B

THE UNIVERSITY OF ADELAIDE
DEPARTMENT OF ECONOMIC GEOLOGY

HONOURS THESIS

THE GEOLOGY OF THE MYLOR - OAKBANK AREA

by, R. L. Wildy, B.Sc.,
Department of Economic Geology,
November, 1963.

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ABSTRACT

A metasomatic - metamorphic origin is suggested for the gneissic granite occurring south-east of Oakbank. Both the field and petrological evidence support granitisation of the original sediments. These rocks are thus Lower Proterozoic in age.

The gold mineralisation was introduced in quartz veins. These have been thoroughly prospected and there is little to suggest that economic quantities remain.

C O N T E N T S

I. INTRODUCTION:

The area was assigned to the author as a mapping project for an Honours Year course in Economic Geology, under the supervision of Mr. A. W. G. Whittle.

Originally the area was limited to the southern portion, from Mylor to Hahndorf, with the object of examining the petrology in relation to the origin of the gold mineralisation. However, this was not particularly rewarding and on Mr. Whittle's suggestion the area was extended in a north-easterly direction to Oakbank in order to study the nature and origin of the gneissic granite and its relation to the country rocks.

(a) Location and Size of Area.

The area investigated is shown on the accompanying locality map.

It is in the eastern Mount Lofty Ranges, approximately 18 miles from Adelaide and extends from Mylor towards and including Hahndorf and on to Oakbank.

The mileages to these towns from Adelaide, are shown on the locality map.

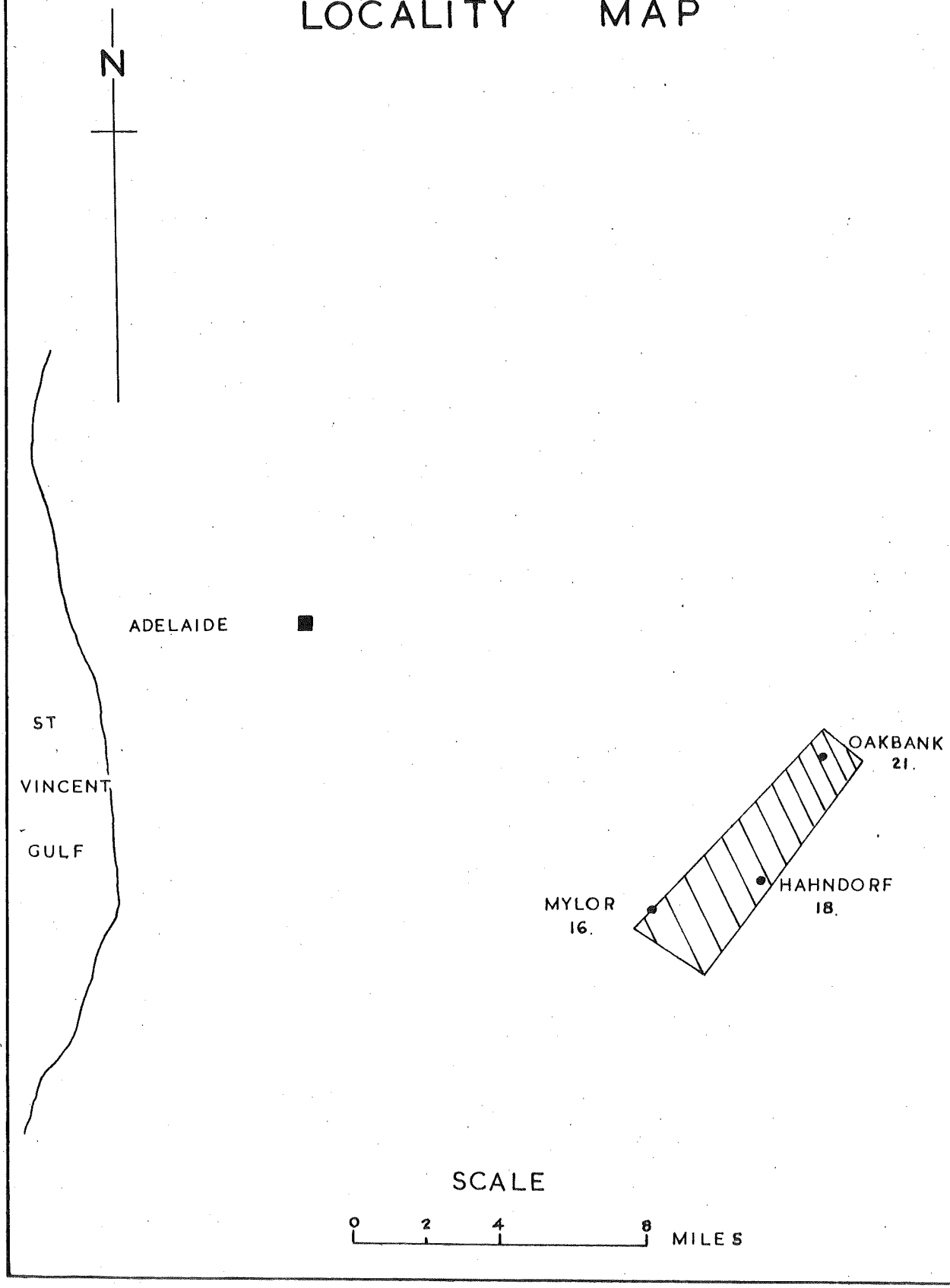
The area is approximately 14 square miles.

(b) Previous Investigations.

The northern part of the area has been investigated previously by Sprigg, Whittle and Campana (1951) during their mapping of the Adelaide 1 mile geological sheet.

The southern and larger portion was investigated by Sprigg and Wilson (1954) and more recently by Thomson and Horwitz (1962) in their preparation of the Barker 4 mile geological sheet.

LOCALITY MAP



(c) Physiography.

The area has a mature topography, consisting of rounded ridges and undulating hills intersected by shallow U-shaped valleys. The present relief is due to tectonic stresses mostly of Upper Tertiary and Quaternary age which caused broad doming and block faulting along the ancient mobile trough of the Adelaide geosyncline. The rejuvenated cycle of erosion so produced has resulted in the present topography. The area has an average height of 1,100 feet above sea level, with the highest hills ranging up to 1,300 feet.

Two of the most prominent ridges in the southern part of the area are formed by thick quartitic beds and run parallel to each other in a north westerly direction.

The drainage system consists of the Onkaparinga River and its numerous small tributaries. The Onkaparinga River meanders through the western side of the area in a roughly north-east direction and generally has a shallow valley associated with flood plains consisting of Recent silts and sands.

The area lies in a 30 to 35 inch rainfall belt and most of the natural vegetation has been cleared to make way for diarying and grazing, several piggeries, and potato and apple growing.

The hills and slopes have good soil cover and the shallow creeks seldom cut into solid rock. Thus, rock exposures are extremely poor, especially in the southern part of the area and the few quarries and old mining sites were used to the best advantage.

The area around Oakbank was considerably better, and the gneissic granites and pegmatites outcrop as shown on the geological map.

(d) Method of Investigation.

Adastra air photographs of the area, having a scale of 4 inches to the mile, and a note book were used to record the field data.

A base map of the same scale was prepared from an enlarged photograph of the area taken from the 1 mile Military Survey Plan.

The field data was then plotted on the base or "fact-map" as it was obtained.

Due to the poor rock exposures it was difficult to obtain any real system in the field mapping and the southern part of the area was more or less randomly "searched" for all available outcrop.

