GEOLOGY AND STRUCTURE OF THE NORTH-WEST PORTION OF THE CAMERAI SHEET

P. G. MILLER, B.Sc.

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Department of Economic Geology
Supervisors: E A Rudd, B Campana, P S Hossfeld

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INTRODUCTION

1. Explanation

The following report is submitted as a thesis for part of an Honours Economic Geology Course. It is a report on a test area allotted as an exercise in field mapping, structural interpretation and aerial photograph interpretation.

2. Location

The area mapped is situated approximately fifty miles by road north-east of Adelaide, in the Hundreds of Moorooroo and Jellicoe, comprising the upper portion of the Cambrai Military Sheet. It consists of a rectangular strip four miles long by fourteen miles (See Locality Map Fig. 1). Keyneton is situated in the centre of the area, which extends approximately seven miles east and west, and two miles north and south of the town. The nearest town of any importance is Angaston, which is four miles north of the upper limit of the area.

3. Method

For the interpretation of the area a combination of ground traverses and aerial photographic interpretation was used. A base map was made by constructing a slotted template of the photographs. By combination with survey trig point controls, scale and orientation could be obtained. The creeks, roads, and townships were then traced directly off the photographs, allowances being made for distortion. The geology was plotted directly onto the photographs and then traced onto the base map, which was drawn on "Kodatrace".

Traverses were made along creek beds and on the ridges, but in many parts, particularly on the western side of the area, there was a scarcity of outcrop and systematic traversing was

impossible. The eastern portion, west of Keyneton, was more rugged country, however, the creeks in particular being almost solid bedrock. The strike of the beds generally being north-south, most of the traverses were made along an east-west line although traverses were of necessity made in other directions.

As well as ground traversing, the aerial photographs were studied under a stereoscope as an aid in structural interpretation. This was successful in certain areas, but on the whole little was determined owing to the unsuitable type of country, and in some cases poor photography. Some of the tight folding, almost indiscernable on the ground, was visible on the photos. The stereoscope was also necessary to plot in many of the creeks which were not visible on the photographs.

All bearings were taken with a prismatic compass and then plotted onto the main sheet, the magnetic variation of approximately five degrees east being added onto the readings.

PHYSIOGRAPHY

Both mature and youthful topographies are present in the area. West of Keyneton it is essentially of a mature nature, averaging 1200 feet above sea-level, with remnants of the old peneplained surface preserved as iron capped hills with an elevation of 1450-1500 feet. The creeks in this area are of the semi-dendritic type, possibly superimposed, with wide open valleys and meandering courses among alluvial flats. Although at present they do in the main favour the softer varieties of rocks, they do cut across harder bands, and although the regional pitch is south in this area, the Tanunda Creek and Flaxman's Valley drain northward, and cappings of gravels containing water worn boulders are found on the higher grounds adjoining the creeks indicating that the courses are similar to that of the old Tertiary rivers. The Somme River drains southward in the softer rocks for a time, but later cuts into harder beds, flowing against the pitch, though it tends to follow the contact between a schist and sandstone.

Further westward in the vicinity of Polnera Trig, the country is of a more youthful type, but signs of maturity are still present in the cappings of gravels and wide alluvial plains, and possibly the streams have been rejuvenated by the Tertiary uplift.

East of Keyneton the topography is youthful with steep gorges and deeply incised creeks flowing in an east-west direction. The hills form a ridge running north-south with an average elevation of 1400-1450 feet, dropping rapidly to 500 feet towards the plains to the east. The drainage is of the trellis type, with Gipps Trig being on the water divide which is probably moving westward with the erosion of the fault scarp. East of the trig point the creeks flow eastward towards the plains through a series of gorges and waterfalls in the upper reaches, and generally cease to flow in the sandy soil at the base of the fault scarp. West of the

trig point the creeks drain westward into the Somme River, although they are not as deeply incised as those to the east, due possibly to the shallower dip of the beds and softer nature of the rocks.

East of the Murray Range Fault there is a flat almost featureless plain known as the Murray Plains. The creeks from the hills to the west rapidly lose their water in the soil of these plains, and only flow after heavy rains.

