R. L. Oliver

GEOLOGY AND PETROLOGY OF PART OF THE ARCHAEAN INLIER NORTH-EAST OF YANKALILLA ON THE FLEURIEU PENINSULA

by

ANDREW J. McEWIN, B.Sc.

Thesis submitted as partial requirement for
the Honours Bachelor of Science Degree,
Department of Geology and Mineralogy,
University of Adelaide.

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CONTENTS.

This should go immediately preceding the Introduction.

ABSTRACT.

The Archaean inlier to the east of Yankalilla on the Fleurieu Peninsula forms the core of an overturned anticlinal structure whose limbs and hinge line dip and plunge to the south-east. The fold is delineated by the overlying unconformable Proterozoic and Cambrian sediments.

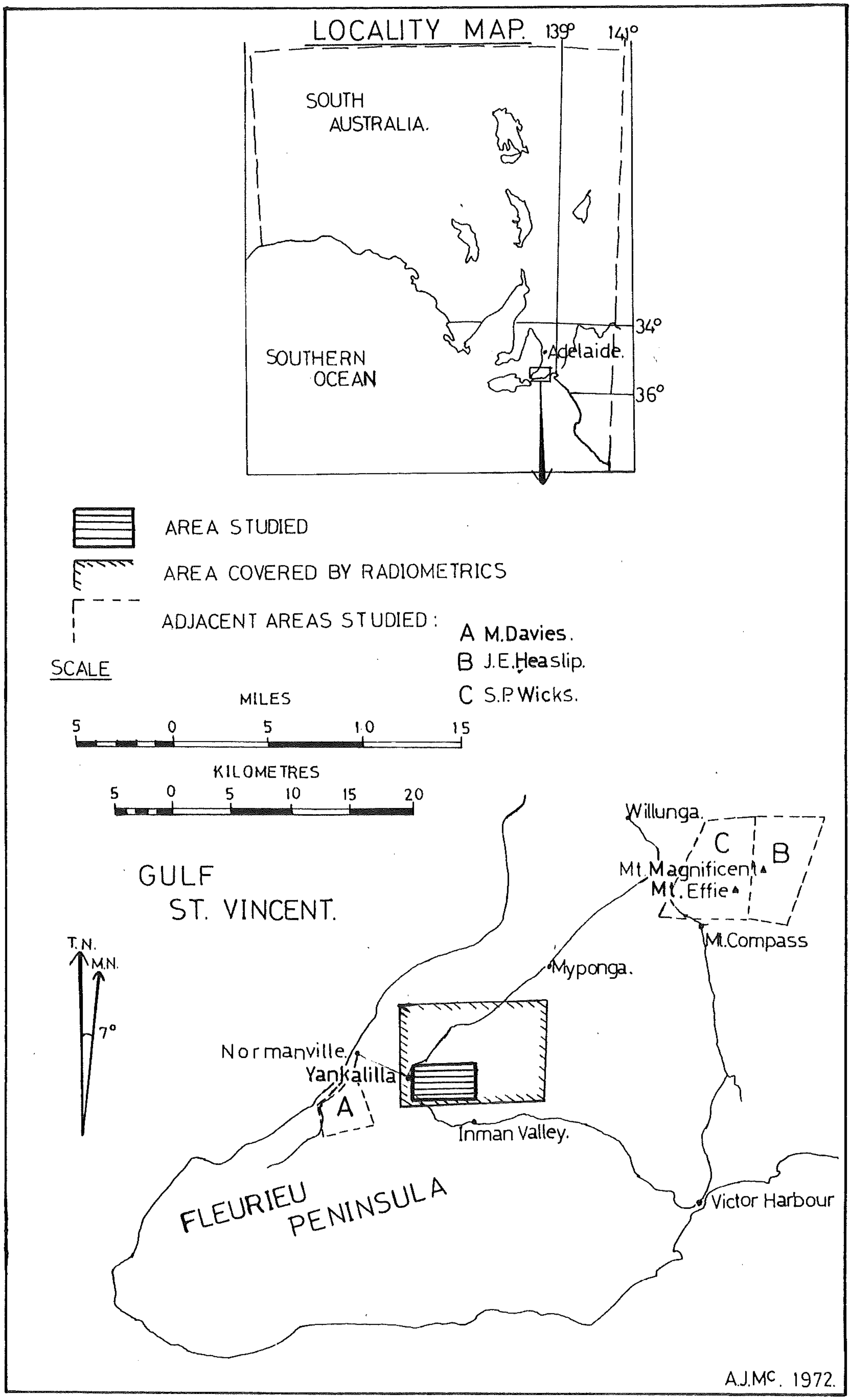
There is evidence of a sheared boundary along the north-western edge of the inlier. The schistosity and layering of the basement schists, quartzofeldspathic schists, gneisses and feldspar gneisses parallels the axial plane structure of the anticline.

The basement has possibly undergone intense deformation before the deposition of the Adelaidean in the form of tight isoclinal folding. It is intruded by amphibolite dykes and pegmatites.

The metamorphic grade has reached at least upper amphibolite facies and has been retrograded to greenschist facies.

FIGURES AND PLATES.

FIG 1.


LOCALITY MAP.
139°
141°
SOUTH AUSTRALIA.
SOUTHERN OCEAN
Adelaide.
34°
36°
AREA STUDIED
AREA COVERED BY RADIOMETRICS
ADJACENT AREAS STUDIED:
A M.Davies.
B J.E.Heaslip.
C S.P.Wicks.
SCALE
MILES
5 0 5 10 15
KILOMETRES
5 0 5 10 15 20
GULF ST. VINCENT.
T.N.
M.N.
7°
Willunga.
Mt.Magnificent
Mt. Effie
Mt.Compass
Myponga.
Normanville.
Yankalilla
Inman Valley.
Victor Harbour
FLEURIEU PENINSULA
A.J.Mc. 1972.

ACKNOWLEDGEMENTS.

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My gratitude goes to my fellow students whose discussions and suggestions were of assistance.

INTRODUCTION.

The study of the Archaean inlier east of Yankalilla was prompted by Dr. Robin Oliver to further the structural and petrological understanding of the area. Other workers are examining similar areas on the Fleurieu Peninsula, namely, S.P. Wicks, Mt. Compass-Mt. Effie area; M. Davies, south of Normanville; and J.E. Heaslip, Mt. Magnificent area. (See locality map, Fig. 1.).

The basement block at Yankalilla forms a south-west to north-east trending range of rounded hills of moderate local relief, dissected by semi-permanent streams. It is mainly grazing land with areas of thick natural vegetation.

Field work was carried out in first term, overlapping into second term, with the aid of stereoscopic aerial photographic pairs at a scale of 1 = 52,000. These provided assistance in suggesting regional trends and locating stations in relation to topography. However, a larger scale would have been more useful, i.e. 1 = 26,000. The base photograph used was an enlargement of one of the above. Enlarged to a scale of 1 = 10,000, it was cut up for fieldwork. As the area mapped was covered by the centre of the photograph, photographic distortion was ignored. However, due to recent clearing of vegetation, exact station positioning was difficult, sometimes impossible, even with the help of the stereoscopic pairs. This, with lack of outcrop (grazing land), soil slides, soil creep and lateritic expressions, made mapping difficult.

The best outcrops were in the creeks and adjacent slopes, but in situ outcrops were rare. Mapping was, therefore, accomplished by creek traverses and outcrop tracing over the intervening ridges, where possible.

Thin sections were cut and selected to permit a discussion of textures with reference to the metamorphic history, petrology and structural deformation of the area in conjunction with field mapping. Reference was made to radiometric data of the area (obtained from the Mines Department), to assist in mapping.

REGIONAL GEOLOGY.

The Archaean inliers form isolated "windows" in the overlying unconformable upper Proterozoic (Adelaide system) and the lower Palaeozoic (Cambrian).

The Adelaide system and Cambrian are exposed as south-west to north-east striking beds, overturned to the west and dipping steeply south-east. They represent the eroded remnants of an overturned anticline whose limbs and hinge line dip and plunge to the south-east. The basement complex forms the core of this structure. The schistosity planes and gneissic layering of the basement parallel the axial surface to this structure.

Stratigraphically there is a break in the sedimentary record from the upper Cambrian (Kanmantoo beds) to the Permian. The Permian glacial and fluvioglacial deposits (sands, silts and clays) form near-horizontal strata in filling the glacial modified valleys and covering the basement and Proterozoic to lower Palaeozoic sequences. Another break occurs after the Permian beds until the Quaternary alluvial deposits. A Tertiary lateritic expression is recognized in the area.

The regional structure is the recumbent anticline (Delamerian Orogeny) (Handbook S.A. Geology, 1969). A tectonic thrust plane is situated on the western limb of the anticline parallelling the limb and upthrusting from the east. The region is block faulted, with the down fault side to the west. This is an expression of the late Tertiary uplift also. Post uplift erosion has modified this uplifted block.

Where is the block fault compared with the thrust.

LITHOLOGIES.

The rocks found in the Archaean basement are classified under four subdivisions; two major - the gneisses and schists, and two minor - the pegmatites and the amphibolites.

The terms gneiss and schist are used in the sense of Williams, Turner and Gilbert as described by Turner and Verhoogen; namely, a gneiss is a "coarse grained, irregularly banded rock with discontinuous rather poorly defined schistosity. The gneissic fabric reflects pre-dominance of quartz and feldspar and a general lack of micaceous minerals." (Turner and Verhoogen, 1960). Schists refer to "strongly schistose, commonly lineated, metamorphic rocks in which the grain is coarse enough to allow macroscopic identification of the component minerals. Segregation banding is usually prominent. Micaceous minerals are abundant; their high degree of preferred orientation is reflected in the development of schistosity." (Turner and Verhoogen, 1960). Pegmatite and amphibolite refer to rocks of original igneous affiliation which have since been metamorphosed.

A continuous gradation exists between the schists and gneisses depending on the relative micaceous mineral, quartz and feldspar content. Hence, the prefix quartzofeldspathic indicates a predominance of quartz and feldspar; the prefix epidote gives the characteristic mineral associated with the epidote gneiss. Similarly, a quartz gneiss indicates the predominant mineral of the gneiss.

The terms mylonite, cataclasite, hornfels and migmatite (Turner and Verhoogen, 1960) have been omitted in the allocation of rock names, as they indicate geneses. However, they will be used as descriptive terms in relation to the various gneisses and schists. Augen is used as a prefix and refers to "large lenticular mineral grain or aggregate of minerals which in cross section have the shape of an eye," i.e., porphyroblasts wrapped by micaceous minerals. (Dictionary of Geol.

Terms. American Geol. Inst., 1962).

Several classifications avoid the use of both schist and gneiss, the rock being classified on its component minerals. Examples are quartz, tourmaline rock and chlorite rock.

Within the basement complex the epidote gneiss has been correlated to the so-called Houghton "Diorite." The name Houghton "Diorite" has been avoided in this treatment as it presupposes an igneous origin as indicated by England (1935). The term gneiss does not, as without the prefixes "ortho" or "para", it is merely a descriptive term applied to a rock which has undergone metamorphism. It does not presuppose either an igneous or a sedimentary origin before metamorphism.

Gneisses.

The gneisses form a predominant rock type in the area. The gneisses are light coloured rocks with quartzofeldspathic bands and/or augen set in a dark schistose ground mass of sericite and quartz, or massive coarse grained quartzofeldspathic rocks with no apparent layering or banding.

The banded and massive gneisses grade into each other, the banding varying considerably in size, clarity and deformation (crenulation). In the central part of the area, the gneisses vary considerably; from a finely banded medium grained gneiss, they pass into a deformed banded gneiss in which the layering is tightly contorted with associated coarse grained, almost granitic, associations, giving the rock a migmatitic character. The augen gneisses are represented along the northwestern side of the basement area especially and probably delineated a zone of thrusting and shearing.

Typical examples of gneisses taken from various areas indicate the nature and variation within the group.

Specimen 378-1 is a massive quartz gneiss from near Yankalilla. Mineralogically, quartz composes greater than 95% of the rock, with

It would be better to describe the different gneisses under subheadings corresponding to those on your map — according to

minor muscovite parallel to the schistosity surface. This surface shows a coarse mineral lineation, almost rodding, due to the alignment of quartz aggregates. The quartz is obviously strained even in hand specimen. The anhedral porphyroblasts show pronounced strain banding in one general orientation. Surrounding and encroaching into the porphyroblasts is a mosaic of fine grained recrystallized quartz grains with straight, curved and sutured boundaries. 120° triple points are common. These grains show no, or very little, undulose extinction. This texture is not unique to the gneisses, but is seen in every rock of the area and must represent nucleation and growth of a new phase in an approach to equilibrium. Minor minerals are retrograde sericite and biotite, with tourmaline, zircon and opaques as accessories.

Rock 378-26 is a coarse grained almost granitic gneiss. It has a coarse porphyroblastic texture. The anhedral quartz porphyroblasts, which together with the quartz mosaic form half of the rock, have strain banding developed. Both the quartz and microcline porphyroblasts (up to 1 cm diameter) have a mortar texture of recrystallized quartz bounding them. This may only be a single layer thick but forms a sutured boundary to the porphyroblasts. The microcline is heavily sericitized and in places perthitic. — K. Can you see the perthitic texture if it is "heavily sericitized"

Sericite has initially preferentially formed parallel to the cleavage traces of the feldspars (e.g. microcline) and then, as the degree of sericitization has increased, it has spread outwards to cover the whole porphyroblast. This is a common feature of the retrograde sericitization of the feldspars in these rocks. Cross hatching of the microcline is frequently visible.

Minor biotite is present in nearly all of these rocks. It is the typical high grade biotite pleochroic in dark to light browns, characteristic of the high grade Archaean rocks in South Australia. (Spry, 1951).