In the northern part an effort was made to follow certain beds along their strike, in order to try and unravel the folded structure to the north-east of Oakbank. However, the scarcity of outcrop and the lack of any persistent marker bed made this difficult, and as a final resort the "nose" of the fold was mapped in detail by pace and compass traverse in order to correlate all the small and scattered rock exposures in that area.

Numerous field samples were collected and examined in thin section in describing the petrology of the area. A representative collection of these macro and micro descriptions is included in the Appendix. Several polished sections were also made in an effort to obtain further information regarding the mineralisation in the Banksia mining area.

II. DESCRIPTIVE PETROLOGY:

(a) General Stratigraphy.

The predominant rocks of the area are geosynclinal sediments of Lower Proterozoic age and lie within the Torrensian Series of the Adelaide System.

Thomson and Horwitz (1962) show the gneissic granite area as an Archaean inlier. The age of these rocks is controversial and their petrology is discussed under a separate heading.

The rock formations are represented in general terms on the geological map (Plan I) and these are amplified in the following discussion.

(1) Aldgate Sandstone. (Thomson and Horwitz 1962)

This is the oldest formation represented in the area and good outcrop occurs in the south west near the River Onkaparinga (sample 87). The rock is a yellowish-coloured, medium grained felspathic sandstone. It is generally massive but in a nearby area a finely laminated variety occurs. Here the sandstone is cross bedded in part, with black iron oxide granules outlining some of the bedding planes. The laminated sandstone is interbedded with weathered, mottled coloured sandy shales which sometimes contain a high percentage of clayey material.

(2) Blue Grey Cherts.

These appear to occur immediately above the Aldgate Sandstone and to penetrate a short distance into it. The greater proportion of the chert occurs as float material scattered over a fairly wide area as shown on the map, but it was found in situ at two places.

At one of these the chert forms irregular layers from 1 to 3 inches thick, interbedded with grey weathered slates dispersed in sandy shales and siltstones. The other occurrence (sample 86) is stratigraphically lower in the sequence and here the chert forms a definite layer 2 inches thick, near the top of a massive yellow sandstone.

The cherts thus seem to furnish a marker horizon for the top of the Aldgate Sandstone in this area. However, they were not located further to the north and the author is thus less confident as to where the boundary should be placed.

(3) Slates and shales with lensing quartzites and thin sandstones.

This is a thick formation in which there is a variation in rock type, although a richness in argillaceous material is the main feature.

The rock exposures in this area are extremely poor and the following information cannot be regarded as complete. For example, it was impossible to locate contacts between the different lithological units as shown on the geological map.

For convenience this formation will be discussed in three separate groups.

(i) Lower group of Slates and Shales.

This group shows a variation in lithology from weathered, mottled coloured shales and slates to a more sandy shale and blue grey siltstone.

These units appear to alternate throughout, but the shales definitely become more sandy as the quartzite is approached, suggesting a gradation of one to the other.

A typical shale occurrence (sample 4) is a mottled, yellowish coloured variety having a well developed foliation often made more obvious with streaks of fibrous limonite.

The shales tend to become coarser grained and thus more silty in nature along their strike. Accompanied with these changes the bedding planes become more apparent and the silty shales are usually well laminated.

A more massive variety of the silty material is a blue-grey siltstone (sample 85). The colour is due to finely disseminated carbonaceous material, which has been metamorphosed to produce carbon.

(ii) Lensing quartzites.

The boundary between the sandy shales and the quartzite is probably gradational and with the scarcity of outcrop is difficult to establish. However, the two quartzitic formations appear to be more or less confined to two broad ridges enabling an approximate boundary to be drawn.

This formation has been mapped as the equivalent of the Stonyfell Quartzite by Sprigg and Wilson (1954) and Thomson and Horwitz (1962). However, it seems that a great deal more work is necessary before similar formations occurring on the west and east sides of the Mount Lofty Ranges can be safely correlated.

I. Mottled coloured shales exposed in small road cutting, looking east from the Mylor-Hahndorf Road.

The formation shows a variation in lithology from a partly quartzitic sandstone to a true quartzite, which is often associated with quartz veins that appear to conform with, and cross-cut, the bedding. Several argillaceous beds (sample 3A) also occur throughout this formation.

Much of the sandstone is massive and partly ferrugineus and forms typical laterite as a result of exposure to fairly prolonged weathering.

Several quarries showed that the massive, coarse grained sandstone (samples 5 and 10) often contained beds of a more silty nature (samples 16 and 51) which were usually well laminated and cross bedded in part, enabling facings to be determined.

The two quartzitic formations appear to lens out northwards. The lack of good outcrop makes it impossible to establish the terminal boundaries with any accuracy, but the few exposures immediately to the north indicate a change to finer grained shaley material usually very weathered and often laterised.

The area in between the two quartzite formations consists of sandy shales with the development of some siltstones and a few thin sandstones which could not be traced for any distance. The shales are well developed in the Warrakilla mining area and the siltstones are represented by sample 40 which is a particularly well laminated variety.

(iii) Upper group of Slates and Shales.

The area east of the quartzite formations up to the inferred fault again consists mainly of shales, often sandy in part, and siltstones similar to those described. However, in this area we have the occurrence of a true slate and not the weathered equivalent as in the area previously discussed. The slate (sample 25) is a blue grey variety having a reasonably well developed slaty cleavage. The colour is derived from black carbonaceous material, now altered to carbon as a result of metamorphism, which is disseminated throughout the rock. The slates occur as a few isolated exposures and it was not possible to map them as a distinct unit.

Further to the north a rock having a similar appearance occurs (sample 153) but it is slightly coarser grained with a less well developed slaty cleavage. The colour in this case is due to the abundance of biotite and chlorite formed during metamorphism. The rock may thus be classified as a metamorphosed siltstone.

(4) Blue grey carbonaceous shale in part dolomitic.

This formation does not outcrop anywhere in the area but is exposed in a railway cutting south east of Balhannah. Its thickness is of the order of 150 feet (Whittle 1947). Generally it is a massive blue to black hard shale, in part dolomitic, and contains occasional small calcite veins. Bedding is completely obscured making it difficult to obtain the attitude. The thin section (sample 118 (5)) shows a well foliated texture of micaceous minerals and fine carbon material occurring in a quartz groundmass associated with concentrations of secondary calcite. The quartz is partially recrystallised and the calcite grains are usually elongated in the foliation direction. Thus it appears that the calcite was introduced prior to the metamorphism or at least before it had ceased.

A marked brecciated zone occurs within this formation (sample 118A). It is several feet wide and suggests the existence of a fault zone more or less parallel with the strike of the rocks.

(5) Sandy schists, phyllites and thin quartzites.

On the eastern side of the inferred fault the grade of metamorphism is slightly higher, exemplified in the development of schists and phyllites.

Two thin, impure, quartzite horizons occur just east of the fault, but owing to poor exposures they could not be traced for any distance and their approximate position inferred from several widely spaced outcrops. A change in lithology apparently occurs along their strike. North of Oakbank they appeared as massive, coarse grained, partly quartzitic sandstones often containing small irregular quartz veins. South-east of Balhannah (sample 155A) the rocks were much finer grained and often well laminated and are actually metamorphosed siltstones. Similarly,

further south (sample 158) the finer grain size persists with the occurrence of a metamorphosed, micaceous siltstone.

An example of the phyllitic rocks in the area is given by sample 188A. These occur in situ on either side of the silty horizons just discussed and as float material over a wide surrounding area.

The sandy schists are seldom exposed, but appear to be more predominant further east and will be described later in the report.

(6) Quartzitic sandstones and grey, well laminated micaceous siltstones.

