrown with phyllosilicates) also occur in the groundmass.

There is one variety of chlorite, P: dark green to yellow; AIC: yellow-green. Some of the chlorite may be metamorphic. Magnetite enclosed by chlorite has been corroded and has developed hematite.

Identification: a (?)rhyolite of indeterminate origin.

RH14 Outcrop: An agglomerate or breccia consisting of chloritic clasts in a matrix of grey tuffaceous sandstone.

Thin section:

Primary features: Abundant, moderately well-sorted angular to subrounded grains of quartz occur in a finer-grained matrix which is locally predominant, locally subordinate. Much of the quartz is polycrystalline (due to deformation?) but the undulose extinction of isolated grains resembles that of phenocryst quartz. Zircon and possibly rutile grains may also be detrital.

Secondary features: The matrix is weathered and sericitic. Chloritic patches are common. Certain opaque grains appear to be corroded and replaced by chlorite. The welldeveloped cleavage is stained by Fe-oxide. Much of the chlorite is yellowed by weathering; where freshest, P: green to yellowish; AIC yellowish - grey.

Identification: (?)tuffaceous quartz sandstone (no larger clasts visible in the thin section).

RH15 Outcrop: Laminated black shale and grey siltstone.

Thin section:

Primary features: Quartz silt grains are subordinate to a finer-grained matrix. Muscovite and zircon are minor detrital components.

Secondary features: The matrix is sericitic and intensely sheared. There is minor chlorite in certain bands (P: pale green to colourless; AIC: blue-black), and sparsely-scattered rutile. A highly-birefringent orange mineral, the product of weathering of sericite, is probably a clay.

Identification: siltstone.

RH16 Outcrop: Massive, hard, pink-brown volcanic rock with abundant phenocrysts of quartz and pink feldspar.

Thin section:

Primary features: Quartz and plagioclase phenocrysts and a lithic fragment rich in plagioclase occur in a fine-grained groundmass.

Secondary features: The quartz phenocrysts have optically-continuous overgrowths. Plagioclase phenocrysts consist of albite (some recrystallised) and are less than 2% replaced by fine-grained sericite and locally by chlorite. The groundmass is a fine-grained, somewhat turbid mixture of quartz/feldspar, chlorite and minor sericite. It includes pieces of quartz, patches of coarser sericite and chlorite, irregular crystals of magnetite, partly replaced by hematite, and sparse grains of rutile. There are scattered bodies resembling crude spherulites or "snowflakes", indicating that the groundmass was once glassy.

The quartz phenocrysts contain abundant secondary fluid inclusions, bubble + liquid, of visually estimated homogenisation temperature of 150-200°C.

A pre-deformation vein of quartz and chlorite cuts the specimen.

There are two varieties of chlorite: (i) in the vein, P: blue-green to colourless; AIC: brown, (ii) P: pale greens; AIC: brown.

Identification: a rhyolitic volcanic rock, possibly a lava.

RH17 Outcrop: Sheared, green pyroclastic agglomerate bearing large pink lithic fragments.

Thin section: (too thick)

Primary features: The matrix consists of phenocrysts of quartz, and phenocrysts and glomerocrysts of plagioclase in a groundmass containing fragments of plagioclase-phyric collapsed pumice. Most of the foliation appears to be primary. The lithic clast intersected is plagioclase phyric with a fine-grained groundmass containing round bodies of quartz (a devitrification texture?). This clast is joined to a pumice fragment. There is accessory zircon.

Secondary feature: The plagioclase phenocrysts are turbid; chlorite and swarms of sphene crystals are recognisable as alteration products. Remaining plagioclase is albitic. The groundmass consists of quartz/feldspar, chlorite and sphene. Little or no sericite is present, except in the pink lithic clast. Very fine-grained pyrite is scattered irregularly and sparsely across the section.

There is one variety of chlorite, P: green to yellowish; AIC: - (grey).

In this section, sphene is recognised from rutile by its rhomb-like cross-section.

Identification: a (?)rhyolitic, quartz-plagioclase phyric ash-flow agglomerate.

RH18 Outcrop: Rather weathered, much sheared grey-green volcanic rock.

Thin section:

Primary features: Embayed quartz and plagioclase occur as phenocrysts in a fine-grained groundmass. There is one lithic fragment, probably of quartz porphyry.

Secondary features: The plagioclase phenocrysts are turbid, and carry some iron oxide and minor sphene. The groundmass consists of two textural varieties. One consists of rounded bodies of polycrystalline quartz/feldspar enveloped in finely-intergrown sericite and chlorite which mark the foliation. Fine-grained, euhedral sphene occurs in the quartz/feldspar bodies. Certain quartz bodies appear to cut across the foliation; such may be replaced phenocrysts. The other variety is of similar mineralogy, but richer in quartz and sphene and poorer in the phyllosilicates. Consequently, the foliation is not so marked as in the former variety.

Chlorite is of one variety only, P: green to yellowish; AIC - (gre

Identification: a quartz-plagioclase phyric, (?)rhyolitic, volcanic rock of unknown origin.

RH19 Outcrop: Massive, pink to green, splintery volcanic rock with chloritic patches and veins of pyrite and chlorite.

Thin section:

Primary features: Relict feldspar phenocrysts (plagioclase?) are set in a fine-grained groundmass.

Secondary features: The feldspar phenocrysts are replaced (commonly entirely) by chlorite and K-feldspar with irregular extinction (of ...) and also carry euhedral magnetite crystals. The groundmass is a medium-grained aggregate of irregular feldspar and quartz crystals possibly after snowflake texture, and also contains much fine-grained magnetite and chlorite. Sericite is not resolvable in the groundmass, but occurs as veinlets and intergrown with coarser-grained chlorites. Opaque minerals, quartz, chlorite (and chlorite-like minerals) make up coarse-grained segregations and veins. The opaque assemblage includes pyrite, magnetite partly replaced by hematite, and chalcopyrite partly replaced by covellite and chalcocite.

There are three forms of chlorite/chlorite-like mineral.

1. P: green to yellowish; AIC: blue-green, occasionally yellowish. This replaces feldspars and occurs scattered through the groundmass and as a selvage to and patches within veins.

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2. P: green to yellowish; AIC: blue-grey to lilac-grey. In pyrite veins with or without quartz, intergrown with the quartz and possibly replacing type 3. (The quartz is of undulose extinction and has the habit of quartz grown under stress - contiguous, parallel, elongate crystals. This chlorite may thus be metamorphic.)

3. P: light brown to dark brownish-green; AIC: yellow-green or colours up to second-order green or blue. This has the uneven appearance of biotite close to the extinction position. It occurs close to pyrite grains, but a few isolated pieces were noted. Between certain pyrite grains it is deformed.

Identification: a (?)rhyolite porphyry of unknown origin.

HENTY FAULT ZONE

HFZ1. Outcrop: Sheared, chlorite-green, feldspar-phyric volcanic rock from a sequence of bedded rocks, some with possible fragmental texture. Basic dykes intrude the volcanics.

Thin section:

Primary features: Plagioclase phenocrysts are set in a fine-grained groundmass which may originally have been glassy.

Secondary features: The plagioclase is albitised and flecked with sericite. Bodies of quartz in the sheared groundmass, some of them rounded, may be incipient augen devoloped from snowflake divitrification products. The remainder of the groundmass consists of quartz/feldspar, sericite, chlorite, minor rutile and iron oxide as a stain.
The chlorite has P:green to pale green; AIC:green on grey.

Identification: a feldspar-phyric, rhyolitic to dacitic volcanic rock, possibly a glassy lava.

HFZ2. Outcrop: Dark green chloritic schist, from the crushed zone of the Henty Fault.

Thin section: Primary features: none

Secondary features: The rock is extremely sheared, and consists of quartz, chlorite, minor serictie, magnetite (altered to hematite) and rutile/sphene. The rock is banded with respect to mineral composition. It is cut by quartz veins which also contain the other minerals cited. There are three generations of quartz. Boudins of turbid deformed, coarse-grained quartz are replaced by and cut by veins of quartz grown under stress. These veins are in turn boudinaged and replaced by another generation of quartz. There is one variety of chlorite, P:blue-green to pale yellow; AIC: yellow-grey.

Identification: a quartz-chlorite schist which has undergone continual deformation.

HFZ4. Outcrop: Vein of quartz, chlorite, chalcopyrite and pyrite from the dump of a working in or near the Henty Fault Zone.

Thin section: Primary features: none

Secondary features: Coarsely crystalline quartz - a turbid, deformed variety and a clear, later variety grown under stress, is intergrown with sulphides. There is a chalcopyrite - rich area in which euhedral pyrite crystals (enclosing small areas of chalcopyrite) are set in irregular masses of chalcopyrite. In a pyrite - rich area, minor chalcopyrite occurs between intergrown pyrite crystals. A trace of sphalerite may be present. There is minor chlorite, P: pale greens, AIC:blues and browns.

Identification: (vein mineralisation).

LAKE SELINA

LS 1. Outcrop: Sheared volcanic rock bearing chlorite, pyrite and magnetite, and with local sericite-rich bands.

Thin section: Primary features: Angular quartz phenocrysts are set in a fine-grained groundmass preserving vague shard - shapes and swarms of round bodies of polycrystalline quartz (possibly filling vesicles in pumice). There is no suggestion of flattening or welding. There is accessory zircon.

Secondary features: The groundmass consists of quartz/feldspar, sericite, chlorite and opaques. The coarser opaques (pyrite) are surrounded by coarser-grained quartz, muscovite and chlorite, which form discontinuous veins. The veins also contain minor amounts of a chlorite - like mineral with birefringence up to second-order. This mineral may be earlier than "true" chlorite in the veins. Magnetite and minor chalcopyrite occur in the veins, and magnetite and pyrite are scattered sparsely elsewhere.
Both the groundmass chlorite and the vein chlorite have P:green to yellowish; AIC:bluish-grey.

Identification: a sheared, mineralised rhyolitic pyroclastic rock, possibly an ash-fall tuff, or the non-welded part of an ash-flow.

LS 2. Outcrop: Sheared chloritic zone with magnetite and pyrite from near the contact of a minor intrusion.

Thin section: Primary features: Phenocrysts of quartz, an unidentifiable feldspar and apatite occur in a fine-grained groundmass. The phenocrysts are concentrated one side of the specimen and may be reworked.

Secondary features: The feldspar phenocrysts are much altered to fine-grained sericite, chlorite and opaques. Distinct, polygonal, monomineralic patches of sericite and chlorite in the groundmass may also represent altered phenocrysts. Other patches of chlorite outline coalescing, rounded bodies of quartz-sericite which may be of primary origin.

The groundmass elsewhere consists of quartz/feldspar, sericite, chlorite and opaques. The phyllosilicates mark a well-developed cleavage. The opaques are mainly magnetite partly altered to hematite. Pyrite is minor. Swarms of small magnetite crystals occur; some are associated with patches of chlorite. The larger magnetite crystals have pressure shadows of quartz with or without muscovite and chlorite.
There are two varieties of chlorite. The variety with P:green to yellow; AIC:yellow-green on grey occurs in the groundmass; another with P:green to yellow; AIC:blue-grey occurs both in the groundmass and in pressure-shadows.

Identification: a quartz and feldspar-phyric rhyolitic volcanic rock, possibly pyroclastic.

LS 5. Outcrop: (from dump of small working). Mineralised chloritic schist.

Thin section: Primary features: Quartz phenocrysts occur in an altered groundmass.

Secondary features: The quartz phenocrysts are somewhat recrystallised and corroded at the edges. The groundmass includes areas of quartz chlorite and opaques. The quartz occurs as very irregular grains, locally with incipient tesselate texture. Chlorite marks the cleavage. Swarms of minute hematite crystals are scattered sporadically throughout. Magnetite, now largely replaced by hematite, is disseminated as fine-ground and coarse-grained euhedra, and occurs also as veins or major replacement zones of coalescing crystals. Associated with the concentrations of magnetite are coarse-grained chlorite and quartz, the latter having grown under stress.
The chlorite has P:green to yellow; AIC:yellow (some green).

Identification: the original rock-type cannot be determined.

SS. 758ft

Core: Red to pink, fine-grained (?) hornfels with veins and patches of pyrite.

Thin section: No primary features are apparent.

Secondary features: The bulk of the specimen consists of a fine-grained intergrowth of quartz/feldspar with scattered pyrite grains and patches of chlorite. Coarse-grained pyrite occurs with quartz and chlorite in veins, and with intergrown chlorite and K-feldspar bears abundant, minute inclusions of hematite. Minor chalcopyrite, sphalerite and rutile occur in association with pyrite. Calcite occurs in small quantities in veins and as an alteration mineral in wallrock. The chlorite in patches in the wallrock is intergrown with rutile and zircon, and has pleochroic haloes around the latter. There is one variety of chlorite, P:green to light yellow, AIC: greenish-grey to bright green.

Identification: the original rock-type cannot be determined.

DDH LS5. 870ft

Core: a pink, (?) intrusive rock with quartz phenocrysts and white and greenish bodies in a fine-grained groundmass.

Thin section: Primary features: Large phenocrysts of quartz, pseudomorphs after feldspar phenocrysts and pseudomorphs after ferromagnesian phenocrysts are set in a medium-grained groundmass. There may be remnants of primary biotite in some of the pseudomorphs with a green-brown colour. Accessory zircon is present, some enclosed within the chloritic pseudomorphs and giving rise to pleochroic haloes.

Secondary features: The feldspar phenocrysts have been entirely replaced by sericite with or without chlorite. Original zoning is marked in some cases by different proportions of the two minerals. The pseudomorphs inferred to have been ferromagnesian are largely replaced by an intergrowth of muscovite and chlorite, apparently preserving the cleavage traces of the original mineral. The groundmass consists of equigranular, subtesselate quartz with varying amounts of interstitial sericite and chlorite. The texture of the groundmass locally suggests that laths of feldspar have been replaced by sericite. A calcite vein cuts the specimen , and minor calcite occurs elsewhere as an alteration product. Another vein consists of sericite and pyrite. Rutile and pyrite are disseminated throughout, and occur on the twin-planes of micas and another crystal now otherwise replaced by quartz and sericite. A little magnetite may be present.

There is one variety of chlorite, P:green to pale yellow; AIC:blue.

Identification and discussion: By virtue of its relatively coarse groundmass, this appears to be an intrusive rhyolitic porphyry. It does not resemble a granitoid in texture (earlier, Mt Lyell Co. geologists had suggested it was part of the Murchison Granite). Alteration style gives no indication whether it is pre - or post-mineralisation. However it cuts the mineralisation of the country rock sharply, and may have been responsible for hornfelsing the country rock.

LAKE DORA

DS 1B. Outcrop: Orange-weathered gritty sandstone from a lens within the Dora Conglomerate.

Thin section: Primary features: Quartz-grains, poorly sorted, angular (some embayed, indicating a volcanic origin) are abundant. Other detrital elements include lithic fragments (some altered, some of volcanic origin) and minor zircon and (?) apatite.

Secondary features: Some of the quartz grains are recrystallised at the edges. Certain lithic fragments show a vague snowflake devitrification texture; others are mottled mixtures of quartz and sericite. The matrix of the rock is sheared, and the cleavage is marked by orange-weathered bands of phyllosilicate. The areas between the cleavage consist of fine-grained quartz sericite and chlorite with rutile/sphene (a few rhombic sections suggesting sphene). There are scattered opaques, now hematite after pyrite, some with pressure shadows. Two specks of galena were noted. Surviving chlorite has P:green to yellowish: AIC:yellow-grey.

Identification: a sheared, altered tuffaceous sandstone.

DS 2. Outcrop: (from the dump of a costean). Chloritic rock with visible quartz grains, veined by quartz, chlorite and pyrite. One quartz-chlorite vein has a pink, felsic selvage.

Thin section: Primary features: Phenocrysts of embayed quartz and K-feldspar are set in a fine-grained groundmass with accessory zircon.

Secondary features: The quartz phenocrysts are recrystallised at the edges. The K-feldspar is much corroded, is varied and replaced by chlorite and contains minute inclusions of hematite. The groundmass consists of fine-grained quartz/feldspar with lesser chlorite and rutile/sphene. Sericite is abundant locally. The texture of interlocking, irregular crystals suggests devitrification, coarser-grained patches of this texture could represent lithic fragments. Certain areas may preserve snowflake devitrification texture. Pyrite crystals are scattered throughout, and have pressure shadows of quartz, chlorite and minor muscovite. Veinlets of sericite + chlorite, quartz + sphene and quartz + chlorite + minor sericite cut the specimen. The quartz-sphene veinlets are discontinuous. Although chlorite occurs in various habits, and some chlorite appears to be earlier than that in the pressure-shadows, only one optical variety is present. It has P:green to yellowish; AIC:yellow-grey.

Identification: a veined altered quartz - and K-feldspar-phyric volcanic rock, probably a rhyolitic lava.

DS 3. Outcrop: (from dump of Lake Dora working). Sheared, chloritic rock bearing quartz grains and sulphides.

Thin section: Primary features: A few broken grains of quartz are set in a altered, fine-grained matrix with accessory zircons.

Secondary features: The matrix consists of concentrations of intergrown chlorite and sulphides, marking the cleavage, and of intervening areas of fine-grained quartz, chlorite, minor sericite and opaques including rutile. There are local areas of coarser-grained polycrystalline quartz with minor chlorite and sericite. The sulphides are in veins, and are associated with minor quartz and sericite grown under stress. Euhedral pyrite crystals are enclosed by large, irregular areas of chalcopyrite. Locally, pyrite encloses chalcopyrite. Minor magnetite (mostly altered to hematite) and rutile are intergrown with the sulphides. Swarms of rutile crystals and scattered grains of pyrite and chalcopyrite occur in the wallrock.
Chlorite occurs in two habits - groundmass and vein - but both have P:green to yellowish; AIC:grey to yellow-grey.

Identification: possibly a sheared tuffaceous sandstone.

DS 4. Outcrop: (from the dump of a small working); sheared chloritic rock with large grains of quartz.

Thin section: Primary features: Quartz grains of volcanic origin, poorly sorted lithic fragments of equigranular and porphyritic textures and accessory zircons are set in a fine-grained matrix.

Altered flakes of muscovite may also have been detrital.

Secondary features: The lithic clasts have been altered to a quartz/feldspar and sericite assemblage. The muscovite flakes are replaced by chlorite. The matrix consists of fine-grained quartz, chlorite and sericite with opaques. It is strongly foliated. Minor calcite occurs as pressure shadows around the larger grains. The opaques include magnetite, sphalerite - magnetite - pyrite intergrowths, sphalerite with exsolved chalcopyrite, and traces of galera and chalcopyrite, all disseminated. A little sphalerite with exsolved chalcopyrite occurs in a quartz vein.
There is one variety of chlorite; P:green to yellow; AIC: yellow-grey to green-grey.

Identification: a sheared, tuffaceous wacke.

DS 8. Outcrop: (dump of small working) - sheared chloritic rock containing quartz grains.

Thin section: Primary features: Quartz phenocrysts are set in a fine-grained groundmass.

Secondary features: The groundmass consists of a fine-grained mosaic of quartz/feldspar with patches of chlorite and sericite. Much of the groundmass is entirely replaced by chlorite which encloses bodies of calcite (including tension gashes), zircons (around which pleochroic haloes have developed), opaque grains, swarms of small rutile crystals and allanite. (This mineral is colour-zoned and strongly pleochroic from red-brown to colourless. The interference colours are anomalous, up to second-order blue). The opaques comprise magnetite, pyrite and sphalerite (with chalcopyrite) as grains, and sphalerite and galena as veinlets in the chlorite.
The chlorite has P:green to yellowish; AIC:yellowish greys. A green, chlorite-like mineral with second-order birefringence occurs in the pressure-shadow of a pyrite grain and was demonstrated by microprobe analysis to be biotite.

