THE UNIVERSITY OF ADELAIDE
DEPARTMENT OF ECONOMIC GEOLOGY

THE GEOLOGY OF PART OF THE CAMBRAI MILITARY SHEET

J.E. Harms,
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Honours thesis 1951
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SUMMARY

This report describes the geology of an area of 48 square miles situated on the Cambrai Military Sheet. It is the result of field and laboratory work during 1951, and was carried out under the guidance of Professor Rudd, of the Economic Geology Dept., University of Adelaide.

CONTENTS

INTRODUCTION

The area concerned in this report is situated about 42 miles E.N.E. of Adelaide, and forms part of the Cambrai Military Sheet. The actual area studied is in the vicinity of 48 square miles, and comprises those parts of the hundreds of Jellicoe, Moorooroo, Jutland, and Angas which occur on Runs 6 and 7 of the Adastra air photos of the Cambrai sheet.

The geological work done in this area was undertaken as part of the requirements for an Honours Degree in Economic Geology at the University of Adelaide.

METHOD OF ATTACK, AND SCOPE OF INVESTIGATION

The mapping of the area was accomplished by using Adastra airphotos of approximately 4.1" = 1 mile scale. The airphotos were utilized in making a map (Scale 4"=1mile) of the area; the scale and orientation of this map were controlled by using a slotted template plot with surveyed Trig. control. The air-photos were also used for preliminary studies of the area in the laboratory, and as maps in actual field work. The geology of areas traversed in field work was plotted on the photos, and transferred to the composite map by tracing. To render the task of tracing the geology more simple, one map was compiled on Ethulon; this Ethulon plot was then traced onto an independently controlled Duralax sheet from which the final prints were made.

In all, about 14 days only were spent in the field, so that by no means all outcrops were inspected; due to the small scale photos used minor structures could not be plotted. This survey must therefore be regarded as a reconnaissance survey only. Due to the small area studied, the regional structure could not in all cases be determined.

PREVIOUS GEOLOGICAL WORK

(1) "The Geology of the North Mount Lofty Ranges". R.S. Hossfeld
(Trans. Royal Soc. S.A. 1935)

This paper contains the only published information on the immediate area concerned in this report. The paper embraces a review of the geology of a very large area. While disagreeing with many of its conclusions I feel that the paper forms a very valuable foundation for more detailed geological work such as that concerned in this report.

(2) UNPUBLISHED WORK on surrounding areas has been consulted in an attempt to determine the regional structures. The area to the north and northwest, around Angaston, has been investigated by Campbell during a search for marble sources for the ICI Company. The mapping done was not sufficiently regional in character to be of much assistance.

The Gawler sheet, to the West, has recently been mapped by Dr. Campana, of the S.A. Mines Dept., but the work remains as yet unpublished. This mapping has not been correlated sufficiently either structurally or stratigraphically with the area here mapped, to be of any great significance.

(3) CONCURRENTLY WITH my own MAPPING, similar areas to the south were mapped by three colleagues Messrs. Rowley, Markham and Kaewbaidhoon. These areas overlap sufficiently to enable geological features to be followed with a high degree of accuracy from one strip to another. The composite area and its relation to that here dealt with, is shown on the locality map. The regional structure and stratigraphy as postulated in this paper, are the result of observations in the composite area, rather than those of observations in the restricted area of Runs 6 and 7 alone.

PHYSIOGRAPHY

The area investigated consists of a series of gently rolling hills, giving way in the east to a flat alluvial plain (the Murray Plain).

Near Eden Valley the slopes of the hills are in general, very gentle, the differences in elevation between hilltop and valley being generally much less than 300 feet. This area has an elevation ranging from 1300 to 1550 feet above sea level, with isolated peaks rising to over 1600'. These higher peaks are flat-topped, and are covered with a lateritic capping. The area is drained by the headwaters of the Gawler R., the water flowing north, and thence westward to Gulf St. Vincent. Its headwaters in this area are characterised by flowing through a wide alluvial valley with only occasional rock outcrops. The topography is mature. The region has a high rainfall, and is covered with red & blue-gums, and grasses.