The sandstone formation is exposed in a small quarry (sample 120). In the hand specimen it appears as a porous micaceous sandstone which is often well laminated with dark minerals. Cross-bedding is not well developed but an exposure further south suggests that the formation could be overturned.

The formation to the north consists predominantly of alternating siltstones and quartzitic sandstones as exposed in the railway cutting just east of Oakbank. The siltstones (sample 127A) are grey and well foliated with abundant muscovite occurring along the foliation planes. The quartzitic sandstones as the name implies vary from an impure sandstone, only partially metamorphosed, to a true quartzite.

An unusual rock type is represented by sample 126A. This was not found in situ but apparently forms a thin bed which overlies the siltstones and quartzites. It consists of about 30% tremolite and minor talc distributed throughout an albite-quartz ground mass and is probably of metasomatic origin rather than true metamorphic.

In the folded area north-east of Oakbank the predominant rock type is a grey, well laminated micaceous siltstone (sample 75).

(7) Sandy schists and laminated quartzitic sandstones.

Although very few actual outcrops were encountered the so-called sandy schists appear to constitute the bulk of the country rock east of the inferred fault. This is supported by the evidence from thin sections of schistose fragments obtained from a bore hole about a mile east of Oakbank (samples 106A, 106B). The schists are exposed along the

edge of the road further to the south east, and a specimen from here was examined in thin section (sample 200). This sample is typically richly micaceous but somewhat quartzitic and contains a high percentage of feldspar associated with the recrystallised quartz in the ground-mass.

The laminated quartzitic sandstones are exposed in several old quarries in the north-eastern part of the area and the occurrence of cross bedding enabled facings to be determined. Similar sandstones formed abundant float material further south and a particularly well laminated variety was sampled. (sample 176). It is a medium to coarse grained, often gritty sandstone, well banded with abundant sub-rounded haematite grains as shown by the polished section (176A).

(b) <u>The Granitic Gneiss.</u>

The granitic rocks are confined to one area south-east of Oakbank. They appear to form separate elongated bodies as indicated by the continuous well exposed outcrop. Since the more friable schistose country rock is very seldom outcropping, the contacts appear relatively sharp and the boundaries are thus reasonably well defined. However, if all rocks in the area were equally represented in outcrop, it would be difficult to establish such boundaries for it appears, from a few examples, that the country schists become coarser and grade into the gneiss.

The granitic gneiss varies in texture from the more massive varieties poor in mica, to strongly gneissic varieties rich in mica. However, gneissic foliation is a dominant feature in most specimens and it generally appears to parallel the foliation of the country rocks. The grain size varies from medium to coarse and the gneissic bands of quartz and feldspar outlined by the micas range up to 3 m.m. in width. The rock generally appears as a pinkish coloured gneiss but darker coloured more schistose varieties occur when richer in biotite.

The granitic gneiss shows only a small variation in mineralogical composition (slides 110A, 111A, 191, 192, 197). In general the rock consists of quartz, microcline, plagioclase, biotite and muscovite with accessory iron oxide minerals, zircons and occasional minor amounts of apatite.

II. General view of granite gneiss looking south along the western outcrop.

III. Close up of granite gneiss outcrop looking south along western outcrop. Hammer handle is approximately parallel to the gneissosity.

The quartz content varies from between 35% and 50% of the rock. It is usually always clear, xenoblastic and relatively free from inclusions. Prominent strain shadows are rare although undulose extinction does occur to a small degree. The quartz grains show a variation in size and often appear to be arranged into coarse and finer bands which parallel the foliation direction.

Microcline, showing the typical cross-hatched twinning occurs in all specimens examined, and ranges in amount from 20% to 40% of the rock. The grains are sub-hedral with regular outlines to anhedral and occasionally contain numerous small inclusions. These inclusions often consists of rounded quartz grains, indicating replacement of the quartz during metasomatism.

Plagioclase varies in amount from 5% to 20% of the rock. The grains are variable in size, anhedral and often very cloudy due to minute inclusions and partial alteration to sericite. Multiple twinning occurs but is often only poorly developed, making compositions difficult to determine. However, it was found to be albite containing about 5% to 8% anorthite.

Biotite occurs in all specimens in amounts varying from 5% to 20%. It is always pleochroic from pale greenish - yellow to dark greenish-brown or black and often shows some alteration to chlorite. It occurs in elongated flakes, usually forming discontinuous gneissic bands throughout the rock.

Muscovite occurs in all specimens examined, but generally in lesser amounts varying from 1% to 5%, and is usually closely associated with the biotite.

Iron oxides, probably mostly haematite, are important accessories in some of the rocks. It generally occurs in close association with the biotite as anhedral grains, although several sub-hedral outlines were observed.

Zircon occurs as an accessory in all specimens, as small rounded aggregates and sometimes as euhedral grains.

Apatite was also observed in minor quantities forming elongated and shorter prismatic grains.

A particularly interesting rock specimen (108A) which may be described as a coarsely crystalline biotite schist outcrops near the granite gneiss. The micaceous bands have been crenulated and the micas are beginning to orientate themselves along this crenulation cleavage. The direction of this cleavage is constant and is parallel to the gneissosity of the nearby granitic rocks. This suggests that the second stage of deformation (forming the crenulation cleavage) and the granitisation, occurred at approximately the same time. Hence the rock represents an early stage in the development of the gneissic texture, where granitisation has not progressed to completion thus preserving the original schist structure. Several similar examples were observed at other localities, all of which were in close vicinity to the granitic gneiss.

The origin of the granite thus appears to be closely associated with granitisation of the original sediments. Both the microcline and plagioclase often appear to replace the original quartz, which suggests a metasomatic origin involving the introduction of liquids rich in potash and soda. The rocks have subsequently been metamorphosed producing the well developed gneissic texture.

(c) Pegmatites.

The pegmatites occur as massive, irregular outcrops in two areas north-east of Oakbank, (Samples 117, 145). The rock is coarse grained with the occasional development of feldspar crystals up to 1 inch in length. The mineralogical composition seems to be constant consisting of plagioclase, orthoclase? and quartz with tourmaline occurring as an accessory in some specimens. In the specimens examined mica was completely absent.

The plagioclase shows a slight variation in composition from 7% An. (albite) to 14% An. (oligoclase) and is often cloudy with inclusions, some of which consist of quartz. Plagioclase is usually the predominant mineral and is closely associated with abundant quartz, while the orthoclase occurs in smaller amounts.

It seems probable that the origin of these pegmatites is metasomatic, involving the final fluids whereby the plagioclase and possibly much of the quartz were introduced and partly replace the orthoclase of the country rock.

(d) Quartz-talc Rocks.

These rocks form an irregular, massive outcrop on top of a small rise to the right of the main road through Oakbank.

When fresh the rock is white in colour, is medium grained and consists of an intimate association of quartz and varying amounts of talc. The slides (97A, 97B) appear to represent a partially recrystallised quartzose rock which has undergone subsequent metasomatic replacement. The talc may be interpreted as replacing the quartz along intergranular boundaries and fractures, which supports the assumption that the metasomatism post dates the recrystallisation involved during metamorphism. In the railway cutting just below this outcrop, the rocks represent a more advanced stage of the metasomatic replacement and a quite extensive deposit of almost pure talc occurs. (samples 151A, 151B).

It must be emphasised that the interpretation of these rocks is open to discussion and it may be argued that the evidence of replacement by the talc in several instances is not convincing. In view of this numerous thin sections of other talc bearing rocks occurring in the area were examined in an effort to obtain information regarding its genesis. Most of these were feldspar rich and exhibited an intimate and irregular association of albite, talc and recrystallised quartz, suggesting that the talc could be genetically related to the albite and introduced during sodic metasomatism.