Identification: the rock may have been volcanic or a tuffaceous sediment, but is now altered beyond recognition.

DS 9. Outcrop: (from the dump of a small working). chloritic rock bearing quartz grains and sulphides.

Thin section: Primary features: Abundant angular and embayed quartz phenocrysts, rare zircons, fiamme and other possible lithic fragments occur in a fine-grained groundmass of eutaxitic texture.

Secondary features: The quartz phenocrysts have diffuse edges. The groundmass consists of quartz/feldspar, chlorite, abundant fine-grained opaques and coarser patches of chlorite muscovite, quartz and opaques. Epidote is rare, and may be associated with quartz grown under stress. This quartz occurs in veins with opaques and minor quartz and sericite. The vein chlorite is of a later generation than the groundmass chlorite which is deformed near the veins. The opaques include pyrite, galena, sphalerite and chalcopyrite in veins. Galena and chalcopyrite are intergrown. The host-rock contains disseminated (?) sphalerite.
The chlorite has P:green to colourless: AIC:yellow-grey to greenish-grey.

Identification: a quartz-phyric rhyolitic ash-flow tuff.

DS 10. Outcrop: Orange-weathered volcanic rock bearing magnetite veins with chloritic selvages.

Thin section: Primary features: Abundant angular quartz phenocrysts, angular bodies now entirely altered to sericite (originally feldspar?), a few feldspar phenocrysts and glomerocrysts, and accessory zircons occur in a fine-grained groundmass with some eutaxitic texture.

Secondary features: The groundmass consists of quartz/feldspar, a chlorite-like mineral, (?) sericite and fine-grained magnetite. The specimen is cut by a vein of magnetite in tabular crystals with minor pyrite. The magnetite has undergone a little alteration to hematite, and the polished surface has a plumose texture. Replacement of wallrock by "chlorite" and of feldspar phenocrysts by sericite becomes more intense and eventually complete (bar quartz phenocrysts) as the vein is approached. There is a veinlet of rutile.

The chlorite-like mineral has P:blue-green to colourless; AIC: yellowish over colours up to second-order blue. It occurs throughout the specimen as a replacement, and may be mingled with a little true chlorite. It gives a chlorite analysis (including ½% Na_2O, which may be spurious).

Identification: The rock is a quartz-phyric, rhyolitic ash-flow tuff.

DS 13. Polished section of ore from a small working.

Description: The ore is compositionally banded in sphalerite, galena and pyrite certain bands being richer in one mineral, compared with other bands. Pyrite occurs as larger subhedral crystals. Sphalerite inclusions are found in some and (?) tetrahedrite inclusions in one. The large crystals are apparently replaced by galena and sphalerite. Minor pyrite occurs intergrown with sphalerite and galena elsewhere. Sphalerite and galena are intergrown along curbed interfaces. Both sphalerite and galena form large monomineralic areas. In one case, galena appears to be the central filling of a vein of sphalerite. Chalcopyrite forms minor areas in contact with sphalerite and galena, and blebs and patches within sphalerite.

Discussion: This is probably recrystallised vein - type mineralisation. Although compositionally banded, it lacks the finer-grained typical texture of massive-sulphide deposits such as Rosebery, Koonya and Hercules where the amount of metamorphism and deformation has been similar.

HOWARDS ROAD
(and neighbouring spurs
of Mt. Read).

HR 1A. Outcrop: Massive, pink, feldspar-phyric volcanic rock with chloritic patches, taken about 1m away from the contact of a more basic intrusion.

Thin section: Primary features: Phenocrysts and glomerocrysts of plagioclase enclosing accessory zircon and apatite are set in a fine-grained groundmass. The groundmass also contains accessory zircon. Areas of epidote may be pseudomorphs of phenocrysts.

Secondary features: The plagioclase phenocrysts are partly replaced by clinozoisitic epidote and chlorite, and remaining plagioclase is albitic. The groundmass consists of fine-grained quartz/feldspar, epidote, chlorite, (?) rutile and goethite. Coarser-grained patches or individual grains of quartz, albite and clinozoisite are scattered unevenly through the groundmass. Some of the clinozoisite is Fe-oxide stained. The specimen is veined by quartz; one vein contains a brownish-green chlorite-like mineral with interference colours up to second-order blue (presumably this is due to weathering). Elsewhere the chlorite has P:green to pale yellow; AIC:blue-green on grey.

Identification and discussion: a plagioclase - phyric rhyolitic or dacitic volcanic rock. The larger quartz grains in the groundmass may represent the annealing of groundmass devitrification products at the time of emplacement of the more basic intrusion.

HR 1B. Outcrop: Grey, plagioclase - phyric volcanic rock from the same area as HRIA, taken 4m from the contact of the basic intrusion.

Thin section: Primary features: Plagioclase phenocrysts are set in a groundmass of plagioclase, amphibole and grains which were originally Fe-oxide (magnetite?). The groundmass consists of randomly oriented laths of these minerals and is vesicular.

Secondary features: Phenocryst and groundmass plagioclase are partly replaced by epidote, and (?) amphiboles by chlorite. The

207

amphiboles are commonly ragged in appearance because of replacement. Goethite replaces the Fe-oxide grains. The vesicles are filled with chlorite and quartz. Intersertal chlorite makes up the rest of the groundmass.

The intersertal chlorite has P:green to colourless; AIC:bluish-grey. The vesicle chlorite is more weathered, and as a result has interference colours up to first-order yellow and red. The freshest has P:green to colourless; AIC:brown or blue.

Identification: a plagioclase-phyric basalt or basaltic andesite, whether intrusive or extrusive uncertain.

HR 2. Outcrop: Massive grey ash-flow with dark green fiamme.

Thin section: Primary features: A few microphenocrysts of feldspar and some small grains of quartz which may be primary occur in a eutaxitic groundmass consisting largely of flattened and bent pumice.

Secondary features: The feldspar microphenocrysts are replaced at the edges by sericite. The groundmass consists largely of fine-grained quartz/feldspar, sericite, chlorite and goethite. Relatively coarse-grained, rounded, polycrystalline patches of quartz and albite also occur. Some fiamme are chloritic. Sericite and chlorite mark the primary and secondary foliations. There are scattered, Fe-oxide stained patches of relatively coarse-grained chlorite.

Fresh chlorite has P:green to colourless; AIC:blue-green on grey.

Identification: a vitric ash-flow tuff, probably rhyolitic to dacitic.

HR 4. Outcrop: Massive, grey volcanic rock with pink feldspar phenocrysts.

Thin section: Primary features: Deformed and broken plagioclase phenocrysts are set in a eutaxitic groundmass with accessory zircon. Pumice in the groundmass is flattened and bent around the phenocrysts.

Secondary features: The plagioclase phenocrysts are riddled with fine-grained sericite and veined with secondary albite containing minute hematite inclusions. Similar secondary albite is found in the groundmass, which, however, consists largely of fine-grained quartz/feldspar and weathered sericite and chlorite. The sericite is yellowed, and marks the cleavage. Chlorite weathering products retain the original habit of the chlorite, but have birefringence up to second-order. Goethite, possibly after magnetite, is scattered throughout the specimen, and there is a little very fine-grained rutile. Quartz veins containing orange clay after chlorite cut the specimen.

Identification: a plagioclase-phyric, (?) dacitic ash-flow tuff.

HR 5. Outcrop: Massive, splintery, pink ash-flow tuff with feldspar phenocrysts and chloritic fiamme.

Thin section: Primary features: Phenocrysts and glomerocrysts of plagioclase are set in a eutaxitic groundmass with accessory zircon. The groundmass pumice locally retains bubble - shapes, i.e. is not entirely flattened.

Secondary features: The plagioclase phenocrysts are altered almost entirely to fine-grained sericite and recrystallised albite. The groundmass consists of quartz/feldspar in bands of finer and coarser grain-size, these marking the structure of the original pumice. There is also weathered sericite and chlorite marking the cleavage and a little very fine-grained rutile.
The chlorite has P:yellowish greens; AIC:yellow on grey. The yellows are probably due to weathering which, where more intense, has given rise to orange (?) clay with interference colours up to second-order blue.

Identification: a plagioclase - phyric, (?) dacitic ash-flow tuff.

6. Outcrop: Massive, grey, quartz and feldspar - phyric volcanic rock, possibly banded according to phenocryst type.

Thin section: Primary features: Phenocrysts and glomerocrysts of plagioclase, subordinate, embayed phenocrysts of quartz and minor phenocrysts of apatite are set in a fine-grained groundmass with accessory zircon. The groundmass has a poorly-developed cellular texture probably due to perlitic cracking.

Secondary features: The plagioclase phenocrysts are turbid, and bear many fine-grained sericite crystals and well as veins and bands of heavy sericite alteration. They also bear clinozoisite and a little chlorite as alteration products. One encloses a patch of (?) goethite and chlorite. A rim of fine-grained, equant quartz surrounds each quartz phenocryst. The groundmass is mainly quartz/ feldspar (some identifiable albite) and chlorite. The albite occurs as ragged intergrowths within the cells, and chlorite marks the boundaries (cracks?) and forms irregular patches. Goethite, probably after primary magnetite, rutile and epidote are minor constituents of the groundmass. The specimen is veined by sericite, and there are discontinuous veins of quartz and sericite.
The chlorite has P:pale brownish-green to colourless; AIC:blue. A chlorite-like grain attached to a rutile crystal has stronger brown pleochroism and a first-order yellow interference colour.

Identification: A quartz and plagioclase - phyric volcanic rock, probably originally a glassy lava.

7. Outcrop: Grey reworked tuff containing quartz and feldspar crystals and fragments of shale.

Thin section: Primary features: Embayed quartz grains of phenocryst origin, plagioclase grains (which may be as common as the quartz, but alteration makes this difficult to judge) and a few quartz-rich rock fragments occur in a fine-grained (?) silty matrix. The rock is very poorly sorted.

Secondary features: The plagioclase grains are extensively altered to sericite, some zones of the crystals being more strongly altered than others. The matrix consists of quartz/feldspar, sericite, chlorite and rutile. Most is very fine-grained, but there are scattered patches of coarser albite, chlorite and sericite.

Sericite forms a network of small crystals along the boundaries of feldspar grains.
The chlorite has P:pale green to pale yellow (some areas are brownish, like pleochroic haloes); AIC: blue.

Identification: reworked rhyolitic volcanic ash, i.e. tuffaceous wacke.

LJ1. Outcrop: Weathered pale greenish quartz-sericite schist.

Thin section:

Primary features: A few small phenocrysts of plagioclase are preserved. Polished-out areas with traces of coarse-grained (?) albite remaining may represent other, sheared phenocrysts.

Secondary features: The groundmass is heavily sheared, and consists of quartz, sericite and minor rutile.

Identification: a rhyolitic to dacitic plagioclase porphyry of indeterminate origin.

BRADSHAWS ROAD & HOWARDS ANOMALY

BR 1. Outcrop: Massive, grey-green hornblende porphyry.

Thin section: Primary features: Phenocrysts and glomerocrysts of plagioclase and hornblende, and possibly some fragments of felsic igneous rock are set in a fine-grained groundmass with needlelike plagioclase microlites. The groundmass texture may be pilotaxitic. Most hornblende phenocrysts include crystals of plagioclase, and some plagioclase phenocrysts include hornblende. There is accessory zircon in the groundmass. Bodies of sphene and chlorite, some of regular form, are common, and may be replacements of an earlier phenocryst phase (ilmenite?).

Secondary features: Plagioclase phenocrysts are albitic and are partly replaced by epidote. Some bear veins and patches of quartz or recrystallised albite, and all are riddled with minute flakes of sericite. Hornblende phenocrysts bear chlorite and a little epidote. They are ragged at the edges, probably because of the uneven development of chlorite. The lithic fragments bear secondary chlorite. The groundmass consists of fine-grained quartz/feldspar, needles of plagioclase, epidote, sphene and patches of chlorite. Hematite or goethite may be replacing original magnetite. Small grains of (?) pyrite are included in epidote crystals.

Identification: a plagioclase-and hornblende-phyric andesite, porphyry, possibly a lava.

BR 2. Outcrop: Sheared green volcanic rock with white feldspar phenocrysts.

Thin section: Primary features: Feldspar phenocrysts (type unrecognisable) and apatite phenocrysts are set in a fine-grained groundmass with accessory zircon.

Secondary features: The feldspar phenocrysts are extensively replaced by sericite (sufficient feldspar remains to show extinction on rotation). Bodies of chlorite, are enclosing crystals of quartz and apatite, may replace original phenocrysts. Quartz occurs in large areas - some as monocrystalline grains, some as strained polycrystalline areas - which are apparently pre-cleavage, and may represent

disrupted veins. The groundmass consists of quartz/feldspar, sericite, chlorite and rutile. Chlorite and sericite mark the cleavage, and chlorite is very abundant in certain bands. Orange, Fe-oxide stained patches are common.
The chlorite has P:blue-green to pale yellow; AIC brown to purple.

Identification: a feldspar-phyric (?) dacitic volcanic rock of unknown mode of deposition.

BR 3. Outcrop: Weathered grey feldspar-phyric porphyry.

Thin section: Primary features: Abundant phenocrysts and glomerocrysts of plagioclase and lithic fragments are set in an originally-glassy groundmass.

Secondary features: The phenocryst plagioclase is riddled with fine-grained sericite, and one bears a patch of (?) clay, possibly after chlorite. The groundmass consists of micropoikilitic quartz (snowflake devitrification texture), and includes abundant fine-grained sericite as flecks within the quartz and as bands marking the cleavage. Goethite staining is widespread, and there is minor fine-grained (?) rutile. Large patches of radiating crystals of yellow-green, pleochroic phyllosilicate (clay after chlorite?) occur; some may replace original phenocrysts.

Identification: a feldspar-phyric, rhyolitic to dacitic (?) lava.

BR 4. Outcrop: Sheared, grey, feldspar-phyric tuff.

Thin section: Primary features: Grains or phenocrysts of quartz and plagioclase (with somewhat irregular twinning) and fragments which may have been pumice occur in a fine-grained matrix or groundmass. Other polycrystalline grains of quartz/feldspar may also be primary. There is accessory zircon.

Secondary features: The feldspars are not significantly replaced. The matrix/groundmass consists of fine-grained quartz/feldspar and sericite with minor very fine-grained rutile/leucoxene and goethite. Two foliations, marked by sericite, intersect at 25^{o}.

There are irregular patches and discontinuous veinlets of quartz.

Identification: a pyroclastic rock, possibly reworked.

BR5. Outcrop: Pale pink to green ash-flow tuff, sericitised and (?) silicified, containing large blocks of black shale (and, elsewhere, green and purple blocks of (?) volcanic rock).

Thin section: Primary features: Embayed quartz phenocrysts are set in a groundmass which contains one definite fragment of flattened pumice and hints of similar texture elsewhere. Round bodies of quartz, surrounded by secondary minerals and in more-or-less regular array, may represent the gas-holes in a non-collapsed pumice fragment.

Secondary features: Some monomineralic areas of alteration products may represent original phenocrysts - e.g. sericite after plagioclase. No unaltered feldspar remains. The groundmass consists mainly of quartz/feldspar and sericite. A little rutile is intergrown with the sericite. The grainsize varies irregularly. Certain patches of unusual grainsize and composition (lacking sericite, or more rutile than elsewhere) may represent lithic fragments. Cleavage is poorly developed. Rare spherulitic devitrification centres are preserved, enclosed entirely within quartz grains.

Identification: a glassy, quartz-phyric pyroclastic of (?) rhyolitic composition; possibly the less-welded part of an ash-flow.

BR 6. Outcrop: Reworked tuff interbedded with shale and greywacke.

Thin section: Primary features: Angular grains of quartz (rarely showing phenocryst characteristics) and more common deformed feldspar grains are set in a fine-grained matrix. The larger grains are sand-size and also include magnetite (altered to goethite), rock fragments and zircon as minor components. Matrix and sand are present in roughly equal proportions.

Secondary features: The feldspars are altered almost entirely to sericite and opaques (goethite?). Orange-weathered, polycrystalline (?) clay bodies bearing a little rutile may replace hornblende.

The groundmass is dark, fine-grained and strongly sheared. It was rich in chlorite, which is mostly weathered to an orange (?) clay, and also contains very fine-grained quartz/feldspar, sericite and opaques.
The little remaining fresh chlorite has P:green to pale yellow; AIC:blue.

Identification: a reworked tuff, probably derived from a rhyolitic source.

BR 7A. Outcrop: Grey-green felsic volcanic rock, weathered.

Thin section: Primary features: Plagioclase phenocrysts are sparse, set in an originally-glassy groundmass.

Secondary features: The plagioclase phenocrysts are riddled with fine-grained sericite and bear patches of weathered chlorite. The groundmass has a coarse-grained, annealed snowflake texture. The micropoikilitic areas of optically continuous quartz make up most of the rock, and are polygonal and contiguous. The microlites within the quartz are mostly chloritised or sericitised, but a little feldspar remains in this form. The groundmass contains local chloritic patches, and several widmannstatten intergrowths of chlorite and rutile. Goethite, in one case replacing pyrite, occurs as scattered grains. The specimen is cut by quartz veins, and much of the vein quartz is optically continuous with neighbouring snowflakes. The freshest remaining chlorite has P:brown-green to pale green; AIC: none (grey). Most is orange form weathering, with interference colours up to second order.

Identification: a plagioclase-phyric, (?) rhyolitic (?) lava.

BR 7B. Outcrop: Pink feldspar porphyry, massive and somewhat weathered, bearing a trace of pyrite.

Thin section: Primary features: Phenocrysts and glomerocrysts of plagioclase are set in an originally-glassy groundmass with accessory zircon. Certain small quartz grains seem embayed and may be microphenocrysts.

Secondary features: Some plagioclase phenocrysts are altered entirely to sericite. Others are albitic, flecked with fine-grained sericite, and partly replaced by carbonate of strong rhombic habit. The groundmass consists of micropoikilitic quartz (snowflake divitrification texture), the areas of quartz being contiguous and polygonal. In places this is so fresh that the plagioclase microlites are preserved. Where snowflakes have not developed, the groundmass contains abundant sericite and carbonate and many fine-grained opaques. The carbonate is iron-stained and may be sideritic, although its minimum refractive index appears to be too low for pure siderite. Goethite occurs near weathered edges, and pyrite grains are scattered throughout the specimen. One pyrite grain and a chalcopyrite grain occur in a veinlet. Grains of rutile - large grains and swarms of finer-grains are scattered throughout. The specimen is cut by a vein of quartz, carbonate and weathered chlorite, and veinlets of sericite.

Identification: a plagioclase-phyric (?) rhyolitic volcanic rock, possibly a lava.

BR 8. Outcrop: Very fine-grained, pink-brown (?) vitric tuff, locally laminated, with devitrification spots.

Thin section: Primary features: The general fine-grain, the spots marked by rings of iron-stained carbonate and the accessory zircons appear to be the only primary features.

Secondary features: The groundmass is a fine-grained intergrowth of irregular quartz-feldspar crystals. Scattered flakes of muscovite and patches of sericite, very fine-grained rutile and rare (?) epidote are lesser components of the groundmass. The rings of Fe-stained carbonate consist of many separate euhedral rhombs, all oriented alike in a given ring, but differing in orientation from ring to ring.

Identification: a rhyolitic to dacitic (?) vitric tuff.

BR 9. Outcrop: Grey, feldspar-phyric tuff with chloritic patches resembling fiamme. Weathered.

Thin section: Primary features: Plagioclase phenocrysts are numerous in a groundmass abounding in vitroclastic textures: shards and pumice, the latter neither bent nor flattened. There are a few lithic fragments, quartz phenocrysts (subordinate to plagioclase) and accessory zircon. The concentration of small phenocrysts in certain areas may reflect the relative distribution of pumice and matrix, otherwise difficult to pick in certain areas. The rock is very poorly sorted.