The watershed of this area is bounded by a line running approximately N-S from Peggy's Hill to just west of Keynes Trig.

To the east of the above watershed, the country is temporarily more rugged, consisting of boulder strewn hills with occasional jagged sawtooth type hills of sandstone. The topography falls away from the watershed (1500-1600 feet), toward Keyne's Valley (1000-1200 feet). The area is drained by small creeks running into either the Marne R. or the Somme R. to the south and east respectively. Keyne's Valley occurs in limestone and schist, and consists of very gentle wellrounded slopes. The eastern walls of the valley consist of sandier beds, and the hills become boulder strewn and less rounded. The Valley is drained by the Somme (North Rhine) R., which flows along a somewhat tortuous route southwards into the Marne and thence eastward into the Murray R. The Somme's appearance would suggest that it is a superimposed stream, being in part a relic of a previous drainage system.

The rainfall of this region is from 14 to 20 inches/annum and large gums are less frequent excepts in valley floors.

To the east of Keynes Valley the country is drained by eastward flowing creeks cutting through boulder covered hills which have steeper slopes than is common elsewhere. Gums are absent except in the creeks, and hilltop vegetation is limited to sheoak, spinifex, and grasses. The more easterly hills are more genlly undulating and less rugged, and give place more or less suddenly to a lowlying (300-500') plain. Both the hills and the plain have a low rainfall (10-14"). The plain is covered with various native bushes and grasses, and by low mallee scrub. It is traversed by various creeks which mostly spread out and lose themselves some distance from the hills.

CULTURE

The valleys and hills of the Eden Valley region are commonly utilized for the cultivation of vines and fruit trees, and for dairying and sheepgrazing, causing relatively close settlement.

To the east of the Keynes Hill watershed, sheep grazing is the dominant industry, although parts of Keynes Valley are suitable for cultivation of horticultural and agricultural crops. The region is sparsely settled. The eastern hills are suitable only for sheepgrazing, and houses are absent.

The Murray Plain is intensely cultivated, producing wheat and barley, and is also used as grazing land for sheep. The mallee scrub is used as a source of firewood. Homesteads are fairly plentiful.

GEOLOGICAL HISTORY

The chief rocks of the area comprise highly metamorphosed sedimentary rocks of uncertain age. To the South rocks presumably equivalent in age have been named as the Kanmantoo Series; Hossfeld, on the basis of work to the north, has divided these rocks into two series, the Narcoota and Barossa. Due to the more widespread usage of the term Kanmantoo Series, and to the lack of evidence (in the area studied) for two unconformable series, my colleagues and I have adopted this term.

The geological history of the area as at present interpreted by us, is as follows:

1. DEPOSITION OF THE KANMANTOO SERIES as a shallow water series of sandstones, limestones and argillaceous beds, and their subsequent consolidation.

2. FOLDING AND FAULTING of the above beds, with contemporaneous or slightly later intrusion of dolerites and possibly some quartz veins.

3. GRANITISATION AND METAMORPHISM of the beds - possibly in part contemporaneous with folding and faulting, and in part later - giving the beds their present character of quartzites, marbles, schists, amphibolites, granite gneisses, granitised sediments; pegmatites and quartz veins, and probably mineralization, as an end stage of granitisation, or of the approach of a magma in depth.

4. SCAPOLITISATION of some areas

5. PENEPLANATION as an end stage of the erosion of the uplifted beds, with the formation of lateritic capping and stream gravels, probably about mid-Tetiary time.

6. BLOCK FAULTING during Pliocene (?) time, forming the eastern fault scarp, causing relative elevation of the western block above the Murray Plain area.

7. EROSION OF THE RELATIVELY UPLIFTED BLOCK giving present topography of the western block. Deposition of fault line talus, gravels, and alluvium on the downfaulted block. Possible deposition of marine limestone on downfaulted block in Tertiary time, with subsequent development of Kunkar surface encrustation.