The country around Keyneton is almost entirely cultivated, only the higher barren hills remaining untouched. Further north around Angaston vineyards are common, but near Keyneton the land is used for cereal cropping or for grazing. Trees are not plentiful in this region as most of the country has been cleared, but occasional large red gums are seen. Further east, on the west slopes of the Sedan Hills, timber is more plentiful with red gums, acacias, and occasional sheoaks. On the eastern slopes of Sedan Hills the country is very bare, only occasional sheoaks being found on the hills, with good red gums lower down in the sandier creek beds. This land is not cultivated at all, being used for sheep raising. The Murray Plains have very little vegetation, the only trees being found in the creek beds. The land has been cleared for wheat growing.

PREVIOUS INVESTIGATIONS

The only published report on this area is that by P.S. Hossfeld in 1934, whose paper "The Geology and Physiography of part of the North Mount Lofty Ranges" included the area mapped by the writer. He allotted the rocks of the area to the Adelaide Series (now System) and called them the Narcoota Series. The slates and schists to the east of Sedan Hill he classified as Tapley's Hill Slates on the basis of glacial erratics found further to the north. No evidence of glacial activity was found in these beds by the writer, and although no attempt was made to correlate the beds with those further north, the rocks are believed to be of shallow water origin of the normal sedimentary type.

A number of unpublished reports on the area are available however and R. Sprigg of the S.A. Mines Department has classified the rocks to the east of the Mount Lofty Ranges as Kanmantoo Series of Cambrian to Ordivician Age. His conclusions are based on work much further to the south, and as the results of his work have been carried so far north the correlation may not necessarily hold.

J.D. Campbell in 1947 mapped the marbles around Angaston for the I.C.I. Alkali Proprietary Limited, and although his area does not include that mapped by the writer it lies directly to the north, and his structural interpretations, while extremely complicated, do serve as a guide to the main structure.

In 1951 the southern half of the Cambrai Military Sheet was mapped by Messers. Harms, Rowley, Markham and Kaewbaidhoon, as part of their Honours Degree. Their areas lie directly to the south, and although disagreements occur as to some of the structure and stratigraphy, the nomenclature adopted by them has been used in this report wherever applicable. They tentatively classified the beds as Kanmantoo Series, although Rowley, on the basis of greater metamorphism placed them below the Adelaide System.

The adjacent area to the west has also been mapped by Dr. Campana of the Mines Department but his report is not yet available. The geology was discussed with Dr. Campana and the views obtained by the writer appeared to substantiate Dr. Campana's ideas which were based on work to the west in the Gawler sheet, and much further to the south in the Milang sheet. The most important fact gained from this discussion was that the marbles and calcareous beds were placed below the Kanmantoo Series, being correlated tentatively with the Cambrian limestone at Rapid Bay.

Concurrently with the writer's investigation the area to the north was mapped by R.D. Pratten, and correlation between the two areas was obtained.

GEOLOGY

1. General Geology and Stratigraphy

The rocks of the area are all shallow water marine sediments formed in littoral to neritic conditions, and metamorphosed to a great extent as a result of deformation and granitisation, the latter being especially prevalent in the areas to the south, though very little was noted in the area mapped. The sediments consist of fine grained quartzites, sandstones, sandy schists, mica schists, limestones and marbles, all extremely deformed to produce a series of tight folds with the incompetent beds producing complex minor folds in the noses of the main folds. The remarkable uniformity of the sediments throughout such a great thickness, and the fact that they are well bedded, indicates a special condition for deposition, possibly deltaic, and current and storm bedding are common, especially in the more siliceous varieties, although much of it may have been destroyed by dynamic metamorphism in the more argillaceous types.

The sediments in the area have been divided into three main groups: the Saunders Creek Formation, the Pine Hut Formation and the Eden Valley Formation. The Saunders Creek Formation which is composed of fine grained mica schists, limestones and marbles, is classed tentatively as Cambrian, corresponding to the Archaeocyathinae limestone at Sellick's Hill, and therefore not part of the Kanmantoo Series which represents a facies change, and lies conformibly on the calcareous beds. Fossil evidence is lacking in the Saunders Creek Formation, as is also the case at Rapid Bay, but in the opinion of the writer correlation can be made because in all cases the sandy Kanmantoo Series lies directly above the calcareous beds, and nowhere is it found in any other position.

The Pine Hut Formation which is composed of fine grained quartzites, sandstones, and micaceous sandstones, is therefore the basal formation of the Kanmantoo Series overlying the Saunders Creek Formation. The break between the Kanmantoo Series and the Cambrian, indefinite though it is, can therefore be shown as a facies change, a fact which is noticed in all other localities, whereby the calcareous and argillaceous beds are overlain by the arenaceous type.