Quartz is abundant in all the augen gneisses and occurs as irregular, often elongated, crystals showing marked undulose extinction. The quartz is often biaxial. Rock 378-7 is a typical example. The texture of the rock is slightly mylonitic or cataclastic. The appearance suggests a shearing of a parent rock such that the augen are fractured and deformed remnants of the original rock. Often, heavily sericitized microcline occurs as augen wrapped around by an intergrowth of secondary sericite and fine biotite aligned in the direction of the foliation. (Plate 1A).

Rock 378-16 is a banded gneiss. The "layerings" have been refolded (crenulated), but are still apparent as concentrations of leucocratic and mafic constituents. This is the only rock in the area in which sillimanite is recognized. Sillimanite occurs as equant and elongate crystals; the equant prisms have an average diameter of 0.1 mm. They exhibit the characteristic diagonal cleavage in elongate aggregates of euhedral crystals. The rock contains the high grade dark to light brown pleochroic biotite as euhedral laths. (Plate 1B).

The remainder of the rock is a granoblastic texture of quartz, microcline, plagioclase and opaques. Using the Carlsbad albite twin law, the plagioclase composition in another banded gneiss is An 30-35, i.e., Andesine.

The banded gneiss 378-33 contains a predominance of antiperthite with minor microcline perthite porphyroblasts. In the microcline perthite the plagioclase occurs as stringers. The antiperthite has a plagioclase host with blebed inclusions of cross hatched microcline. The microcline inclusion is perthitic itself, with plagioclase stringers. These stringers are parallel to one cross hatching direction and is normal to a faint albite twinning present in parts of the host crystal. The microcline cross hatching has parallel aligning in all blebs within the same plagioclase host. The inclusions themselves are very irregular in shape. Some of the antiperthite contain rounded inclusions of quartz. (Plates 2A, 2B, 3A).

A.

Augen gneiss with quartz strain banding.
Note the recrystallized quartz mosaic. The relict feldspar is heavily sericitized.

Crossed Nicols x 1.

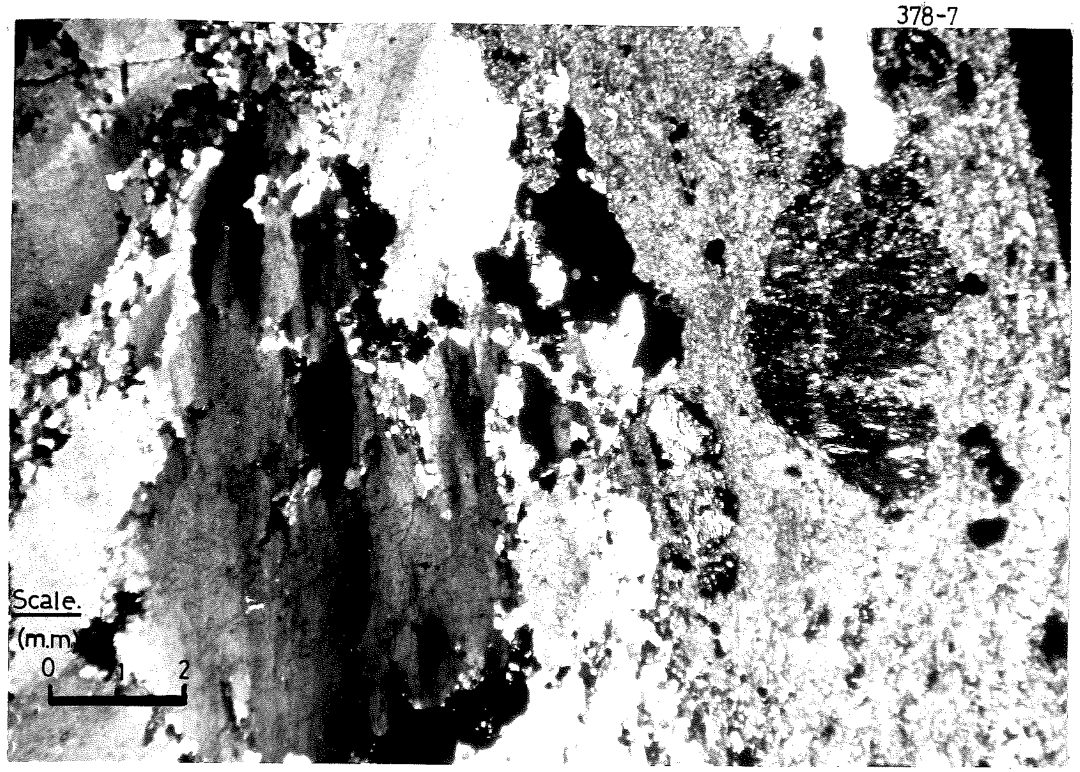
B.

Sillimanite euhedra and anhedra with distinctive diagonal cleavage. Unsericitized.

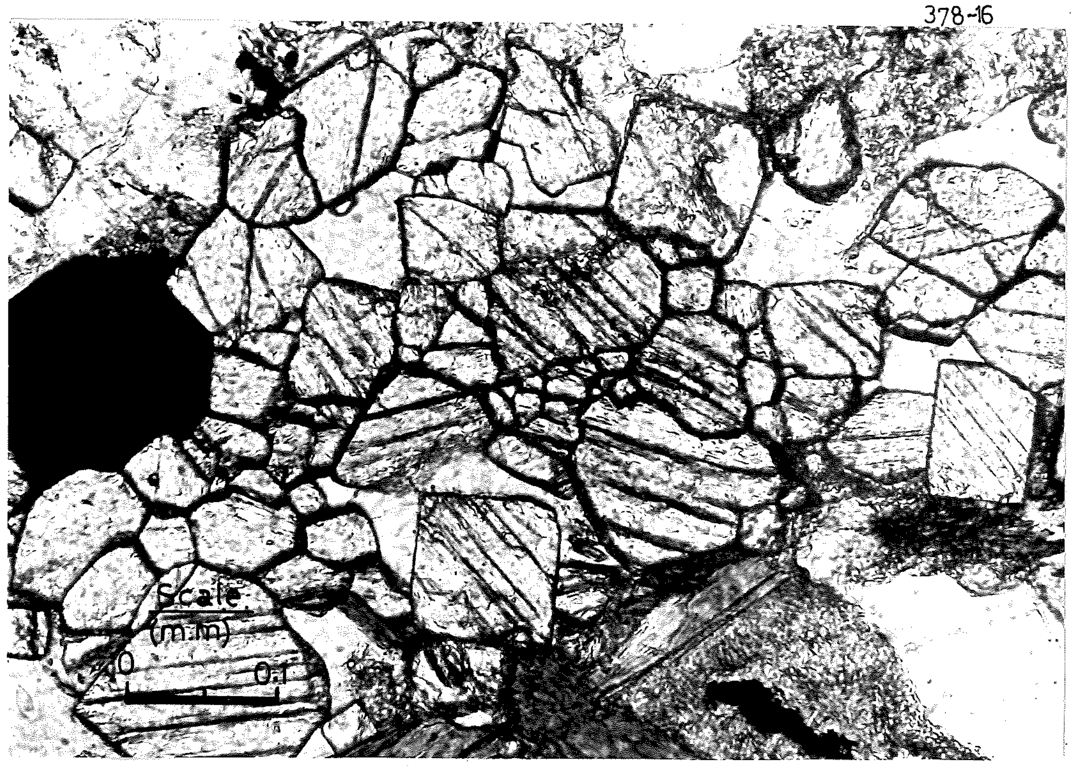
Plane polarized light x 10.

PLATE I.

A.



B.



A.

Antiperthite with inclusions of microcline perthite, some cross hatching. Note sericitization of the plagioclase and unaltered character of the microcline. Typical anhedral crystals.

Crossed Nichols 4x.

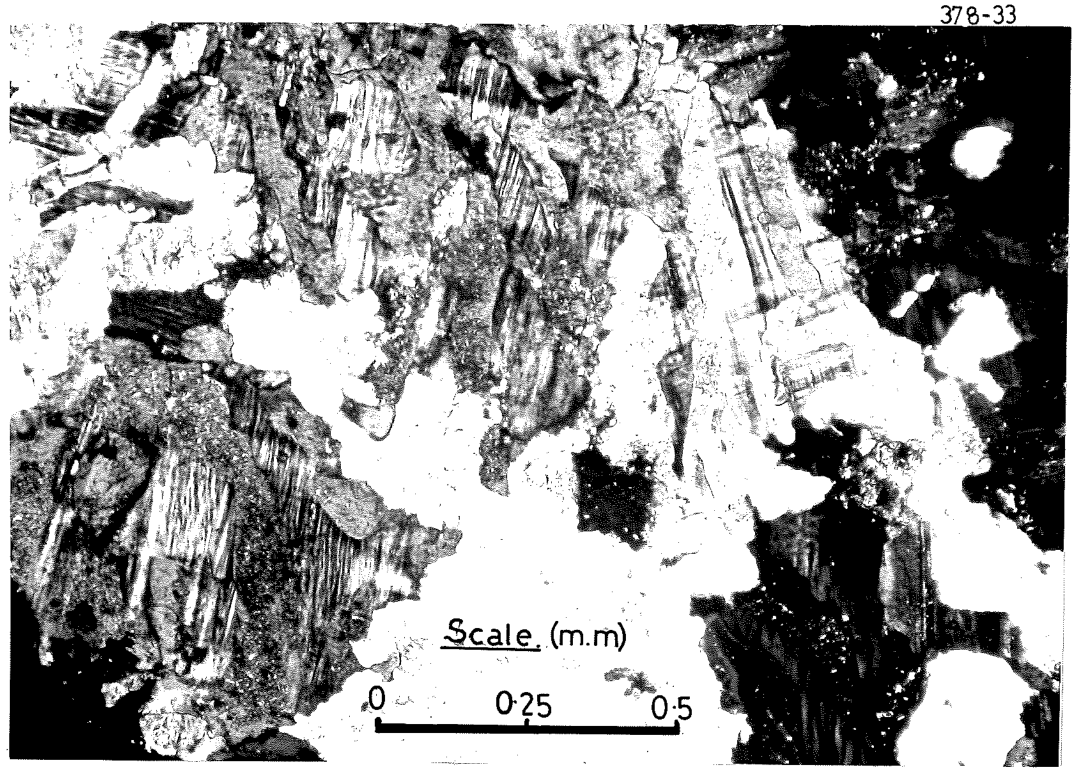
B.

Antiperthite with inclusions of microcline perthite with constant orientation of perthite stringers. Note rounded quartz inclusion.

Crossed Nicols 4x.

PLATE 2r

378-33



A.

378-9

B.

A.

"Checker Board" antiperthite.

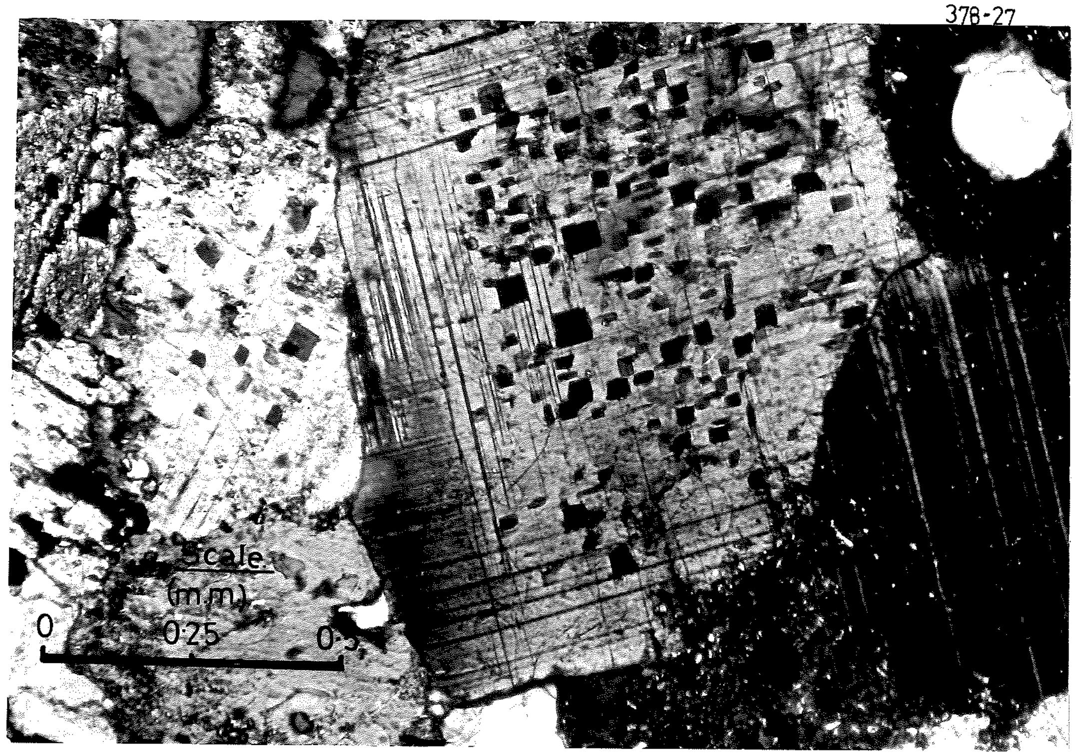
Crossed Nicols 4x.

B.