STRATIGRAPHY

(a) STRATIGRAPHY OF THE KANMANTOO SERIES

As developed in Runs 6 and 7, the series is made up of the following horizons, from youngest to oldest:

1. Pine Hut Quartzites.

An arenaceous series of beds consisting typically of well-bedded and often banded quartzites, with some massive quartzite bands. Bensing and crossbedding, present in a few localities, indicate shallow water deposition. Under the microscope the quartzites consist mainly of quartz grains cemented by later quartz, with some felspar and mica, chiefly biotite. The rocks are invariably fine to very fine grained. In many cases the quartzites weather to a light pink or white soft and sandy rock, boulders of which cover many of the hills in the Pine Hut road region; it is difficult to find a series of fresh exposures illustrating the whole group, but sections of the group are well developed in various creeks adjoining the central portion of the Pine Hut road, and near Mons Trig.

These quartzites have an aggregate thickness exceeding 9,000 ft The older beds grade into the Somme River Micaceous quartzite horizon.

2. Somme River Micaceous Quartzites

The Pine Hut quartzites gradually grade down into more micaceous quartzites. The dividing line has been arbitrarily chosen and is not well defined. However the Somme R. horizon differs from the younger series in that, as a whole, its beds are much more micaceous. The horizon is well exposed along the Somme R., where it consists of micaceous quartzites, quartzites, and very sandy mica schists. Crossbedding is an extremely common feature of these beds. The beds appear to weather more rapidly than the Pine Hut group, possibly due to the schistose nature of the more micaceous layers. The rocks are invariably fine to very fine grained, and generally show excellent bedding, The lower members grade into the Saunders Creek schists. The minimum thickness is of the order of 3,500 feet.

3. Saunders Creek Marbles and Schists.

The Somme R. beds are underlain by a group of marbles separated by sandy schists. The marble bands are very prone to lensing, and the individual bands cannot be traced along the strike for more than a few miles. Locally five bands of marble may be distinguished but generally only two or three bands are met with in any one section line. The lens-like character of the beds, and the poor outcrop over this region, prevent the detection of folding of the bands; in some cases the outcrop pattern suggests that some bands may be due to repetition of others by folding, but it is possible to explain this by lensing also. The lenslike character of the marbles, together with crossbedding seen in the interbedded sandy schists, is taken to indicate relatively shallow water deposition.

Some of the marbles have an apparent thickness of up to 600 feet; however it is apparent that much of this thickness is due to intense folding within the bed itself - in places the limestones appear to have been forced into knots like toothpaste - and it is thought that the actual thickness would rarely exceed 100'. The marbles vary from fairly pure grey and white marble, to very impure sideritic and amphibolitic types, with biotite rich bands. The grain size varies from coarse to fine. The marbles are intruded by dolerites, and by haematite "lodes", which are dealt with later. Quartz veins are also fairly common.

The schists bearing the marble lenses vary in nature. On the western limb of the main syncline they rarely outcrop, but are occasionally seen as sandy biotite - muscovite schist, with rare garnets. On the eastern limb the schists form the great bulk of the series. The typical schist here found is very fine grained, the grains usually being smaller than .1 mm, with flakes of biotite up to 1 mm. The rock is made up chiefly of quartz and felspar (both plagioclase and potash felspar) with biotite and muscovite and rare amphibole. Apatite, zircon, sphene, and magnetite are present as accessory minerals. The rocks frequently appear somewhat banded, especially in thin section, and crossbedding is sometimes seen. Knotted schists are developed in the more argillaceous types. Many of the eastern schists are calcareous, but marbles are not prominent.

The thickness of the Saunder's Creek horizon varies from about 3,500 feet (containing up to 1,000 Ft of marble, though for reasons stated before, this should probably be of the order of 400 ft true thickness) in the west, to 6,000 ft on the east (containing generally less than 500 feet of marble).