One of these slides (178AI) showed the talc in close association with tremolite. The specimen is a typical albitised rock showing no preferred orientation of grains. The tremolite thus appears to be of metasomatic origin rather than metamorphic, and was probably introduced with the albite with which it is often closely associated. Thus the origins of the talc and tremolite appear to be closely related and were apparently formed during the introduction of the albite rich solutions.

(e) Coarsely Crystalline quartzite.

The rocks constituting this formation occur as outcrop and float material distributed in elongates bands, which more or less parallel the foliation of the country rock. Much of the formation consists of epigenetic quartz reef material (sample 174B), but a large amount is actually a coarsely crystalline quartzite (sample 98A).

The latter specimen represents an original quartz rich sediment which has been partially recrystallised and silicified during the introduction of quartz, which formed the small veins traversing the rock.

Another rock type within this formation may be described as a coarse grained gneissic quartzite. (sample 174A). This rock represents the recrystallisation of a micaceous sandstone during normal metamorphism, causing the development of a roughly gneissic texture, and presents good evidence of alteration of the country rock.

Thus a great proportion of this formation consists of altered sediments which are probably more extensive than shown, for exposures are generally poor.

A portion of one of these sandy formations occurs in close association with the quartzite in the northern part of the area (samples 179A, 187). The former specimen represents a feldspathic sandstone that has been partially recrystallised and affected by subsequent metasomatism causing the formation of disseminated talc grains. The latter specimen is coarser grained and contains a much greater development of talc, indicating a more advanced stage of recrystallisation and of the associated metasomatism.

(f) Quartz-feldspar-hornblende schists (Sample 210)

These rocks were not found in situ but as quite extensive float material in an area near the southern end of the long gneissic granite formation. They are find grained, dark greenish coloured rocks with a well developed schistosity. Their mineral composition consists of quartz, associated with lesser amounts of feldspar and green hornblende which forms about 30% to 40% of the rock. The feldspar is probably plagioclase but it is untwinned and its composition was impossible to determine. The origin of the rock is somewhat obscure, but it is possibly a metamorphosed micro-tonalite.

III. METAMORPHISM.

A brief inspection of the geological map suggests that the grade of metamorphism is higher on the eastern side of the inferred fault than on the western side. This is exemplified in the development of phyllites, schists and quartzites in the east in comparison to the shales, slates and sandstones occurring in the western part of the area. This general pattern is borne out by the mineralogical assemblages.

The highest grade reached in the west is represented by samples (47A, 25, 153, 118 (5)) which contain associations of quartz, muscovite and chlorite with biotite just beginning to form. These assemblages suggest the Lower Greenschist Facies.

The grade of metamorphism on the eastern side of the inferred fault is represented by samples (155A, 158, 127A, 188A, 75, 200) which contain the minerals quartz, muscovite, chlorite, biotite, tourmaline and minor albite. The biotite is much more abundant in these rocks and indicates the Middle Greenschist Facies.

Thus there is only a small increase in metamorphic grade between the two areas. However, in several localities close to the rocks of metamorphic - metasomatic origin there appears to be a general upgrading of the degree of metamorphism. This is exemplified in the development of kyanite in samples 106A and 106B which has probably formed as a result of increased temperatures associated with the granitisation of the nearby gneissic rocks.

The grade of metamorphism is consistent with the effect of burial and subsequent stresses associated with a geosynclinal belt.

IV. STRUCTURAL GEOLOGY:

(a) Area west of inferred fault.

These beds are relatively undisturbed and lie on the western limb of a large drag fold. (Sprigg and Wilson 1954). They have an average strike of about 20° and a dip of about 55° to the east. Facings in the area were obtained from the finely laminated siltstones which were often partly cross-bedded.

A large proportion of the quartz reef and vein material occurring in the vicinity of the old mining areas appeared to be brecciated. The veins, which were usually cross cutting, were suggestive of epigenetic introduction associated with later shearing along these planes of weakness. Thus, although this could not be established with any certainty it is apparent that a fair amount of faulting has occurred in these areas.

A large proportion of the so called tectonic breccia (Sprigg and Wilson 1954) occurring on the extreme western side of the area is made up of severely sheared quartz material (sample 95A). This specimen consists of an association of large elongated quartz grains up to 8 m.m. across and 15 m.m. long, separated by finely granulated quartz which has resulted from crushing during the shearing movements. These movements appear to have affected the rocks throughout the length of the brecciated area shown on the map, but only a few typical breccias were observed.

(b) <u>The inferred fault.</u>

This feature was first established in the south by Sprigg and Wilson (1954) and extended northwards by Thomson and Horwitz (1962). Probably the best evidence as to the existence of this fault is the well developed fault breccia occurring in a railway cutting east of Balhannah (sample 118A). The brecciated zone is several feet wide and suggests the existence of a fault parallel to the strike of the enclosing rocks. Because it runs more or less parallel to the railway cutting, its true width is difficult to estimate. The thin section shows an intimate association of quartz, sericite, chlorite and disseminated carbon which has been cut by numerous large fractures and filled with secondary calcite. Several other examples of fault breccia and brecciated quartz material occurring, both in situ and as float, along this line support the existence of a major shear running approximately parallel to the strike of the beds.

(c) Area east of inferred fault.

The rocks in this area are considerably more disturbed and have been involved in tight folding associated with overturning. Owing to the scarcity of outcrop it was impossible to obtain a complete structural interpretation in the time available.

However, a detailed survey was conducted in the area north east of Oakbank in an attempt to establish the hinge position of the folded beds in this area. The rocks are well laminated, micaceous siltstones (sample 75) and occurred in small, widely scattered outcrops. The pace and compass survey was thus necessary to correlate the information gained from each of these small exposures and the results are shown on plan II. A second phase of deformation occurring in this area is exemplified in a crenulation cleavage. However, the rocks in which this was best developed were not in situ and its direction could not be accurately determined. Thus, all data recorded is due to the first phase of deformation.

The fold as outlined by the bedding trends (plan II) is a south plunging, asymmetrical syncline which has been overturned to the east. Several lineations formed by bedding-cleavage intersection were measured and plotted on an equal area net in order to obtain further information as to the style of folding.

According to Ramsay (1960), the following conditions apply.

(i) Lineations lying on a surface which is deformed by concentric folding have their locus on a partial cone, giving a stereogram plot of a partial small circle.

(ii) Lineations lying on a surface folded in a similar manner have their locus on a plane, giving stereogram plots of great circles.

However, the lineations from this area show a spread in all directions and thus do not furnish very much information. This random spread is due to the fact that the plunge of the axial line is not constant, but varies along the length of the fold. This could be partly overcome by taking a greater number of lineation measurements over a wider area, but it is not possible in the area concerned.

IV. A typical exposure of the laminated micaceous siltstones north-east of Oakbank.

V. Close up of the same outcrop as IV looking north. The pencil is parallel to the axial plane cleavage and makes a high angle with the bedding laminations.

Eighteen axial plane (slaty) cleavage directions were measured and their poles plotted on an equal area net (plan II). These cleavages show a spread along a great circle and the pole thereof defines the fold axis about which the cleavages have been folded during the second deformation. The fold axis was found to plunge 77° with a trend of 115°. This is in agreement with the expected orientation, since the trend parallels the direction of the crenulation cleavage obtained approximately from several of the loosely occurring rocks.

The syncline just discussed, merges into a south plunging anticline to the east which was well established with the aid of good exposures in an old quarry and along a small ridge just north of the main road.