Above the Pine Hut Formation lies the Eden Valley Formation, which is composed of sandy biotitic schists with occasional quartzitic bands. The boundary between the two formations is not sharp and has been arbitrarily chosen on lithological grounds.

These formations are the only old sedimentary rocks in the area, but also present are some alluvial gravels, limonitic cappings, clays and sands, which are most likely Tertiary in age, representing remnants of what may have been more extensive deposits. East of the Murray Range Fault the Murray Plains are underlain by late Tertiary (Miocene or younger) limestones, which are however covered by soil and no outcrop can be found, but that a considerable thickness is present is shown by the various bores which have been sunk in search of water.

Although the nomenclature of the investigators who mapped the areas to the south has been adopted wherever possible, several important differences occur. A formation which had been called the Keynes Gap Sandstones was considered by the writer to be identical with the Pine Hut Formation, owing its position to anticlinal folding. The previous investigators had also divided the Pine Hut Formation into two sections, the other being the Somme River Micaceous Sandstones, but both R.D. Pratten and myself consider that there is no real boundary between the two and that there is merely a change from the bottom upwards, the beds becoming less micaceous and more massive towards the top of the formation.

The stratigraphic column advocated by the previous workers has also been revised. At the base of the Kanmantoo Series they had placed the Eden Valley Group, with the Saunders Creek Formation higher up in the sequence, whereas R.D. Pratten and myself placed the Saunders Creek Formation below the Eden Valley Formation, and the writer believes them not to be part of the Kanmantoo Series, but lying conformibly below it. This difference was probably brought about by the previous workers' different structural interpretation of the western side of the military sheet, a fact which will be discussed later under structure.

The sequence in the area mapped can then be summarised in the following table:

Recent to Present

Alluvium and some river gravels, both consolidated and unconsolidated.

Tertiary:

Limestones (inferred beneath Murray Plains) lateric cappings, clays, sands, river gravels.

Palaeozoic:

(Cambrian to Ordivician)?

Kanmantoo Series:

Eden Valley Formation: Sandy mica schists.

Pine Hut Formation: Quartzites, sandstones and micaceous sandstones.

Cambrian ?

Saunders Creek Formation: Marbles, limestones, schists, phyllites, slates.

The above summary is tentative, and is based on correlation with other areas, and the formations in the area can only be definitely regarded as post-Adelaide System, early Palaeozoic in age.

PETROLOGY AND DISTRIBUTION OF THE FORMATIONS

1. Sedimentary Rocks

These beds comprising almost all of the area mapped will be discussed from the base upwards.

(a) Saunders Creek Formation

This formation, classed tentatively as Cambrian, consists of the following rock types:

i Marbles

These range from coarse grained crystalline types to the finer grained impure type which grade into limestones. They consist of white, pink, or green-blue calcite crystals often ironstained with quartz, biotite, muscovite, magnetite, limonite and other accessory minerals. Even when completely recrystallised traces of the original bedding are usually present in the form of banding.

Occurrence: They occur as lenses among the schists, and when found appear in a very contorted state due to flowage. They do not appear to be a continuous bed throughout the formation, usually only occurring in the noses of minor contortions. Due to their soft nature they do as a rule outcrop strongly except in the creek beds, but isolated occurrences of small hills of marble were reported in the area mapped by R.D. Pratten. Their presence is usually indicated by well grassed depressions or by Kunkar capping and often the weathering leaves a residual capping of quartz which is usually porous in nature, sometimes with well formed crystals. The marbles are not well developed on the western portion of the area mapped, being found only in isolated outcrops, the main marble beds being further north. In the eastern portion, on the eastern slopes of Sedan Hill, marbles occur as a well defined band running N-S, approximately two miles east of Gipps Trig.

and appear to be favourable for mineralisation as several small mines occur in the locality. A further band is found a mile to the east of this band, and again there are several small mines situated on it, with traces of mineralisation very common.

ii Limestones

These are similar in many respects to the marbles and possibly the marbles are a purer recrystallised form. They are fine grained grey rocks, consisting of small crystals of calcite, quartz, biotite, muscovite, magnetite and limonite. They grade into marbles in several places and into quartzites in others, probably being a variety of calc-arenite as they usually contain a lot of silica.