4. Keynes Gap Sandstones.

The schists and marbles are underlain by a somewhat unique band of epidote-quartz-amphibole rock which rarely exceeds 20 feet in thickness. This rock is very well banded and extremely fine-grained, so much so that the components cannot be accurately determined even under the microscope. The bed has behaved incompetently and often shows extreme folding. To the north a lens of sandstone over 1,000 Feet thick separates this band from what is taken to be the Saunders Creek beds base, but the band has a useful function as a marker band. It is underlain by the typical sandstones (with some quartzites) of the Keyne's Gap group. These sandstones are generally massive, and bedding is rarely shown. The rock has a saccharoidal appearance, the predominant mineral being quartz, with some felspar; in a few places the rock is flecked with light greem or black micas, probably a variety of muscovite, and biotite respectively. The weathering varies from almost torlike, to the commoner cleavage slab type; the latter type produces the jagged hills around Keyne's Gap.

It is possible that these beds are in part thickened by folding, but so far only one instance of folding has been observed, and that only in a large boulder not in situ.

Toward the north the sandstone becomes slightly more micaceous and in parts, tends toward a slightly gneissic appearance. However with the structure as present conceived, the sandstones do not grade into anything approaching a mica schist, within this area, any such change being ascribed to structural change.

The underlying Keyne's Hill gneisses may belong to this horizon. At and near the contact of the gneisses and sandstones, the beds have been intruded by dolerite. The thickness of the Keynes Gap sandstones (excluding the possible presence of the Keynes Hill gneisses in this group) is approximately 6,000 feet.

Keyne's Hill Gneisses These granitised beds may be alterations of either the Keynes Gap sandstone horizon, or of the Eden Valley Schists. /As at present interpreted these beds are derived from the

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Eden Valley Schists/ As at present interpreted these beds are derived from the Eden Valley Schists, but it is by no means certain that this interpretation is correct. It is proposed to leave these doubtful beds out of the stratigraphic column, since their development is obviously a specialized local case.

5. Eden Valley Mica Schists

As seen further south, the Keyne's Gap beds are underlain conformably by a series of schists and sandy schists exceeding

4,500' in thickness. In runs 6 and 7 the Keyne's Hill gneisses prevent any decision as to the conformable nature of the beds underlying the sandstone. To the west of these gneisses, schists and sandy schists similar to those to the south outcrop rather poorly. It is not possible to trace these northern beds and join them up stratigraphically with the Eden Valley schists to the south, but it is reasonable to assume that they represent a similar horizon. No marker bands are present. The schists are made up predominantly of quartz with microcline and albite, the micaceous minerals being muscovite and biotite. Muscovite seems to be slightly more abundant than biotite. The predominance of quartz and felspar gives the schists a gritty feel in most cases. Bedding is frequently still well shown, the originally more arenaceous layers not having been destroyed by metamorphism.

In many places these schists have been granitised, and granitised sediments, tonalite, "aplite" and pegmatites are found enclosed in this horizon. It is thought that some of the granitised beds may represent what were originally more arenaceous beds. Along part of the bed of the Gawler R. the schists are distinctly more sandy than those occurring elsewhere, but this may be a local change only.

The probable thickness of these northern schists is well in excess of the estimated minimum of 4,500' which occurs to the south.

(b) Stratigraphy of the younger rocks

The younger rocks in the area are not present in comparable amounts to the Kanmantoo Series.

1. Tertiary rocks, probably pre Pliocene.

(i) Lateritic and leached cappings are present on the higher peaks, such as Keyne's Trig, and Peggy's Hill; these are considered to be the residual remains of a surface crust developed before blockfaulting broke up the old peneplain in ? Pliocene time. The cappings have a maximum apparent thickness of about 6 feet, and take the form of a crust of iron (haematite and limonite) rich mica-bearing nodular rock underlain by white leached material which has the appearance of a clay mineral. The cappings generally have a steep cliff like face toward the north or west, while the eastern and southern sides are gentle slopes generally covered with alluvium. Their elevation ranges from 1450 to 1644 feet.

(ii) Gravel beds are present in two places. These are considered to be relics of ancient streams, and are either pre-block faulting in age, or were formed at the time of the first movements along these faults.

(iii) Possibility of marine Tertiary beds being below the surface of the present Murray Plain.