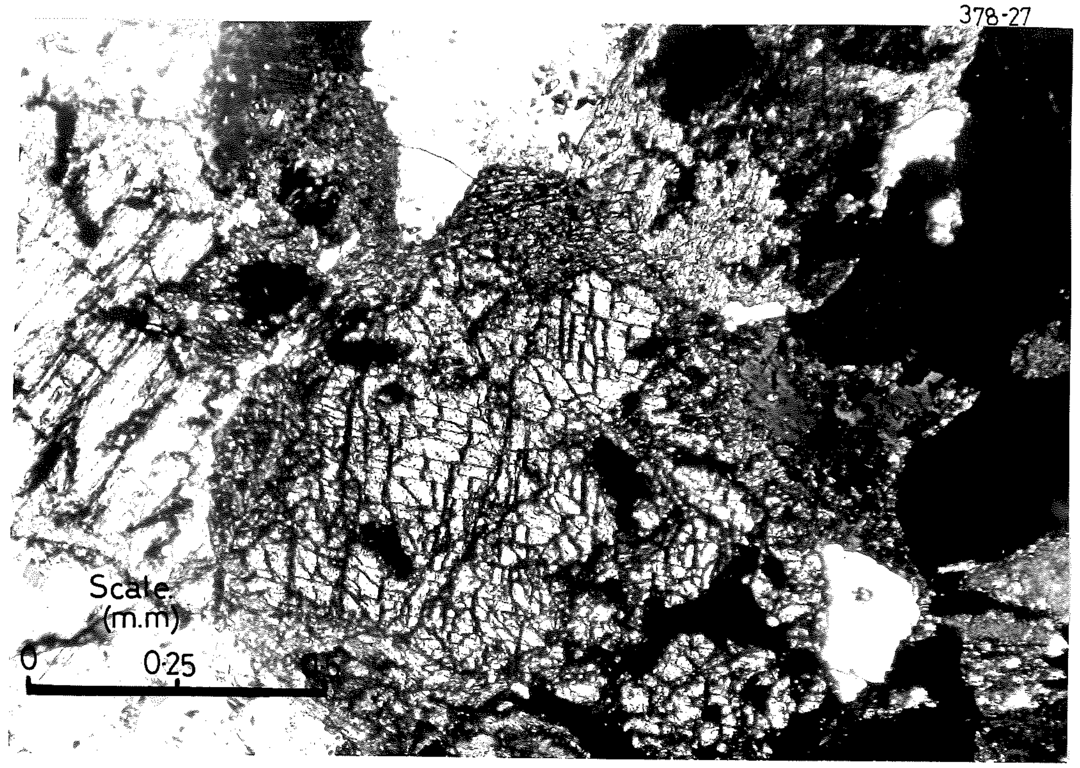
Clinopyroxene with typical pyroxene cleavage rimmed by amphibole with characteristic cleavage.

Crossed Nicols 4x.

PLATE 3.



A



B

There is at least one case where the host plagioclase with inclusions of microcline is rimmed by a plagioclase of possibly different composition with a faint albite twinning. This is revealed by the different extinction positions of the core and rim. The rim itself has an antiperthitic texture in places. The orientation of the inclusions in the rim and core, as defined by maximum extinction position, is slightly different.

The genesis of the antiperthite, perthite structures will be discussed later.

Finally 378-2, 3, 27, 35, 36 are the Epidote gneisses. The banding is usually strongly developed and continuous for several feet. This foliation is due to the segregation of the coloured minerals, such as hornblende and epidote, in the darker bands, with quartz and feldspar in the more leucocratic portions. Retrograde metamorphism seems to be more advanced in the lighter bands, with sericitization of the major plagioclase and, to a lesser extent, the minor microcline. Much of the plagioclase is antiperthitic with blebs of microcline perthite in the plagioclase host.

Light green epidote and dark green amphibole (hornblende) are easily recognizable in hand specimen. The amphibole exists as anhedral porphyroblasts up to 4 mm diameter, showing a blue green to yellow green, or a brown to green pleochroism. Closely associated with the amphibole (spatially) is the epidote, which occurs as the pleochroic yellow variety, as anhedral crystals and as aggregates of tiny colourless crystals formed possibly by saussuritization of the plagioclase (see later).

In 378-35, 36 a garnet appears associated with the epidote. The mineral assemblage of the epidote gneisses, namely, epidote, hornblende, augite and sphene, implies a calcium rich association, and the garnet would be expected to be grossularite-andradite, the calcium rich members. The colour confirms this. The grains are yellowish brown to dark brown and the thin section colour is light brown.

Sphene is a common accessory as euhedral to anhedral grains with high relief, brown colour and often rhombic cross sections. Quartz forms a major component of the rock, mainly as mosaic aggregates. Apatite also occurs as minor, anhedral grains birefringent in low greys.

In 378-27, 35, 36 clinopyroxene forms a respectable portion of the rock. The clinopyroxene is augite distinguished from diopside by $2V(+) = 50^{o}$ and larger extinction angles of $40-50^{o}$. In thin section 378-27 it is rimmed by an amphibole. The core shows the true pryoxene cleavage and the rim the amphibole cleavage. (Plate 3B).

The epidote gneiss has not been affected by the retrograde metamorphism as much as the other gneisses. There is less sericite developed.

Schists.

All the schists of the area are rich in quartz and feldspar, quite a few having either augens of quartz or quartz and feldspar.

Rock 378-4 is a grey quartzofeldspathic schist with a distinct banding or layering and a poor fissility parallel to the banding. The fissility is due to the parallel alignment of micaceous minerals. The layering is up to 0.5 cm. thick and is delineated by the segregation of the light and dark minerals. The layering is folded by a coarse crenulation in this particular specimen, but there is no axial plane development. The rock is essentially granoblastic with minor porphyroblasts of quartz and feldspar (both microcline and plagioclase). The rock has small patches of sericite scattered over it. The original biotite present is the high grade dark to light brown pleochroic type.

Rock 378-11 is a fine grained crenulated quartz schist with a granoblastic texture and minor, small, anhedral porphyroblasts of quartz.

The small crenulations have a wave length of 0.5 cm., and are imposed on a larger crenulation of several centimetre wavelength. The rock shows a marked mineral and crenulation lineation parallelling each other in the schistosity plane. The mica which delineates the crenulations in thin section is fine grained muscovite with minor biotite.

Rock 378-12 is a quartzofeldspathic crenulated schist with augen of plagioclase and quartz. These are crenulated. The plagioclase is sericitized and wrapped by the micaceous minerals muscovite and biotite. The quartz porphyroblasts are anhedral, elongate and either composed of quartz mosaics or strain banded crystals. As in 378-11, there is a fine crenulation imposed on the layering. The fine crenulation is outlined only by the micas; it does not affect the augen. Accessories are zircon and opaques.

Amphibolites and Pegmatites.

The amphibolites of the basement can be visually subdivided into two; a medium grained rock with a large proportion of feldspar, and a finer darker rock with lesser feldspar. 378-14 is an example of the first type and 378-25, 29 the second.

The amphibole is hornblende, pleochroic in blue green to yellow green, or in olive green to brown. In 378-14 the hornblende appears as elongate, anhedral to subhedral crystals with interstitial plagioclase, or as an equidimensional matrix with plagioclase, depending whether the section parallels or cuts across the schistosity plane. In 378-25,29 there is no difference. The amphibole in 378-14 often exhibits twinning. One such twinned crystal is of interest. It resembles a relict pyroxene twin replaced by amphibole. One half of the twin has an extinction angle of 40^o (i.e., a clinopyroxene?), while the other half has near parallel extinction. In 378-29 a carlsbad-albite twin in the plagioclase gave a composition of An 28-30. The quartz content varies from minor to 30% in 378-14. Both 378-25 and 29 have 10% quartz or less.

It occurs as a recrystallized aggregate and as inclusions in the hornblende. Minor epidote is present in 378-25, 29 as fine grained aggregates. It is not present in 378-14.

The visual subdivision made earlier can be extended to the mineralogy. The first (378-14) has a high percentage of quartz and plagioclase, remnant clinopyroxene twins, no epidote and is the coarser grained. The second (378-25, 29) is finer grained, has less feldspar and quartz, contains epidote and is obviously of a different generation. In both, the original igneous texture has been modified by metamorphism. The amphibolites, as with the pegmatites, show cross cutting relationship in the field.

The pegmatites show a mineral lineation on poorly developed schistosity planes. They are coarse grained rocks of microcline and quartz with minor plagioclase and muscovite. The feldspar shows sericitization with minor perthitic and antiperthitic textures.

Rock 378-20 is a very coarse bimineralic rock composed of quartz and tourmaline. The tourmaline is black and typically striated. It is fractured in thin section with quartz filling. These are visible in hand specimen.

Non Basement Rocks.

These are those rocks not associated with the Archaean at Yankalilla, but which occur either in the cover rocks adjacent to the inlier or are found within it.

The first is an arkosic sandstone (378-17) of rounded to angular, subspherical grains of maximum diameter 1 mm. The grains are detrital quartz, feldspar and minor quartzite in a fine grained, limonitic matrix. Some of the feldspar shows albite twinning. The other rock found adjacent to the inlier comes from the Proterozoic sequence to the northwest of the inlier as exposed in a quarry. It is a phyllite showing relict bedding with essentially a granoblastic texture of recrystallized quartz and feldspar, the majority of which has been heavily sericitized. The rock shows a heavy mineral lineation on the schistosity surface. Relict scour and fill structure gives younging relation - overturned in the field.

Finally, a rounded boulder was found protruding from, and obviously associated with, Permian sands within the boundaries of the basement. The rock (378-30) has large phenocrysts of quartz and feldspar up to 2 cm. diameter, in a fine matrix. Some of the phenocrysts are nearly spherical, but the majority are anhedral with rounded corners. Plagioclase forms a major constituent of the rock, both as phenocrysts and in the matrix. It shows carlsbad-albite twinning (An 20-30), undulose extinction, rare zoning and sericitization in parts. The quartz phenocrysts show slight undulose extinction in the embayed, anhedral crystal. Quartz is the other main component of the matrix. Biotite appears as larger anhedral plates and as smaller subhedral laths in the matrix. It is the dark brown to light brown biotite characteristic of the Archaean high grade rocks. The matrix is lightly sericitized.

Stratigraphy.

It is not possible to talk of the stratigraphy of the basement as such, due to the inherent nature of the rocks which represent end processes of high grade metamorphism, partial melting, metamorphic differentiation, deformation by shearing and thrusting to produce mylonitization (on the north-western edge of the inlier). Hence only general lithologies have been examined.

Proceeding south-east from the north-west boundary, (at the NW boundary?) the number of schist beds decreases relative to the gneisses. Here the geology is an alternating series of schists and gneisses striking north-east to south-west, and dipping at 30 to 50^{o} south-east. The gneisses become more closely related. Local spots of migmatitic gneiss occur with massive granitic textured gneiss outcropping in intricate association with finely layered gneisses. This is in keeping with approaching a region of higher temperature and pressure in the core of the Proterozoic anticline giving rise to partial melting and differentiation.

It is not certain whether the schists represent the end product of shearing as proposed by Spry (1951) or not, although there is evidence of such a process taking place. This will be discussed later.

Another complication in establishing a sequence, is the proposed isoclinal folding in the basement prior to sedimentation of the Proterozoic. This would cause repetition of lithologies.

To the south-west a series of lithologies outcrop on the hill just east of the Yankalilla cemetery. A great proportion of the outcrop is the epidote gneiss which occurs in three bands interlayered with schists and quartz gneisses. Injected along one contact of the epidote gneiss with the underlying schist, is a pegmatite that soon dies out. The lower schist beds are more augen rich than the ones above, indicating a closer association with a shear zone. To the east is a large quartz gneiss which cuts across the lithological layering developed elsewhere.

No chronological sequence of beds can be discerned without a much more detailed study. It can only be stated that in association with the cover rocks, the sequence in the north-west is overturned and the core is to the south-east. It isprobably represented by the gneissic rich associations towards the south-east of the area.

STRUCTURE.

The gneissosity of the gneissic rocks defined by the parallellism of the micaceous mineral was found to be parallel and equivalent to the banding or layering of the gneisses. Hence only the gneissic layering or banding will be referred to here, it being equivalent to the gneissosity.

The schistosity is the plane of alignment of micas giving rise to a fissility. Only one schistosity or foliation is recognized in the area.

The readings taken were of the foliation and the gneissic layering. Generally these were found to be parallel. In only onecase was it not so, but the layering in this case is thought to be original layering in a nose of a fold cutting across the regional foliation.

The regional trend of the foliation and gneissic layering over the whole area is north-east to south-west and dipping 30 to 60° throughout the area generally. There are slight variations to this, but these are only local effects.

In the south-west corner of the area, just east of the Yankalilla cemetery, is a hill around and over which the epidote gneiss outcrops. The lower schists, which outcrop near the base of the hill, have a texture that looks as if they have resulted from the shearing and retrogradation of a gneiss. They contain fractured augen wrapped by micaceous minerals.

The orientation of the gneissic layering and foliation of the schists varies around the hill. On the southern side it strikes to the north-west and dips north-east. Going northwards around the hill the trend swings north and finally north-east and dips south-east, which is the orientation exhibited regionally over the rest of the area. This trend is accentuated on the map by the outcrop pattern due to the topography.

In the schists which contain the augen is an example of three generations of small mesoscopic folds superimposed on each other. The plunge of their fold axes varies from north-north-east to east and is shallow (less than 20^{o}) in all three cases. The last is a gentle warping; the first two are tight folds.

Within the epidote gneiss several interesting structures occur. On the south-west face of the hill is a mesoscopic fold. A layering is being folded with the axis plunging 40^{o} towards 032. A broken quartz band is also folded around the structure. The quartz layer is irregularly and tightly crenulated with the axial plane of the crenulation parallelling the axial plane of the mesoscopic structure. In fact, the quartz layer consists of a series of individual elongated blebs parallel to the axial plane structure, but still defining a broad band.

Further around the hill to the north and south-east, a tight isoclinal folding is found in outcrop in the epidote gneiss. The scale is of the order of 50 cm. in length (amplitude) and 15 cm. wide at the crests (30 cm. wave length). These are defined by quartz and feldspar.

No axial plane structure is developed, but the axial plane coincides with the foliation and banding of the immediately adjacent rocks. The south-east example is the better developed, but the northern one is more interesting. On top of this small scale isoclinal folding are feldspar-rich aggregates cutting across it in a migmatitic sense; as if the rock has undergone partial melting. (Plates 4A, 4B, 5A).