Complications occur in the area south of Oakbank. It appears that the sandstone formation to the east is overturned but this could not be established with any certainty. The thin quartzites near the inferred fault definitely dip to the east as shown, but the lack of available data in the central area make it difficult to even postulate a possible structural interpretation.

V. ECONOMIC GEOLOGY

(a) Mineralisation

Within the area mapped several old gold mines occur. The majority of these consist of shallow shafts and pits exposing irregular quartz veins of varying dimensions, which carried the gold. These veins are usually partly ferruginous and often of a brecciated nature.

A survey of the literature concerning the operation of these mines, indicates that in most cases the yields were very low. Only two of the mining areas, from which the best results were obtained, will be discussed.

(i) Warrakilla Mines

Numerous shallow diggings and shafts up to 25 feet deep occur along a low ridge in soft yellow to white partly kaolinised shales and clays. Parts of the area are quite honey-combed underground and

VL. General views of the Warrakilla Mines.

Top - looking east from the road.

Bottom - looking north from the road.

some of the openings are still accessible. Several partly ferruginous quartz veins up to 6 inches thick, are exposed in the walls of these workings. The shales strike at about 20° and dip 30° to 40° east and the veins although striking about the same have a much steeper dip eastwards.

The shales (sample 2B) consist of abundant limonite associated with chlorite, sericite and occasional muscovite flakes, forming a fibrous network throughout which numerous anhedral quartz grains occur. The limonite appears to be derived from the opaque iron oxides (haematite) and several euhedral relicts suggest the pre-existence of pyrite.

The lode material (sample 2A) consists of angular quartz fragments occurring in a fine grained matrix of iron oxides and clay minerals. It is suggestive of an epigenetic quartz vein which has been affected by subsequent brecciation. Several samples of this material were crushed and panned with a prospector's dish. However, no traces of gold were observed.

(ii) Banksia Mines.

Several shallow shafts occur on the side of a small hill, just above one of the outcropping gneissic granites.

According to the literature the gold was obtained from a series of more or less parallel leaders striking north-east and south-west and dipping at 45° to the south-east. The veinstone consisted of quartz, cellular and ferruginous iron oxide, and micaceous iron. The ore averaged about 10 dwts to 1 ounce of gold per ton but assays of pyrites from this claim gave much higher yields - varying up to 10 ounces of gold per ton.

In view of this the area was searched for pyrite mineralisation, but only a few very small grains were observed occurring in the quartz-iron rich lode material (see later).

The rocks in the area (samples 185C, 185D) are of metasomatic-metamorphic origin. They consist predominantly of quartz, muscovite, which is often closely associated with haematite, and

VII. General view of the Banksia Mines looking up hill in an easterly direction.

microline. The microcline appears to partly replace the quartz of the country rock and metasomatism is suggested, involving reaction between solutions rich in potash and iron. Some vein material (sample 185B) occurring in the area was examined in thin section and this supports the above metasomatic origin for the microcline, muscovite and haematite. The roughly gneissic texture of the country rocks has been produced by subsequent metamorphism.

The polished sections (63W-2, 63W-3) give further evidence in support of the epigenetic nature of the iron. Apparently the iron rich hydrothermal solutions were introduced along fractures in the quartz and crystallised in these confined spaces to form acicular haematite (specularite). A few anhedral grains of pyrite and several box works structures formed of goethite were observed. Thus the original gangue probably consisted of quartz-specularite-pyrite, but the latter mineral has now mainly decomposed leaving relicts (boxworks structures) as to its former existence. The gold was apparently closely associated with the pyrite, but none was observed in these specimens. However, it is believed that in areas of strong pyrite mineralisation (if they exist) the information would be much more rewarding.

Much of the haematite in the gangue material has become concentrated into layers, giving it a banded appearance. This apparently occurred during the later metamorphism which affected the area as a whole.

(b) Industrial Rocks

Several of the quartzitic sandstone formations have been quite extensively quarried in the past. In most cases they are readily accessible but reserves of the better quality, harder quartzitic material are probably low. However, quite large reserves of the more friable, feldspathic sandstone (samples 5, 10) still exist which could have some use as a road metal.

A reasonably large clay deposit occurs in the area. It consists predominantly of kaolin and although much material has been extracted, moderate reserves still exist. However, the clay is often sandy in part which would seriously limit its value.

The talc deposit in the railway cutting (samples 151A, 151B) appears worthy of further investigation. However, its association with brown clayey matter suggests that the talc may contain too high a percentage of impurities for commercial exploitation.

VI. DISCUSSION AND CONCLUSIONS:

In the light of the preceding evidence several conclusions regarding the petrogenesis of the rocks in the area may be advanced.

(1) The Gneissic Granite.

Evidence with a strong bearing on the origin of the granite is as follows.

(i) The granite forms elongated bodies which parallel the foliation of the country rock.

(ii) Its contacts with the surrounding schists appear to be gradational.

(iii) The predominance of microcline feldspar in the granite and its absence in the surrounding schists.

(iv) The plagioclase in the granite and surrounding schists have approximately the same composition (albite, containing 4-8% An).

(v) The biotite in the granite appears to be identical with that in the schists.

Thus there is little evidence to support an igneous origin but many factors suggest a metasomatic - metamorphic origin involving the introduction of solutions rich in potash and soda. Hence it is suggested that these rocks are the result of granitisation of the original sediments. They are thus of the same age as the surrounding rocks (Lower Proterozoic) and not Archaean as indicated by Thomson and Horwitz (1962).

(2) Quartz-talc Rocks

The complete lack of any preferred orientation within the grains constituting these rocks, suggests that the metasomatism occurred as a last stage of alteration. Any subsequent metamorphic effects were only very mild.

The intimate association of albite and talc occurring in some of the rocks indicates that they may be genetically related. Thus it is suggested that reaction between the sodic solutions and biotite (rich in the country schists) could have formed the albite and talc according to the following equation.

Biotite + Quartz + Soda --➢ Albite + Talc + Potash + Iron

This is supported in the Banksia mining area, where haematite is often closely associated with muscovite and is of epigenetic origin involving reaction between solutions rich in potash and soda.

The regional metamorphism is represented generally by the Lower to Middle Greenschist Facies, with upgrading effects occurring in the vicinity of areas of metasomatic alteration.

A survey of the old mining sites occurring in the area revealed little of interest. The gold was introduced in quartz veins which were often involved in later brecciation. Most of these have been thoroughly prospected over a period of several years, even after the main lodes had been worked out, and the results were not encouraging. Thus it is believed that the gold remaining would certainly not constitute economic quantities. However, any strong pyrite mineralisation occurring in the vicinity of the Banksia mine would be worthy of further investigation.

ACKNOWLEDGEMENTS

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A P P E N D I X

Petrological Descriptions

All the samples referred to in the text have been studied in detail, but only certain selected descriptions are included here. These have been filed with the prefix 63W.

1. General Stratigraphy.

Aldgate Sandstone.

Sample 87.

MACRO: A coarse grained yellowish coloured sandstone in which large quartz grains are embedded in a finer grained sandy matrix. It is somewhat porous and massive, without sign of bedding.

MICRO: Quartz 80%. A fine equigranular association of interlocking grains with numerous larger grains up to 1.5 m.m. across. The fine fraction is sub-angular to angular while the larger grains are considerably more rounded. Undulose extinction is common and irregular fractures occur particularly in the larger grains.

Feldspar 15% Mainly plagioclase - multiple twinning common - composition albite (6-7% An) often cloudy - shows some alteration to sericite.

Microcline occurs in lesser amounts - shows cross-hatched twinning.