2. Deposits of Post-block fault age.

These are chiefly the alluvium and soils of the Eden Valley region, and the gravels, talus, travertine (in part) and soils of the Murray Plain.

METAMORPHISM

The rocks of the Kanmantoo Series have undergone high grade regional metamorphism forming the quartzites, schists, marbles etc. described above. The chief metamorphic minerals found are muscovite and biotite, but andalusite, kyanite, garnet, epidote and amphiboles are by no means uncommon. In the composite area studied by my colleagues and myself, there seems to be no reasonable basis for assuming that metamorphism decreases in grade toward the north. However very little petrological work was done on the area, emphasis being placed on structure, so that small differences in metamorphism may have escaped our notice.

There seems to be no clue as to the actual time of metamorphism; dolerites are now found metamorphosed to amphibolites, but since the age relations of the dolerites are unknown, this is not much help.

GRANITISATION

The Eden Valley schists, and possibly the lower members of the Keyne's Gap sandstones; have been subjected to intense granitisation, forming gneisses, "aplite" and other "igneous" rocks. The sedimentary origin of these rocks is rarely in doubt when seen in the field. In the extreme stages of granitisation, (or by intrusion of magma "granite" which would produce the same effect), nongneissic tonalite, "aplite", and granite pegmatites have been formed. These latter rocks are for convenience referred to as igneous rocks, although it is probable that most of them are derived from a "migma" rather than a "magma", and all stages exist between them and the granitised sediments.

The granitised sediments proper are regarded as such for the following reasons:

(1) Bedding can still be observed within such rocks in a few favourable cases.

(2) The gneissosity is regionally parallel to the regional strike.

(3) The outcrop trend of the rocks is in general parallel to the strike of the enclosing sediments. This is taken to represent evidence for replacement of favorable beds, probably the more felspathic arenaceous ones.

(4) No definite contacts, and especially no chilled contacts have been observed anywhere.

(5) The relation of the granitised beds to structure is in some cases indicative of replacement of a favorable band. This is especially noticeable to the south in Messrs Markham and Rowley's area, where the core of a flat pitching anticline has been granitised for several miles.

The intensity of granitisation probably increases toward the south, although this is not apparent within Runs 6 and 7.

Granitised beds occur chiefly to the south-east of Keynes Trig. Here they take the form of compact siliceous gneisses which approach a torlike weathering in some case. A typical gneiss consist of quartz, scapolitised plagioclase (Basic albite), microcline, biotite, muscovite apatite and haematite (possibly magnetite); the micas and accessory minerals are not very abundant. All traces of bedding are removed. It is not certain whether these rocks were originally sandstone or schists; on lithological grounds the former seems the more probable, but on structural grounds the latter is possibly the more likely. More detailed mapping might throw some light on this problem, especially if used in conjunction with numerous thin sections of the rocks.

In addition to these gneisses, granitised sediments occur in numerous small outcrops in, and on the eastern side of the large belt of alluvium north west of Eden Valley. These are generally less gneissic, and resemble fine grained pegmatites, or aplites, although their field occurrence suggests their sedimentary origin. A large and apparently corsscutting bed of this type occurs on Photo 13-51 Run 7; however the field exposures of the schists are not good here, and it is possible that this body is conformable. If not it may be due to granitisation along a shear or by some means of echeloning.

Granitisation and metamorphism were no doubt contemporaneous.

IGNEOUS ACTIVITY

Igneous rocks and their derivations are fairly common in the area, although acid igneous rocks are confined to the Eden Valley Schists in this area. With the exception of quartz veins, no acid igneous rocks or derivatives are found above the base of the Keyne's Gap Sandstones; no basic igneous rocks are found in rocks above the base of the Somme River Micaceous quartzites. The igneous rocks fall into the following groups.