The main lineation is a coarse mineral lineation plunging to the south-east. Throughout the basement it has a constant orientation within a small degree of scatter. A crenulation lineation is sometimes developed and usually parallels the mineral lineation.

In the north-west area of the map the outcrop pattern is due to the superposition of a topography of deeply dissected hills on north-east striking beds, dipping 30 to 50^{o} to the south-east producing the wavy outcrop pattern. Here the beds can be traced over a reasonable

A.

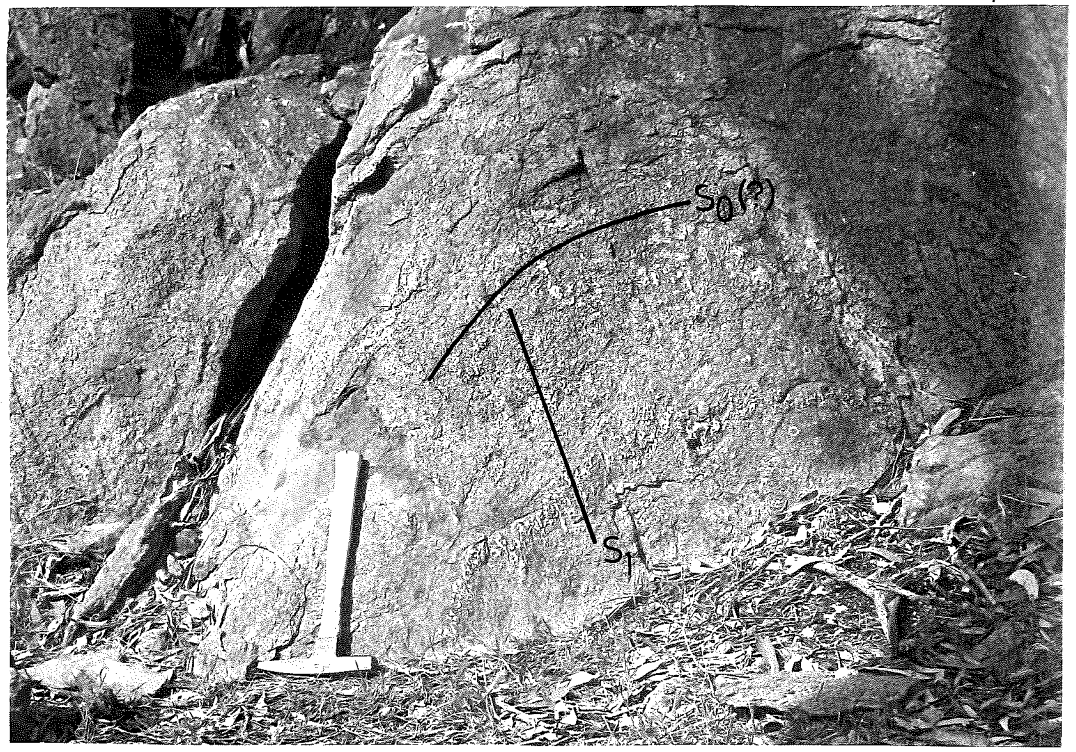
Isoclinal Closure of F_1 phase of folding in the epidote gneiss. Note developed axial plane structure S_1 relict bedding (?) S_o.

B.

Detail of quartz band associated with fold showing pods of quartz aligned to S_1 with the band defining S_o.

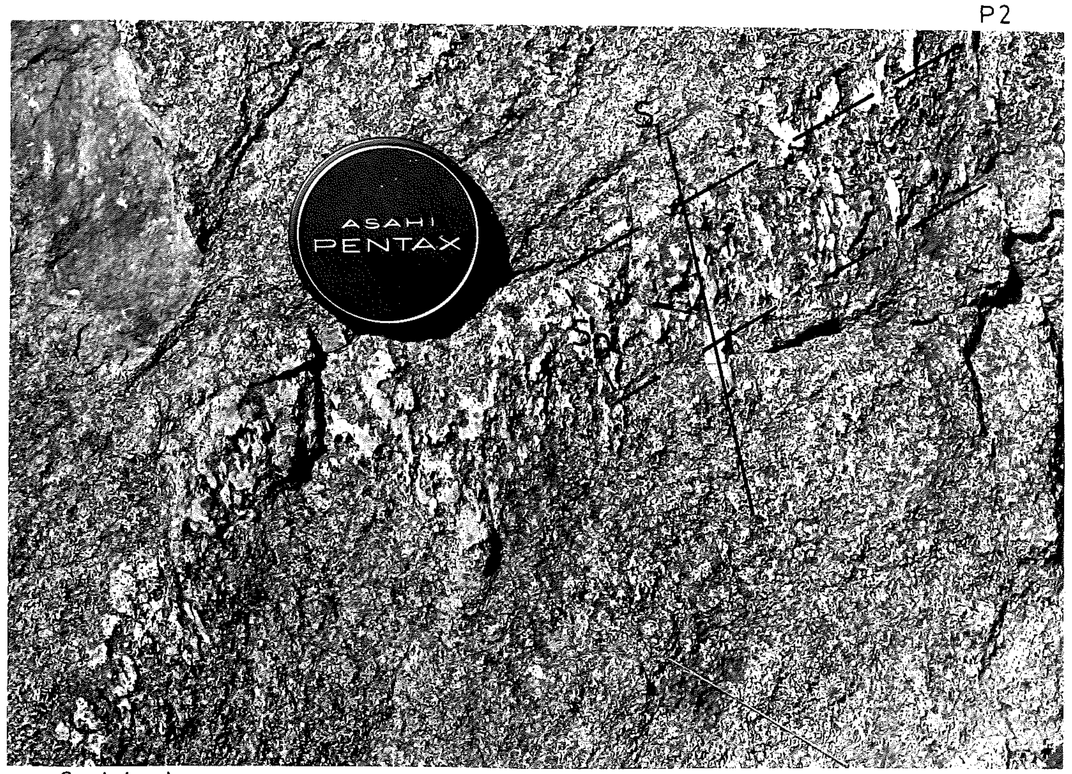
PLATE 4.

P1 A



Scale.(cm)
0 15 30.

P2 B



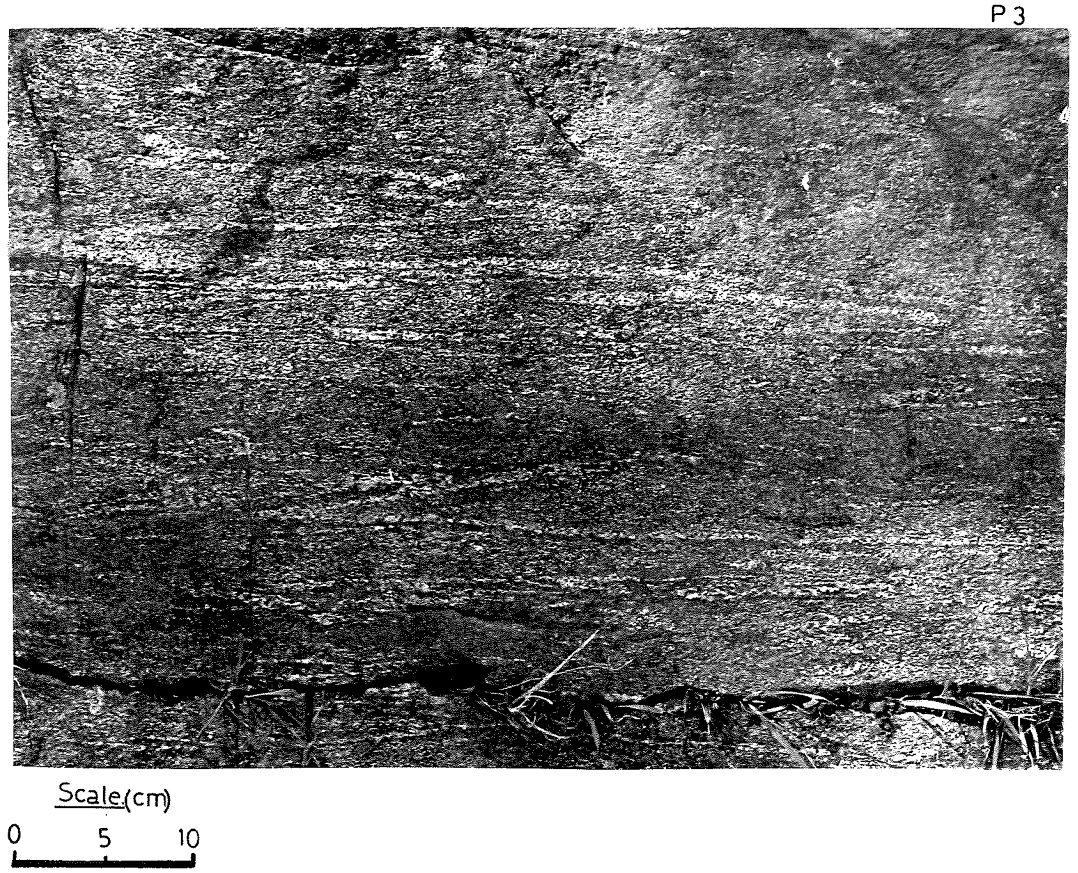
Scale(cm)
0 2.5 5

PLATE 5.

A.

Small scale isoclinal folding in epidote gneiss parallel to neighbouring layering. South of 4A.

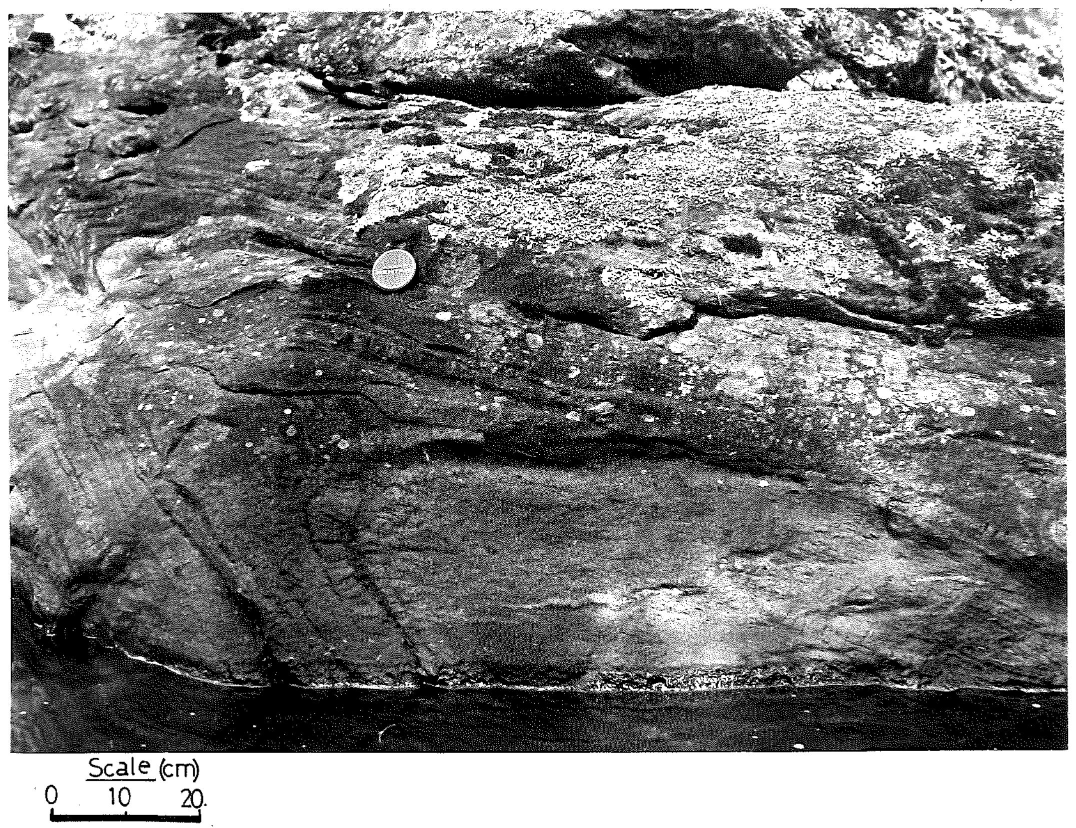
P 3 A.



B.

Typical F_2 fold, folding S_1 and S_0 (parallel). Characteristic is one steeply dipping to overturned limb; in this case overturned to the east.

P 4 B.



A.

Rodding of quartz with coarse mineral lineation.

B.

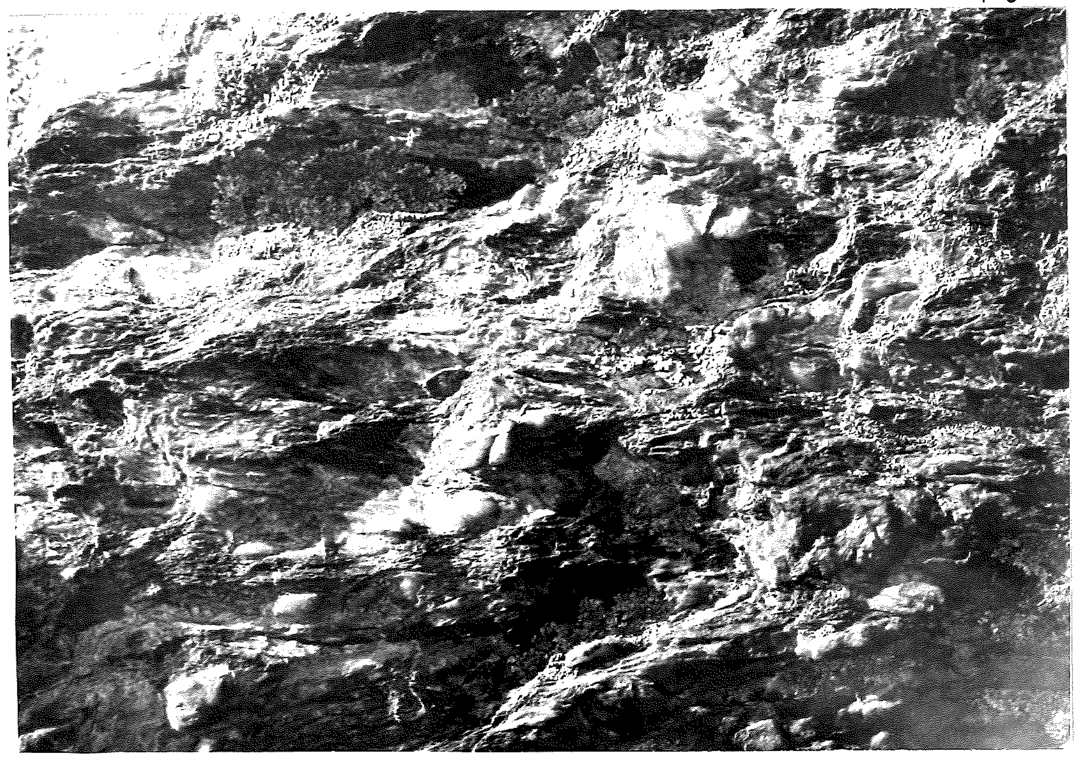
Typical schist with augen of quartz. Marked mineral lineation parallelling a crenulation lineation.