Occurrence: The limestones occur associated with the marbles, and like them form a kunkar capping. They do not appear to be as soft as the marbles, and so do not form the pronounced depressions. Possibly the leached quartz associated with the marbles results from the weathering of these limestones, as they contain a considerable amount of silica, and weathered specimens are almost a friable sandstone. As with the marbles they are not prevalent in the western portion of the area, being found mainly east of Gipps Trig Point.

iii Schists (Including slates and phyllites)

These are fine grained grey to black micaceous schists, phyllites, and slates, often banded. They consist of muscovite, biotite, and quartz, and have been considerably metamorphosed. This degree of metamorphism is greater on the western portion, west of the Somme River Shear, possibly because of the greater amount of contortion that has taken place. The slates and phyllites, which occur east of the East Limb Fault are not found in the western portion, possibly because the schists are the more

metamorphosed varieties, the series progressing slates-phyllites-schists. Knotted schists are found further north and south of the area, as reported by other investigators, occurring especially in the noses of the folds, but none of this variety was found by the writer. The andalusite schists reported by the workers to the south, do not occur in the area mapped.

Occurrence: These beds are very soft and as a result weather very easily and outcrops, especially in the western portion, are scarce. When found, the rock is usually very weathered and difficulty was encountered in obtaining a fresh specimen. They are often very calcareous, especially in the regions of the marble, and a kunkar capping is often formed on the hillslopes. They contain interbedded quartzitic rocks which often metamorphosed to a siliceous hornfels, and form the more pronounced ridges in the formation. The schists are best exposed in the Somme River north-east of Keyneton, although they do not outcrop strongly. The less metamorphosed variety of slates and phyllites occur abundantly east of the East Limb Fault, where the topography is more youthful, and outcrop is plentiful especially in the creek beds.

iv Quartzites

These are dark fine grained siliceous varieties containing both primary and secondary quartz, biotite, muscovite, feldspar and other accessary minerals such as apatite. They are in places a type of hornfels, though in others occur as a normal type of quartzite.

Occurrence: They occur as bands in the schists and marbles and form the more pronounced ridges among the Saunders Creek Formation. They are best exposed west of the Murray Range Fault where a contact between the siliceous beds and a limestone has been a favourable locus for mineralisation.

(b) Pine Hut Formation

This has been regarded by the writer as the base of the Kanmantoo Series. It lies conformibly on the Saunders Creek Formation but constitutes a facies change, the argillaceous beds giving way to arenaceous types, possibly due to an uplift giving rise to increased erosion. The change is not abrupt, and no boulder beds are found; the lower horizons being of the micaceous type becoming more massive further up the series. The rocks are fine grained recrystallised quartzites, with micaceous bands, probably due to shaley beds which have been metamorphosed. The quartzites are composed of quartz, biotite, magnetite, muscovite, and some plagioclase. The weathering of the iron rich biotite and magnetite causes the weathered surface of the rock to assume a reddish colour, but freshly broken specimens are often white. The biotitic layers give the rock a banded appearance, especially in the lower portions, but higher up in the sequence the bands become less frequent, until the rock is a massive quartzite. The biotitic bands appear to be parallel to the bedding, and were taken as bedding direction. Current and storm bedding is common in these rocks with the unreliable storm bedding being more prevalent, making the determination of facings indefinite. In the more massive varieties bedding is scarce, and an unusual feature of these varieties is that much of the tight folding has taken place within their limits, whereas the banded rocks do not show it to such an extent. This is possibly due to the biotitic bands taking up the deformation in the banded rocks, and in one instance a cleavage denoting that the beds had been overturned occurred in the less competent biotite bands, but was not present in the massive quartzite bands.

Occurrence: The Pine Hut Formation forms ridges which stand out in bold relief among the softer varieties. The Sedan Hill is a strong ridge running N-S, the Gipps and Mons trig points being situated on the higher portions. These rocks also occur west

of the Somme River Shear where a synclinal nose is found one and a half miles due south of Keyneton. The beds then swing off the map and return on the western portion near Flaxman's Valley, continuing in a NNW direction towards Angaston.

Owing to their harder nature, erosion has not reached as advanced a stage in these rocks as in the softer varieties, and in these beds the creeks are usually deeply incised with a bedrock bottom and little alluvium. It was noticed also that sharp bends in the creeks were often associated with minor folds, and close examination of the cliff faces produced by the sharp bends usually revealed such structures.