1. Tonalite: This rock is found in a small outcrop in Photo 13-52 Run 7, north of Eden Valley. In appearance it resembles the Palmer tonalite, being grey and of an even medium grained nature. The chief minerals present are Andesine (some crystals of which show zoning), orthoclase, quartz, biotite, apatite and zircon. The plagioclase has in many cases been altered to scapolite, and a fibrous mineral which is probably sericite. Biotite is found

partially or completely altered to chlorite, which is usually also associated with epidote. The lack of gneissic structure, and the obvious zoning of the plagioclase, distinguishes this rock from all others in the district.

Pegmatites. Pegmatisation is widespread in the Eden Valley Schists; it is difficult to draw the line between granitised sediments, and intrusive (or at least mobilized) pegmatites. Coarse grained pegmatites, obviously intrusive, are not widespread, but can be found to the north of Eden Valley. Here dykes of coarse grained felspar, quartz, and muscovite, with very rare tourmaline and beryl, are found intruding the schists. As a general rule the dykes are conformable with the bedding, but locally they are found crosscutting.

"Aplites" Finegrained leucocratic rocks with the appearance of aplites are common along the Eden Valley -Angaston road. These rocks are probably more in the nature of finegrained adamellites, as they contain a high proportion of plagioclase. Other minerals prese t are quartz, orthoclase, muscovite, and possibly talc. In spite of the igneous appearance, it is thought that the rock is a granitised sediment. In common with other rocks of this area, the rock's plagioclase has been largely altered, probably to scapolite.

Dolerites: These rocks have been altered since intrusion (by regional metamorphism) to amphibolites. They are the most widespread igneous rocks of the area, and are found near Keyne's Trig., and in the area to the south of Run 7, bordering the Plain, in most quantity. However they intrude the Eden Valley Schists, Keyne's Gap Sandstone, and Saunder's Creek.beds. The texture of the dolerites varies from fine even grained, to coarsely porphyritic with phenocrysts of felspar up to $\frac{3}{4}$" long. The minerals forming the rock are Labradorite, a light green slightly pleochroic amphibole, biotite, and sphene - the latter two being accessory only. In the case of the Eastern dolerites (Photo 13 - 42 Run 7) the plagioclase has undergone scapolitization. The northern members (photo 13-25 Run 6) are not scapolitized, while the remaining groups have not been examined under the microscope.

The main groups of dolerites appear to have been localized by shearing. Some of the dolerites appear to be conformable and sill-like, while others are definitely transgressive. The heat of their intrusion does not appear to have markedly affected marbles in contact with the dolerite, but any effect may have been masked by subsequent metamorphism. In one place (photo 13-42 Run 7) what appears to be a dolerite invading a dolerite (shown by a possible chilled edge, and by difference in weathering) is interpreted as being a slightly later phase of the same period, rather than indicative of two periods of basic igneous activity.

The dolerites are resistant to weathering and form low rounded hills; in the eastern area the dolerites are often covered with Kunkar.

Sheared dolerite has been found in several localities, but it is thought that minor activity since the main period of shearing could account for this discrepancy in age relation, the age of the dolerites being proposed as being contemporaneous or slightly later than the main folding and shearing.

Haematite "Lodes" in the western limb of the Saunders Creek Marbles group, marble beds are associated with haematite bodies of small size. These haematite"lodes" show no boxwork structure and are not thought to be derived from sulphides. Campbell found similar "lodes" associated with the marbles at Angaston, and on the basis of exposures in open cuts, and by drillcore results, he puts forward the theory that these bodies are definitely "intrusive", and are probably associated with the dolerites. The evidence in this area tends to support Campbells theory.

Quartz Tourmaline "Lodes".

These lodes are numerous in the area of the east limb of the Saunder's Creek beds. (Photo 13-30 Run 6). It is thought that they follow certain horizons in the schists, and they are usually associated with knotted schist. Their outcrop is often bold. They appear to consist of brecciated rock, brecciated quartz, quartz, and fine grained tourmaline. In a section of what was taken to be the end phase of one of these lodes exposed in a creek, a slightly gossaniferous ironstone band was surrounded by a thin band of well crystallized garnets, and this in turn by the unaltered bountry rock. This is taken to indicate high temperature formation.