Secondary features: The plagioclase phenocrysts are riddled with fine-grained sericite. Some areas of Fe-stained weathered phyllo-silicates may be after other sorts of phenocrysts. The pumice and groundmass consist of fine-grained quartz/feldspar and a yellow weather phyllosilicate (after chlorite) which also occurs in coarser-grained patches with recrystallised albite. There is scattered rutile (some associated with weathered chlorite). goethite patches replace primary iron oxide or pyrite. One such area encloses small pyrite crystals.

Identification: a vitric-crystal, plagioclase - and quartz-phyric, rhyolitic to dacite, ash-fall tuff.

[illegible] 13. Outcrop: Green quartz- and feldspar-phyric crystal-lithic tuff containing large rock-fragments and a few cavities.

Thin section: Primary features: Plagioclase phenocrysts are set in a fine-grained groundmass of uneven but uninterpretable texture. Accessory zircon and apatite occur in the groundmass.

Secondary features: The plagioclase phenocrysts are riddled with fine-grained sericite and are replaced completely in some growth zones by sericite. The groundmass is a turbid mixture of quartz/feldspar sericite, chlorite, a little rutile and a trace of pyrite. The rutile and pyrite are widely distributed as minute grains. Patches of relatively coarse grain-size consist of quartz and chlorite, the chlorite bodies possibly representing former pheno-crysts. Folded veinlets of albite, some with quartz and chlorite, cut the specimen.

The chlorite has P:green to pale yellow; AIC:purple and blue.

Identification: a(?) dacitic, plagioclase (and quartz?) phyric crystal-lithic tuff.

HA 15. Outcrop: Pink and green massive banded and mottled feldspar-phyric tuff.

Thin section: Primary features: Almost the entire rock consists of moderately well - sorted crystals 1-2 mm long of plagioclase and subordinate quartz, and there are minor lithic fragments. there is very little matrix; it contains magnetite (possibly primary) and accessory zircon. Some of the plagioclase crystals are deformed as a result of compaction. Some plagioclase grains include apatite.

Secondary features: The plagioclase crystals are albitic, and riddled with fine-grained sericite. They contain minute inclusions of hematite which impart a reddish turbidity. The edges of the plagioclase crystals are recrystallised, particularly where they join other plagioclase crystals. The matrix consists of albite, quartz (in patches enclosing plagioclase crystals), chlorite and magnetite. A little sericite and chlorite lines grain boundaries. Some chlorite encloses zircon crystals and may replace a primary ferromagnesian mineral. Rutile occurs as rare minute inclusions in the larger grains.
The chlorite is very fine-grained and appears almost isotropic, but has P:green to pale yellow: AIC:purplish brown to blue.

Identification: A rhyolitic to dacitic, well-winnowed, crystal ash-fall tuff. N.B. Specimen HA20 is a section through a more mafic specimen from the same outcrop.

16. Outcrop: Grey crystal - lithic tuff with quartz and feldspar phenocrysts.

Thin section: Primary features: Quartz phenocrysts, some euhedral, some embayed, some broken and angular, and plagioclase phenocrysts are set in a very fine-grained groundmass with accessory zircon. The groundmass textures include dark swirls and closed loops, some concentric, in come cases enclosing phenocrysts. Presumably this is a texture inherited from glass. The broken pieces of phenocrysts are very poorly sorted and are irregular in distribution.

Secondary features: The plagioclase phenocrysts are riddled with fine-grained sericite. The groundmass consists mainly of very fine-grained quartz/feldspar with scattered coarser patches. Rutile and chlorite are minor constituents and appear to be responsible for the dark colour of the swirls and loops (above). Bodies of rutile/sphene and chlorite may represent original phenocrysts. The chlorite has P:pale green to pale yellow; AIC:blue-grey.

Identification: a quartz - and feldspar - phyric, (?) rhyolitic volcanic rock of unknown mode of deposition.

HA 20. Outcrop: as HA15, feldspar and quartz phyric tuff banded and mottled in pink and green. Epidote occurs locally.

Thin section:

Primary features: Plagioclase phenocrysts and (in pink areas only), subordinate quartz phenocrysts are set in a fine-grained groundmass with accessory zircon. In pink areas, the groundmass predominates over phenocrysts. A few feldspars have a perthitic appearance and may be K-feldspar

Secondary features: In the green areas, the plagioclase phenocrysts are deformed, with ragged ends, or skeletal; in both cases replaced by chlorite. Some phenocrysts also bear secondary sericite which appears to be earlier than the chlorite. The groundmass consists entirely of secondary chlorite with streaks and composite grains of opaques. It is heavily sheared.
In the pink areas, the plagioclase phenocrysts are sparsely flecked with minute crystals of sericite. The groundmass consists of an irregular intergrowth of albite and (?) quartz of fine to medium grain. The groundmass has a brownish turbidity due to Fe-oxides. Some areas are rich in opaques. Some phenocrysts have pressure shadows of quartz/feldspar.

Areas intermediate between pink and green contain chlorite, sericite, quartz/feldspar and opaques, and have a continuous lamellar deformation fabric of alternating phyllosilicates and quartz/feldspar. The chlorite has P:green to pale green; AIC:salmon to purplish grey. Chloritisation appears to have been pre-tectonic.

Identification: a rhyolitic volcanic rock, probably a crystal tuff.

MT. SEDGWICK SECTION

SE 0: Outcrop: Green sheared (?) volcanic rock.

Thin section: Primary features: There are no definite primary features apart from accessory zircon. Patches of quartz and chlorite may represent phenocrysts or vesicles or both.

Secondary features: Relatively coarse-grained patches of polycrystalline quartz and chlorite(both in some cases) occur in a heavily sheared groundmass consisting of quartz, sericite, chlorite rutile and minor goethite. The texture is of deformation: equant, polycrystalline quartz grains are enclosed by and somewhat penetrated by phyllosilicates marking the cleavage.
The chlorite has P:bluish green to pale yellow; AIC:slight bluish-green on grey.

Identification: no textural evidence for origin; a quartz-chlorite-sericite schist.

SE 1. Outcrop: Massive, pink quartz-feldspar porphyry.

Thin section: Primary features: Large, deeply embayed phenocrysts of quartz and phenocrysts of plagioclase are set in a fine-grained groundmass with accessory zircon. A primary magnetite grain is attached to one plagioclase phenocryst.

Secondary features: The plagioclase phenocrysts are albite, and are riddled with fine-grained sericite and with calcite. A patch of sericite and rutile may be the pseudomorph of another kind of phenocryst. Goethite replaces primary magnetite. The groundmass consists of grains of quartz (intermediate in size between the phenocrysts and the remainder of the groundmass) and fine-grained quartz/feldspar, sericite, scattered concentrations of calcite and a little rutile and goethite. The intermediate grains of quartz are of two types: one clear, mono - or poly-crystalline; the other micropoikilitic. Concentrations of sericite mark the cleavage and give rise to an imperfect network pattern. Rutile and sericite form veinlets. Calcite and sericite occur as pressure-shadows of quartz phenocrysts.

Identification: a quartz- and feldspar-phyric rhyolite of uncertain origin; it may have been a glassy lava.

SE 4. Outcrop: Sheared, light green to brown, fragmental volcanic rock with chloritic spots. Weathered.

Thin section: Primary features: Sparse, poorly-sorted, subrounded quartz grains and patches of secondary minerals pseudomorphing magnetite or (?) feldspar phenocrysts are set in a fine-grained groundmass/matrix with accessory zircon.

Secondary features: The pseudomorphs (above) consist of chlorite, quartz, goethite and sericite. Residual magnetite and quartz occupy the centres of some. The groundmass/matrix is sheared and consists of very fine-grained quartz/feldspar, sericite, chlorite, goethite and a little rutile.
The chlorite has P:green to pale yellow; AIC:yellow-green on grey.

Identification: possibly a reworked lithic-crystal tuff (on the basis of the outcrop texture and the quartz grains).

SE 6. Outcrop: Massive grey-green ash-flow tuff with sparse fiamme, and containing blocks of black shale and massive fine-grained sphalerite and galena.

Thin section: Primary features: Quartz phenocrysts, embayed, and polygonal bodies of secondary feldspar after other varieties of phenocryst (including plagioclase?) occur with rounded pieces of fine-grained (?) sedimentary rock in a fine-grained groundmass. Accessory zircon is present.

Secondary features: The quartz phenocrysts bear overgrowths of quartz. The other phenocrysts have been altered to K-feldspar of uneven extinction (cf. HF and RH specimens), plus subordinate chlorite and in some cases sericite and calcite. The groundmass consists of quartz/feldspar, chlorite, sericite, calcite (all fine-grained) and scattered larger grains of rutile and pyrite (possibly primary). A few pyrite grains have silicate centres.

Chlorite and sericite occur as enriched patches, and sericite marks the cleavage.
The are two varieties of chlorite : 1. P:green to pale yellow, some with brown pleochroic haloes and patches, AIC:bluish-grey to yellowish-grey, 2. P:green-brown to colourless, AIC:yellowish-orange.
The second type could be a weathering product of the first.

Identification: a quartz- and (?) plagioclase - phyric-crystal-lithic-vitric ash-flow tuff (no microscopic evidence for origin) of (?) rhyolitic composition.

SE 7. Outcrop: Weathered, sheared chloritic quartz-feldspar porphyry.

Thin section: Primary features: Broken and embayed quartz phenocrysts and phenocrysts of feldspar(plagioclase and possibly some K-feldspar)are set in a fine-grained groundmass with accessory zircon and many grains of quartz which are smaller than the phenocrysts and may also be primary.

Secondary features: The feldspar phenocrysts are heavily altered to sericite and rutile. Other areas of yellow to orange to greenish clay (weathered chlorite) with hematite/goethite rims may be replacements of other phenocryst species. The groundmass consists of quartz/feldspar, sericite, rutile and goethite composing of fine-grained, turbid mass. The cleavage is marked by sericite which is yellowed by weathering.
Some relatively unoxidised chlorite remains, and has P:bright green to pale green; AIC:greenish-grey, in one area purple.

Identification: a quartz- and feldspar-phyric, rhyolitic volcanic rock of indeterminate origin.

SE 8. Outcrop: Weathered, sheared, green quartz-feldspar porphyry.

Thin section: Primary features: The phenocryst assemblage comprises rounded, embayed quartzes, relict feldspars, minor apatites, some in association with areas of secondary minerals possibly after other species. These are set in a fine-grained groundmass bearing accessory zircon.

Secondary features: The feldspars - and other phenocrysts except quartz and apatite - are replaced by yellow-brown (?) clay after chlorite and sericite. The quartz phenocrysts have diffuse edges due to either overgrowth or alteration. The groundmass consists of quartz/feldspar grains in a regular array, surrounded by weathered chlorite. The texture is probably tectonic.
The chlorite, where not weathered, has P:blue-greens, AIC:none (gey). Weathering has given rise to interference colours up to second-order.

Identification: a quartz-, feldspar- and apatite-phyric porphyry of indeterminate origin.

SE 9. Outcrop: Sheared, greenish volcanic rock with pink feldspar phenocrysts.

Thin section: Primary features: Plagioclase phenocrysts and glomerocrysts with zircon inclusions are set in a fine-grained groundmass in which the shapes of shards are preserved. The texture is not eutaxitic.

Secondary features: The plagioclase phenocrysts are replaced by coarsely-crystalline chlorite and patches of sericite and secondary albite. Replacement is zonal in some cases. The groundmass is a fine-grained intergrowth of irregular crystals of quartz/feldspar, sericite, chlorite, rutile/leucoxene and minor goethite. It is sheared locally, and the texture in such areas in granular, of bodies of quartz surrounded by sericite.
The chlorite has P:dark green to yellow; AIC:greenich or yellow-brown.

Identification: a plagioclase-phyric, crystal-vitric (?) dacitic tuff, possibly an ash-fall tuff.

LAKE MARGARET ROAD & AREA

LM 2. Outcrop: Sheared, grey, feldspar-phyric tuff bearing clasts of black shale. Heavily weathered.

Thin section: Primary features: Relict feldspar phenocrysts and uncommon angular grains of quartz occur in a fine-grained matrix/ groundmass.

Secondary features: The feldspar phenocrysts are altered to sericite, chlorite and opaques. The groundmass is a very fine-grained, turbid mixture of quartz/feldspar, sericite, chlorite, rutile and goethite. Scattered large crystals and clusters of rutile also occur. Coarsely-crystalline patches of chlorite and sericite are common. The chlorite has P:pale yellow-green to colourless; AIC:pale blue-grey, occurs as thick tabular crystals with imperfect cleavage and straight extinction and is unaffected by weathering. Another green mineral, apparently an oxidised chlorite, has P:yellow-greens to orange; AIC:yellow-green on grey and occurs as patches and scattered crystals in the groundmass.

Identification: a feldspar-phyric tuff, probably reworked.

LM 3. Outcrop: Grey-green, feldspar - phyric ash-flow tuff with dark green fiamme. Weathered and heavily sheared.

Thin section: Primary features: The forms of phenocrysts and glomerocrysts of feldspar, and one fragment of collapsed pumice, are preserved in a fine-grained groundmass with accessory zircon.

Secondary features: The feldspar phenocrysts are turbid and have been completely replaced by sericite and subordinate chlorite and quartz/feldspar. The groundmass consists largely of quartz/feldspar, chlorite, sericite and unresolvable turbid material, a fine-grained intergrowth of equant quartz/feldspar grains interspersed with the phyllosilicates. There is a little rutile or leucoxene.
The chlorite has P:green to pale yellow; AIC:slightly greenish-grey.

Identification: a feldspar-phyric (?) dacitic ash-flow tuff.

LM 6. Outcrop: Sheared, green, sericitic volcanic rock with pink feldspar phenocrysts, from a sequence consisting mainly of bedded sandstone and shale.

Thin section: Primary features: Plagioclase phenocrysts are set in a groundmass preserving large pieces of bent and collapsed pumice. Accessory zircon is present.

Secondary features: The plagioclase phenocrysts are riddled and veined with sericite, and many bear a few minute calcite rhombs. Goethite replaces what may have been primary magnetite grains. The groundmass consists of quartz/feldspar, sericite and scattered clusters of rutile crystals. The quartz/feldspar is fine-grained and equant; sericite marks the cleavage and much fine detail of the pumice structure.

Identification: a plagioclase-phyric (?) dacitic ash-flow tuff.

HUXLEY TRACK

(order, east to west across a generalised stratigraphic section is HX 6, 7 8B, 8A, 4, 2, 3).

HX 2. Outcrop: Least weathered unit of a heavily weathered section; grey, feldspar-phyric volcanic rock with streaks of iron oxide.

Thin section: Primary features: Phenocrysts and glomerocrysts of plagioclase are set in an originally-glassy groundmass with accessory zircon. The rock may have been vesicular. Other phenocryst phases may have been present.

Secondary features: The plagioclase phenocrysts are albitised, and bear fine-grained flecks of sericite. Certain glomerocrysts are accompanied by areas of chlorite which may be pseudomorphs of amphibole phenocrysts. Other, separate patches of chlorite and chlorite with rutile/sphene may also be pseudomorphs of phenocrysts. Radial patches of yellowed chlorite may represent filled vesicles. Grains now composed of goethite may be after magnetite. The groundmass consists largely of quartz, albite, sericite, goethite and rutile/sphene. The texture is of irregular snowflake devitrification type, consisting of irregular areas of quartz, turbid with sericitised microlites. The remainder of the groundmass consists of veinlets and patches richer in sericte, chlorite or albite. The chlorite is somewhat weathered. One variety commonly is associated with rutile/sphene, has P:pale green to pale yellow; AIC:blue; another (after phenocrysts?) has P:pale green to colourless; AIC:yellow-grey. A little chlorite with olive-green AIC is also present. The specimen is cut by a vein of quartz, albite and weathered phyllosilicate.

Identification: a plagioclase-phyric (possibly other phenocrysts species also) lava, possibly rhyolitic to dacitic.

HX 3. Outcrop: Grey, feldspar-phyric volcanic rock from a sequence of grey tuffaceous shales.

Thin section: Primary features: Plagioclase glomerocrysts and phenocrysts, some broken, are set in a groundmass preserving pumice textures. Some pumice is bent and flattened while other pieces retain round bubble-shapes. Some phenocrysts appear to have broad rims (not due to devitrifictation) around earlier cores. Some of the glomerocrysts are clumps of angular (not euhedral) crystals. Certain plagioclase phenocrysts are attached to large opaque grains now goethite. Accessory zircon is present.

Secondary features: The plagioclase phenocrysts are lightly dusted with flecks of sericite, and are veined and rimmed by secondary albite. A little chlorite and quartz are also present as alteration products. The groundmass is sheared and consists of fine-grained quartz/feldspar, sericite, chlorite and minor goethite. The phyllosilicates are weathered, and there is much staining due to iron oxides. The specimen is cut be veinlets of quartz and albite. Groundmass (fine-grained chlorite has P:green-brown to colourless; AIC:yellow-grey. There are a few chlorite-rich patches in the groundmass, and in those, the chlorite has P:pale green to colourless; AIC:none (grey).

Identification: a plagioclase-phyric, (?) dacitic vitric-crystal ash-flow tuff.

HX 4. Outcrop: Sheared, pinkish (?) ash flow tuff with green fiamme.

Thin section: Primary features: Plagioclase phenocrysts are set in dominant groundmass with a vague texture suggesting shards and chlorite bodies resembling fiamme.

Secondary features: The plagioclase phenocrysts are altered to sericite, the degree varying between scattered flecks and heavy riddling. They are veined by secondary albite associated with rhombic inclusions (in the albite); some of these inclusions are calcite, some are iron-stained and some appear to be cavities. These occur in the groundmass also. The groundmass is sheared and consists of fine-grained quartz/feldspar, sericite, chlorite and minor goethite.

The groundmass is an intergrowth of irregular grains, irregular both in size and in shape. Chlorite occurs both as concentrations (fiamme?) with P:green to pale yellow; AIC:blue and purple; and in fine-grained from in the groundmass, with P:brown-greens; AIC: green on grey.

Identification: a plagioclase-phyric, (?) dacitic vitric-crystal tuffs possibly an ash-flow tuff.

HX 6. Outcrops: Sheared, heavily weathered bleached volcanic rock.

Thin section: Primary features: Phenocrysts of feldspar, probably plagioclase, occur in a fine-grained groundmass with accessory zircon.

Secondary features: The feldspar phenocrysts are iron oxide-stained. The groundmass is sheared, and consists of fine-grained quartz/ feldspar, sericite, goethite (after magnetite?) and rutile (as scattered groups of crystals). Sericite marks the cleavage. A relatively large grain, removed by polishing, has pressure shadows of quartz. The specimen is cut by a quartz vein, the centre and selvages of which are stained by iron oxide.

Identification: a plagioclase-phyric volcanic rock of unknown origin.

HX 7. Outcrop: Pink and green volcanic rock, possibly flow-banded lava.

Thin section: Primary features: A few feldspar phenocrysts probably plagioclase of very irregular form, are set in a recrystallised groundmass bearing accessory zircon.

Secondary features: The feldspar phenocrysts bear a little sericite and have probably been albitised. They have been deformed. The groundmass is sheared, and consists largely of quartz and sericite. Albite is a minor component, along with rutile and goethite. Sericite marks the cleavage. The quartz appears to be recrystallised. Quartz veinlets cut the specimen.

Identification: a silicified, feldspar-phyric volcanic rock, possibly lava.

HX 8A. Outcrop: Grey-green, bedded, siltstone.