(c) Eden Valley Formation

This formation consists of dark banded sandy schists, containing quartz biotite and muscovite. They weather very easily, and few outcrops are found, and even then only more resistant bands occur. The specimens obtained were all extremely weathered and soft, but showed the siliceous nature of the rocks. The beds occur only in south west portion of the area near the Tanunda Creek where they are covered by alluvium. They lie above the Pine Hut Formation but the boundary as shown on the map is extremely indefinite owing to the gradational nature of the change and the lack of outcrop, topography being used as the main indication of the boundary.

(d) Tertiary (?) Rocks

These consist of river gravels, and yellow, red and purple sands, situated on the higher portions and are probably of fresh water (alluvial) origin, as no fossils were found. They constitute the remnants of what may have been more extensive deposits which have been since removed.

Beneath the Murray Plains Tertiary marine limestones occur, but do not outcrop, being found only in bores.

(e) Recent to Present

These are alluvial sands found in the more mature rivers, and river conglomerates which are found in the creeks at the base of the Murray Range Fault scarp.

2. Igneous

Igneous activity although prevalent south and west of the area is almost absent in the area mapped. The only igneous rocks were found in the extreme southern portion of the area. Although granitic boulders were found, no outcrops were seen. The rock types noted were as follows:-

(a) Dolerites (Amphibolites)

A dolerite dyke or plug was found in the nose of the syncline just east of the Somme River, among the beds of the Pine Hut Formation. It is a dark fine grained rock with a typical doleritic ophitic to sub-ophitic texture. On microscopic examination it was seen that the pyroxene has been completely altered to green amphibole, although some pseudomorph textures were retained. The feldspar appears little altered having the composition of Andesine. No signs of scapolitization were present. The age of the dolerite is uncertain but is probably post folding, contemporaneous with the metamorphism.

(b) Pegmatite

A lens of coarse grained pinkish pegmatite was found in the southern portion of the area one mile east of Flaxman's Valley. The pegmatite is composed of quartz, feldspar and micas but owing to the weathered nature of the specimen no thin section was made. The pegmatite occurs interbedded with the country rock, following the bedding in every detail, and appears to be a replacement, as no signs of fracturing or deformation were present, although the contact between schist and pegmatite was fairly sharp.

(c) Quartz Blows

These are fairly common throughout the area, particularly in the noses of the folds. In some of the blows traces of mineralisation were present and although these indications were slight, there may be greater mineralisation at depth. The most noticeable example is the Conical Hill Trig point, a mile from Keyneton in the direction of Angaston, just north off the main road. The blows appear to be hydrothermal in origin, possibly

related to the granitization, their present position being related to lines of weakness.

3. Miscellaneous

(a) Residual Lateritic Cappings

These occur as limonitic capped hills, formed apparently on the old peneplaned surface, as they have a similar elevation of 1500 feet above present sea level. They are composed of limonite with some hematite and quartz, and are underlain by pockets of clay and weathered shaley country rock. The cappings do not appear confined to any particular horizon but in the area mapped occur only over the Saunders Creek Formation. Mica crystals are common in the cappings and seem to indicate that the iron has been dissolved and then reprecipitated as limonite by a process of upward leaching, the joints of the rock being first filled to give a boxwork type of structure.

(b) Kunkar Cappings

These occur over the calcareous beds of the Saunders Creek Formation, and over the Tertiary limestone in the Murray Plains. The kunkar is white compact and nodular, varying in thickness from two to three feet down to less than an inch.

(c) Quartz Epidote Rock

This rock is found as a green banded rock forming beds thirty to forty feet thick, interbedded with quartzites in a south plunging syncline two miles south of Keyneton. The bed has acted incompetently between the quartzites and shows very well developed dragfolding. In thin section it is seen to be composed of quartz bands and epidote bands with some green amphibole and brown biotite, while traces of pyrite mineralisation are present. Lineation is present with the elongation parallel to the beddi ng. The origin is uncertain but the thickness and abrupt boundary with the quartzites suggest a sedimentary origin with recrystallisation, although the bed appears to end against a dolerite, which may have had an influence on its composition.

STRUCTURE

The structure of the area is complex and many difficulties were encountered in the interpretation. This was due mainly to two factors, the regularity of the type sediments, and the lack of outcrop in some regions. Only three main rock types could be distinguished, while the gradational nature of the boundaries and slight variation between the different types made it impossible to follow any particular band, and no suitable marker horizon could be found in the area. Lack of bedding was common, especially in some of the schists and more massive quartzites, and in the schists some of the banding which was taken as bedding was possibly only lineation due to metamorphism. This was especially noticed in the area east of the East Limb Shear, amongst the Saunders Creek Formation, and probably much of the structure in this area was overlooked. Soil creep was noticeable, particularly in the hilly country and departures of as much as 60°-70° from the true dip were encountered, so little reliance was placed on dip readings measured on the hill slopes.