Quartz Veins These derivations of igneous rocks are the only indication of such action in the Somme River and Pine Hut quartzites. Here small bands of quartz, and sometimes a little tourmaline, are occasionally to be seen. Quartz veins are common in all other horizons other than the Keyne's Gap Sandstones, where they are rare or absent. The age of the quartz veins appears to be later than that of the pegmatites, and post-shearing, but no definite age can be assigned. Very much sheared quartz found near Keyne's Trig. may be of an earlier age of vein formation.

SCAPOLITISATION

The mineral scapolite is abundant throughout the area, although in the eastern part there seems to be a notable decrease in the amount of scapolitisation as one goes north. However in the west, around Eden Valley, and in the south of the eastern area, all the rocks have been scapolitised to some extent. A few bands of scapolite diopside rock have been noted in the southern part of the two limbs of the Saunders Creek beds, but generally speaking this rock is absent; this contasts with the abundance of that rock immediately to the south of Run 7 in those horizons. Doubtful scapolite-diopside rock was observed in a small road cutting on Photo 13-51 Run 6 in the west. Scapolitisation is especially noticeable in the dolerites, and in the granitised sediments and igneous rocks, and in the calcareous rocks. Scapolitisation may be an end phase of the basic igneous activity, but its widespread occurrence (especially further south) may render this unlikely in the present case.

STRUCTURE

(a) The dominating structure of the area is a large northpitching syncline. This syncline is well shown by the outcrop pattern of the Saunders Creek beds on the eastern half of the composite map. The syncline is modified by faulting, the east limb being relatively upfaulted along a plane which probably dips to the east; this faulting has produced a resultant westward movement of the sediments affected. The fault-plane has not been observed anywhere in Runs 6 and 7, and very little brecciation, or silicification has been found near or at the suspected position of the fault. The rock types either side of the fault are not sufficiently distinctive to allow their use in its location. The fault has therefore been located by the boundary of structural features (such as "rolling" in the quartzite, east-west strikes, and uninterrupted N-S strikes). The fault-line strikes approximately north-south. In the south the fault is almost an axial line fault, while in the extreme north it is almost a strike fault, with all gradations in between.

In the area of Run 6 and 7, the nose of the syncline is developed in competent rocks of the Pine Hut Quartzite horizons, and these rocks have been thrown into a series of "rolls" in the immediate vicinity of the nose. The nose is thus made up of a succession of small folds. (approximately 6 folds to one chain horizontal distance), and the outcrop pattern of any bed resembles outsize corrugations. These rolls are very gentle folds pitching at angles of 20 to 60 degrees northerly; their average pitch, about 35 to 40 degrees, is taken to indicate the pitch of the main syncline which they form. Any one bed can never be traced for more than several chains due to poor exposures, and marker bands are absent, so the actual position of the synclinal axis is largely guesswork. In the north, where the eastern limbs of some of the higher beds should be unaffected by the fault, the lack of outcrop and of marker beds prevents any bed's outcrop being plotted.

The axial line of the syncline strikes a little west of north, but appears to swing to east of north to the south. This swing is thought to be more apparent than real, and is due to the faulting of the east limb. Both limbs of the syncline dip steeply inward at angles of about 60 to 80 degrees.

(b) Relation of Structure to Strain Ellipsoid

The eastern syncline is pictured as being due primarily to an approximately east-west compression. Probably the active compressive force was from the east, thus causing the tendency towards overthrusting as evidenced in the faulting described above, and the undoubted overthrusting found by Campana on the Gawler Sheet.

In the Cambrai sheet only one shear direction is at all prominent; it is evidenced by joints, and creek lineations, and has a strike from 50° to 80°. Displacement along this direction is rarely observed, but small faults with the theoretical displacement of north block east, have been seenin the south.

Axial plane cleavage, fracture cleavage, and tension cracks are very poorly shown, or absent, no doubt due to the unfavorable nature of the sediments.

The fault along the east limb of the syncline is approximately parallel to the axial plane tension direction.