Thin section: Primary features: Fine sand-grade grains (and smaller) of quartz and feldspar, all fresh and angular and poorly sorted, occur in a matrix of finer grain-size. There appear also to be abundant fragments of sedimentary and volcanic rock.

Secondary features: The plagioclase grains are lightly dusted with fine-grained sericite. The groundmass consists of fine-grained quartz/feldspar (recrystallised) and chlorite and minor rutile. The chlorite has P:green to yellowish; AIC:grey-brown. A little monazite was discovered in association with chlorite by microprobe analysis.

Identification: a tuffaceous wacke.

HX 8B. Outcrop: Sheared, sericitised volcanic rock.

Thin section: Primary features: Phenocrysts and glomerocrysts of plagioclase and polycrystalline quartz grains which may be primary are set in a groundmass bearing accessory zircon. The groundmass may have been glassy.

Secondary features: The plagioclase phenocrysts bear a light dusting of sericite and veins and patches of chlorite and sericite. The groundmass consists of quartz, (?) feldspar, sericite, chlorite and rutile. Irregular quartz - rich areas are separated by a network of sericite veinlets which are more or less controlled by the cleavage. The quartz-rich areas are polycrystalline, and bear chlorite (and sericite?), some of the phyllosilicates replacing original feldspar microlites. This represents snowflake devitrification texture either of an imperfectly developed kind or changed by subsequent deformation.

Chlorite also occurs as euhedral chlorite-rutile pseudomorphs, probably after phenocrysts. In those, the chlorite has P:green to yellow; AIC:yellow-green on grey. Chlorite in the groundmass is finer in grain and paler in colour.

Identification: a plagioclase- and possibly quartz-phyric (?) rhyolitic volcanic rock probably a lava.

KING RIVER

KR1 Outcrop: Quartz-phyric, pink to grey agglomerate or blocky lava. The blocks are rounded to angular, pink, green or purple, quartz-phyric lavas, elongate parallel to the cleavage and up to 1 m long. Quartz-chlorite and quartz-epidote-albite veins occur.

Thin section:

Primary features: Broken quartz phenocrysts, subordinate plagioclase phenocrysts and a few apatite phenocrysts, as well as fragments of felsic volcanic rock and accessory zircon occur in a fine-grained, dominant matrix/groundmass. The matrix/groundmass shows no primary texture. Certain large crystals of magnetite could be primary.

Secondary features: The plagioclase phenocrysts are partly replaced by calcite and by fine-grained sericite. The large magnetite crystals are replaced by hematite. Calcite also occurs as an alteration product of lithic fragments. The groundmass/matrix is foliated. It consists of fine-grained quartz/feldspar and sericite, with swarms of rutile/sphene crystals and patches of calcite and chlorite. Opaques, probably corroded magnetite, also occur in the groundmass. A chlorite veinlet cuts one opaque grain, and patches of chlorite are associated with calcite in one case and rutile/sphene in another. The chlorite has P: green to yellow and AIC: slightly greenish-grey.

Identification: It is not possible to tell whether this is a pyroclastic rock or a blocky lava. It is a quartz-phyric, (?)rhyolitic, coarse-fragmental volcanic rock.

KR3 Outcrop: Massive purple-pink, quartz-phyric volcanic rock, not coarsely-fragmental.

Thin section:

Primary features: Phenocrysts and glomerocrysts of plagioclase, and phenocrysts of quartz (unembayed) and (?)apatite occur in a fine-grained groundmass. Some large opaques (originally magnetite) and rutile crystals may be primary. The groundmass has a streaky texture, but this is probably not eutaxitic texture. Accessory zircon is present, some attached to a large opaque grain.

Secondary features: The plagioclase phenocrysts are replaced by calcite and very fine-grained (?)sericite. Some are replaced by recrystallised quartz/albite. The large opaque grains appear to be replaced by goethite. The groundmass consists of quartz/feldspar, sericite, calcite, rutile/sphene and a trace of chlorite. Fine-grained opaques (goethite after magnetite?) are locally abundant. The quartz/feldspar occurs also as relatively coarse-grained recrystallised patches and as veins. The chlorite is in part associated with calcite, and has P: greens; AIC: green-grey. The streaky texture of the groundmass results from alternations of quartz/feldspar and calcite.

Identification: A plagioclase- and quartz-phyric (?)rhyolitic volcanic rock, mode of deposition not determined.

KR4 Outcrop: Sheared, greenish rock bearing large grains of quartz and blocks of pink quartz porphyry.

Thin section:

Primary features: Fragments of shale, siltstone and sandstone, and broken quartz grains, some of them embayed phenocrysts, occur in a subordinate, fine-grained matrix. There is rare detrital zircon and apatite, and one (?)feldspar grain. The coarser clasts are poorly sorted.

Secondary features: The (?)feldspar grain is fractured and altered to sericite. The matrix consists of quartz/feldspar and sericite. It is foliated; in one place, the foliation encloses bent muscovite crystals perpendicular to it, the effect being that of a crenulation cleavage. Rutile grains are scattered sparsely throughout, and concentrated along one foliation band. Goethite appears to replace primary iron oxides. Thin, discontinuous quartz veins cut the specimen.

Identification: a tuffaceous-lithic wacke.

KR6 Outcrop: Massive pink to green porphyry bearing a few quartz phenocrysts; heavily quartz-veined and iron-stained.

Thin section:

Primary features: Phenocrysts of plagioclase and embayed quartz occur in a fine-grained groundmass. Accessory zircon occurs both in the groundmass and as inclusions in plagioclase phenocrysts.

Secondary features: The plagioclase phenocrysts are riddled with very fine-grained sericite. Patches of sericite (?)chlorite, orange-weathered (?)clay and rutile/sphene pseudomorph large cyrstals, possibly originally mica phenocrysts. The groundmass consists of fine-grained, equigranular quartz/feldspar with sericite, rutile/sphene, goethite and a trace of chlorite. The sericite marks the cleavage, and also occurs (less abundantly) along the boundaries of quartz/feldspar grains. This texture is interrupted by numerous vague spherulitic devitrification structures (quartz or feldspar), one forming an overgrowth to a quartz phenocryst. Some of the chlorite occurs in veins; beside one of these, a little (?)epidote is present. Other veins consist of quartz and albite grown under stress.

The chlorite has P: green to pale yellow; AIC: greenish-blue on grey.

Identification: a quartz-phyric, (?)rhyolitic volcanic rock, originally glassy, probably a lava.

JUKES PROPRIETARY

JP3A Outcrop: (from no. 2 adit dump, a quartz-chlorite-sulphide vein in pink volcanic rock.)

Thin section:

Primary features: Abundant quartz and much less common, relict plagioclase phenocrysts occur in a fine-grained groundmass, originally glassy. The quartz phenocrysts are smaller than the plagioclase phenocrysts.

Secondary features: The quartz phenocrysts are fractured and partly replaced by fine-grained quartz/feldspar. Each phenocryst bears a micropoikilitic, optically-continuous overgrowth of quartz. Similar snowflake-like bodies of micropoikilitic quartz without nuclei are abundant. The plagioclase phenocrysts have been entirely replaced by sericite and minor chlorite. The remaining groundmass between the snowflake-like bodies is a turbid mixture, probably of quartz/feldspar, sericite, chlorite and opaques. The opaques may be iron oxides.

The specimen is veined by quartz and chlorite. The larger quartz veins also contain chlorite, chalcopyrite (oxidised partly to covellite), sphalerite, galena, pyrite and a mineral of high relief, high birefringence and rhombic section which may be siderite. The vein chlorite has been weathered locally to an orange, pleochroic, highly birefringent clay.

The chlorite has P: bright green to yellow-green; AIC: green to yellow-grey.

Identification: an originally glassy, quartz and feldspar phyric, rhyolitic volcanic rock, probably a lava.

JP3B Outcrop: (from no. 2 adit dump; veined, chloritised volcanic rock.)

Thin section:

Primary features: Quartz and relict feldspar grains (phenocrysts?) and rounded (?)lithic fragments are set in a fine-grained groundmass. The grains are abundant and could be detrital.

Secondary features: Certain quartz grains have optically-continuous, micropoikilitic overgrowths, and the supposed lithic fragments have a well-developed snowflake texture. The remainder of the rock is a fine-grained mixture of chlorite, sericite and magnetite with scattered, large, euhedral cyrstals of magnetite with quartz pressure shadows. A vein of carbonate (calcite?) cuts the specimen, and has a selvage of chlorite, quartz and magnetite. There are also discontinuous veinlets of chlorite.

There is one variety of chlorite, P: bright green to yellow; AIC: green to yellow.

Identification: an altered, mineralised rock of volcanic derivation, possibly a reworked tuff.

JP4 Outcrop: (from trench between nos. 2 and 3 adits). A chloritic breccia containing (?)barite.

Thin section:

Primary features: Quartz phenocrysts are set in a fine-grained groundmass.

Secondary features: The quartz grains are fractured, and each bears an overgrowth of quartz. There is no sign of plagioclase phenocrysts, but the rock is extremely altered. The groundmass consists of fine-grained, subhedral magnetite, clear quartz crystals, chlorite, and colourless, poikiloblastic crystals which may be albite or quartz. Calcite occurs as pressure shadows around quartz grains and no veins within them. Calcite patches also occur in association with chlorite and chalcopyrite. The chalcopyrite encloses calcite.

Two, or possibly three, varieties of chlorite are recognised:
1. Occuring in patches suggesting replaced phenocrysts, also interleaved with magnetite, quartz and sericite. Replaced by (2); P: green to yellowish; AIC: yellowish.
2. Fine- to medium-grained crystals marking the foliation and locally intergrown with minor sericite; associated with calcite, fine-grained magnetite and chalcopyrite. There may be two sub-types, (a) the finer-grained, more oriented variety, P: green to yellowish; AIC: grey-green, (b) the coarser-grained, less oriented variety in the centres of areas of type (2); P: green to yellowish, AIC: blue-grey. Varieties (a) and (b) may only appear to be different because of different grain-size.

Identification: a quartz-phyric, originally glassy, rhyolitic (?)lava.

JP7 Outcrop: a body of iron oxide and quartz capping a ridge north of the workings.

Thin section:

Primary features: none.

Secondary features: The rock consists largely of hematite after magnetite, quartz and blue-green tourmaline. Quartz occurs as relatively large polycrystalline patches and veins. Both the quartz and the iron oxides enclose needles, laths and irregular crystals of the tourmaline. (cf. specimen PD3).

Identification: a completely replaced volcanic rock.

JP10 Outcrop: Iron-oxide-pyrite mineralisation from a small surface-digging north-west of adit no. 1.

Thin section:

Primary features: none.

Secondary features: The rock is heavily veined with martitised magnetite, and also bears minor pyrite. The silicate fraction consists largely of granular quartz, possible minor albite, chlorite and sericite. The chlorite is weathered and yellowish. A fine-grained yellow phyllosilicate which is also present may be a weathering-product of chlorite. There are scattered crystals of blue-green tourmaline.

Identification: Completely replaced (?)volcanic rock.

JP11 Outcrop: Chloritic felsic volcanic rock with devitrification texture (visible in hand-specimen as fine, round granules on weathered surface).

Thin section:

Primary features: Feldspar phenocrysts of unknown variety and quartz microphenocrysts, some embayed, occur in an originally-glassy groundmass.

Secondary features: The feldspar phenocrysts are completely altered to sericite, or sericite and chlorite. Many of the quartz grains bear radial overgrowths of quartz in optical continuity with the central grain, but of somewhat fibrous appearance. Many such overgrowths contain microlites of feldspar, or sericite after feldspar. This is a variety of snowflake texture. Between the "snowflakes", the groundmass is made up of relatively coarse-grained quartz and fine-grained chlorite and sericite. Small crystals of rutile are scattered through the groundmass.

The chlorite has P: green to pale yellow; AIC: yellowish colours up to first-order red, or grey-green. The yellowish colours may be due to weathering.

Identification: a (?)rhyolitic volcanic porphyry, probably a glassy lava. Typical of the potassic "Darwin-type" rhyolites but not obviously potassic in this case because of alteration.

JP12 Outcrop: Grey, siliceous volcanic rock poor in feldspar phenocrysts, showing snowflake-granules on weathered surfaces and many small iron oxide spots.

Thin section:

Primary features: Feldspar phenocrysts - two showing twinning typical of plagioclase; others not twinned, possibly K-feldspar; yet others completely replaced - and embayed quartz microphenocrysts occur in an originally-glassy groundmass. A large magnetite crystal may also be primary. It and plagioclase phenocrysts enclose zircon crystals.

Secondary features: The feldspar phenocrysts are partly or completely replaced by yellowish (?)clay or weathered sericite. The quartz microphenocrysts have overgrowths (as in JP11), the included, sericitised, feldspar laths being larger in this case. The area between the "snowflakes" is composed of quartz/feldspar, sericite, opaques and a little chlorite. In places the phyllosilicates are relatively coarse-grained. Some chlorite or oxidised sericite occurs with sericite in colour-banded, minute radial aggregates. There are many small crystals of magnetite, a few of rutile and one of pyrite.

Identification: a (?)rhyolitic feldspar porphyry, probably a glassy lava and probably potassic.

JP13 Outcrop: A heavily-sheared volcanic rock with a granular weathered surface and rare quartz phenocrysts. On fresh surfaces, the rock has a hematitic purple colour, and veins of hematite and cherty silica are present.

Thin section:

Primary features: Unidentifiable feldspar phenocrysts and one large phenocryst of quartz, as well as abundant microphenocrysts of quartz are set in an originally-glassy groundmass. A cluster of large magnetite crystals may be primary.

Secondary features: The feldspar phenocrysts have been completely sericitised. The quartz microphenocrysts bear micropoikilitic quartz overgrowths (as in JP11). The microlites in the "snowflakes" are numerous and make the "snowflakes" turbid. Between the snowflakes, turbid, fine-grained quartz/feldspar, sericite and opaques (mainly magnetite) make up the groundmass. These areas contain scattered relatively coarse-grained flakes of muscovite. The opaque grains may be altered to hematite, but this is not definitely visible in the section.

Identification: a quartz- and feldspar-phyric, (?)rhyolitic volcanic rock, probably originally a glassy lava.

NORTH DARWIN

(including Findons and East Darwin)

ND2 Outcrop: Pink to purple, finely-mottled volcanic rock with spots of green material.

Thin section:

Primary features: Euhedral feldspar phenocrysts (completely replaced) and embayed on angular microphenocrysts of quartz are set in an originally-glassy groundmass. Magnetite, probably primary, is intergrown with feldspar phenocrysts, and both phases include zircon. The feldspars preserve vague indications of simple twinning, and were probably K-feldspar.

Secondary features: The feldspar phenocrysts are replaced by sericite, and some bear rutile and opaque crystals as well. The microphenocrysts of quartz bear radial overgrowths of quartz of fibrous appearance, but optically continuous with the nuclei. This is a variety of snowflake texture. The "snowflakes" are micropoikilitic, containing sericitised laths of feldspar. The areas between snowflakes consist of quartz, sericite (after (?)feldspar laths) and opaques, and preserves an igneous texture of randomly-oriented, interlocking feldspar laths. The "snowflakes" occur singly and in bunches, the ratio of "snowflakes" to other groundmass varying accordingly across the section. Some of the opaques (which were probably magnetite) may be altered to hematite. The habit of others - sheaves of crystals intergrown with secondary silicates - suggests goethite.

Identification: a feldspar-phyric (?)rhyolite, probably potassic, a glassy lava. Note that devitrification has concentrated iron in the areas between "snowflakes". This is visible as minute-scale mottling in hand-specimen.

ED3 Outcrop: Chlorite-pyrite-sericite rock.

Thin section:

Primary features: Nothing definite, certain round to polygonal bodies may be pseudomorphs after phenocrysts.

Secondary features: The rock is foliated; a penetrative cleavage marked by sericite and chlorite is intersected at 40° to 50° by an incipient crenulation cleavage which is variable in development and direction. Other secondary minerals include quartz, pyrite and siderite. The minerals are concentrated in bands - e.g. predominantly chlorite and pyrite; predominantly sericite; and fine-grained mixtures of quartz/feldspar and chlorite bearing rhombs of siderite. Siderite is predominant in certain areas. The large pyrite crystals in the pyrite-chlorite bands have pressure shadows of quartz, chlorite, muscovite and siderite. Areas of similar appearance without pyrite nuclei are intersected.

There may be three varieties of chlorite, all with P: bluish green to pale yellow. The chlorite in pressure shadows has AIC: purple; fine-grained foliated material has AIC: blue; other patches of coarse-grained chlorite have no AIC.

Identification: originally a volcanic rock, now a chlorite-pyrite-sericite-quartz schist.

ED4 Outcrop: Chloritic rock bearing pyrite and chalcopyrite, from the dump of the Darwin Pty. Ltd. working.

Thin section:

Primary features: Some tabular patches of fine-grained secondary minerals may be replaced phenocrysts.

Groundmass textures include an area of subtaxitic texture - feldspar laths, not interlocking - and patches of turbid equigranular quartz which may be altered snowflake divitrification texture. There are accessory zircons.

Secondary features: The groundmass is not heavily sheared, and consists of quartz, chlorite, siderite, hematite, magnetite and chalcopyrite. Chlorite is interstitial to the feldspar laths in areas of subtaxitic texture. Chlorite , siderite and opaques occur with the areas of turbid quartz. Other areas consist of various proportions of quartz, chlorite, siderite and opaques. Patches of clear secondary quartz are intergrown with large blades of hematite. Chalcopyrite is intergrown with both the bladed hematite and the magnetite (which some of the hematite replaces). In one instance magnetite appears to replace chalcopyrite. One pyrite grain and a few rutile grains were noted.

The chlorite has P: green to yellow; AIC: yellow on grey.

Identification and discussion: possibly a lithic pyroclastic rock. Note that remobilisation of the chalcopyrite took place under conditions sufficiently oxidising to replace magnetite with hematite, and that the hematite is not the product of weathering.

ED21 Outcrop: Light green, lightly-sheared quartz- and feldspar-phyric volcanic rock.

Thin section:

Primary features: Poorly sorted, embayed quartz phenocrysts, feldspar phenocrysts (largely replaced) and accessory zircons occur in a fine-grained groundmass.

Secondary features: Most of the feldspar phenocrysts are replaced by sericite, but two bear epidote as an alteration product. The quartz phenocrysts have overgrowths of poikilitic quartz. The groundmass consists of patches of micropoikilitic quartz (snowflake devitrification), fine-grained areas of quartz/feldspar with (?)sericite and coarser-grained patches of sericite, epidote and chlorite. Rutile and epidote are scattered throughout. The groundmass is not heavily sheared.

The chlorite has P: green to pale yellow; AIC: bluish-grey.

Identification: a quartz- and plagioclase-phyric rhyolitic volcanic rock, possibly a lava.

ED22 Outcrop: Brown, weathered, sheared, quartz-feldspar-phyric volcanic rock.

Thin section:

Primary features: Embayed quartz phenocrysts and heavily-altered feldspar phenocrysts (plagioclase?) are set in a groundmass with accessory zircon. Bodies of yellowish (?)clay and rutile, each rimmed with rutile, may also be the alteration products of phenocrysts.

Secondary features: Sericite replaces the feldspar phenocrysts. Parts of the groundmass may consist of sheared snowflake texture with fine-grained inclusions of sericite. Elsewhere, it is composed of fine-grained quartz/feldspar with chlorite, rutile and sericite. The chlorite is weathered and yellowish. Two cleavages, intersecting at an angle of about 50°, are marked by sericite.

Identification: a quartz- and feldspar-phyric, rhyolitic volcanic rock, possibly a lava.

F3 Outcrop: (from the dump of a small working)
Chloritised volcanic rock with pyrite, chalcopyrite and Fe-oxide.