PLATE 6.

A.

Scale (cm)
0 5 10

B.



Scale (cm)
0 5

distance, slightly less than a kilometre.

Mesoscopic folds with various orientations are recognized in this area. These fold the layering and foliation. No foliation was found developed in the gneissic layers defining the folds, but a foliation was recognized in the schists at a low angle to the boundaries of the schists associated with these folds. Elsewhere a coarse, almost isoclinal, crenulation is developed on the foliation surface. The crenulation lineation, which parallels the mineral lineation as elsewhere in the basement, plunges to the south-east. The mineral lineation is so well developed in parts that rods of quartz are apparent with the same orientation as the lineations. (Plates 5B, 6A).

To the north of the road on the eastern side of the map, a series of gneisses and schists pass into a highly crenulated gneiss with associated banded and massive gneiss. The transition zone shows prominent small crenulations like small isoclinal folding plunging to the south. There is one tight mesoscopic fold plunging south-west in this area. There is a concentration of schists within thiszone which tends north-south. (Plate 6B).

On the western side of the map, north of the road are several amphibolite dykes. Mesoscopic folds in this area have various orientations of plunging, from south-west to south-east. Here again they fold the gneissic layering and the foliation. A schist with quartz augen is crenulated in this area. The crenulations plunge south to south-east. The amphibolites are cross cutting and folded mesoscopically. They show the coarse mineral lineation and have developed a foliation which parallels that locally and regionally. There is evidence of a minor fault following a creek as the amphibolite and epidote gneiss is cut off. The fault trends north-south.

The central area of the map is a complex of finely banded gneisses and interlayed schists, where outcropping. The schists show the common augen association. Plotting of the gneissic layering data on a stereo net, delineates a fold or series of mesoscopic folds plunging to the south-east generally. Lack of outcrop makes mapping difficult. Mesoscopic folds recognized in the field show a scatter of orientations from south-east to south-west. Amphibolite dykes in the area are again cross cutting and show the regional lineation and foliation.

Fig. 4

Folding.

Three phases of folding are recognized in the area. Two Archaean episodes before the deposition of the Proterozoic Adelaide Group; the third is post-Proterozoic or early Palaeozoic and gives the regional structure evident in the cover.

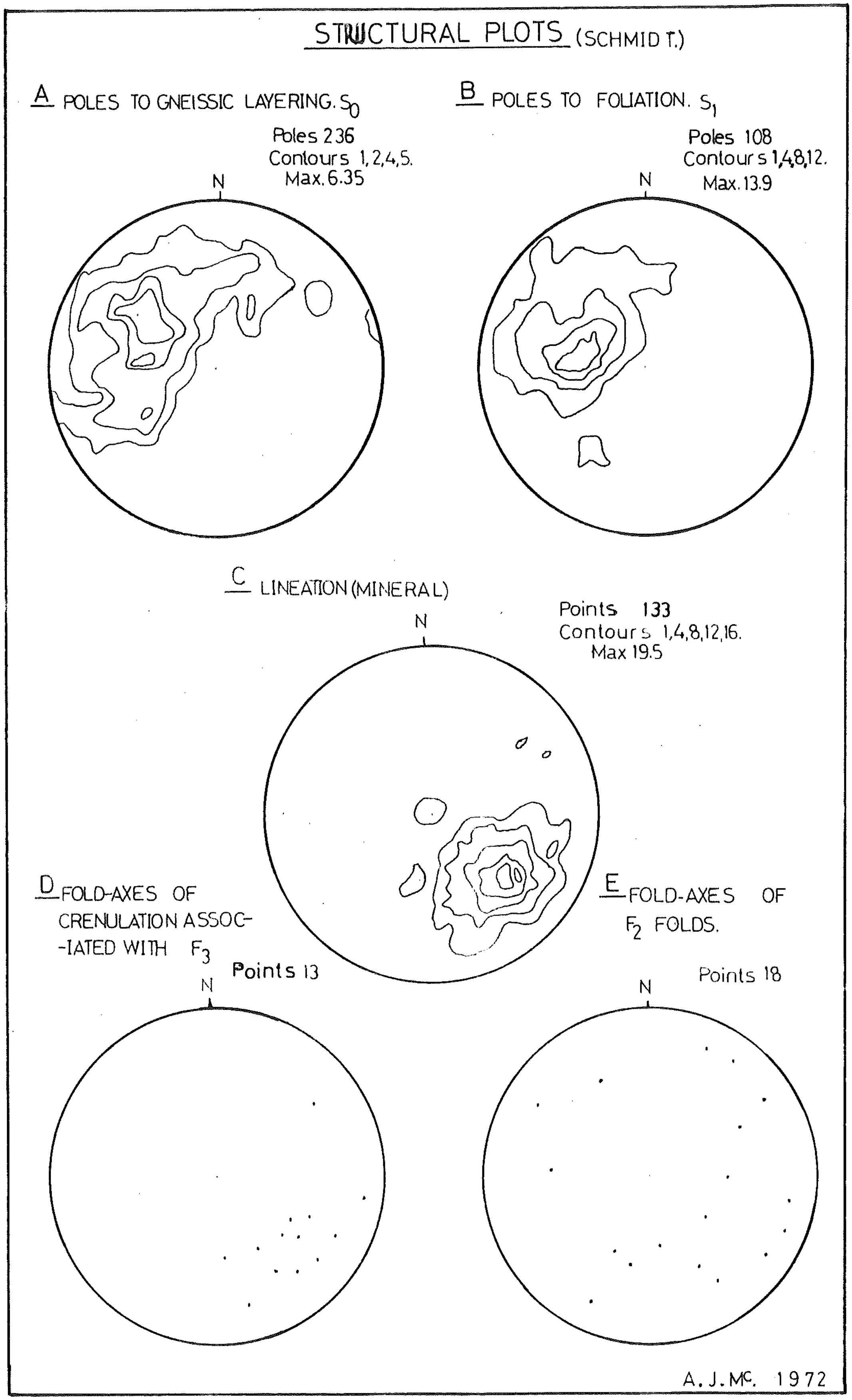
Nomenclature used will be the symbols F_x, S_x, L_x where S_x is the axial plane surface to the F_x structure. L_x is the lineation (mineral or crenulation) produced during the F_x folding.

F_1 folding is recognized as the isoclinal folding (parallel limbs) in the Archaean. The axial plane structure S_1 (foliation) was produced during this phase and because of the geometry of the folds parallels the limbs so that S_1 is parallel to the gneissic layering assumed to be S_0 accentuated by metamorphic differentiation. S_0 is the original bedding of the sedimentary pile. This parallelism is shown in Fig. 2A and 2B in which the poles to gneissic layering and poles to foliation overlie each other. Is the foliation in Fig. 4B S_1 or the later development?

Only one closure has been recognized. This is east of Yankalilla cemetery. It has already been described (page 15). Here S_1, axial plane to the folded S_0 is parallel to the regional foliation. Other evidence of isoclinal folding occurs north and south of this in the epidote gneiss. This is the isoclinal folding described before. No L_1 is recognized.

F_2 folding is manifested by the mesoscopic folds varying from one to fifty metres across. The F_2 structures fold S_0 and S_1 surfaces. No S_2 is developed. These structures are not recognized in the cover rocks. Their fold axes

FIG. 2.


STRUCTURAL PLOTS (SCHMID T.)
A POLES TO GNEISSIC LAYERING. S_0
Poles 236
Contours 1, 2, 4, 5.
Max. 6.35
N
B POLES TO FOLIATION. S_1
Poles 108
Contours 1, 4, 8, 12.
Max. 13.9
N
C LINEATION (MINERAL)
Points 133
Contours 1, 4, 8, 12, 16.
Max 19.5
N
D FOLD-AXES OF CRENULATION ASSOC-IATED WITH F_3
Points 13
N
E FOLD-AXES OF F_2 FOLDS.
Points 18
N
A. J. Mc. 1972

have an apparently random distribution (Fig. 2C) caused by the later F_3 folding. There is not enough data to interpret properly.

Finally the F_3 structure which folds the Proterozoic and Cambrian beds has been radiometrically dated as late Cambrian (White, Compston, Kleeman, 1967). This is referred to as the Delamerian Orogeny (Handbook of S.A. Geology). The structure developed was a regional anticline overturned to the west with the Proterozoic dipping eastwards under the basement. The hinge line and limbs plunge and dip south-eastwards. The main lineation of the basement is L_3 associated with this structure and plunges south-east. L_3 is both a mineral and a crenulation lineation (Fig. 2C and 2D). The crenulation developed folds S_1 and S_0. The major foliation of the area is S_3 associated with F_3 and parallels S_1 and S_0.

No other folding is recognized in the area. Offler and Fleming (1968) quote F_3 as F_1 and recognize folds up to F_4 in the cover. These are not recognized in the basement.

Faulting.

Other than one minor fault, there are no faults immediately recognizable in the field due to poor outcrop.

However, regionally two may be delineated. The first is actually a shear zone parallelling the overturned limb of the anticline, i.e., on the north-west boundary of the Archaean. Approaching this zone, the sheared character of the Archaean rocks increases. This, together with the erosional feature, i.e., valley and basement scarp along this boundary, indicates a zone of weakness and shearing. It is not marked on the geological map due to the uncertainty of its position. It is marked on the tectonic map.

In the south-west of the area a fault is inferred orientated north-west to south-east to explain the marked difference in character of the rocks on either side of this zone - the epidote gneiss and quartz gneiss on one side and the layered gneisses and schists on the other.

METAMORPHISM AND PETROLOGY.

The rocks of the Archaean inlier, now retrograded to greenschist facies, have been at least of upper amphibolite facies grade.

Winkler (1967) states that the grossularite-andradite garnet indicates that the metamorphic grade has reached at least lower amphibolite facies. Conditions of its formation have been studied within the range pressure 2 to 4 kilobars and at temperatures greater than 600°C. The reaction is as follows:

Epidote + Quartz $\rightleftharpoons$ Grossularite/Andradite + Anorthite + water. (1)

With an increase in pressure (P) the temperature (T) increases rapidly to 700°C at 4-5 to 7 kilobars. The anorthite is taken up in the plagioclase solid solution series. However, the formation of the garnet at lower T has yet to be examined.

Many of the rocks contain perthites and antiperthites. The microcline commonly the fine veined perthite. Recent workers (Hubbard 1965, Carstens, 1966, Vogel et al, 1968) consider most antiperthites to be of exsolution origin, although they recognize replacement can occur. The perthite, antiperthite appear to be exsolution features. If this is correct, then the feldspar must havereached temperatures above the solvus before cooling, i.e., greater than 680°C. (Deer, Howie, Zussman, 1967) which implies at least upper amphibolite facies.

Under these conditions (upper amphibolite facies) muscovite is unstable and in the rocks of the area under consideration, is rarely recognized. The presence of muscovite is not characteristic, but its disappearance is (Winkler, 1967). In the course of metamorphism at very high temperatures, muscovite is unstable irrespective of different pressures, i.e., at temperatures of 650° to 700°C.

1 Muscovite + 1 Quartz $\rightleftharpoons$ 1 Orthoclase (K feldspar) + 1 Sillimanite + Water (2)

also

1 Muscovite + 1 Biotite + 3 Quartz $\rightleftharpoons$ Almandine + 2 K feldspar + 2 water (3)

However, no almandine is recognized in the rock, although it is a characteristic mineral of this grade. This is explained by referring to Fig. 3A. (AKF diagram). The bulk chemical composition being in the field, potassium feldspar, sillimanite, biotite field would gi ve the corresponding mineral assemblage. This mineral assemblage is one that is characteristic of the sillimanite, almandine, orthoclase subfacies for petitic and quartzofeldspathic assemblage (Turner and Verhoogen, 1960).