The lack of outcrop and deep weathering effect, which occurs on the western portion of the area, the Tanunda Creek and the Somme River made the interpretation of structure difficult, especially as the structure appeared to be very complex. The form lines shown on the map, although serving as an indication of what the structure may be, can scarcely be taken as what the structure actually is.

It is in the structural interpretation that the most disagreement occurred between the writer and previous investigators and this will be discussed under the separate sections.

1. Folding

The folding in the area can be divided into two main sections, an eastern synclinal sector plunging north, and a western anticlinal sector plunging south, separated by the Somme River Shear.

(a) Eastern Synclinal Sector

This consists of a main syncline with subsidiary anticlines and synclines on the western limb. The eastern limb is cut off by East Limb Fault, the main synclinal axis being one mile west of the fault. Altogether two subsidiary anticlines and one subsidiary syncline were noted on the western limb. The axial planes of these folds strike from 170°-175° and dip steeply to the west at 75°-80°. The eastern limb of the anticlinal folds generally dips at 70° to the east whereas the western limb has a shallower dip of 40°-60° to the west. Some evidence of overturning was found from bedding-cleavage relationships but generally the beds are not overturned, a fact which is confirmed by current bedding. The only evidence of overturning was found just east of Gippe Trig on the eastern limb of the anticline and this may be the only overturned portion in the eastern sector. The folds plunge to the north at 20°-25° and although several instances of a reversal in plunge were noticed, they were of limited extent due probably to crumpling in the noses of the folds.

The rocks between the Somme River Shear and East Limb Fault are all of the Pine Hut Formation consisting of quartzites and micaceous sandstones. In spite of the apparent competency of the beds, however, they behaved more as plastic rocks under deformation, indicating that the folding took place at considerable depth under conditions of high temperature and pressure. In all of the main folds extensive contortion and crumpling occurs in the noses while drag folds are developed on the limbs. This results in a thickening in the noses with a slight attenuation on the limbs, but in spite of so much contortion there is little evidence of shattering which would have occurred if the rocks had behaved competently under the stress.

East of the East Limb Fault the rocks are the finer grained calcareous argillaceous type of the Saunders Creek Formation and have behaved even more incompetently than the

quartzitic beds, tight folding and shearing resulting. Although this undoubtedly occurred as is evidenced by the western part of the area, little sign of folding was noticed and apart from minor structures only one definite synclinal fold was found, the axis lying just east of the East Limb Fault. A doubtful anticlinal fold with the axis just west of the Murray Range Fault was indicated by strike lines from the photographs but was not seen on the ground.

The structure in this sector as advocated by the writer is essentially similar to that proposed by the workers to the south although some of the subsidiary folds were not shown by them as structures of such magnitude.

(b) Western Anticlinal Sector

This consists essentially of a south plunging anticline with a subsidiary syncline just west of the Somme River Shear. The relative difference in competency between the Saunders Creek Formation and Pine Hut formation is well shown here as the folds in the quartzitic beds are more open and regular with less signs of flowage than in the eastern sector, whereas the beds of the Saunders Creek Formation are extremely contorted with much thickening in the noses and attenuation on the limbs. Minor folds appear and then disappear on the flanks, while the axial lines of the folds vary in direction and magnitude.

The axial plane direction of the folds in the Pine Hut Formation is strike 170°, dip 75°-80° west, with a southerly plunge of 40°-60°. This is not always the case in the Saunders Creek Formation owing to the complex folding but the south plunge appears to hold throughout the area.

It is in this sector that the difference in opinion between the writer and the previous investigators occurs. Rowley and Harms, mapping the area to the south had considered the beds as part of a synclinal fold with minor anticlines and synclines on the flanks, although the general trend lines were that of a south pitching anticline, the south pitch although mentioned by

them, appeared to be ignored. The Keynes Gap Sandstones which were designated by them as a separate formation lying below the Saunders Creek Formation were considered by myself to be identical with the Pine Hut Formation owing their position to an anticlinal fold with the Somme River Shear occurring in the fold, the arch of the anticline being eroded away leaving the core of Saunders Creek Formation. The apparent swinging around of the Keynes Gap Sandstones to follow the Saunders Creek Formation can be explained by the hinge shear which causes the nose of the anticline to be to the south on one side of the shear and to the north on the other side of the shear. The swinging around of the Keynes Gap Sandstones is then due to anticlinal fold with a south plunge whereas the swing of the Pine Hut formation is due to an anticlinal fold with a north plunge. There is no necessity for cutting off the Keynes Gap Sandstone by fault as shown by Rowley and Harms, as according to the writer it swings around to the western side of the map in an anticlinal fold, the western limb trending towards Angaston.