Muscovite - occasional elongated grains

Hornblende - minor accessory grains

Corundum - " " "

Black opaques - anhedral grains with associated limonite filling intergranular spaces.

Sample 25.

MACRO: A blue-grey slate with a fairly well developed slaty cleavage.

MICRO: Has a well foliated texture formed by abundant black, fibrous carbonaceous material (probably altered to graphite) and micaceous minerals which form a closely knit mesh.

Sericite. Numerous small grains occurring throughout the mesh having a preferred oreitnation.

Chlorite. Occurs in minute flakes intimately associated with the sericite.

Muscovite. Several larger elongated flakes occur sometimes inclined to the foliation direction.

Limonite. Fibrous irregular bands occur throughout the mesh.

Quartz 60%. Equi-granular grains filling spaces in the mesh network.

The grains are often elongated in the preferred direction and are largely recrystallised.

Indicates Lower Greenschist Facies of metamorphism.

Sample 126A.

MACRO: A medium grained greenish coloured, well metamorphosed rock. The green minerals are more or less segregated into layers giving the rock a semi-banded structure.

MICRO: Tremolite 30%. Occurs as columnar and fibrous aggregates.

Talc 10%. Several well formed grains - others anhedral and could be alteration products from the tremolite.

Plagioclase 55%. Constitutes bulk of ground mass as interlocking xenoblastic grains - it is cloudy with minute inclusions. Composition is albite (4% An).

Quartz 5%. A few grains occur in the groundmass.

The radiating crystals of tremolite indicate a metasomatic origin rather than normal metamorphism. Thus the rock probably represents metasomatism of an original calcareous rich sediment, causing the formation of tremolite in preference to talc.

Sample 75.

MACRO: A grey, well laminated micaceous siltstone, having a well developed crenulation cleavage.

MICRO: Biotite, Muscovite } 50% These minerals are intimately associated forming parallel layers which have been crenulated forming the crenulation cleavage. This cleavage was probably formed before metamorphism ceased, since the micas occur as well formed grains and are not bent by the crenulation.

Quartz 40%. Constitutes the bulk of the recrystallised ground mass.

Plagioclase 5%. Scattered grains occurring in the ground mass. Composition - albite.

Tourmaline 3%. Scattered semi-elongated grains usually more or less parallel to the foliation of the micas.

Sample 106A. Mica-schist material obtained from bore hole 0 to 170 feet.

MICRO: A well foliated rock having abundant micaceous minerals with a preferred orientation occurring throughout a quartz-feldspar matrix.

Quartz 40%. Constitutes bulk of groundmass and shows marked evidence of recrystallisation.

Feldspar 10%. Appears to be albite. Very cloudy and shows alteration to sericite.

Biotite 25%. Occurs in fibrous masses of elongated cleavage flakes.

Muscovite 10%. Elongated flakes closely associated with the biotite.

Chlorite 5%. Forms around edges of biotite grains.

Tourmaline. Several aggregates occur. Appears to have grown in place and is not detrital.

Kyanite. Numerous broad elongated grains occur scattered throughout - often closely associated with the micaceous minerals.

Corundum. Several blue grains occur. These are uniaxial negative as distinct from the kyanite (biaxial).

Apparently the quartz and corundum are stable together under certain temperature and pressure conditions.

Rutile. Several small prismatic grains occur.

Black opaque iron minerals occur in exonblastic grains with minor amounts of limonite.

The opaques are often closely associated with the chlorite.

A quartz-mica schist, in which the normal metamorphic facies has been upgraded by the formation of kyanite.

2. The Granitic Gneiss.

Sample 191

MACRO: A coarse grained, roughly gneissic rock with biotites occurring in a pinkish coloured matrix of quartz and feldspars.

MICRO: Plagioclase 15%. Grains often cloudy and altered to sericite and sometimes slightly bent. Occurs as sub-hedral grains intimately associated with quartz. Multiple twinning usually not well developed. Composition is albite (8% An).

Microcline 35%. Anhedral grains often closely associated with the quartz. Cross-hatched twinning not well developed.

Biotite 5%. Scattered, fibrous aggregates greenish in colour, often partly altered to chlorite.

Muscovite 2%. Associated with the biotite.

Opaque Minerals. Anhedral grains associated with the biotite.

Zircon. Scattered rounded aggregates.

Quartz 40%. Anhedral grains - often recrystallised forming coarser grained areas.

The microcline and plagioclase often contain rounded quartz inclusions, indicating replacement, of the quartz during metasomatism.

3. Pegmatites.

Sample 145.

MACRO: A pale coloured, coarsely crystalline rock consisting of quartz and two varieties of feldspar.

MICRO: The slide consists predominantly of feldspar intimately associated with quartz.

The feldspar is of two types, representing two generations.

Albite. Subhedral grains, often cloudy and contain inclusions of quartz. Has well defined multiple twinning and contains about 7% Anonthite.

Some of the grains show obvious bending.

Orthoclase? Anhedral grains - very cloudy containing much opaque dusty material. It could be microcline without the development of cross-hatched twinning.

It appears that the plagioclase and much of the quartz were formed during late stage metasomatism, partly replacing the orthoclase of the country rock.

4. Quartz-talc Rocks.

Sample 97A.

MACRO: A weathered, pinkish coloured quartz-talc rock containing irregular bands and blebs of brown limonitic material.

MICRO: Consists of abundant anhedral quartz grains associated with scattered concentrations of talc fibres and minor amounts of limonite.

Several sub-hedral quartz grains occur often with rims of brown impurities, which have been included during crystal growth as recrystallisation of the anhedral, country-rock quartz proceeded.

The talc often occurs along the intergranular boundaries and fills fractures within the quartz. It may thus be interpreted as replacing the quartz, although this is controversial.

5. Coarsely Crystalline Quartzite.

Sample 98A

MACRO: A buff-coloured coarse grained quartzite.

MICRO: Consists of quartz grains - often partially recrystallised and minor amounts of muscovite.

The quartz grains show two distinct sizes.

The finer grains are probably of original sedimentary origin and are associated with oriented muscovite occurring along the foliation planes.
The coarser grains are probably secondary and occurred during introduction of the siliceous fluids forming the veins.

The rock is thus a hybrid between introduced silica and original sedimentary silica.

6. Quartz - feldspar - hornblende schist (sample 210)

MACRO: A fine grained, greenish-black schistose rock.

MICRO: Hornblende 35%. Greenish in colour - pleochroic, occurs as columnar aggregates having a roughly preferred orientation forming a network throughout the slide.

Feldspar, 60%: Undetermined - since completely untwinned. Contains some quartz inclusions and exhibits zoning and cleavages. Probably plagioclase.

Quartz: Anhedral grains - equigranular association appears to be in excess of the plagioclase.

Opaques 5%. Anhedral grains scattered throughout, associated with some limonite.

Origin of this rock obscure - possibly a metamorphosed microtonalite.

7. Fault Breccia.

Sample 118A.

MACRO: A blue - grey coloured, brecciated shale.

MICRO: The slide consists of abundant fine grained quartz associated with sericite, chlorite and carbonaceous material.

The rock has been severely brecciated and filled with secondary calcite and minor amounts of limonite.

8. Tectonic Breccia.

Sample 95A.

MACRO: An agglomeration of elongated and angular quartz grains - the intergranular spaces being filled with limonite.

MICRO: The slide consists of large angular grains of quartz, containing numerous fractures and well developed undulose extinction which indicates severe strain in a preferred direction. The grains and often elongated in this direction and separated by large areas of finely granulated quartz fragments, which are the result of crushing during shearing. Limonite occurs throughout but is more concentrated in the fine grained areas.