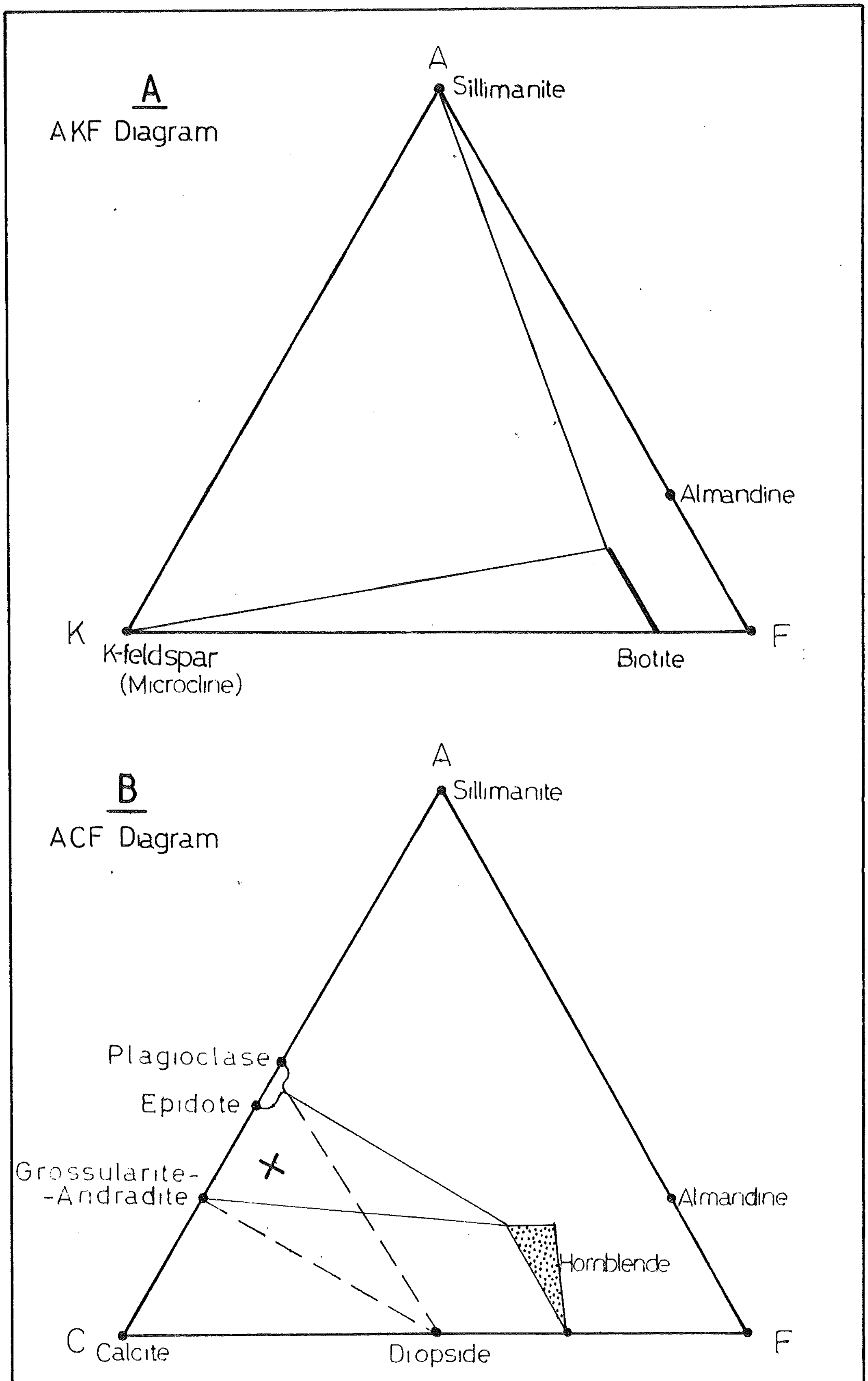
At these temperatures (650-700^{o}C), with a high water pressure (Pw) it is possible to have partial melting, recognized by local migmatitic characters. In fact water release by (1) and (2) could raise the Pw enough to melt quartzofeldspathic gneisses partially, even when there is only a small amount of water present, depending on the mineralogical composition of the feldspar in the gneisses.

Reaction (2) is promoted by temperature increases, and reversed by decreases. Muscovite flakes are rarely recognized. Most of the muscovite occurs as sericite, a retrograde product. But sillimanite appears as good euhedral crystals apparently stable. There is no close association of sillimanite and the retrograde product sericite, as exhibited in the area being studied by S.P. Wicks. There is no evidence of relict kyonite or andalusite. Therefore, sillimanite was probably not formed by an increase in temperature and/or pressure from its polymorphs.

The calc-silicate mineral assemblage recognized in the epidote gneiss is grossularite-andradite, epidote with hornblende. Hornblende (amphibole) could easily be produced by the breakdown of the unstable clinopyroxene diopside. A rock with the chemical composition of the cross in Fig. 3B could equally well be in the epidote grossularite-andradite, hornblende field or the field containing diopside instead of hornblende. This does not necessitate a change of composition.

The area has been retrograded down to the present greenschist facies, as evidenced by chlorites, muscovite associations. In fact reaction (1) could be regarded as a retrograde process from high meta-

FIG. 3.



A.J.Mc. 1972 after Turner & Verhoogen 1960.

morphic epidote. still above the greenschist-amphibolite boundary.

The plagioclase shows differential alteration in which the microcline is less altered than the plagioclase. In fact the microcline may show no alteration while the calcic plagioclase is highly altered. There are two types of retrogradation of plagioclase. The first, sericitization; the second, formation of fine grains of epidote. These two processes appear to bear no relation to each other. Lime plagioclase is very unstable in the presence of excess calcite. The two react to give epidote or grossularite-andradite. This relation can be seen from the relative position of epidote and the garnet on the calcite-lime feldspar join in Fig. 3B.

An important retrograde product is that physically produced, i.e., in shear zones. Spry (1951) claims that the schists are retrograde products of a gneiss produced by step-by-step development under a shearing action. The augen textures in the schists indicate halfway progress. Other textures show steps in the process of mylonitization, i.e., the schists are a trend "towards a fine grained more schistose rock with no high grade minerals." (Spry, 1951). The proposal is an attractive one to apply to the area. It fits in so well with the observed textures.

Talbot (1963) recognizes two greenschist facies retrograde events in his study of the Houghton inlier. The evidence for the first is in the boulders of the basal conglomerate. There is no evidence within the basement. It preceded the deposition of the Torrens Group and could possibly be the same time as the F_2 folding discussed above. The second corresponds to the Delamerian Orogeny.

GEOPHYSICS.

With the kind permission of Noranda Australia Ltd., radiometric data which covered the Yankalilla inlier was obtained from the South Australian Mines Department.

The data was in the form of isoradiometric maps. It was hoped that a study of these would help in the interpretation of the geological trends in the area. The data covered an area larger than that under consideration. The area extended to the north-east to include a greater proportion of the Archaean inlier (Fig. 1). The survey was flown by Geophoto Services Incorporated. The data was recorded in digital form on magnetic tape and processed in the United States.

A topographical contour map was enlarged from the Yankalilla one mile geological sheet, to a scale of 1 = 24,000.

Anomalies of interest on the Bi^{214} isorad map coincided with quartz scree possibly of pegmatitic origin and pegmatitic scree and outcrop. It was concluded that the radiometric association in the pegmatites caused the phenomena.

A feature that was interesting was the lineation (north-east to south-west) in the basement where the Bi^{214} reduced sum was greater than 100 counts per second. This lineation parallels roughly the foliation and gneissic layering of the Archaean rocks. However, this feature was found to parallel the flight lines of the survey and was considered to be a function of this, with nothing to do with the geology. These reduced sums occur almost exclusively within the basement. – Significance ?

It was found that the Archaean generally could be differentiated from the isorad contour maps. In both the Bi^{214}/K^{40} and the Bi^{214}/Tl^{208} were generally areas of low values, indicating low Bi^{214} relatively. However, the Tertiary laterite expression causes high values in both the cover and the Archaean rocks on the Bi^{214}/K^{40} map. Comparing with the Bi^{214}/Tl^{208} map in which this does not show, it was concluded these high values were due to greater K^{40} concentration in the laterite than in the surrounding rocks relatively. In general in the non-basement areas, the Bi^{214}/Tl^{208} isorad map shows higher values.

These features served to delineate the basement areas. No structural assistance was obtained from the maps, other than a very general elongation of contour lines on the Bi^{214} isorad map towards the south-east, which may reflect some sort of radioactive mineral distribution by the F_3 fold. The study on the whole was disappointing in the lack of application of the data to the geology, for any greater detail than delineation of basement areas and laterite expressions.

Why not show some of the maps, despite their disappointing value.

CONCLUSIONS.

Three phases of folding are recognized in the Archaean inlier. The first two, pre-Proterozoic and the third, lower Palaeozoic. The first, isoclinal folding, was accompanied by metamorphism to at least the upper amphibolite facies. The other two were of retrograde nature, the final grade being recognized in the basal conglomerate by Talbot (1963) in the Houghton region. The second is recognized in the Yankalilla inlier by intense sericitization, saussuritization and shearing. The shearing is associated with the F_3 fold, the overturned anticline with the shear plane on the overturned western limb. The schists associated with the gneisses and augen gneisses were formed by retrograde shearing (Spry, 1951), the augen gneisses being a midway step.

The amphibolites are of igneous origin and were emplaced between the F_1 and F_2 folding phases. The pegmatites were pre-F_3, but no evidence is known to place them either pre- or post-F_2. They both have cross cutting relationships.

A Tertiary (Handbook S.A. Geology) lateritic expression is recognized in the basement resulting from earlier uplift and exposure. Before this Tertiary expression there is a stratigraphical break back to the Permian and then another to the upper Cambrian. This uplift represents the last recognized orogenic phase.

Pegmatites are post F_1 ?

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A P P E N D I X I.

THIN SECTION DESCRIPTIONS.

The terminology anhedral - subhedral - euhedral has been used throughout to describe the form (or lack thereof) of the constituent minerals.

378-1 : Quartz gneiss.

Macro : Massive quartz gneiss with a pronounced coarse mineral lineation on the schistosity surface. Quartz forms at least 95% of the hand specimen, with minor muscovite parallel to the schistosity surface and minor dark minerals. The quartz is obviously strained, even in hand specimen.

Micro : Porphyritic texture.

95% Quartz: The porphyroblasts (up to 5 mm) are strain banded with undulose extinction, the banding having a general preferred orientation. Porphyroblasts are anhedral, elongate parallel to schistosity, boundaries formed by a mortar texture of recrystallized fine graned quartz. The matrix is a mosaic of polygonal recrystallized quartz, unstrained and granoblastic. Grain size averages 0.1 mm, with many triple points.

3% Muscovite: Anhedral. Grain size averaging 0.5 mm. Aligned parallel to schistosity. Occurs also as sericite.

Accessories :

Biotite. Yellow brown pleochroism. Euhedral. Fine grained.

Tourmaline. Uniaxial (-). Maximum absorption when elongation of crystal is perpendicular to vibration plane of polarizer.

Zircon. Uniaxial (+). High relief. Many rings in figure.

Opaques. Anhedral. Less than 1 mm.

378-2, 3 : Epidote gneiss.

Macro : Medium grained gneiss with green epidote grains, but no apparent mica. Mineral segregation of epidote, pink feldspar and dark green amphibole gives a discontinuous layering to the rock.

Micro : Porphyroblastic in amphibole, feldspar and epidote in an essentially quartz matrix.

40% Epidote: Sub to anhedral. 1 mm crystals and smaller scattered aggregates. Parallel extinction $2V(-) = 65^{\circ}$.

(Composition?)

10% Hornblende: Anhedral to 3 mm. Cross hatched. Slight sericitization.

Plagioclase: Minor. Anhedral. Albite twinning. Sericitized.

20% Quartz: Mosaic polygonal aggregates elongated parallel to schistosity. Unstrained with 120° triple points. Many of grain boundaries are sutured. Grain size averages 0.2 mm.

Accessories :

Sphene. Euhedral, brown, high relief with rhombic cross sections.

Apatite. Anhedral. Low birefringent greys.

378-4 : Quartzofeldspathic schist.

Macro : Fine grained with minor mica on the schistosity surface parallelling the layering. The layering is up to 0.5 cm thick and is delineated by the segregation of light and dark minerals. It is folded in this particular specimen, but there is no apparent development of an axial plane structure. Predominantly quartz with minor biotite, muscovite and feldspar.

Micro : Essentially granoblastic with minor porphyroblasts of quartz and feldspar.

90% Quartz: Fine grained (0.1 mm) mosaic with polygonal and sutured grain boundaries. Triple points common. The porphyroblastic quartz is anhedral with undulose extinction. The porphyroblasts are surrounded by a mortar texture of recrystallized grains.

5% Feldspar: Microcline perthite, anhedral and minor (0.5 mm).

Plagioclase. Sericitized, anhedral with albite twinning.

5% Mica: Biotite. Pleochroic in green-brown. Sub to euhedral (0.2 mm). Minor.

Muscovite. Sub to euhedral (0.2 mm). Aligned with schistosity.

Accessories:

Opaques. Minor square sections.

378-5 : Coarse grained quartzofeldspathic gneiss.

Macro : Aggregates of K feldspar with smaller quartz and minor biotite, muscovite and opaques. Much of feldspar shows inclusions of quartz.

Micro : Porphyroblastic in feldspar and quartz.

45% Microcline: Cloudy, cross hatched, anhedral, fractured grains (6 mm). Microcline perthite with plagioclase as stringers and perthite with plagioclase as blebs are present.

5% Plagioclase: Minor. Sericitized. Anhedral to 3 mm. Crystals with Albite twinning often have fractured and kinked twin lamellae.

35% Quartz: Large (up to 6 mm), elongate porphyroblasts with undulose extinction and strain banding. Some mosaics of recrystallized unstrained quartz with ploygonal and sutured boundaries. Occasional triple points. Also as mosaic mortar texture bounding porphyroblasts.

10% Sericite: Most of feldspar show sericitization to some extent. Also as elongate aggregates.

2% Biotite: Fine grained (0.1 mm). Euhedral. Red brown and green brown plechroism.

Accessories :

Opaques. 5%. Anhedral. Fractured by veins of quartz mosaic and sericite.

Tourmaline. Minor. Anhedral. Uniaxial (-). Parallel extinction. Characteristic maximum absorption orientation.

378-6 : Medium grained quartzofeldspathic schist.

Macro : Aggregates of intergrown quartz and feldspar (crystals not well defined) with mica aligned parallel to the schistosity. No prominent layering developed. On the foliation surface is exhibited a penetrative mineral lineation.

Micro : Porphyroblastic with much secondary biotite and muscovite.