2. Faulting

Faulting is not common in the area and even the major faults or shears indicated on the plan are inferred, as there is no visible sign of them on the ground. Probably the only major fault in the area where there has been a clean break is the Murray Range Fault. The Somme River Shear and East Limb Fault are shears where attenuation has proceeded to such an extent that breaking has occurred. Apart from minor faults of small displacement there is no sign of shearing or faulting in the shear directions all the major faults being of the axial plane type with a general N-S strike. The main faults in the area are: (1) Murray Range Fault (2) Somme River Shear (3) East Limb Fault.

(1) Murray Range Fault

This fault occurs on the eastern extremity of the area mapped, and has a strike of approximately 175°. The actual fault zone is not visible on the ground, and apart from a little dragging down of the beds near its supposed location and slight traces of shattering and pyrite mineralisation there are few signs of its effect. A few iron stained breccia boulders are found in the boulder beds of the creeks below the fault but these may have come from a source higher upstream. The fault zone is probably under the alluvium formed by the weathering of the scarp. No estimate of movement is possible but from the topographical effect the relative movement appears to be west side up. The fault is most likely one of the Tertiary block faults which are so common in the Mount Lofty Ranges, but it may be an older fault reopened.

(2) Somme River Shear Zone

This is a zone striking approximately 160°-170°, running parallel to the Somme River and may have had an influence on the course of the river. Again no sign of the shear is apparent on the ground or on the photographs, although it was found that some quartzitic beds of the Pine Hut Formation change along the strike to the schistose beds of the Saunders Creek Formation.

Despite the absence of any sign, the explanation of the abrupt change in plunge which is found necessitates some form of fault or shear. This change of plunge cannot be explained by a crossfold as it occurs across the strike. Although the movement may have been taken up by the incompetent Saunders Creek Formation the change is very abrupt and the zone of shearing cannot be particularly wide, possibly not more than two or three hundred feet. No movement can be estimated, and the position of the pivot of the fault is uncertain, but in the area mapped the movement is east side down and possibly the pivot is further south, the shear being of the scissor type.

The dip of the zone cannot be determined but must be steep as topography has no effect on the trace, and assuming the

shear to be due to the failing of an anticlinal structure, the dip would probably be steeply to the west. The shear is not Tertiary as there has not been sufficient time for erosion to have reached the present stage, but the shearing probably occurred just after the folding, possibly in mid-Palaeozoic times.

This shear was not proposed by Rowley and Harms, who recognised no anticlinal structure along the Somme River, but no attempt was made by them to account for the change in plunge. Another fault striking N-E and running through Keynes Trig was proposed by Rowley and Harms, but the writer found no evidence to support a continuation of this fault into the area mapped.

(3) East Limb Fault

This fault striking 160°-170° lies approximately three quarters of a mile east of Gipps Trig. There is more evidence for this fault than the others previously discussed, as the marbles near the contact are sheared and mineralisation is present. It is also noticed that the east limb of the main syncline in the Pine Hut Formation is not as thick as the west limb, and it is assumed that the east limb has been cut off by the fault along the axis of a minor anticline on the east limb of the syncline. The movement would be east side up with the Pine Hut Formation eroded away leaving the Saunders Creek Formation exposed. The latter is a softer rock type and weathers more easily and so the present topography gives a reverse effect to the actual movement. The dip must be steep, probably that of the axial plane direction i.e. 70°-80° to the west, so that both the East Limb and Somme River Faults appear to represent failing along an anticlinal axis. The fault is not Tertiary in age but was probably formed at the same time as the Somme River Shear i.e. mid Palaeozoic.

3. Jointing

A series of joints are present in the area and can be resolved into a pattern determined by the strain ellipsoid. The tension joint strike 75°-85° is the most common and was used in many cases as a guide in determining plunge. In the eastern sector the joints dip at 60°-70° to the south, but in the western sector have a shallower dip to the north.