Thin section:

Primary features: Heavily replaced phenocrysts and glomerocrysts of feldspar survive in a groundmass with no primary texture.

Secondary features: The feldspar phenocrysts are replaced by fine-grained chlorite and sericite, in some cases zonally. The groundmass consists largely of fine-grained chlorite and magnetite, with scattared grains of quartz/feldspar. There are veins and patches of coarse-grained chalcopyrite and quartz, the chalcopyrite enclosing grains of pyrite. Veins of sericite and chlorite without opaques also occur.

The chlorite has P: green to pale yellow; AIC: greenish to yellowish greys.

Identification: a feldspar porphyry, altered beyond recognition of the mode of formation.

F4 Outcrop: (from the dump of a small working) chloritised volcanic rock bearing chalcopyrite.

Thin section:

Primary features: Residual areas of quartz/feldspar may represent phenocrysts or devitrified groundmass. Patches of sericite may represent feldspar phenocrysts. Accessory zircon and apatite are preserved.

Secondary features: Sericite, chlorite, quartz/feldspar, chalcopyrite and rutile make up the rock. The sericite after plagioclase survives only within areas composed of chlorite. Such areas are interlayered with turbid, almost unresolvable areas consisting of all of the minerals listed, and this might represent a relict primary foliation. Scattered grains of quartz with diffuse edges occur, locally in clusters. There are irregular areas of chalcopyrite.

The chlorite has P: green to yellow; AIC: yellowish green on grey.

Identification: probably a porphyry, otherwise altered beyond recognition.

SOUTH DARWIN

(including Prince Darwin)

SD9 Outcrop: Altered, weathered, volcanic rock bearing pyrite, magnetite and chlorite.

Thin section:

Primary features: Grains of quartz, angular and poorly sorted, some of phenocryst origin and some of polycrystalline quartz, occur with accessory zircon in a fine-grained groundmass.

Secondary features: All quartz grains are deformed and recrystallised. Some may be disrupted vein-quartz. The groundmass consists of deformed quartz, chlorite, magnetite and minor sericite marking the cleavage. Much of the rock is replaced by magnetite (which includes coarse blades of hematite) and subordinate pyrite. Such areas are veined by chlorite and quartz grown under stress.

The chlorite has P: green to yellowish; AIC: blue to blue-green on grey.

Identification: a much altered quartz-phyric volcanic rock or sediment consisting of reworked volcanic material.

SD12 Outcrop: A lens, about 4 m long, of greenish rock enclosed in sheared lava.

Thin section:

Primary features: One rounded quartz grain and several polygonal pseudomorphs (consisting of secondary minerals and possibly after feldspar) occur in a finer-grained groundmass.

Secondary features: The pseudomorphs consist of brown-green biotite and sericite. The schistose groundmass consists of the same biotite, quartz, sericite, opaques and minor rutile/sphene and chlorite. The biotite is unusual in being relatively pale in colour. The pleochroism is khaki to colourless (rare grains show the more usual red-brown colour) and the interference colours, strongly masked, are at least of third order.

Identification: possibly originally a porphyritic volcanic rock, now a biotite-quartz schist.

SD14 Outcrop: Altered granite with chlorite and quartz veins.

Thin section:

Primary features: A typical granitic intergrowth of coarse-grained quartz, perthitic K-feldspar, plagioclase, green biotite (mostly replaced), magnetite and rutile with accessory zircon.

Secondary features: Some of the quartz has been fractured and recrystallised. The plagioclase is albitic, and is riddled and veined with fine-grained sericite. The potash feldspar contains many small inclusions of hematite. Biotite is altered to chlorite, with which the remnants of biotite are interleaved. Intergrown chlorite and sericite occupy the interstices between the large primary grains. The major vein consists of chlorite only (P: green to pale yellow; AIC: purple to pinkish-brown) at the centre. The margin, which is subordinate, consists of quartz and minor albite with inclusions of chlorite. The wallrock on one side of the vein consists of coarse-grained sericite and chlorite, aligned sub-parallel to the vein and deformed. Smaller sericite veins occur throughout the specimen.

Identification: veined, altered granite.

SD30 Outcrop: White, weathered, sheared volcanic rock, host of barite veins.

Thin section:

Primary features: Quartz and plagioclase phenocrysts and sub-rounded fragments of volcanic and sedimentary rocks are set in a groundmass preserving shard-shapes and a eutaxitic texture defined by bent and flattened pumice. Accessory zircon is present.

Secondary features: The plagioclase phenocrysts are albitic, and are little altered. The groundmass consists of fine-grained quartz/feldspar, sericite, minor rutile and very weathered iron oxides. Sericite marks the cleavage, and much is iron-stained from weathering. Certain areas of quartz contain swarms of high-relief, rhombic crystals. These do not appear to have a high birefringence (but are very thin). They could be sphene.

Identification: a rhyolitic, quartz- and feldspar-phyric vitric-crystal-lithic ash-flow tuff.

SD32 Outcrop: Green, quartz-phyric agglomerate.

Thin section:

Primary features: Rounded lithic fragments, some of sedimentary rock, some of porphyritic devitrified volcanic rock, occur with embayed quartz phenocrysts, rare plagioclase phenocrysts and accessory zircon in a fine-grained groundmass.

Secondary features: The plagioclase phenocrysts are partly altered to fine-grained sericite. The groundmass consists of fine-grained quartz/feldspar and sericite with local swarms of transparent, high-relief grains - probably rutile. In reflected light, rutile is seen to occur as large and small grains, and along the cleavage of silicates. Two small crystals of pyrite are enclosed in a larger grain of silicate. The specimen is cut by disrupted and folded quartz veins.

Identification: a rhyolitic, plagioclase- and quartz-phyric volcanic agglomerate.

SD33 Outcrop: Fresh, grey, quartz-phyric volcanic rock with lithic blocks.

Thin section:

Primary features: Plagioclase and embayed quartz phenocrysts, the plagioclase predominating, occur with accessory zircons in a fine-grained groundmass. Large subhedral crystals of magnetite may also be of primary origin.

Secondary features: Plagioclase phenocrysts are altered to sericite at the edges, and are riddled with tiny crystals of (?)sericite. The surviving plagioclase is albitic, and some phenocrysts have areas of recrystallised albite. The groundmass consists of a foliated, fine-grained mass of quartz/feldspar, sericite and rutile/ sphene. Sericite marks the cleavage and is predominant locally. Rutile/sphene occurs in aggregates of small grains.

Identification: a rhyolitic, plagioclase- and quartz-phyric volcanic rock, possibly a lava.

PD1 Outcrop: Massive magnetite replacing volcanic rock, with pyrite, quartz and chlorite. The specimen is from a silicate-rich variety.

Thin section:

Primary features: Phenocrysts of embayed quartz, and one of simply-twinned K-feldspar (others may have been completely altered) are set in a fine-grained, originally glassy groundmass.

Secondary features: The quartz phenocrysts bear overgrowths of quartz. The feldspar is veined and riddled with fine-grained chlorite. The groundmass in its freshest state consists of areas of micropoikilitic quartz without nuclei. Some of the quartz areas are arranged in subradial groups, suggesting snowflake texture. The microlites are green-brown chlorite. The groundmass is veined and replaced by quartz, sericite, three green minerals and opaques. The green minerals are as follows:

1. A chlorite, P:green to pale yellow; AIC: none (grey), occurring intergrown with quartz, muscovite and opaques, and replaced by no. 2.
2. A biotite, green-brown, fine-grained or in typical flakes, containing zircon inclusions with pleochroic haloes, occurring in the groundmass as patches and microlites in quartz, and in veins, associated with magnetite.
3. A biotite, P:brownish-green to colourless; second order interference colours; straight extinction relative to an perfect cleavage. It is associated with quartz grown under stress around opaque grains, and, therefore, is later than the opaques.

The veins include an early quartz variety, disrupted and cut by opaques, a biotite vein which cuts a vein bearing magnetite and a quartz vein with groups of radiating acicular crystals, altered to sericite.

Identification: A glassy volcanic rock, quartz and K-feldspar phyric, possibly a rhyolite lava.

PD3 Outcrop: (?)Volcanic rock replaced by magnetite and a green, chlorite-like mineral.

Thin section:

Primary features: none.

Secondary features: Parts of the specimen consist entirely of magnetite (now replaced by hematite). The rest consists of a mixture of scattered magnetite (mostly replaced by hematite), bodies of polycrystalline quartz and crystals of a blue-green tourmaline. (A similar tourmaline occurs in an iron-oxide body at Jukes Proprietary, JP7).

Identification: none, completely metasomatised.

Clark Valley

The Clark Valley, S.W. of Mt. Darwin, was not visited as part of this study. A number of thin sections are available in the Mt. Lyell M. &. R. Co. collection, and these were examined. Full descriptions will not be given; the following is a summary of points relevant to this study.

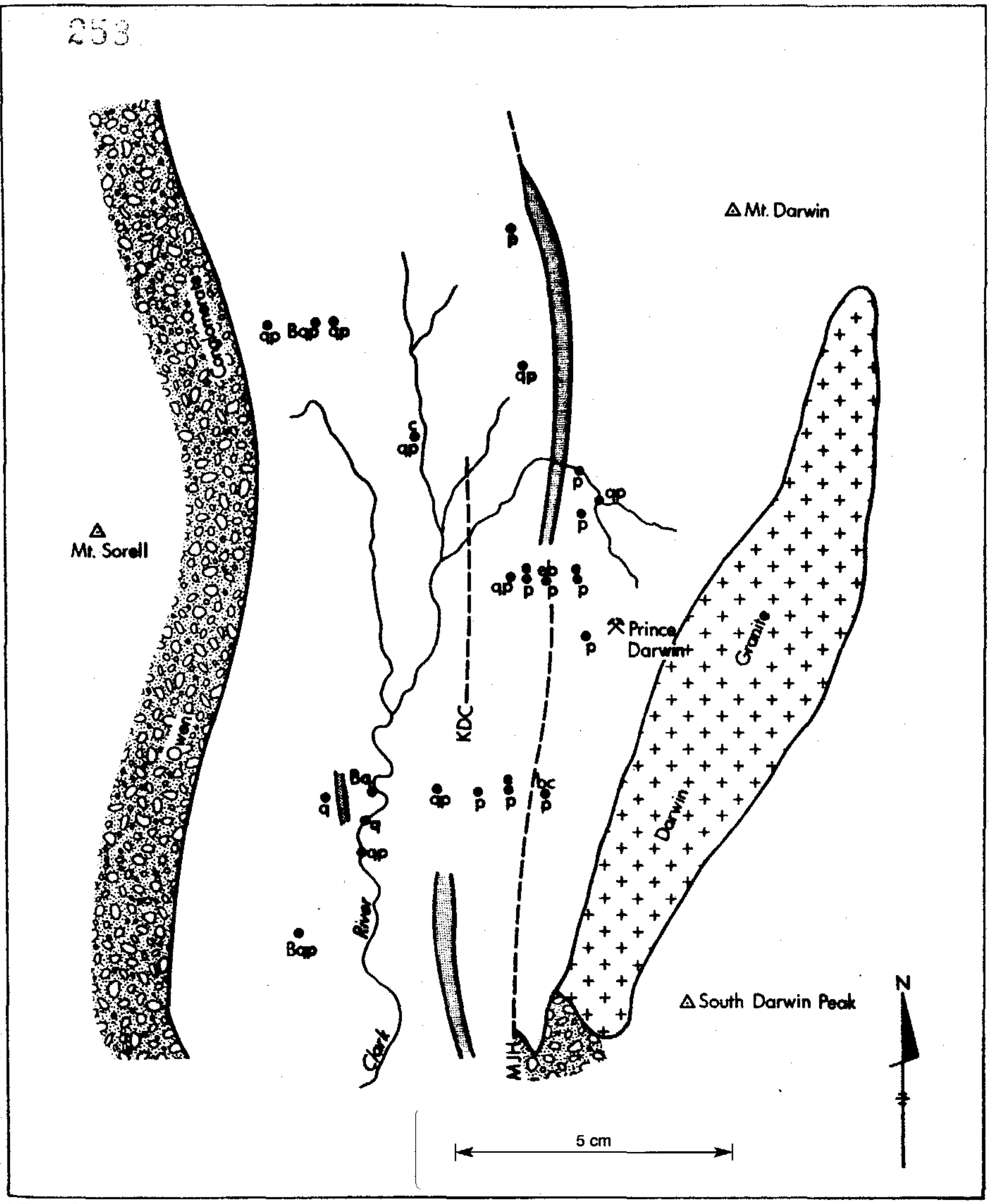
The volcanic rocks are quartz-plagioclase and plagioclase porphyries, many of which preserve textures suggesting ash-flow or lava origins. Quartz-plagioclase porphyries occur throughout the area. Plagioclase alone as phenocrysts is limited to the area east of the Clark River.

The alteration of plagioclase phenocrysts is generally to albite with flecks of sericite and, in some cases, chlorite. Calcic minerals (epidote and calcite) occur locally - see accompanying figure. In such specimens, the calcic minerals may also occur in the groundmass and in veins. Calcic alteration occurs near the Prince Darwin group of workings, with the exception of one sample from the bed of the Clark River.

Three samples from west of the Clark River preserve more or less fresh biotite phenocrysts. Biotite also occurs in secondary mode in samples from the volcanics just west of the Prince Darwin group of workings. The primary biotite is brown, the secondary bright green.

913262

253



LEGEND:

(shale pattern)	Shale lens
•	Sample locality
— — —	Suggested boundaries (Hutton 1978, Corbett 1979)
B	Biotite phenocrysts
p	Plagioclase phenocrysts
q	Quartz phenocrysts
e	Epidote (secondary)
c	Calcite (secondary)
b	Biotite (secondary)

Notes:- After M.J.Hutton, M.L.M & RCo Rept. 1977 - 78

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GETTY OIL DEVELOPMENT

TASMANIA
CLARK VALLEY

PETROGRAPHY OF VOLCANICS

Author: C. Easton
Drawn: K. Turner
Revised:

FIGURE No.

APPENDIX 2

AMG COORDINATES OF SAMPLE POINTS

	N	E
BD1	5376450	377850
BD2	5376750	378600
BD4	5375700	377800
BD5	5375700	377100
BD6	5377200	377850
BG1	5390300	381700
BG2	5387700	382400
BL1	5373850	383870
BL2	5372830	383480
BL3	5373390	382340
BL4	5372930	381440
BL5	5373130	380540
BL6	5373730	379210
BPO	5383270	376940
BP1	5383360	377360
BP2	5383580	377700
BP3	5384950	378430
BP4	5385270	383950
BP5	5385570	382640
BP6	5385240	381770
BP7	5385395	381050
BP8A	5385430	380430
BP8B	5385430	380500
BP9	5385160	378740
BP10	5385210	377150
BP11	5384700	377900
BP12	5388200	385500
BR1	5355700	380200
BR2	5354950	379600
BR3	5354450	379100
BR4	5353750	378700
BR5	5353600	378450
BR6	5352750	377550
BR7	5352050	377350
BR8	5351400	376700

	N	E
BR9	5350100	376250
CH0 to CH2000 approx	5373100 5374750	387400 388600
	(CH samples, from the Sophia tunnel, are distributed between these two points according to chainage)	
CS1	5377550	378700 (approx)
CS2	5377750	378800
DJ1	5368190	377940
DJ2	5367960	377650
DJ3	5368560	376680
DJ4	5368530	377240
DJ5	5368630	376830
DJ6	5368540	376480
DS1	5352300	388500
DS2	5353900	387750
DS3	5354400	387600
DS4	5354750	387400
DS5	5356450	386750
DS6	5356800	386600
DS8	5356300	386500
DS9	5356100	386700
DS10	5355200	386700
DS13	5353500	388000
DS14	5353500	388000
ED1	5322600	384200
ED2	5322600	384250
ED3	5323100	384250
ED4	5323550	384200
ED5	5323400 (approx)	384400
ED6	5323200 (approx)	384800

255

	N	E
ED20	5322800	384200
ED21	5323200 (approx)	384800
ED22	5323000	385350
F1	5323400	383000
F2	5323400	383000
F3	5323400	383000
F4	5323200	382950
F5	5323200	382950
F6	5323050	383550
F7	5322400	383550
H1	5325300	383200
H2	5325300	383200
H3	5325900	383100
H4	5325900	383100
H5	5325900	383100
H6	5325300	383200
HA10	5357670	380550
HA11	5357700	380785
HA12	5357700	380830
HA13	5358000	380680
HA13A	5358000	380700
HA14	5357405	380670
HA15	5357150	381200
HA16	5357960	380975
HA17	5357990	380930
HA18	5357150	381200
HF1	5367315	376430
HF2	5367940	376420
HF3	5367570	376610
HF4	5366980	376440
HF5	5365870	376530
HF6	5366130	376490
HF7	5366180	376400
HF8	5366580	376510
HF9	5366500	376470

	N	E
HF10	5366500	376320
HF13	5365090	376130
HF15	5365630	376500
HF21	5365700	377000
HF21A	5366145	377140
HF22	5366600	377170
HF23	5367640	376410
HF24	5368050	376210
HF35	5365440	377760
HF39	5363300	377770
HF41A	5365400	378200
HF42A	5365220	378450
HF53A	5363430	376960
HF61	5367210	376450
HF62	5367145	376450
HF63	5367050	376445
HF64A	5366960	376450
HF64B	5366990	376440
HF65	5366890	376480
HF66	5366800	376500
HF67	5366680	376500
HFZ1	5366200	380435
HFZ2	5366170	380650
HFZ3	5366720	380940
HFZ4	5366665	380790
HFZ5	5363875	380140
HR1	5362740	379540
HR2	5362360	378795
HR3	5361750	377850
HR4	5361700	377800
HR5	5361350	377650
HR6	5360300	377500
HR7	5357600	376750
HX1	5334300	380700
HX2	5335900	381300
HX3	5336500	380650

259

	N	E
HX4	5334550	383600
HX5	5334550	383450
HX6	5334600	383850
HX7	5335600	384000
HX8A	5336750	382500
HX8B	5337000	382650
HX9	5336100	381750
HX10	5334300	383450
I1	5324950	383400
I2	5324950	383400
I3	5324950	383400
JP1	5330850	383400
JP2	5330850	383400
JP3 (A&B)	5331250	383650
JP4	5331150	383650
JP5	5331050	383600
JP6	5331000	383500
JP7	5331350	383550
JP8	5331250	383550
JP9	5331200	383550
JP10	5331050	383450
JP11	5331100	383450
JP12	5331100	383000
JP13	5331250	382700
KJ1	5370000	379560
KJ2	5370000	379500
KJ3	5370000	379280
KJ4	5370000	379050
KJ5	5370200	378410
KJ6	5370225	378360
KJ7	5370860	378310
KJ8	5370775	378340
KJ9	5370785	378440

	N	E
KJ10	5370520	378410
KJ11	5370030	377570
KJ12	5370510	377970
KJ13	5371455	378060
KJ14	5371380	377670
KJ15	5369680	376830
KJ16	5369440	376870
KJ17	5369360	376990
KJ18	5369680	376680
KJ19	-------	------
KJ20	5369820	377030
KR1	5331700	385100
KR2	5331750	384250
KR3	5331900	383900
KR4	5332000	378950
KR5	5332550	379550
KR6	5332750	380050
LJ1	5363225	378420
LJ2	5363390	378680
LM1	5345600	379300
LM2	5346200	379600
LM3	5345250	380050
LM4	5347550	378350
LM5	5347050	376660
LM6	5346960	376400
LS1	5362450	385450
LS2	5364250	386100
LS3	5360000	386000
LS4	5360000	386100
LS5	5361100	385700
LS7	5363250	385400
LS8	5364300	386150
LS9	5364500	386350
LS10	5364650	386600