60% <u>Quartz</u>: Porphyroblasts of quartz up to 4 mm, anhedral with strain bands of undulose extinction. Fractured. Veins filled by fine grained quartz mosaic and sericite. Rest of quartz occurs as aggregates of fine grained quartz with polygonal and sutured boundaries and some triple points.

20% <u>Plagioclase</u>: Albite and pericline twinning. Anhedral, much sericitized.

15% <u>Muscovite</u>: As sericite overgrowing most of the slide. Secondary.

5% <u>Biotite</u>: Red brown pleochroism. Secondary.

Accessories :

Opaques. Anhedral. Occasional square cross sections.

378-7 : Augen gneiss.

Macro : Quartz rich gneiss with large quartz "augens" wrapped by mica, quartz, feldspar layers. Augens up to 2 cm long. Mineral lineation is apparent on the schistosity plane which parallels the layering.

Micro : Porphyroblastic in quartz with muscovite and biotite alteration products and mosaics of recrystallized quartz.

80% <u>Quartz</u>: Large porphyroblasts all sizes up to 2 cm with undulose extinction and some strain banding. Boundaries of porphyroblasts seriate sutured with narrow borders of fine grained quartz mosaics. Matrix of mosaic quartz with polygonal and sutured boundaries.

5% <u>Plagioclase</u>: Anhedral. Heavily sericitized.

10% <u>Sericite</u>; Long aggregates parallelling schistosity.

5% <u>Biotite</u>: Pleochroism is green brown to red brown.

Accessories :

Opaques. Generally anhedral, some square and rhombic cross sections.

Magnetite. Minor.

Zircon. Fine grained (0.1 mm) prismatic crystals, high relief, generally square cross section. Often with rounded centres. Rims are zoned outwards. Some rounded anhedral crystals. Uniaxial (+).

378-8 : Medium grained quartzofeldspathic schist.

Macro : Layering is delineated by elongate pods of quartz and feldspar wrapped by mica rich layers. Layering parallels foliation surface which exhibits a fine mineral lineation. Pods are up to 2 cm in length and 0.5 cm in width.

Mciro : Elongate porphyroblasts of quartz and feldspar wrapped by mica in a fine grained quartz mosaic. The whole being sericitized.

50% Quartz: Large (6 mm) strained porphyroblasts (undulose extinction). Fine grained quartz mosaic ground mass.

5% Biotite: Red brown pleochroism.

35% Muscovite: Fine grained aggregates parallel to schistosity. Sericite.

10% Feldspar: Anhedral, sericitized perthite and plagioclase.

Accessories :

Opaques. Anhedral. Some square cross sections.

Limonite. Anhedral, red.

Tourmaline. Minor, anhedral (0.1 mm).

Zircon. High relief. Equant. Euhedral to anhedral (0.1 mm).

378-9 : Medium grained leucocratic gneiss.

Macro : Rough layering parallels schistosity. Layering is due to elongation of feldspar and alignment of the micas. A coarse mineral lineation is present on the schistosity plane. Some of the feldspar shows quartz inclusions.

Micro : Porphyroblastic with intergrowing feldspar and quartz with sericite bands parallelling schistosity.

; the [illegible] for host + included plag.

20% Quartz: Elongate porphyroblasts parallelling foliation. Euhedral, with undulose extinction. Fine grained mosaic. Some triple points.

5% Microcline: Anhedral, cross hatched, perthitic with bulbous texture.

25% Perthite: Microcline perthite. Textures of perthite range from stringers to blebs to bulbous variety. Host crystal is anhedral.

30% Plagioclase: Subhedral aggregates, some with carlsbad albite twins giving compositions. An 30-35. Sericitized.

5% Biotite: Red brown pleochroism.

20% Muscovite: As secondary sericite aggregates, parallelling foliation.

Accessories :

Zircon. High relief, euhedral to subhedral. Fine grained (0.1 mm).

378-10 : Fine grained mica gneiss.

Macro : Pronounced mineral lineation on schistosity surface which is parallel to a suggestion of layering produced by mineral differentiation. Main minerals feldspar, quartz and mica.

Micro : Porphyroblastic in feldspar and minor quartz in a quartz mosaic. Heavily sericitized.

40% Quartz: Anhedral porphyroblasts up to 1 mm. Undulose extinction. Recrystallized fine grained quartz mosaics, polygonal and sutured grain boundaries.

5% Biotite: Red brown pleochroism. Euhedral. Fine grained (0.1 mm).

10% Muscovite: as sericite and muscovite stringers.

45% Plagioclase: Anhedral. 3 mm. Heavily sericitized in patches. Some albite twinning with dislocation of twin lamellae.

378-11 : Fine grained crenulated quartz schist.

Macro : Axes of the crenulations are parallel to the mineral lineation in the schistosity plane. A few prophyroblasts of quartz are apparent, surrounded by green mica.

Micro : Porphyroblastic in quartz.

45% Muscovite: Fine grained. Crenulated with a faint development of an axial plane structure. Much appears to be secondary.

5% Biotite: Red brown pleochroism.

50% Quartz: A few porphyroblasts 0.5 mm. Anhedral. Mainly as a fine grained polygonal mosaic with straight and sutured grain boundaries. Some triple points.

Accessories :

Opaques. Minor. Rhombic section. (Magnetite?)

378-12 : Quartzofeldspathic Schist.

Macro : Medium to coarse grained quartzofeldspathic schist with layers of leucratic and mafic minerals. Crenulations up to 2 cm wavelength. Assymmetric.

Micro : Porphyroblastic texture.

60% Quartz: Anhedral strained porphyroblasts and aggregates of fine quartz. Mosaic ground mass. Unstrained.

25% Muscovite: Fine grained. Crenulated. Secondary. Recrystallization. Start of axial plane structure in hinge zones of crenulations.

5% Biotite: Brown pleochroism.

10% Plagioclase: Minor. Albite twinning. Sericitized. Anhedral.

Accessories :

Opaques. Magnetite. Minor.

Zircon. Minor.

378-13 : Amphibolite.

Macro : Slightly foliated rock with green amphibole and white feldspar, with amineral lineation of the amphiboles. In section cut parallel to foliation the amphibole forms elongate grains with interstitial fledspar and quartz.

Micro :

60% Hornblende: Pleochroic in blue-green to yellow-green and green to brown. Very few cross sections. Lengths low elongate grains. Extinction angle maximum of 22°. Large 2V(-). Other sections have parallel extinction.

25% Quartz: Recrystallized fine grain mosaic.

10% Feldspar: Plagioclase. Heavily sericitized. Anhedral.

5% Biotite: Yellow brown pleochroism. Some basal sections.

Accessories :

Opaques. Minor.

378-14 : Amphibolite.

Macro : See 378-13.

In section cut across the foliation plane the feldspar and amphibole form equigranular texture.

Micro :

60% Hornblende: Anedral to subhedral (2 mm). Some twinned. One in particular has a pyroxene twin, with hornblende replacing the pyroxene. One half of the twin has an extinction angle of 40°.

30% Quartz: Recrystallized mosaic matrix.

5% Plagioclase: Heavily sericitized.

5% Sericite:

Accessories :

Opaques. Minor. Magnetite.

Zircon. Minor. Fine grained.

Biotite. Minor. Yellow basal section.

378-15 : Medium grained pink feldspar gneiss.

Macro : Porphyroblasts of feldspar elongated parallel to a very poor layering with quartz and mica (muscovite).

Micro :

40% Microcline: Anhedral (2 mm). Carlsbad twinning with cross hatching. Sericitized with occasional rounded quartz inclusions.

50% Quartz: Few strained porphyroblasts (1 mm). Mostly as unstrained mosaic matrix.

8% Muscovite: Generally fine grained, parallelling foliation.

2% Biotite: Red brown to yellow brown pleochroism.

Accessories :

Opaques. Minor. Rhombic cross sections. Others anhedral.

Zircon. Minor (0.1 mm). Rounded. Zoned.

378-16 : Foliated medium grained gneiss.

Macro : Pronounced thin mafic and leucocratic layering. Foliation plane parallels the layering and shows a mineral lineation.

Micro : Granoblastic texture.

50% Quartz: Minor straining. Few porphyroblasts. Fine grained mosaic.

20% Microcline perthite: (1 mm). Anhedral.

10% Plagioclase: Albite twinning. Both feldspars have rounded quartz inclusions and show sericitization.

5% Sillimanite: Diagonal cleavage. Equant and elongate prismatic crystals (0.1 mm). Length slow elongation. $2V(+) = 20^{\circ}$.

10% Biotite: Brown pleochroism. 1 mm. Euhedral to subhedral. Generally aligned parallel to foliation.

5% Sericite: Secondary.

378-17 ; Arkosic sandstone.

Macro : Reddish sandstone with rounded grains (1 mm) of feldspar and quartz in a clay matrix.

Micro :

60% Quartz: Rounded to angular, sub spherical grains (maximum of 1 mm in size).

35% Feldspar: Rounded, spherical to sub spherical grains some with albite twinning (Plagioclase).

Accessories :

Opaques. Minor.

Matrix. Limonitic clay.

378-18 : Coarse grained gneiss.

Macro : The porphyroblasts of feldspar (2 cm) not well defined, but are obscured by intergrowths of quartz and mica. There is no recognizable layering. Only a faint foliation present with a mineral lineation.

Micro : Porphyroblastic texture.

50% Plagioclase: Sub to anhedral, (to 2 mm). Albite twinning. Some Carlsbad-albite twinning (An_{20}). Sericitized with quartz inclusions.

K Feldspar: Minor. Sericitized. Carlsbad twinning.

40% QMartz: Anedral, strained porphyroblasts (to 6 mm). Generally as a fine grained recrystallized mosaic. Unstrained. Some triple points (120^{o}). Many sutured grain boundaries.

5% Biotite: Brown pleochroism. Fine grained. Euhedral.

5% Muscovite: Parallels foliation. Fine grained.

Accessories :

Opaques. Minor. (Magnetite).

Zircon. Minor.

378-19 : Phyllite.

Macro : Fine to medium grained phyllite with relict bedding. Lighter layering grading upwards to a fine grained dark layering.

Clastic grains havebeen recrystallized. Relict scour and fill structure gives younging relationship. (Overturned in field).

Micro : Porphyroblastic texture.

40% Quartz: Porphyroblasts (1 mm). Strained. Anhedral. Generally aligned to relict bedding. Fine grained recrystallized matrix, with polygonal (rare) and sutured grain boundaries.

50% Feldspar: (1 mm). Rest as fine grained sericitized matrix.

10% Muscovite: Very fine grained. Sericite.

378-20 : Coarse grained quartz tourmaline rock.

Macro : Large crystals of striated black tourmaline and quartz.

Microm :

20% Tourmaline: Pleochroic in grey green to olive green. Uniaxial (-). Subhedral (to 6 mm). Fractured.

80% Quartz: Large porphyroblasts (1 cm) with undulose extinction. Anhedral. Polygonal and sutured quartz mosaic matrix.

Accessories :

Zircon. Minor. Rounded (0.1 mm).

378-21 : Quartz gneiss.

Macro : White quartz aggregate, fractured, rodded with minor muscovite on foliation surface.

Micro : Granoblastic texture with minor smaller grains.

95% Quartz: Anhedral (4 mm) with sutured boundaries. Not heavily strained.

5% Chlorite: Aggregate of euhedral kinked crystals associated with the minor recrystallized quartz mosaics in the fractures. Secondary. One needle, pleochroic, colourless to pale green. Length fast.

378-22, 23, 24 : Fine grained gneiss.

Macro : Layering due to mafic and leucocratic segregations. Not well defined. One medium to coarse grained layer of K feldspar.

Micro : Porphyroblastic texture.

40% Microcline: Microcline perthite (stringers). Cross hatching. Anhedral. Embayed.

Plagioclase: Minor. Heavily sericitized.

45% Quartz: Anhedral grains (to 1 mm). Undulose extinction. Quartz mosaic aggregates and ground mass. Unstrained.

5% Biotite: Red brown pleochroism. Fine grained. Euhedral.

5% Sericite: As with biotite, parallels foliation.

Accessories :

Opaques. Minor (Magnetite).

Apatite: Minor. Biaxial. Length fast. High relief. Low birefringence. Colourless.

378-25 : Amphibolite.

Macro : Dark grey green amphibole and minor white feldspar compose the fine grained Amphibolite.

Micro :

50% Hornblende: Pleochroic in blue greens to yellow green and in olive green to brown. Length slow. Extinction angle 16-20°. Amphibole cleavage.

30% Plagioclase: Sericitized. Albite twinning. Sub to anhedral (2 mm).

10% Quartz: Undulose extinction. Anhedral. (0.1 mm). Ground mass. Also as inclusions in hornblende.

5% Epidote: Fine grained. Anhedral (0.1 mm). Straight extinction. One good cleavage.

Accessories :

Zircons (0.1 mm).

Opaques. (associated with the hornblende?)

378-26 : Coarse grained granite gneiss.

Macro : Coarse porphyroblastic texture with anhedral quartz, K feldspar, mica and opaques. The mica is preferentially aligned along minor shear zones of finer grained material. Layering is very poorly developed.

Micro : Porphyroblastic texture.

50% Quartz: Anhedral (to 1 cm). Embayed. Undulose extinction. Aggregates of fine grained recrystallized unstrained quartz. Strain bands in porphyroblasts. Small crystals bound most of porphyroblasts. relationship?

40% Feldspar: Perthite (blebed). Microcline perthite (stringers). Very heavily sericitized. Anhedral (to 1 cm).

5% Biotite: Aggregates of fine grained euhedral plates. Brown pleochroism.

5% Muscovite: Fine grained aggregates. Sericite. Secondary.

378-27 : Epidote gneiss.

Macro : Medium grained granoblastic texture. The rock contains light green epidote, dark green amphibole, plagioclase and K feldspar. Very faint layering apparent.

Micro :

20% Hornbelnde: Pleochroic in greens. Extinction angles 18°, 30°, 22°. Anhedral. Composition?