9. Banksia Mining Area.

Sample 185D.

MACRO: A pink coloured, quartzitic rock with poorly developed gneissic texture.

MICRO: Quartz 60%. Anhedral grains, partially recrystallised. They are often fractured and show undulose extinction.

Muscovite 20%. Elongated grains - mainly having a random orientation.

Microcline 10%. Anhedral cloudy grains - contains inclusions of quartz.

Opaques 10%. Probably haematite. Anhedral and sub-hedral elongated grains (specularite) occur and are usually confined to the muscovite rich areas and appears to be contemporaneous with it.

The rock presents evidence of feldspathisation, whereby the microcline is replacing the quartz.

The rock is thus of metasomatic origin, with mild metamorphic effects occurring at a later stage.

VL. General views of the Warrakilla Mines.

Top - looking east from the road.

Bottom - looking north from the road.

some of the openings are still accessible. Several partly ferruginous quartz veins up to 6 inches thick, are exposed in the walls of these workings. The shales strike at about 20° and dip 30° to 40° east and the veins although striking about the same have a much steeper dip eastwards.

The shales (sample 2B) consist of abundant limonite associated with chlorite, sericite and occasional muscovite flakes, forming a fibrous network throughout which numerous anhedral quartz grains occur. The limonite appears to be derived from the opaque iron oxides (haematite) and several euhedral relicts suggest the pre-existence of pyrite.

The lode material (sample 2A) consists of angular quartz fragments occurring in a fine grained matrix of iron oxides and clay minerals. It is suggestive of an epigenetic quartz vein which has been affected by subsequent brecciation. Several samples of this material were crushed and panned with a prospector's dish. However, no traces of gold were observed.

(ii) Banksia Mines.

Several shallow shafts occur on the side of a small hill, just above one of the outcropping gneissic granites.

According to the literature the gold was obtained from a series of more or less parallel leaders striking north-east and south-west and dipping at 45° to the south-east. The veinstone consisted of quartz, cellular and ferruginous iron oxide, and micaceous iron. The ore averaged about 10 dwts to 1 ounce of gold per ton but assays of pyrites from this claim gave much higher yields - varying up to 10 ounces of gold per ton.

In view of this the area was searched for pyrite mineralisation, but only a few very small grains were observed occurring in the quartz-iron rich lode material (see later).

The rocks in the area (samples 185C, 185D) are of metasomatic-metamorphic origin. They consist predominantly of quartz, muscovite, which is often closely associated with haematite, and

VII. General view of the Banksia Mines looking up hill in an easterly direction.

GEOLOGICAL MAP

MYLOR OAKBANK AREA

STRATIGRAPHIC SEQUENCES

CAINOZOIC — QUATERNARY Recent

Qrs — Alluvial flood plains.

UPPER TERTIARY Pliocene

Tpf — Lateritised gravels and sandstones.

PROTEROZOIC — SERIES

SEQUENCE EAST OF INFERRED FAULT

Sandy schists and laminated quartzitic sandstones.

Alternating quartzitic sandstones and grey well laminated micaceous siltstones.

Poorly exposed sandy schists and phyllites with thin quartzites near the base.

Blue grey carbonaceous shale in part dolomitic.

SEQUENCE WEST OF INFERRED FAULT

LOWER — TORRENSIAN

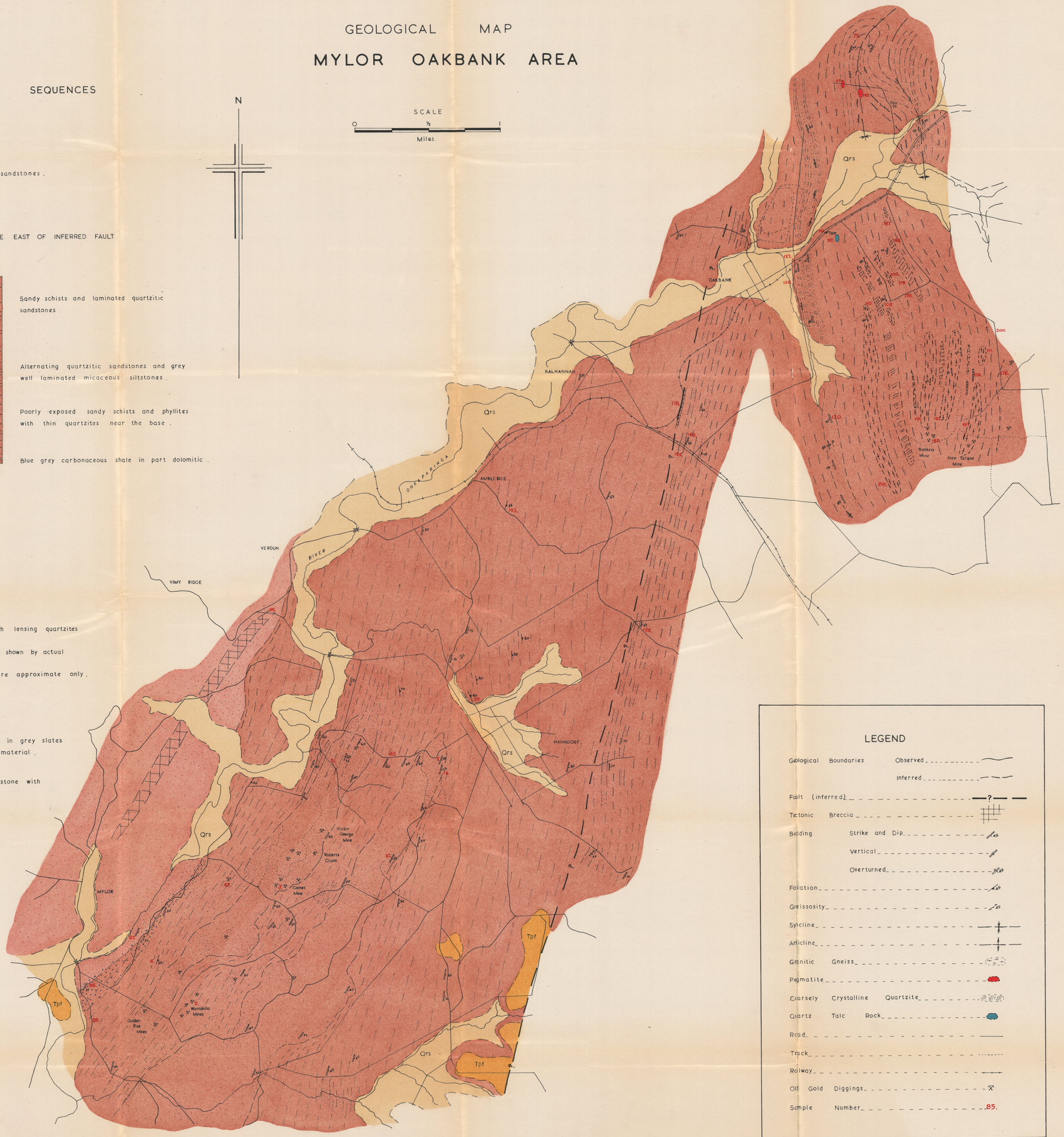
Mainly slates and shales with lensing quartzites and thin sandstones.
Exposures occur only where shown by actual measurement.
The structural trends are approximate only.

Blue grey cherts dispersed in grey slates and siltstones and as float material.

Aldgate Sandstone.
Principally feldspathic sandstone with interbedded sandy shales.

N

SCALE
0 ½ 1
Miles.