	N	E
MC1	5391300	389550
MC2	5391300	389550
MH1	5382140	383660
MH2	5382900	383500
MH3	5383900	383860
MH4	5384750	383800
MR1	5374150	387650
MR2	5373850	387700
MR3	5373600	387500
MR4	5373250	387400
MR5	5372550	387050
MR6	5372550	387050
MR7	5372450	387100
MR8	5374950	387450
MR9	5375800	387100
MR10	5376100	386550
MR11	5376200	386000
MR12	5375750	386700
MS1	5375900	385700
MS2	5375900	385900
MS3	5376100	386100
MS4	5375750	386700
MS5	5375750	386700
ND1	5322500	383800
ND2	5322600	384000
PD1	5318000	382700
PD2	5318650	382700
PD3	5318650	382700
PM1	5374100	378100
PR1	5378740	377620
PR2	5379440	378310
PR3	5380280	379250
PR4	5380210	379920

	N	E
PR5	5379900	381000
PR6A	5380410	381700
PR6B	5380410	381820
PR7	5381070	382930
PR8	5381250	383560
PR9	5380200	385400
PR13	5378740	377620
PR20	5379500	378950
PR21	5378400	377550
RA1	5386220	378660
RA2	5386290	379000
RD1	5366410	379640
RD2	5366285	379350
RD3	5366170	379200
RD4	5366340	378840
RD5	5366120	378260
RD6	5366370	377110
RD7	5366130	376900
RD8	5366630	377610
RH1	5365625	383250
RH2	5365680	382940
RH3	5365460	382640
RH4	5365475	382725
RH5	5365590	382670
RH6	5365860	382520
RH7	5365770	382500
RH8	5365790	382810
RH9	5364500	382820
RH10	5364920	382660
RH11	5365250	382570
RH12	5365330	382500
RH13	5365370	382350
RH14	5365300	382440
RH15	5365240	382290
RH16	5366000	381000

	N	E
RH17	5365800	381600
RH18	5365340	382070
RH19	5366430	382700
RH20	5365050	381960
RH21	5366070	381090
RR1	5367675	375470
RR2	5367635	375320
RR3	5367635	375265
RR4	5367590	375280
RR5	5367400	375250
RR6	5367240	375130
RR7	5367230	375125
RR8	5366980	374980
RR9	5366930	375050
RR10	5366820	374860
RR11	5366860	374820
RR12	5367170	374700
RR13	5367230	374690
RR14	5367345	374570
RR15	5367495	374330
RR16	5367505	374280
RR17	5367705	374160
SD1	5317650	383200
SD2	5317650	383200
SD3	5317650	383200
SD4	5317500	383200
SD5	5317200	383150
SD6	5317100	383150
SD7	5317050	383200
SD8	5317200	383150
SD9	5317400	383150

	N	E
SD10	5317550	383400
SD11	5317700	383600
SD12	5318600	383100
SD13	5318600	383650
SD14	5318600	383650
SD15	5318200	383900
SD15A	5318600	383650
SD16	5318550	384100
SD17	5318650	383800
SD18	5318550	383850
SD30	5317550	383700
SD31	5318150	383300
SD32	5318800	384000
SD33	5318300	384400
SD34	5317950	385050
SE0	5347000	387300
SE0A	5346250	387000
SE1	5347950	385700
SE2	5347600	386250
SE3	5347450	386000
SE4	5347550	385700
SE5	5347550	385550
SE6	5347500	385450
SE7	5347200	384950
SE8	5347250	384300
SE9	5345550	381750
ST1	5368500	381700
ST2	5370400	381900
ST3	5370700	382000
ST4	5371500	382300

	N	E
ST5	5372200	382500
ST6	5369000	379150
ST7	5369920	379050
ST8	5370800	377850
ST9	5372000	378200
ST10	5372550	379550

Appendix 3

Table of petrographic and analytical data

Explanation:

Column 1: Specimen number (see Appendix 2 for locations).

Column 2: Phenocryst Assemblage

A = apatite	M = magnetite
H = hornblende	P = plagioclase
I = ilmenite	Q = quartz
K = K-feldspar	

Column 3: Alteration assemblages

Left hand side - of plagioclase phenocrysts (albite ommitted; present throughout).

Right hand side - of whole rock

C/Calcic assemblage	a = albite	k* = high-birefringent chlorite
c/assemblage with minor calcic component	b = biotite	m = magnetite
	c = calcite	o = K-feldspar
N/non-calcic assemblage	e = epidote	p = pyrite
	f = sphene	q = quartz
	h = hematite	r = rutile
	k = chlorite	s = sericite
		t = tourmaline

Others are cited in the last column.

Column 4: Rock Type

Left hand side: Textural

A = ash	L = lava	X = ash-flow
T = tuff	S = sediment	Y = autobrecciated
G = agglomerate	W = ash-fall	Z = flow-banded or pilotaxitic

L*= lava according to presence of snowflake or spherulitic devitrification or perlitic cracks.

Right-hand side: composition (of volcanics only).

R = rhyolite	A = andesite
D = dacite	B = basalt

Column 5: Stratigraphic position, where known.

E = Eastern sequence and correlates
H = Hangingwall) in Central (Mineralised) Volcanics
O = Host horizon) relative to a known host horizon.
F = Footwall)
W = Western Sequence
R = flysch sequence exposed in Ring River

Column 6: Chlorite Data

Habit:
- F = fiamma
- G = groundmass
- O = vesicle
- P = pressure shadow
- S = with sulphides
- V = vein
- X = phenocryst replacement

IC: Interference colour
- 1: first order
- 2: second order

Anomalous:
- B = blue
- Br= brown
- G = green
- P = purple
- S = salmon pink

Al no = Al/Al+Si , mol %
Mg no = Mg/Mg+Fe , mol %
MnO = molecular proportion per 28 O atoms

S.F. total = Structural formula total for 28 O - atoms
Original probe printout value.
inc. = inconsistent, i.e. <20 and >20
within one group of analyses.

Alkalis = Na, K, Ca (also Ti) if present, Na listed only if $Na_2O > 0.5\%$

No. Anal. = number of analyses; result listed is the average

Other data: State of chlorites; significant components not listed elsewhere, analytical data for:
plagioclase (plag.phx = plagioclase phenocryst)
sphene
epidote

No	Phenocrysts	Alteration plag phx	bulk	Rock type Text	Comp	Pos	Chlorite S.F. Habit	IC	Al no	Mg no	MnO	Total	Alkalis	No. Anal	Other analytical data Remarks
BD1	PQ	s	N/a sr(k?)	XT	R-D	?									
BD2	M		N/skr	L*	R-D	H									
BD6	PQ	s	N/askrp	?	R-D	F									
BG1	PQ	se	c/aser	?	R	?									
BG2	PQ	s	N/ar	L*	R-D	?									
BL1	PA	?	C/kear	?	A-B	H									
BL2	P	sk	N/skrmp	L*	R-D	H	G	P	48.5	42.5	0.07	20.2	-	3	
							V	P1	49.1	40.7	0.08	20.2	-	2	
BL3	PHQ	sek	C/asekmr	L?	D	H	G	P	48.5	43.8	0.11	20.2	-	1	
BL4	PQ	sk	N/skrmb	L*	R-D	H	G	G1	47.6	34.4	0.06	20.2	-	1	
							G	2	46.0	32.9	0.07	inc.	K,Ca,Ti	3	weathered?
							G	2	44.8	31.9	0.05	19.3	K,Ca,Ti	1	
BL5	PQ	s	c/ske	L*	R	H	G	2	50.0	21.6	0.06	inc.	K Ti	2	
BL6	P	sr	N/sarmp	L*	R	H									
BP2	P	ks	N/aker	XT	R-D	?	G	B	52.0	41.1	0.19	inc	-	3	plag ph = Ab 100
BP4	PQ?M?	se	C/aekrsp	WT	R-D	?									
BP5	P	spr	N/aspr	?	R-D	?									Vein plag = Ab 100
BP6	P	s	N/qaskr	L*	R-D	?									
BP7	PM?	se	C/qaeskrp	L*	R-D	?	G	Y1	47.8	45.5	0.14	19.5	Ti	3	Plag phx = Ab 96 Epidote:Al/Fe+Al 0.79
BP9	QP	s?	N/qsk?pr	G/S	-	?									
BP10	PQ	sk	N/qaskr	?	R-D	?									
BP11	Q?	-	N/qasr	L	R-D	?									
BP12	PQ	s	N/qasrk*	L?	R-D	?	G	2	47.8	28.2	0.10	18.4	Na	2	Probably a clay
BR1	PHI?	es	C/qekafp	L	A	F	G	BBr							
BR2	P?A	s	N/qaskr	?	D	F	GX	PBr							
BR3	P	sk?	N/ask?r	L*	R-D	F									Chlorite weathered to clay
BR4	PQ	s?	N/qasr	WT/S	R-D	W									
BR5	QP?	s?	N/qasr	XT	R	W									
BR6	QPM	s	N/qaksr	S		W	G	B							
BR7A	PI?	sk	N/qskarp	L*	R	W	G	1							
BR7B	PQ	sc	C/qskcrp	L*	R	W									Chlorite weathered
BR8	?	-	C/qasrc?e?	A	R-D	W									
BR9	PQ	s	N/qaskrp	WT	R-D	W									Chlorite weathered

No	Phenocrysts	Alteration plag phx	Alteration bulk	Rock type Text	Rock type Comp	Pos	Chlorite S.F. Habit	IC	Al no	Mg no	MnO	Total	Alkalis	No. Anal	Other analytical data Remarks
CH345	?	-	C/qskrmp	?	?	F	G	P	50.3	40.8	0.20	20.2	-	3	Allanite containing Ce, La,Nd & Molybdenite present.
							G	G	49.5	33.8	0.20	20.2	Ti	2	
							G	Br	48.5	39.5	0.21	20.2	KTi	2	
CH360	-	-	C/qckamp	Granite		F	G	P	47.0	49.9	0.11	20.0	KTi	1	K-feldspar-rich graphic granite brecciated
							V	P-Br	47.6	48.2	0.13	20.2	Ca	1	
							G	G	48.0	48.2	0.13	20.2	Ca	1	
CH885	-	se	C/qaefs	Granite		F									
CS2	AQ	-	N/qaskm	L*	R	H	G	G1							
DJI	PQ	s	N/qaksr	YL	R	H	G	G1	51.9	20.2	0.23	inc.			Analyses of poor quality-imperfect surface
DJ2	P	sk*	N/qask*r	?	R-D	H	G	2	49.5	39.1	0.20	20.1	KTi	4	Composition is chlorite end-member of an inter-layered species
DJ3	P	e	C/qakerb	W/XT	D	H	G	2	44.0	58.6	0.05	18.5	K	1	1.Other high-birefringent chlorites contain up to 1% K_2O and give low totals. The birefringence may be due to K-content (interlayers) or to weathering. 2.Rim of plag.phx: Ca:Na:K=3:94:3 3.Epidote:Al/Fe + Al = 0.33
							G	2	47.1	54.9	0.12	20.0	Na	1	
							G	P-Br	47.6	54.9	0.11	20.1	-	1	
DJ4	P?	sk*o	N/qask*r	XT	D	H	G	2	50.0	38.7	0.18	19.5	KTi	1	
							G	1	48.2	39.1	0.23	20.0	-	1	
DJ6	P?	s	N/qsr	X/WT	R-D	F									
DS1B	Q	-	N/qskr	S	-	E	G	Y1							
DS2	Q,K?	?	N/qaskrp	?	R	E	P	Y1	51.6	16.7	0.55	20.1	Na	2	
							G	Y1	51.0	15.7	0.51	inc.	-	2	
DS3	Q	-	N/qskrpm	?	?	E	G	Y1	49.0	18.6	0.26	inc.	Na	3	Chalcopyrite present
							S	Y1	52.7	17.4	0.26	20.1	Na	2	

No	Phenocrysts	Alteration plag phx	Alteration bulk	Rock type Text	Rock type Comp	Pos	Chlorite S.F. Habit	IC	Al no	Mg no	MnO	Total	Alkalis	No. Anal	Other analytical data Remarks
DS4	Q	-	C/qaskpmc	S?	-	E	G	G1-Y1							Sphalerite, galena and chalcopyrite present. Calcite in pressure shadows only
DS8	Q	-	C/qakmpr	?		E	G	Y1	47.8	29.0	0.12	20.1	Na	2	Allanite common. Sphalerite and galena present. Biotite in pressure shadow. Mgno=30
DS9	Q	-	c/qakspe	XT	R	E	G	G1-Y1							Sphalerite, galena and chalcopyrite present
DS10	P?Q	s	N/qask*mpr	XT	R	E	G	Y2	48.7	25.2	0.12	inc.	-	3	
ED3	?	-	N/qksp	?	?	F	G PS G	B P G	52.3	39.2	0.00	20.0	-	2	Siderite present
ED4	?	-	N/qkhmpr	L*	?	F	VG	Y1							Siderite chalcopyrite present
ED21	PQ	se	C/qasker	L*	R	E?	G	B1	49.7	38.8	0.19	inc.	-	2	
ED22	PQI?	s	N/qaskr	L*	R	E									Chlorite weathered
F3	P	sk	N/kmqas	?	?	F	GX	G1-Y1	48.9	25.3	0.00	20.1	Na	5	Unusual bright area chlorite with ave 0.35% Cr_2O_3
F4	?	-	N/skqar	?	?	F	G	YG1	51.3	25.8	0.05	20.1	-	3	Chalcopyrite present
HA13	P	s	N/qaskrp	T	D	F	GV	PB							
HA15	PQ	s	N/qaksmr	S/WT	R-D	E	G	PBr-B							
HA16	PQI?	s	N/qaskr	?	R	H	GX	B1							
HA20	PQ	ks	N/1.qas 2.ks	WT?	R-D	E	GX	S-P1							Note. two distinct assemblages
HF1	P?	o	N/qaskr?	XT	R-D?	F	GF	1	48.8	61.5	0.25	-	-	3	Sericite Mg-no.= 59.6 Chalcopyrite, sphalerite present. Chlorite very pale pleochroism.
HF3	P?	okk* qsr?	N/qsrk*	XT	R-D	H?	X X	G1 Y2	44.8 49.7	36.9 34.2	0.07 0.06	-	K,Ca -	1 1	Poor analyses-low totals Y2 chlorite may be weathered

No	Phenocrysts	Alteration plag phx	Alteration bulk	Rock type Text	Rock type Comp	Pos	Habit	IC	Al no	Mg no	MnO	Total	Alkalis	No. Anal	Other analytical data Remarks
HF4	?	-	N/qaskpr?	XT	R-D	F	GF	B1	52.0	37.3	0.26	20.2	Na	4	Sericite Mg no. = 55.0
HF5	?	-	N/qask	XT	R-D	F	F	1	50.0	51.0	0.41	20.2	NaK	5	
HF6		-	N/qaskp?r?	XT	R-D	F	G	1	49.5	62.5	0.33	20.1	K	5	Sericite Mg no. = 66.4 Chlorite end-member from 5 analyses.
HF8	-	-	N/qaskr?	XT	R-D	F	G	1	48.9	65.1	0.36	20.2	Na	4	Sericite Mg no =72.5
HF9	?	osk	N/qaskr?	XT	R-D	F	G	Y1	48.7	58.9	0.47	20.1	Na	2	weathered chlorite? Sericite Mg no. = 74.8
HF15	?	osk	N/qaskr?	XT	R-D	F	G	1	50.5	60.3	0.41	inc.	NaK	4	
HF23	P?	ckos	C/qask	XT	R-D	H?	X	Br1	47.0	71.6	0.31	20.4	Na	2	Sericite Mg no = 66.8
							F	Br1	45.0	69.5	0.21	inc.	NaK	2	
HF24	?	-	N/qaskr?	XT	R-D	F	G	G1	50.2	31.8	0.20.	20.3	NaK	4	
HF61	?	-	N/qaskr?	XT	R-D	F	G	Br1	46.8	67.5	0.16	20.0	-	3	Poor analyses - weathered sample
HF62	?	-	N/qaskr?	XT	R-D	F	G	Br1	47.3	77.5	0.21	19.7	-	3	
HF63	?	-	N/qaskr?	XT	R-D	F	F	Br1	47.2	67.2	0.24	19.6	K	3	Low total may be due to high K_2O
HF64	?	-	N/qaskr?	XT	R-D	F	F	Br1	50.7	46.9	0.37	inc.	K	4	Average of 4 low-K analyses
HF65	?	-	N/qaskr?	XT	R-D	F	GF	Br1	48.5	71.1	0.26	20.0	-	5	
HF66	?	-	N/qaskr?	XT	R-D	F	F	B1	50.5	52.3	0.30	20.0	-	3	
							P	Br1	50.8	53.8	0.31	20.0	-	2	
HF67	?	-	N/qaskr?	XT	R-D	F	G	Br1	48.6	58.0	0.31	inc	-	2	weathered
HFZ1	P	s	N/qaskr	L*	R-D	?	G	G1							
HFZ2	-	-	N/qaskmr	?	?	?	G Y1								Henty fault zone material
HFZ4	-	-	N/qkp	-	-	-	V	B,Br							Vein containing chalcopyrite
HR1A	P	ek	C/qaekr	?	R-D	?	G	BGr1							
HR1B	P	e	C/qek	?	A-B	?	G	B1							amphibole persists in groundmass

No	Phenocrysts	Alteration plag phx	bulk	Rock type Text	Comp	Pos	Habit	Chlorite S.F. IC	Al no	Mg no	MnO	Total	Alkalis	No. Anal	Other analytical data Remarks
HR2	PQ?	s	N/qask	XT	R-D	F?	G	BG1							
HR4	P	s	N/qaskr	XT	D	H?	G								Chlorite weathered
HR5	P	s	N/qaskr	XT	D	H	G	Y1							Chlorite weathered
HR6	PQA	sek	c/qakser	L*	R-D	W	G	B							
HR7	QP	s	N/qaskr	S	-	W	G	B							
HX2	PH?I?	s	N/qaskm?r	L*	R-D	W	X(P)	Y1	48.3	53.0	0.00	18.6	-	3	Probably a clay; Fe + Mg too low
							X(I)	B	46.7	52.4	0.00	19.8	-	2	Chlorite contains 0.5% Cr_2O_3
HX3	PM?	s	N/qaskm?	XT	D	W	G	Y1,1	41.0	46.4	0.00	19.0	-	2	K & Ca in analysis print out are due to Sn interference (polishing compound)
HX4	P	sc	C/qaskrc	XT	D	?	F?	B,P	48.9	47.4	0.10	20.0	-	2	
HX6	P?	s?	N/qas	?	R-D	?									
HX7	P?	s	N/qasr	L?	R-D	?									
HX8A	P	s	N/qaskr	S	-	?	G	Br1	49.2	38.4	0.11	20.0	-	2	Trace monazite present
HX8B	PQ?I?	sk'	N/qaskr	L*	R	?	X	YG1	49.6	36.8	0.00	20.1	Ti	2	
JP3A	PQ	sk	N/qask	L*	R	F	V	GY1	46.8	13.5	0.11	inc	KNa	4	Sphalerite, chalcopyrite, galena and pyrite present in a vein. Consistent analyses of chlorite (clay?) not obtained. Some bear TiO_2, Cr_2O_3
JP3B	PQ	s	N/qskm	L*	R	F	V	GY	47.7	16.0	0.06	inc	NaTi	2	Carbonate vein
							G	G	47.4	14.8	0.05	inc	NaKTi	5	
JP4	Q	-	C/qackam	L*	R	F	X?	Y							Chalcopyrite present
							G	B1							
JP?	-	-	N qmt	?	?	F									