55% Plagioclase: Albite twinning. Anhedral. Sericitized. Antiperthite (blebed). Many of the blebs are perthitic.

10% Epidote: Anhedral and embayed aggregates (to 1 mm).

10% Clino Pyroxene: Augite 2V(+) = 50. Extinction angles 40°, 50°. Rimmed by Amphibole. The grains show true pyroxene cleavage with the rims often showing Amphibole cleavage.

Quartz: Minor. Anhedral. Inclusions in feldspars (rounded).

Accessories :

5% Sphene. Brown subhedral grains with high relief 2V(+) = 20o.
Opaques. Minor

378-28 : Medium grained feldspar gneiss.

Macro : Predominantly K feldspar layering with mafic interlayers. Layering is reasonably well defined with gradational boundaries.

Micro : Porphyroblastic texture.

55% Quartz: Mosaic aggregates (to 1 mm) of recrystallized grains. Elsewhere as groundmass mosaic and as boundaries to the porphyroblasts.

35% Feldspar: Microcline perthite. Totally anhedral, clouded by sericitization. Inclusions of quartz.

Plagioclase: Rare. Greater degree of sericitization.

5% Biotite: Brown pleochroism. Fine grained.

5% Sericite: Bundles. Minor Muscovite grains.

Accessories :

Opaques. Minor.

378-29 : Amphibolite.

Macro : Dark green medium grained amphibolite with minor feldspar laths.

Micro :

50% Hornblende: Pleochroic in greens and browns. Extinction angles 20^{o}, 22^{o}. Anhedral.

40% Plagioclase: Laths (to 1 mm) with Carlsbad albite twinning. Anhedral to subhedral. An_{28} to An_{30}.

5% Quartz: Fine grained recrystallized aggregates.

5% Epidote: Fine grained (0.1 mm) aggregates. Anhedral.

378-30 : Porphyritic quartz gabbro.

Macro : Rounded coarse grained phenocrysts in a fine grained matrix of mica, feldspar and quartz.

Micro :

70% Plagioclase: Rare zoning. Anhedral. Phenocrysts up to 2 cm. Carlsbad Albite twinning. An 20, 25, 30. Undulose extinction. 30% of feldspar occurs in the matrix. Fine grained (0.1 mm). Sericitized.

20% Quartz: Minor quartz up to 4 mm. Anhedral. Rest of quartz in the fine grained matrix. Anhedral. Embayed. Slight undulose extinction.

10% Biotite: Brown pleochroism. Anhedral grains up to 1 mm. Rest as subhedral grains (0.1 mm).

Accessories :

Opaques. Minor.

378-311 : Chlorite Rock.

Macro : Clusters of a dark green foliated mineral composes 90% of the rock. The rock is generally fine grained with coarse grained quartz porphyroblasts.

Micro :

10% Quartz: Porphyroblasts (to 1 cm). Anhedral, fractured.

80% Chlorite: Pale green to light brown pleochroism. Fibrous acicular bundles, radiating. (1 mm). Length fast 2V (+) small, 5 to 10^{o}.

10% Opaques: Associated with chlorite.

378-32 : Quartzofeldspathic schist.

Macro : Layered due to segregation of mafic and leucocratic components. Layers up to 1 cm thick. Some elongated quartz grains parallelling layering and schistosity.

Micro : Foliated, generally granoblastic texture with a few porphyroblasts.

65% Quartz: A few porphyroblasts up to 6 mm. Rest, mosaic of fine grains. Anhedral. Polygonal and sutured boundaries. The porphyroblasts are strained.

15% Muscovite: Subhedral (1 mm), parallel foliation. Also as fine grained aggregate stringers.

10% Biotite: Fine grained strings parallel to foliation.

5% Epidote: Fine grained (0.1 mm) parallel extinction.

Accessories :

Tourmaline. Minor.

378-33 : Medium grained feldspar gneiss.

Macro : Coarse poorly defined layering results from concentration of mafics between the orange feldspar layers.

Micro : Porphyroblastic texture.

10% Biotite: Subhedral. Brown pleochroism (to 3 mm).

20% Quartz: Anhedral (3 mm). Weakly to strongly strained. Fractured. Boundaries sutured. As inclusions in the feldspar.

70% Pagioclase: Antiperthite containing blebs of perthite. (Becke line test for comparative refractive index). Albite twinning in Plagioclase. Anhedral.

Minor Microcline perthite (stringers).

Accessories :

Opaques. Minor.

Sphene. Rounded, high relief, brown. Minor.

378-34 : Medium to fine grained gneiss.

Macro : Mafelsic finely layered (not well defined) gneiss. Weathered to a red colour in parts.

Micro : Porphyroblastic.

30% Quartz: Rounded grains and anhedral aggregates in a fine grained sericite matrix. Larger grains (to 1 mm) are strained.

50% Sericite: (from feldspar). Parallels foliation. Minor feldspar distinguishable, but heavily sericitized.

10% <u>Hornblende</u>: Pleochroic in greens. Length slow. Extinction angle 20°.

5% <u>Biotite</u>: Red brown pleochroism.

Accessories :

Opaques. Minor.

Chlorite. Minor.

378-35, 36 : Epidote gneiss.

Macro : Medium grained gneiss with apparent epidote, amphibole, feldspar, garnet and scapolite.

Micro : Essentially granoblastic.

10% <u>Garnet</u>: Light brown anhedral crystals (1 mm). Fractured. Isotropic. Some rimmed by Hornblende.

15% <u>Hornblende</u>: Pleochroic in greens. Anhedral (1 mm).

20% <u>Epidote</u>: Fine grained anhedral aggregates.

10% <u>Quartz</u>: Anhedral. Embayed (0.5 mm).

30% <u>Plagioclase</u>: Albite pericline twinning. Anhedral.

10% <u>Scapolite</u>: Poikiloblastic with muscovite.

5% <u>Clinopyroxene</u>: Augite 2V (+) = 60. Extinction angle 50°. Anhedral.

APPENDIX II.

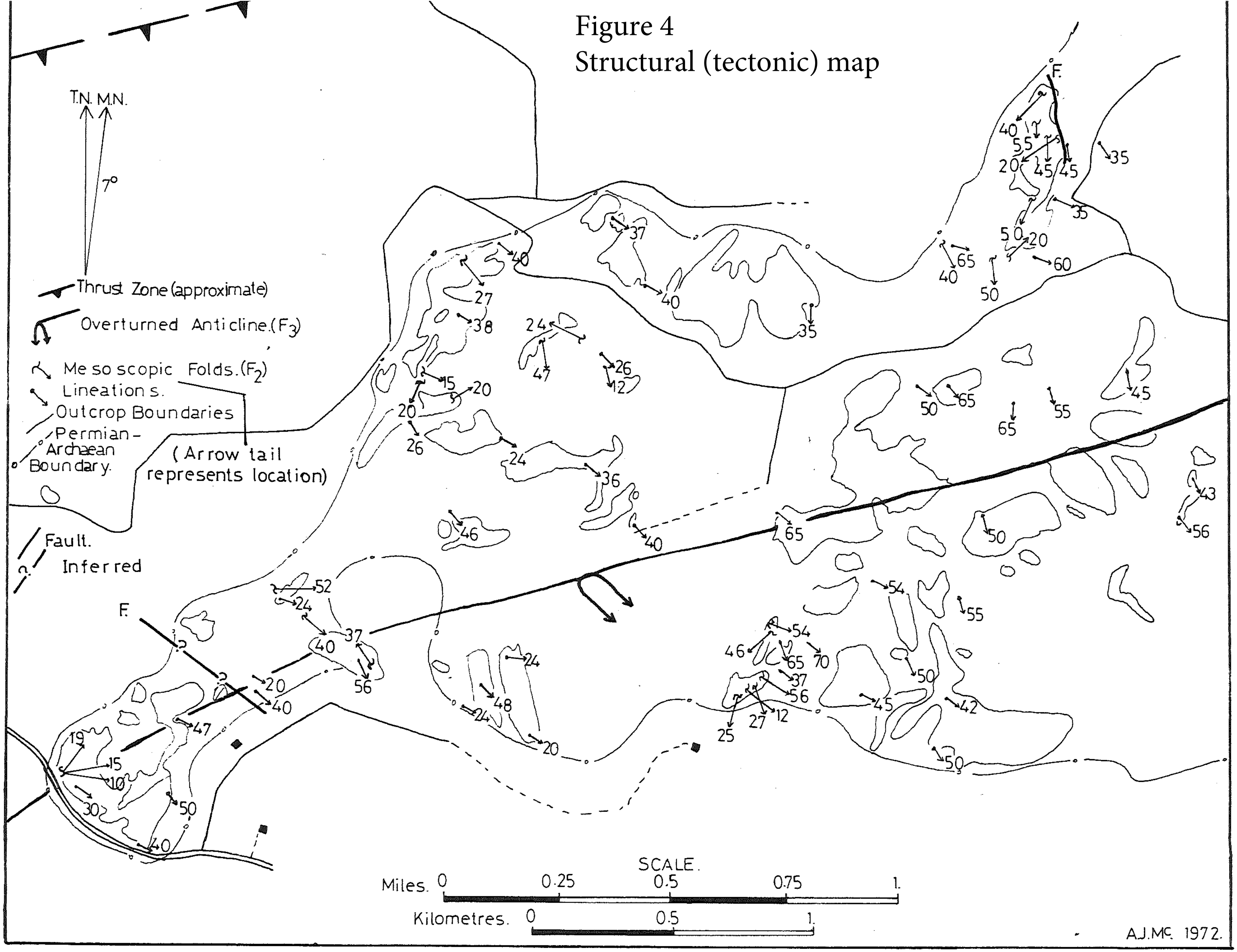
Thin Sections and Rock Specimens.

The slide numbers and rock specimen numbers submitted correspond.

Thin sections and rock specimens submitted are numbers:

378-1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34.

Figure 4
Structural (tectonic) map



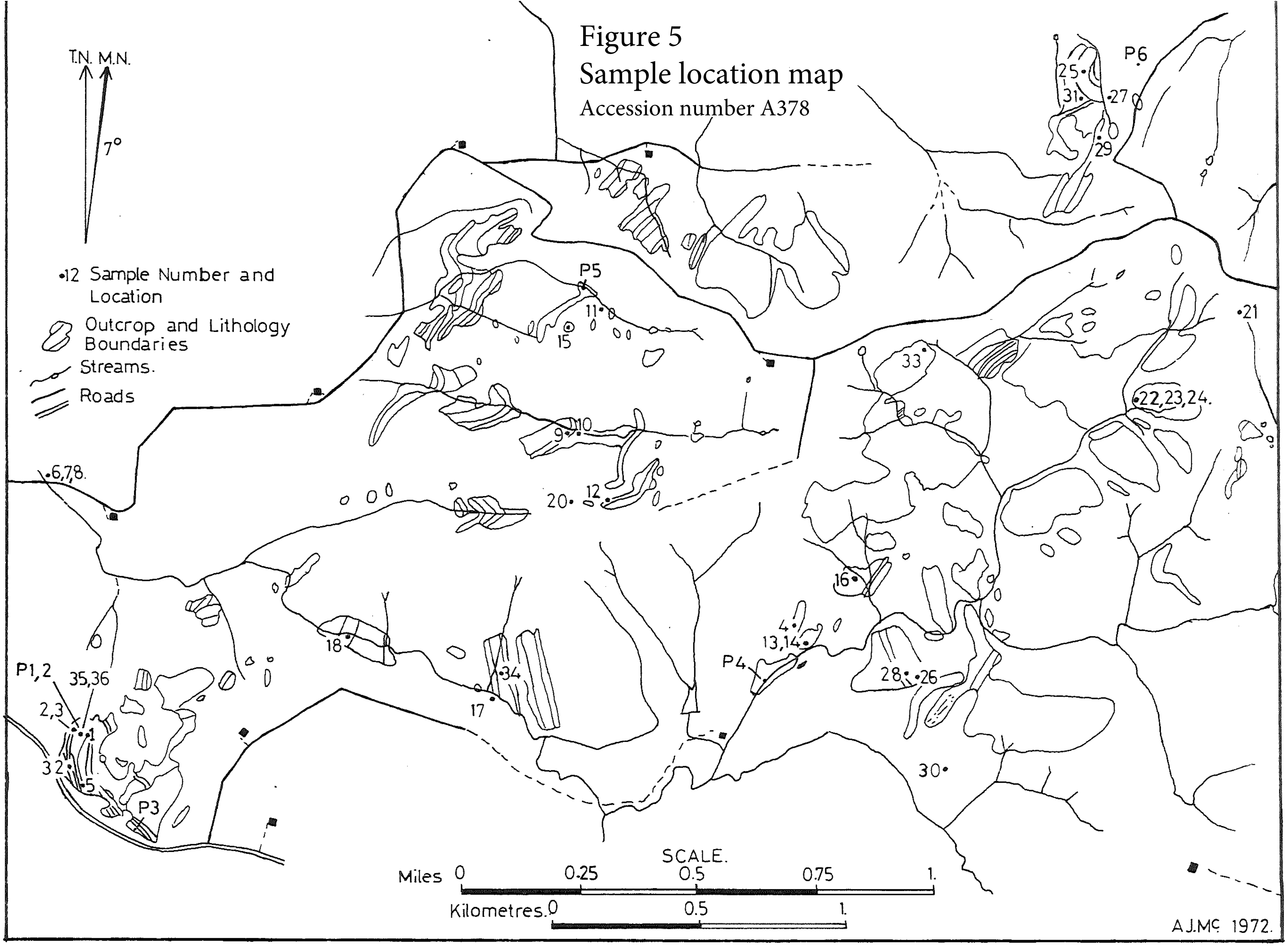


Figure 5
Sample location map
Accession number A378

GEOLOGICAL MAP
OF PART
OF THE ARCHAEAN INLIER
NORTH-EAST OF YANKALILLA

FIG. 6