The axial plane direction strike 170°, dip 70°-80° west was also very common, especially in the noses of the folds. Two sets of shear direction joints were present, one striking from 40°-60° and being the most common, whereas the other striking from 110°-120° was only developed in certain localities. The variation in strike of these shear directions is probably due to the difference in physical properties of the rock types, and it was noticed that in the more incompetent beds the angle between the axial plane direction and the shear direction was more acute than in the more competent varieties of quartzite.

From the diagram of the strain ellipsoid (Fig. 2), it can be seen that the deformation in the area resulted from an east-west compression and that a series of joints were developed as shown. The faulting in the area is of the axial plane type, although small movements were noticed on the shear directions.

METAMORPHISM

The area mapped does not appear to be as metamorphosed as the areas further to the south which are in the granitisation complex, the intensity of metamorphism decreasing towards the north. No evidence of zoning was found in the area mapped, the metamorphism being fairly uniform. The only variation found was east of the East Limb Fault where Saunders Creek Formation does not appear to be as metamorphosed as it is in the areas west of the Somme River Shear.

The rocks are all recrystallised, but although the folding appears to have taken place at considerable depth the effect of temperature and pressure is not as great as might be expected. East of the East Limb Fault the metamorphism appears to have reached the Albite-Epidote Amphibolite Facies in the Chloritoid Almandine Subfacies. The rest of the area has reached a further stage, passing into the Kyanite Staurolite Subfacies, although the kyanite and staurolite schists reported to the south were not found in the area mapped. The fact that these schists were found to the south shows the increase in metamorphism in that direction.

Except for the quartz blows and dolerites, no evidence of introduced material was found, and the frequent diopside-scapolite rocks found further south do not occur here. The metamorphism is probably a combination of regional metamorphism and the effects of the granitisation, and although the former predominates it is not possible to differentiate the two.

ECONOMIC GEOLOGY

No deposits of economic significance occur in the area mapped, the great marble quarries of the I.C.I. lying further north in the area mapped by R.D. Fratten. Although the marbles do occur in the area mapped, they are not of high enough quality or quantity to be exploited commercially.

Traces of mineralisation, possibly hydrothermal, are found in the calcareous bands in the eastern sector. Several small mines occur in this area, though all except one were old abandoned workings. The mine that was being worked, was a reopening of an older holding, but unfortunately was filled with water and could not be investigated. Examination of the dumps in this area which lies on the East Limb Fault about half a mile north of the Sedan Hill Road, showed galena and sphalerite mineralisation with traces of copper minerals in the oxidised form. Limonite was abundant with occasional boxwork structures, but there was no sign of pyrite. The marble in which this occurs is extremely sheared and slickensided probably due to the East Limb Fault.

Another band of mineralisation occurs a mile east of the first band on the contact between a limestone and quartzite. Oxidised copper minerals were prevalent but no primary minerals were found. The lode appeared to be in the shear direction and consisted of limonite and quartz with copper stains. Several small pits and shafts had been sunk but soon abandoned.

Some of quartz blows in the area contained traces of hematite, but in negligible quantities, although there might be an increase in depth. The residual cappings on the hills contained limonite and hematite, but although several attempts had been made to work them, the country rock below the cappings was soon encountered.

The Tertiary gravels found on the hill tops had also been worked to a small extent, possibly for road metal or aggregate.

GEOLOGICAL HISTORY

1. Deposition of the Saunders Creek Formation under shallow water marine conditions from a stable mature land mass.
2. Deposition of Pine Hut Formation and Eden Valley Formation under shallow water marine conditions with an unstable land mass, due possibly to an uplift.
3. Deep burial under later sediments not revealed in the area.
4. East-west compression resulting in tight folding, followed by axial plane faulting giving rise to the East Limb Fault and Somme River Shear.
5. Intrusion of the dolerites, contemporaneous with or followed by granitisation and development of quartz blows.
6. Uplift above sea level followed by a long erosional period resulting in a peneplaned surface.
7. Deposition of the Tertiary shallow fresh water sediments and the formation of the residual deposits.
8. Early Tertiary blockfaulting resulting in the formation of the Murray Range Fault.
9. Deposition of the later Tertiary limestones of the Murray Plains with erosion of the uplifted block.
10. Uplift of the whole area with recession of the Murravian Gulf.
11. Deposition of recent deposits and erosion giving the present topography.

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LIST OF PLANS AND SECTIONS

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