No	Phenocrysts	Alteration		Rock type		Pos	Chlorite S.F.							No.	Other analytical data
		plag phx	bulk	Text	Comp		Habit	IC	Al no	Mg no	MnO	Total	Alkalis	Anal	Remarks
JP10	-	-	N/qa?mpkt	?	?	F									Chlorite weathered to clay
JP11	PQ	sk	N/qskr	L*	R	F	G	Y							Chlorite weathered
JP12	PO?QM?	s?	N/qaskrp	L*	R	F									Chlorite weathered
JP13	PQM?	s	N/qasm	L*	R	F									
KJ1	PQA	sk	C/qasksf?mb	L?	R	H	G	G1	46.9	48.1	0.11	20.2	KTi	1	
							G	P	47.8	48.1	0.10	20.1	-	1	
KJ4	P	sk	N/qaskr	L?	R-D	H?	GV	1	51.1	32.5	0.00	20.1	Ti	1	
KJ6	-	-	N/pksr?	?	?	D?	S	B1	51.2	33.1	0.16	20.2	-	5	
KJ7	P	sk	N/qaskrm	L*?	R-D	?	O	B1							
							V	Y1							
KJ8A	-	-	N/qksp	?	?	O	S	B1	51.0	38.8	0.64	inc	-	2	Galena, sphalerite and chalcopyrite present
KJ8C	-	-	N/qksp	?	?	O	S	B1	51.2	34.5	0.75	20.2	-	4	Galena and sphalerite present
KJ12	-	-	N/qsr	?	?	F									
KJ13	P?	obkr	N/qasb	?	R-D	F	G	Br1	47.5	52.3	0.07	19.9	KTiCa	11	Chlorite end-member of inlerlayer series with biotite. Biotite has Mg No = 61.8
KP196 77 ft	-	-	N/qaskp	XT	R-D	H	GF	BG1							
KP196 377ft	-	-	c/qaskpr	XT	R-D	H?	G	BG1							Minor galena and sphalerite present
KP196 420ft	P	s	C/qaskc	XT?	R-D	F?	G	Br							Minor sphalerite?
KR1	QPAM?	cs	C/qasrck	L/G	R	E	G	G1							
KR3	PQAM?	cs	C/qascrk	?	R	E	G	G1							
KR4	QP?	s	N/qasr	S	-	W									
KR6	PQ	s	N/qasrk	L*	R	W	G	GB1							
LM2	PQ?	sk	N/qaskr	S/T	R-D	W	G	B1	50.3	36.7	0.08	20.0	-	3	
LM3	P	skq?	N/qaskr	XT	D	?	G	1	51.3	26.9	0.05	19.7	-	3	

No	Phenocrysts	Alteration plag phx	bulk	Rock type Text	Comp	Pos	Habit	IC	Al no	Mg no	MnO	Total	Alkalis	No. Anal	Other analytical data Remarks
LM6	PM?	sc	c/qascr	XT	D	W									
LS1	Q	-	N/qaskpm	WT?	R	?	GV	B1							Chalcopyrite present
							V	2							
LS2	QP?A	skm	N/qaskmp	?	R	?	G	YG1							
							GP	B1							
LS5	Q	-	N/qchm	?	?	?	G	YG							
LS5 758ft	-	-	C/qao?kprc	?	?	?	G	G-G1							DDH sample
LS5 870ft	QP?	sk	c/qskcprm?	intrusive	R	?									DDH sample
MH1	P	ck	c/qackrpm	L*	D	?	GX	G1							
MH2	P	s	N/qasrk?	L?	R-D	?									
MH3	P	eks	C/qaserkp	L*	R-D	?	GX	B1-P1							
MH4	P	sc	c/qaskcrp	L	R-D	?	G	B1							
MR7	QP?	kbe	C/kbef?	?	R-D	F	GX	B	49.0	44.9	0.19	20.1	-	3	Biotite has Mg no = 40.1
MR8A	QP	ke	C/qakce	intrusive?	R-D	F	XV	P	48.6	42.0	0.14	20.3	-	3	
MR9B	Q	-	c/qaskempc	T?	R	F	X	G1	48.6	29.4	0.22	-	KTi	4	Chlorite end member of potassic series.
							G	G1	47.2	24.7	0.22	15.8	KTi	1	K_2O = 1.37%; Total?
							V	G1	52.9	24.0	0.28	20.3	-	1	
MR11A	P	ksr	N/qskopr	?	R-D	F	G	Y1	48.5	27.6	0.08	20.3	-	2	Chalcopyrite present K-feldspar contains a little Ba
MR11B	-	-	N/qasrm?	?	?	F									
MR12	QPK?A	s	N/qaoskbrm	?	R	F	X?	P1							
							G	1							
MS1	QP	s	N/qasr	YL*	R	F									
MS2	QM	-	N/qaoskhm	L	R	F	G	YG	48.6	32.4	0.10	19.9	KTi	8	Chlorite end member of chlorite-biotite series Biotite Mgno = 23.6

No	Phenocrysts	Alteration plag phx	bulk	Rock type Text	Comp	Pos	Habit	Chlorite S.F. IC	Al no	Mg no	MnO	Total	Alkalis	No. Anal	Other analytical data Remarks
MS3	QPK	sce	C/qaskecpr	WT	R	F	P	Y1	40.1	51.3	0.08	20.0	K	3	Y1 chlorite weathered? (low totals)
		(b in press. shadow)													
							G	P	49.0	45.6	0.08	20.2	-	1	Biotite Mg no = 56.9
ND2	P?QM	sr	N/qam	L*	R	F									
PD1	QK	-	N/qskk*bm	?	?	F	G	1	47.6	39.0	0.00	20.1	Na	4	Biotite Mg no = 49, 56 Biotite contains appreciable Cl
PD3	-	-	N/mqt	?	?	F									Tourmaline: Na_2O = 1.3%, Al no = 50, Mg no = 40 Minor Ca, Ti
PM1	QK?	-	N/qsprm	?	R	H									
PR1B	-	-	N/qa?skp	?	?	?	G	B1	52.1	32.2	0.02	20.2	NaKCa	2	
PR2A	P	cks	C/qaskc	XG	R-D	H	X	G-P1	51.3	35.5	0.06	20.2	-	2	
PR3	PQ	cks	C/qaskcpr	XT?	R	H	X	BG1	50.1	26.5	0.03	inc	NaK	2	
PR4	PQ	csrk	C/qaskcpr	L*orXG?	R	H	V	BG1	49.9	23.8	0.00	20.2	-	1	
							X	BG1	47.1	24.3	0.00	20.2	-	1	
PR5B	P	sr	N/qskrp?	L*?	R-D	?	G	G1	48.7	21.5	0.06	19.6	KCa	1	
PR6B	PQ	ksr	N/qas	?	R-D	?	X	G1	44.4	24.7	0.00	19.2	KCaNa	1	3.7% K_2O
PR7A	P	cksr	C/qaskcrp	XT	R-D	?	G	BP	49.5	38.0	0.06	20.1	KTiCa	5	(20.1=S.F. total for the 4 analyses without K_2O)
PR8B	PH	skr	C/qakebrp	WT?	D	?	G	P	45.7	43.0	0.08	inc	Ti	4	
PR9	P	qkrse?	c/qaskerm	WT?	R-D	?	X	BG	48.0	48.5	0.10	20.1	-	1	
RA1	PH?	s?k?	N/qaskr	L?	D	?	X	1							
RA2	PQ	se	C/qakefs	WT	R	?	XF	B1	51.4	28.3	0.09	inc	Na	2	Epidote. Al/Al+Fe=0.88 Sphene contains 8% Al_2O_3 FeO 2.3%
RD1	PQ?	s	N/qaskrm	S/G	R-D	H?	V	B1	50.7	37.7	0.09	20.2	Na	2	
							G	B1	50.4	37.2	0.09	20.1	Na	1	
RD2	PQ	cr?	C/qasrpm	L*	R	H									
RD3	PQ	s	C/qasrpm	L*	R	H									
RD4	P	cs	C/qascrp?	?	R-D	H									
RD5	P	s	N/qaskr	?	R-D	?	G	B-Y1	50.2	36.1	0.38	20.2	Na	2	

No	Phenocrysts	Alteration plag phx	Alteration bulk	Rock type Text	Rock type Comp	Pos	Habit	IC	Chlorite S.F. Al no	Mg no	MnO	Total	Alkalis	No. Anal	Other analytical data Remarks
RD6	P	oqa	N/qasr	XT	R-D	H									
RD7	PM?	oqask	N/qaoskrm	XT	R-D	H	V	B1	50.5	39.4	0.59	20.3	Na	2	
RD8	PQ	s	N/qaskrm	L*?	R	H	V	B1	49.6	37.4	0.14	19.9	KCa	1	
RH1	QK	-	N/qeskmr	WT?	R	E?	V	B1							
							G	YG1							
RH2	-	-	c/qaskk*mps	?	?	F	G	Y1							Chalcopyrite present
							V	G2							
RH4	K?	-	K/qakk*r	?	R?	F	G	G1	49.2	35.1	0.00	20.1	-	4	
							GV	G2	47.3	33.9	0.00	17-20	KNa	6	Some G2 analyses give Cl peaks. These are not true chlorite analyses. MgO+FeO is variable, 30% in some cases.
RH5	-	-	N/qsokk*mr	?	?	F	G	Br2	47.6	39.4	0.00	17-19	KNa	3	Low MgO+FeO (as above); inconsistent Mg no. in Br2 chlorite.
							G	BG	47.7	38.8	0.00	20.0	KNa	2	Cl present in BG & YG chlorites, MgO + FeO normal.
							G	YG	46.4	41.1	0.00	inc	KNa	2	
RH6A	-	-	N/qk	?	?	F	V	B1-P	50.8	33.9	0.00	20.1	-	6	Chalcopyrite present (6 most recent analyses)
RH6B	-	-	N/qakpm	L*?	R?	F	G	B1							Chalcopyrite present
RH9A	P?	okm?	N/qakmr	XT	R?	F	G	Br-G1	47.9	39.3	0.06	inc	Na	2	
RH9B	Q	-	N/qaksm	XT?	R?	F	P	1							
							G	Y1							
RH10	P?	ok	N/qao?kk*smr	L/XT?	R?	F	G	YG	49.9	40.6	0.06	20.0	KNa	1	
							X	G2	49.9	37.5	0.07	inc	KNa	3	
RH11	P?	oks?	N/qaokk*srm	XT	R?	F	G	G2	50.0	25.0	0.06	inc	-	3	
							G	GY1	47.7	25.3	0.05	19.9	-	1	
RH12	QM?P?	oksm	N/qaskmpr	?	R?	F	G	YG							Chalcopyrite present
RH14	Q	-	N/qskr	S		O	G	Y1							Chlorite weathered

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162.

No	Phenocrysts	Alteration plag phx	Alteration bulk	Rock type Text	Rock type Comp	Pos	Chlorite S.F. Habit	IC	Al no	Mg no	MnO	Total	Alkalis	No. Anal	Other analytical data Remarks
RH15	-	-	N/qskr	S		O	G	B							
RH16	QP	sk	N/qaskmr	L*	R	E	GV	Br							
RH17	PQ	kf	C/qakfp	XG	R	H	G	1	48.9	43.3	0.01	inc	Na	3	Plagioclase phx = Ab 100 Chlorite analyses are inconsistent
RH18	PQ	f?	c/qaskf	?	R	H	G	1	51.4	52.0	0.10	19.9	K	2	
RH19	P?	kom	N/qaskk*pm	?	R?	F	G	BG1	44.6	40.0	0.00	20.1	KNa	2	Chalcopyrite present
							V	G2	45.3	37.7	0.00	19.8	Na	2	BG1 chlorite contains Cl
RL1	P	skbr	N/qaskbr	XT	R-D	F	GX	BG1							Minor Calcite in a late vein only
RR4	QP?	s	N/qsrpm	S	-	R									
RR8	-	-	C/acr	Altered limestone ?		R									Chalcopyrite & ? cassiterite present. Albite is secondary.
RR9A	QP	K	N/qkrm	S		R									
RR9B	P	sk	N/qask	XT	R-D	R?									
RR11	-	-	C/cqrm	S	Limestone	R									Dolomite & chalcopyrite present
RR13	(Q)	-	N/qkrs	S		R									
RR14	(QPA)	s	N/qaskpm	S		R									
RR17	(Q)	-	N/qaskpm	S		R									
SD9	Q	-	N/qkmsp	T/S?	R?	F	GV	B1-BG1							
SD12	QP?	bs	N/qbsrk	?	?	F									Biotite Mg no. = 49.3
SD14	-		N/qesk	Granite		F	G	P-S							
SD30	PQ	s?	N/qasr	XT	R	E									
SD32	QP	s	N/qasrp	G	R	E									
SD33	PQM?	s	N/qasr	L?	R	E									
SE0	-	-	N/qskr	?	?	?	G	BG1							
SE1	QPM	cs	C/qacr	?	R	H									
SE4	QP?	kqsm	N/qaskr	T/G?	R-D	F	G	YG1							
SE6	QP?	oskc	C/qaskcrp	XT	R	H	X	Y1-B1	51.5	27.0	0.17	20.3	Na	2	K-feldspar - Or 96,Ab4
SE7	QPK?	sr	N/qasr	?	R	H									Chlorite completely weathered to clay

No	Phenocrysts	Alteration plag phx	Alteration bulk	Rock type Text	Rock type Comp	Pos	Chlorite S.F. Habit	IC	Al no	Mg no	MnO	Total	Alkalis	No. Anal	Other analytical data Remarks
SE8	QPA	sk?	N/qak?	?	R	?	G	1							Chlorite mostly weathered to clay.
SE9	P	ks	N/qaskr	WT?	D	F?	G	G-YBr	52.0	13.7	0.06	inc	-	2	Plag. phx = Ab 99
ST1	QP?	s	N/qasr	S		?									
ST2	P	ek	C/qaek	Intrusive?	D	H	GV	BPBr							Also brown secondary material:leucoxene+clay?
ST3	PK?	sek	C/qake	T/L?	D	H	G	BBr	47.7	55.2	0.05	19.8	-	1	" "
ST4	PHI	esk	C/qaefsk	XT	D-A	H	G	B	47.3	54.5	0.03	inc	-	2	Ilmenite bears 3.6% MnO. Plag.phx = Ab90 An4 Or 6 Sphene bears 4.4% MgO, 7.6% FeO
ST5	PHI	eckbs	C/qabefksp	ZL	D-A	H	G	BBr							
ST6	PI?M?	sek	C/qaskf?	?	R-D	H	G	BP							
ST7	P	sk?	N/qask?	?	R-D	?									Chlorite completely weathered to clay
ST8	P?	os	N/qasr	?	R-D	F?									
ST9	P	s	N/qaskr	XT	D	?	G	Br1							
ST10	PHIA	e	C/qakbef	?	A	H	G	BBr	48.0	54.9	0.04	20.0	-	2	Plag Phx = Ab92,An6, Or 2. Biotite MgNo=62.4
STP1	P	cesk	C/akfces	ZL(part)	A-B	H	G	PBS	49.0	51.5	0.09	20.0	-	3	Chalcopyrite present. Sphene bears 1.6% FeO; 3.8% Al_2O_3

Calculation of Chlorite Structural Formulae from Electron Microprobe Analyses

Appendix 4

The following are typical electron microprobe analyses of chlorites (wt%):

		RD7	PR7A
	Na_2O	0.47	0.00
	MgO	12.46	9.94
	Al_2O_3	22.99	20.50
	SiO_2	26.73	25.56
	K_2O	0.00	0.99
	MnO	3.64	0.24
	FeO	33.73	29.74
Total		86.71	86.98

Note the following considerations:

1. There is no place for alkalis in the chlorite structure (see Deer, Howie and Zussman, 1966). These may be present because chlorite and another phyllosilicate are interlayered at sub-microscopic level. The other phyllosilicate could be sericite, biotite, smectite etc.

In the case of K_2O, the composition of the chlorite can generally be deduced from 4 or more analyses differing in K_2O, and the value at $K_2O = 0$ is determined by linear regression or graphical means. It is not sufficient to ignore the K_2O content. A little CaO may be engendered in an analysis because of calibration problems - the Ca and K K_α X-ray peaks overlap a little - but if CaO $>\sim$10% of the K_2O analysis, another source of Ca should be considered.

Na_2O may be introduced in phyllosilicate interlayers in a similar way. But where the analysis is low (say $Na_2O < 0.5$%) it is thought to be spurious, due to calibration problems. The Mg and Na K_α peaks are close, and are at the low-intensity end of the spectrum so that it is difficult to avoid interference in a Mg-rich chlorite. No Na was found in a wet-chemical analysis of a chlorite (RH6A) which gave 0-0.5% Na_2O in microprobe analyses.

For this reason, Na_2O is regarded as spurious in this study.

2. Fe is reported as FeO, even though some is almost always present in trivalent from. The X-ray fluorescence technique cannot distinguish valence states. This affects the structural formula calculation (see below).

3. The total is less than 100%, and should ideally be about 85-90%. In energy-dispersive mode, the electron microprobe system cannot determine elements lighter than Na. Chlorites contain at least 10% H_2O, and this accounts for most of the discrepancy.

It should also be remembered, however, that
(i) The analysis is accurate to $\pm$ 2%.
(ii) Cl may also be present, but the analytical correction programme does not (at present) cater for Cl. If present at significant levels, Cl gives a visible peak on the X-ray spectrum. F, if present, is not detected.
(iii) Surface imperfections on the sample tend to reduce X-ray counts. Chlorite is particularly difficult to polish well, especially when slightly weathered. This effect should not destroy the relative quantities of the various components. For this reason, the calculation of structural formulae is a useful way of comparing analyses.

Structural formula

An ideal (i.e. non-existent) chlorite is charge-balanced with
12 divalent cations in octahedral sites
8 tetravalent cations in tetrahedral sites
20 oxygens and } effectively
16 OH groups } 28 oxygens
i.e. 20 cations to 28 oxygens.

In practice, trivalent ions (Al, Fe and less commonly Cr) may be included. Charge balance may be maintained in three ways.
Case 1. Coupling of tetrahedral and octahedral substitution: for each M3+ ion in a tetrahedral site, one is placed in an octahedral site.

Case 2: Creation of vacancies. For each pair of M^{3+} ions in octahedral sites, an octahedral site is left vacant.
Case 3: Removal of H^+. For each M^{3+} ion in a tetravalent site, one H^+ is removed from an OH^- group.

Case 1 substitution leads to an apparent overestimation of the number of cations. FeO has more cations per oxygen atom than Fe_2O_3, so that reporting all Fe as FeO gives a structural formula total (ideally 20 cations) somewhat greater than 20.

Case 2 substitution leads to a structural formula total less than 20.

The calculation described below calculates the structural proportions of each component, and the amount of Fe^{3+} corresponding to the apparent excess of cations (case 1).

If data for a case 2 chlorite are used, the proportions are valid except for Fe, where a meaningless negative value for Fe^{3+} is obtained. Nonetheless, the proportion of Fe (total) = Fe^{2+} + Fe^{3+}.

A structural formula programme for a HP34C calculater is given at the end.

Calculation

For each oxide, the input is a weight percentage, W.
These are converted to molar proportions:

$$M = \frac{W}{\text{mol.wt.}}$$ (lines 2 - 21 of programme).

The moles of oxygen are summed (lines 22 - 34)

and the number of atoms of each metal are adjusted to correspond to 28 oxygen atoms (lines 35 - 60)

The metal atoms are summed to give the structural formula total, assuming all Fe is as FeO. (lines 61 - 68)

The total is divided by 20

$$\frac{\text{S.F.T.}}{20} = 1 + x$$ (lines 69 - 72)

The excess X corresponds to an equivalent excess of
O - atoms = 28(1 + x) - 28
= 28x (lines 73 - 76).