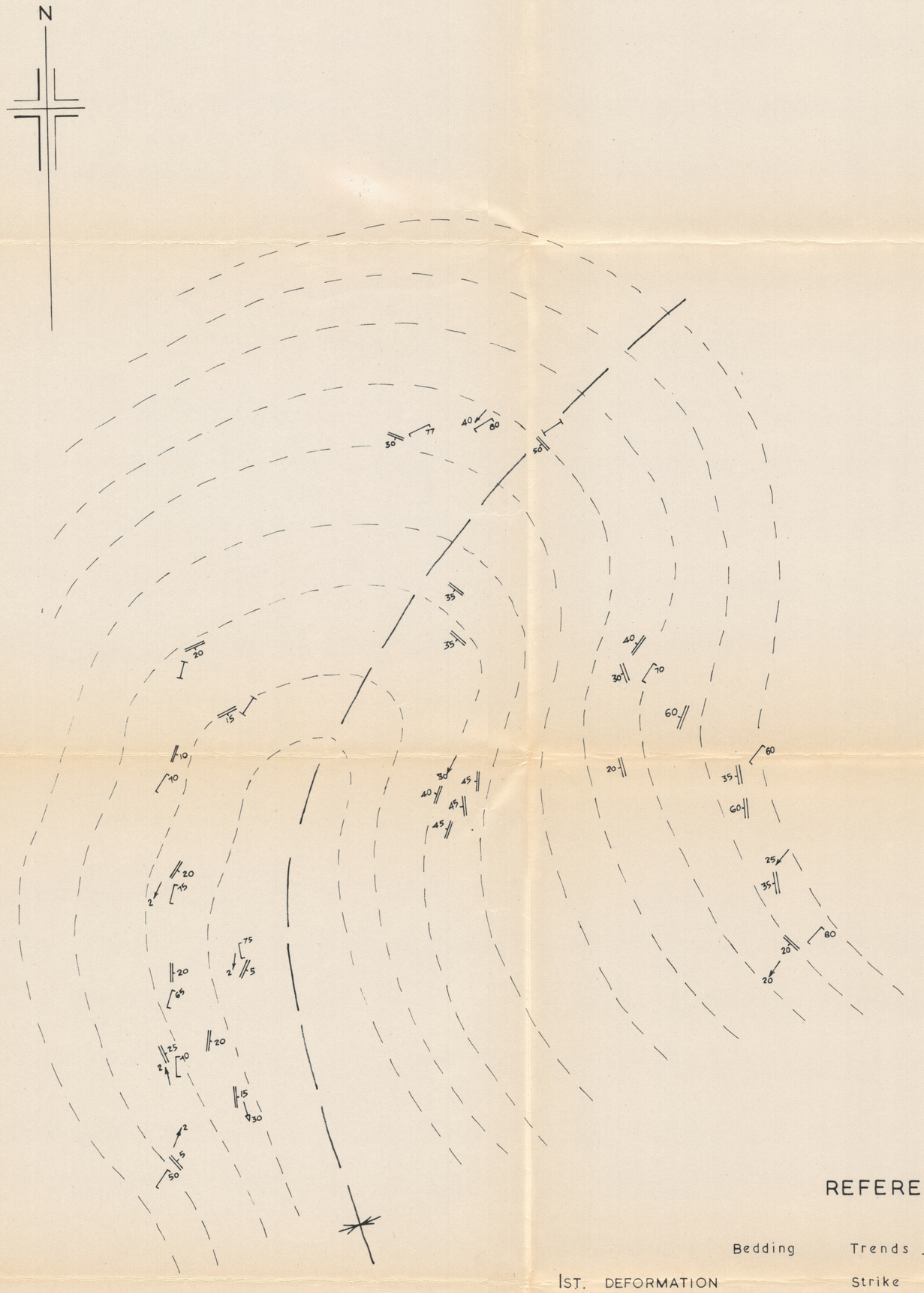
LEGEND

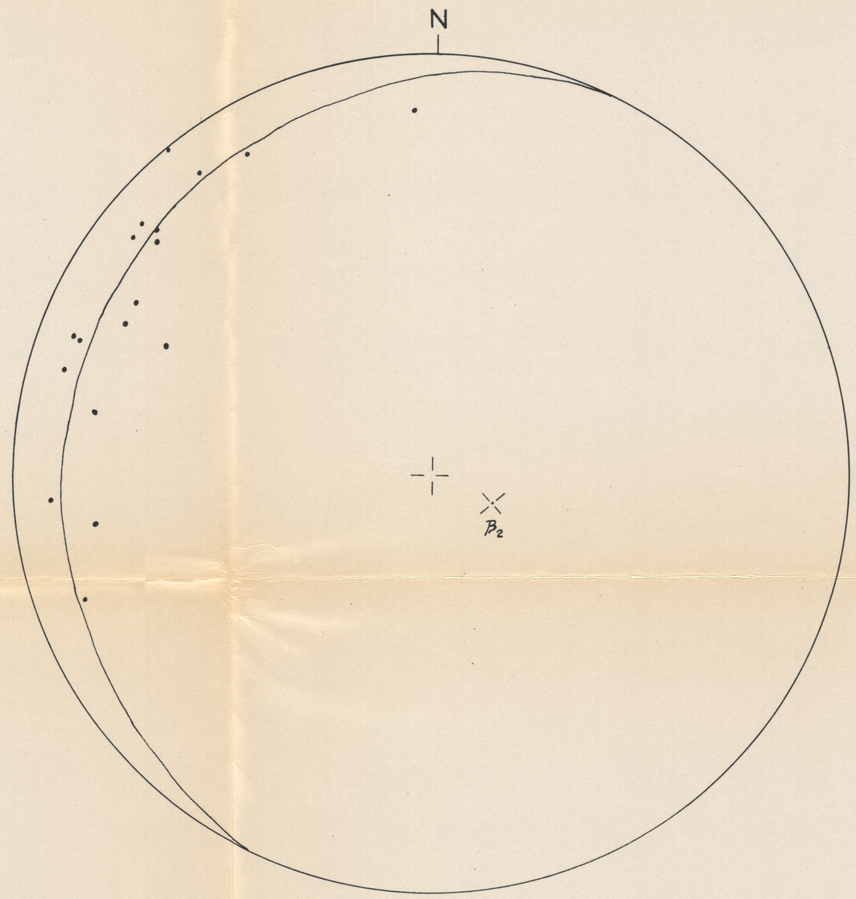
- Geological Boundaries — Observed
- Inferred
- Fault (inferred)
- Tectonic Breccia
- Bedding — Strike and Dip
- Vertical
- Overturned
- Foliation
- Greissosity
- Syncline
- Anticline
- Granitic Gneiss
- Pegmatite
- Coarsely Crystalline Quartzite
- Quartz Talc Rock
- Road
- Track
- Railway
- Old Gold Diggings
- Sample Number — 85.

R.L. Wildy.
1963

DETAILED SURVEY

NOSE OF FOLD N.E. OF OAKBANK





Equal area projection of poles of axial plane cleavage measured around nose of fold opposite .

β_2 = Fold Axis of 2nd Deformation .
Plunge = 77°
Trend = 115°

REFERENCE

1ST. DEFORMATION

- Bedding Trends
- Strike and Dip 20
- Axial Plane Cleavage
  - Strike and Dip 60
  - Vertical
- Lineation 25
- Plunge of Small Scale Fold Axis 30
- Trace of Axial Plane
- Syncline

APPROXIMATE SCALE

0 50 100 150

YARDS

2ND. DEFORMATION No Data Recorded .

R.L.Wildy.
1963