Each excess O atom (divalent) corresponds to two Fe^{3+} atoms reported as Fe^{2+}, hence one surplus charge each; alternatively $Fe_2O_3 = 2FeO + \frac{1}{2}O_2$)

Hence no. of Fe^{3+} atoms = 2 x 28x (line 83).

According to the assumption of case 1 substitution, there must be 20 cations to 28 effective oxygens. Hence the calculated proportion of atoms of each metal is reduced by a factor of 1/(1+x). (lines 83 - 105)
and Fe^{3+} (line 83) is subtracted from total Fe to give Fe^{2+}.

To test the calculation, calculate the tetrahedral trivalent cations ($Al_T = 8 - Si$) and compare with the octahedral trivalent cations($Al_0 + Fe_0^{3+} = Al - Al_T + Fe^{3+}$). These should be identical. Note that for convenience, all tetrahedral trivalent cations are considered to be Al. For these calculations, it makes no difference which trivalent cations occupy which sites.

Example: analysis of chlorite in RD7, given above. atoms /28 O's

Si	5.1555	Al_T	2.8445
Al	5.2265	Al_o	2.3820
Fe^{3+}	0.4624	Al_o+Fe^{3+}	2.8445
Fe^{2+}	4.9784		
Mg	3.5824		
Mn	0.5947		

Comment: By these means it is possible to calculate the amount of Fe^{3+} in coupled tetrahedral - octahedral substitution. The calculation is perturbed by small errors - in all likelihood, those within the range of accuracy of the microprobe. In addition, it is observed that there is some correlation between calculated Fe^{3+} and supposedly spurious Na_2O in an analysis. Lastly, because oxygen cannot be determined, we have no way of determining how much Fe is substituted according to case 3. It appears, on the basis of experience, that the microprobe analyses obtained for this study are not good enough for more than a rough appraisal of Fe^{3+} content in chlorites.

Programme for HP 34 C Calculator, Case 1.

```
h LBL A
RCL.0
RCL 0
÷
STO 5
RCL .1
RCL  1
÷
STO 6
RCL.2
RCL 2
÷
STO 7
RCL.3
RCL 3
÷
STO 8
RCL f I
RCL 4
÷
STO 9
RCL 5
2
x
RCL 6
3
x
+
RCL 7
+
RCL 8
+
RCL 9
+
h 1/x
2
8
x
STO.1
RCL 5
x
STO 5
RCL.1
RCL 6
x
2
x
STO 6
RCL.1
RCL 7
x
STO 7
RCL.1
RCL 8
x
STO 8
RCL.1
RCL 9
x
STO 9
RCL 8
+
RCL 7
+
RCL 6
+
RCL 5
+
2
0
÷
STO.1
2
8
x
2
8
-
2
x
RCL.1
÷
STO.2
RCL 5
RCL.1
÷
STO 5
RCL 6
RCL.1
÷
STO 6
RCL 7
RCL.1
÷
RCL.2
-
STO 7
RCL 8
RCL.1
÷
STO 8
RCL 9
RCL.1
÷
STO 9
h RTN 9
```

Input:

Permanent:	STO 0 :	60.09	(M.W. SiO_2)
	STO 1 :	101.96	(Al_2O_3)
	STO 2 :	71.85	(FeO)
	STO 3 :	40.31	(MgO)
	STO 4 :	70.94	(MnO)

These need not be renewed between runs.

Each run:	STO.0 :	wt % SiO_2
	STO.1 :	wt % Al_2O_3
	STO.2 :	wt % FeO (all Fe as FeO)
	STO.3 :	wt % MgO
	STO f I :	wt % MnO

\- - -

Begin: press A

Note: if the regression or statistical routines are used between runs, it is necessary to reload lines 106 and the permanent input.

\- - -

Output:	RCL 2	Fe^{3+})	
	RCL 5	Si)	
	RCL 6	Al)	atoms per
	RCL 7	Fe^{2+})	28 oxygens
	RCL 8	Mg)	
	RCL 9	Mn)	

Appendix 5

List and classification of significant sulphide and sulphate deposits in the Mt. Read Volcanics.

1. Pieman Valley and areas to the north

Que River: (i) massive, syngenetic, Pb-Zn-Cu-Fe sulphide lenses
(ii) barite, probably syngenetic, separated 1000 m N along strike from (i)
(iii) pyrite, diagenetic, in black slate from the Murchison Highway near the Que River bridge.

Mt. Charter: barite, probably syngenetic (much is recrystallised, but a little is sugary and vaguely banded with pyrite, sphalerite and galena).

Mt. Block: barite, habit not known.

Pinnacles: Pb-Zn-Cu-Fe sulphides as stringers and also as syngenetic bands (Green et al, 1981). There is said to be a large block of massive syngenetic-type ore in Pleistocene till nearly (J. C. van Moort, pers. comm.).

Burns Peak: barite, sphalerite, galena, pyrite. Probably veins.

Chester: pyrite and chert, interbedded. Syngenetic in its original position, but possibly not in situ now. Also a little Pb-Zn sulphide mineralisation from a drill-hole 500m SSW of the Chester Mine. Collins (1975) considers the Pb-Zn mineralisation to be fracture-fillings unrelated to the Chester pyrite.

Langdons: a fracture filling of sphalerite, galena, siderite and chlorite.

Cutty Sark: (hand specimens only examined) (vein or replacement consisting of chlorite and pyrite).

2. Rosebery area

Rosebery: Massive, syngenetic, zoned Pb-Zn-Cu-Fe sulphides with manganiferous carbonates and barite. Also pyrite disseminated in footwall rocks; pyrite (diagenetic) in black slate; pyrrhotite associated with tourmaline, fluorite and marcasite cutting massive syngenetic ore.

Mt. Black Pty: small; habit as for Rosebery.

Dalmeny: Specimens examined are veins or replacement of Pb-Zn--Fe sulphides.

Rosebery Lodes: Small occurrence of low-grade syngenetic Pb-Zn-Cu-Fe ore as at Rosebery. Also quartz-tourmaline-pyrite veins considered to be Devonian.

Salisbury: Pyrite chalcopyrite and tourmaline veins and replacements considered to be Devonian.

Chamberlain: probably as for Salisbury. Workings may have been obliterated.

Koonya: Massive, syngenetic Pb-Zn-Cn-Fe sulphides, apparently zoned. Siliceous ore varieties with no sedimentary textures occur on certain dumps.

Jupiter: (i) Lead-zinc. Minor syngenetic Pb-Zn sulphides. On the dumps there are blocks of massive rhodochrosite.

(ii) Copper. Massive pyrite, probably syngenetic. Visible chalcopyrite is mostly remobilised.

Dallwitz: Sphalerite disseminated in siltstone.

Williamsford: Massive syngenetic Pb-Zn-Cu-Fe sulphides.

Ring PA: Massive barite and disseminated pyrite, possibly syngenetic.

Hercules: Massive, syngenetic Pb-Zn-Cu-Fe sulphides with manganiferous carbonates and barite.

Williams: Pyrite and galena, probably syngenetic.

Dunn's Blocks: Pyrite disseminated in quartz-sericite rock.

East Hercules: (and the line of workings to the south): Veins bearing pyrite and sphalerite, and replacement zones of chlorite and pyrite.

White Spur: Blocks of massive pyrite, occurring in reworked pyroclastic material.

3. Farrell to Sedgwick

Farrell Lode: Pb-Zn-Cu-Fe sulphides and rare barite in a number of small-to medium-sized vein-like deposits contained within the Farrell Slates. The origin of this mineralisation (Cambrian syngenetic, Devonian veins or elements of both) is much-debated. Intense shearing associated with the Henty Fault has affected the sulphides.

Murchison Lode: Pb-Zn-Cu-Fe-As sulphides in veins transgressing the Farrell Slates. Possibly Devonian.

Murchison Gorge: (i) a little disseminated and vein chalcopyrite in pink potassic rhyolites west of the Owen Conglomerate. (ii) replacements and disseminations of pyrite and magnetite from near the contact of the Murchison Granite. (iii) Veins of undeformed pyrite, galena, sphalerite and carbonate from near the granite contact.

Sterling Valley: Vein-like deposits Cu-Pb-Zn-Fe sulphides associated with the southward continuation of the Farrell Slates.

Red Hills: (i) Massive Pb-Zn-Cu-Fe mineralisation associated with shale and reworked pyroclastics.

(ii) Veins of pyrite, chalcopyrite and magnetite to the east of (i)

(iii) Pyrite, diagenetic, in black shale.

(iv) Galena and chalcopyrite-bearing veins from massive pink rhyolites (including Tyndall Group) west of (i).

Henty Fault Zone: (i) Veins of pyrite and chalcoprite in the fault zone east of Mt. Read.

(ii) Massive, syngenetic Cu-Pb-Zn-Fe sulphides west of the Gooseneck.

Howards Anomaly: Bedded hematite, carbonate and barite with minor magnetite, chert and pyrite, beds containing disseminated pyrite; one minor occurrence syngenetic Pb-Zn sulphides (transported?).

Tyndall Mine: Veins of Cu-Pb-Zn-Fe sulphides.

Basin Lake Prospect: Beds of pyrite and pyritic shale and tuff in a sedimentary-tuffaceous sequence.

Lake Selina: Veins and replacements of pyrite, chalcopyrite and magnetite, in some cases associated with minor granitic intrusions. Minor molybdenite is reported.

Lake Dora: Veins of Cu-Pb-Zn-Fe sulphides, some with magnetite.

Mt. Sedgwick: (i) Transported blocks of massive Pb-Zn sulphides occurring with blocks of black shale in an ash-flow tuff overlying black shale at Itat Creek.

(ii) Veins of magnetite and (?) pyrite in pink rhyolite on the south-eastern spur of Mt. Sedgwick.

Lake Margaret Tramway: Massive, syngenetic pyrite.

Madame Howard's Plains: Vein of barite.

4. Mt. Lyell - King River

Mt. Lyell: (i) Massive syngenetic ore at Tasman and Crown Lyell Extended (Pb-Zn-Fe sulphides), Comstock (pyrite-chert), Iron Blow (pyrite-barite-hematite-minor Pb-Zn-Cu sulphides, the hematite may be secondary.).

(ii) Disseminated and replacement ores, mostly pyrite and chalcopyrite, in some cases with hematite, magnetite, molybdenite, barite and bornite, in the other Lyell deposits between Comstock, Cape Horn to the north and King Lyell, Great Lyell and Duke Lyell on Little Owen Ridge to the south.

Mt. Huxley: (i) A very small syngenetic body containing disseminated pyrite in brecciated grey chert.

(ii) barite veins from near a minor shale lens.

5. South of King River

Jukes Propriety: Veins and disseminations of Cu-Fe sulphides and Fe oxides; minor barite veining.

Lake Jukes: Veins of Cu-Fe sulphides.

Hydes: Disseminated pyrite and chalcopyrite.

Tayour's Reward: barite veins with minor sulphides.

Findons-Allans Creek: (i) veins/disseminations of pyrite, chalcopyrite and magnetite.

(ii) an ancient gossan (beneath the Owen Conglomerte) containing remnants of pyrite, magnetite and barite.

(iii) barite veins.

East Darwin: Veins and disseminations of Cu-Pb-Zn-Fe sulphides.

Darwin Plateau: (i) Veins and disseminations of pyrite and magnetite within the Darwin Granite and near the contacts.

(ii) Barite veins above the unconformity to the east of the Darwin Granite.

Prince Darwin: Replacement of volcanics by pyrite and massive magnetite. Barite is reported.

APPENDIX 6. SULPHUR ISOTOPE RESULTS

No.	Min	Habit	Pos	$\delta^{34}S$‰
Prince Darwin				
PD1	py	R	F	+8.7
PD2	py	R	F	+9.0
South Darwin				
SD1	py	V	F	+13.5
SD9A	py	D	F	+9.3
SD9B	py	D	F	+10.5
SD11	py	D	F	+10.3
SD17	py	D	F	+11.3
SD31	ba	V	F	+29.1
East Darwin				
ED4	ccp	V	F	+15.7
ED5	ccp	V	F	+13.5
Findons & Allans Ck				
F1	py	V	F	+15.4
F2	ccp	D	F	+14.0
F3	ccp	D	F	+15.8
F4	ccp	D	F	+15.3
F5	ccp	D	F	+15.4
F6	py	G	F	+14.8
F7	py	D	F	+13.6
ND1	ba	V	F	+30.0
Intercolonial Spur				
H1C	ccp	V	F	+4.9
H1C	ba	V	F	+28.3
H1	py	V	F	+5.6
H1	ba	V	F	+27.4
H1S	ba	V	F	+28.5
H2	ba	V	F	+26.8
H3	ba	V	F	+26.4
H4	ba	V	F	+28.3
H7	ba	V	F	+27.2
I3	ba	V	F	+27.9
Tyndall Mine Area				
ET	py	D	F?	+ 9.4
Henty Fault Zone				
HFZ5	py	S	O	+ 7.3
Lake Dora				
DS2	py	V	E	+11.8
DS8	ccp	V	E	+13.0
DS13	py+ccp	V	E	+10.4
Salisbury				
S1	py	V	O?	+16.0
Koonya				
J8	py	S	O	+13.0
J8	py	S	O	+12.7
Dalmeny	sp	V*	H	+10.6
angdons				
1	gn	V*	H	+11.6
2	sp	V*	H	+12.9
ieman Road				
R13	py	D	H	+7.4

No.	Min	Habit	Pos	$\delta^{34}S$‰
Lake Jukes				
LJ	bn	V	F	+17.0
Jukes Proprietary				
JP3	ccp	V	F	+12.3
JP3	ccp	V	F	+10.5
JP4	ccp	V	F	+11.9
JP8	ba	V	F	+29.9
JP10	py	D	F	+10.6
Huxley				
HX4	ba	V	?	+26.9
HX10	py	S	O?	-5.5
Little Owen				
RM30	ba	V	?	+29.5
Mt. Lyell				
1. North Lyell				
NL1	ba	S	O	+27.5
2. Crown Lyell no.3				
CL1	py	R	F	+1.4
CL2	py	R	F	+0.5
Mt. Sedgwick (Itat Ck.)				
SE6	sp-gn	S	O	+10.2
Lake Margaret Tramway				
LM1	py	S	W	+5.2
Madam Howards Plains				
MHB	ba	V	W	+32.5
Basin Lake DDH BL4				
17.9m	py	S	O	+0.1
50.0m	py	S	O	-0.9
53.2m	py	S	O	-4.6
65.2m	py	S	O	+1.7
70.0m	py	S	O	+2.4
Mt. Farrell				
Mac 1	ba	V*	O	+23.2
Mac 1	ba	V*	O	+22.3
Mac 1	gn	V*	O	+14.2
Williamsford - Ring PA				
W1	gn	S	O	+7.5
W2	gy	S	O	+9.4
W3	ccp	V*	O	+9.1
Ring1	py	S?	O	+12.7
Ring2	ba	S?	O	+42.7
Grand Centre				
GC1	py	S?	O?	+14.3
GC2	ccp	V*	O?	+13.2
Ring River				
RR3	py	S	W	+2.2
Burns Peak				
BP3	ba	V	?	+37.6
BP3	gn	V	?	+16.0
BP3	sp	V	?	+10.7

No.	Min	Habit	Pos	$\delta^{34}S$
Howards Anomaly				
D[illegible]H:HA2,494	py	S	O	+16.8
H[illegible]4,137m	sp-gn	S	O	+8.3
HA4	ba	S	O	+33.1
H[illegible]5,250m	py	S	O	+6.0
[illegible]6,111m	py	S	O	-5.4
spec.HA14	py	D	?	-8.3
[illegible]ake Selina				
[illegible]	py	D	F?	+9.8
[illegible]24N,2900W	py	V	F?	+10.9
144N,290E	py	D	F?	+9.8
[illegible]4N,452E	py	R/V	F?	+10.2
[illegible] Hills				
RH2	py	V	F	+10.8
[illegible]6A	ccp	V*	F	+13.0
[illegible]6B	ccp	V	F	+12.4
DDH RH5				
196.1m	sp	S	O	+15.8
[illegible]7.3m	sp+gn	S	O	+17.2
[illegible]8.1m	sp+gn	S	O	+11.4
Jupiter				
[illegible]ad: J2	gn	S	O	+11.2
[illegible]pper: J1	py	S	O	+12.4
Rosebery Lodes				
[illegible]H RLP147				
365ft	py	S	O	+14.2
360ft	ba	S	O	+37.7
[illegible]L3	py	V*	F?	+18.6
[illegible]4	py	D/S	O?	+10.9
[illegible]nnacles				
DDH PP34				
280ft	py	V/S	O?	+14.0
[illegible]H PP36,				
357ft	py	V/S	O?	+9.1
DDH PP40,				
29ft	sp	V/S	O?	+8.1

No.	Min	Habit	Pos	$\delta^{34}S$
Hercules Area				
1. Dunn's Blocks				
SDB	py	D	F?	-2.6
2. Williams				
W1	py	S?	O	+11.6
W2	gn	S?	O	+19.2
3. Hercules DDH H672				
92ft.	ba	S	O	+42.7
4. Hercules DDH H464				
444ft	py	S	O	+12.5
445ft	py	S	O	+12.5
478ft	gn	S	O	+14.0
478ft	sp	S	O	+14.5
478ft	py	S	O	+13.5
570ft	gn	S	O	+10.7
573ft	py	S	O	+14.0
580ft	py	S	O	+13.8
5. Hercules Footwall				
HF4	py	D	F	+15.3
HF7	py	D	F	+14.5
6. East Hercules line of workings				
HF21	py	V	H	+18.4
HF21	ccp	V	H	+18.6
HF21A	py	V	H	+10.0
Mount Charter				
MC1B	ba	S?	O?	+46,9
MC1B	py	S?	O?	+10.7
MC2	py	S?	O?	+12.8
Que River				
102901	sp+gn	S	O	+5.9
102901	sp+gn	S	O	+5.9
QR1	ba	S?	O?	+44.4
Colebrook				
CH1	po	V	-	+3.8
CH2	po	V	-	+5.9
CH3	po	V	-	+4.2

Explanation

Min = mineral

py = pyrite, sp = sphalerite, gn - galena, ccp = chalcopyrite, bn = bornite, po = pyrrhotite, ba = barite.

Habit: B = in black shale, D = disseminated, G = gossan, R = replacement, S = stratiform, V = vein, V* = vein of remobilised material.

Pos: position (stratigraphic

E = Eastern sequence (Corbett, 1979)

W = Western sequence (Corbett, 1979)

In the Central sequence volcanics

H = hangingwall) with respect to known
O = host horizon) stratiform mineralisation
F = footwall)

Sulphur Isotope results from Polya (1981) - Honours

Thesis:

Murchison Gorge:

Disseminated in Murchison Granite, middle of sill:
py : +10.1‰.

Altered granite, Sophia Tunnel: py + 9.0‰

Volcanics immediately above granite:

Sophia valley	1.	py :	+12.4‰
		gn :	+14.2‰
		sp :	+11.5‰
	2.	sp :	+ 8.8‰
		sp :	+ 7.7‰

Granite contact, Western abutment of dam: py +12.3‰

Chloritised volcanics near contact: py +11.5‰
vein of sp 10.2‰

From chloritised rhyolites west of Jukes Breccia:
ccp +12.7‰

Sterling Valley

DDH STP 221, vein/replacement, po + 8.6 +8.7

Table Sulphur Isotope Thermometry

Locality	Pair	Δ ‰	T°C
Taylour's Reward	barite - chalcopyrite	23.4	279±8
	barite-pyrite	21.8	270±9
Burns Peak	barite-galena	21.6	348±23
	barite-sphalerite	26.9	217±34
	galena-sphalerite	5.3	96±13
Tullah	barite-galena	9.0	711±58