(c) The Western Structure To the west of Keyne's Valley, especially west of the Keyne's Gap Sandstones, the structure becomes more complicated. The lack of outcrops in critical places, and the entire lack of any marker beds prevents an accurate elucidation of structure. The beds are thought to strike in the manner indicated by pencilled strike lines on the composite 4"=1 mile geological map. However this structure does not correlate with any to the south, and definitely does not correlate with Campbell's structures some miles to the north. The south pitch (30° to 60°) when considered in the light of our composite stratigraphy, and Campbell's mapping to the north, seems to suggest that the structure in this area has very little relation to the main eastern syncline. However to the south, in Runs 8 - 13, the structure in the Eden Valley schists is that of gentle folding (of flat pitch) on the limb of the main syncline.

In an attempt to decipher the structure of Runs 6 - 8, Mr. Rowley and myself attempted to tie in the mapping of the Angaston marbles by Campbell, with the Saunder's Creek beds. A reconnaissance in the area indicated a probable correlation (shown on Military Sheet - Cambrai), and it is now considered that the two marble groups are of similar stratigraphic horizons. Assuming Campbell's outcrop mapping to be correct, we interpret the structure in that area as essentially a north pitching anticline (probably modified by faulting) and syncline modifying the outcrop pattern of the main eastern syncline. This structure disagrees with that mapped by Campbell, who assumes that the syncline postulated above is actually a south pitching anticline. His structure seems impossible on the basis of our regional stratigraphy, but agrees rather well with the south pitch of the rocks in Runs 6 and 7. As the evidence stands at present our suggestion seems the more probable.

There is the possibility of overturned beds, and even of overturned pitch, but the comparatively gentle folding elsewhere (in the composite area) militates against this. The structure of Runs 6,7 and 8 is thought to be due to crossfolding and faulting modifying the simple structure suggested above. The true structure, and its origin, will not be satisfactorily known until mapping to the north and west has given the regional setting - especially in relation to the Saunders Creek and Penrice (Angaston) Marble horizons. This mapping should if possible be carried out by someone familiar with the stratigraphy as seen in a cross section say on Run 10.

The faults shown on the composite Geological map in this western area are suspected on lithological and topographic grounds only,

(d) <u>Tertiary Block-faulting</u>: Faulting during ? Pliocene time occurred along what is now the eastern boundary of the Murray Range (and also of the known outcrop of Kanmantoo rocks), the western block being elevated relative to the eastern (Murray Plain) block. The fault is now given topographic expression by the abrupt rise of the hills from the plain. The evidence for the faulting is almost entirely topographic, but the eastern most exposures of Kanmantoo rocks are usually shattered and sometimes sheared.

The actual position of the fault is not known, but has been taken to be a few chains east of the exposures referred to above. The fault zone was probably broad, and not confined to a single plane.

This fault strikes approximately north-south, with periodic offsets of up to $\frac{1}{4}$ mile in an easterly direction as one goes north. The main fault direction parallels the pre-existing fault direction seen in the eastern syncline, while the offsets approximately parallel the shear direction shown in the older structures. The fault appears to have followed these pre existing directions of weakness.

The vertical displacement appears to have been of the order of 1,000', the eastern block being relatively downthrown and the western block elevated. The estimate of the magnitude of the displacement is based on the present day level of the plain (approx 500' near the fault) and of lateritic cappings and gravel beds on the western block (1300 to 1640 feet), and is not thought to be very reliable.

AGE OF KANMANTOO SERIES, AND OF THE FOLDING

There is no general agreement on the age of the Kanmantoo Series.

Hossfeld has advanced the theory that the Series (as here defined) is of Adelaide System age, with the exception of the Eden Valley Schists, which he suggests are unconformable and older in age. The latter possibility is supported in the area of Runs 6 and 7 by the fact that the schists are the only granitised beds of the Series, and cannot be seen to be conformable with the Keyne's Gap Sandstones. However the findings of my colleagues do not support either the unconformable nature, or the lack of granitisation in overlying beds, and it is considered that the beds form one conformable series; any apparent departures are thought to be due to structural causes.

Hossfeld has reported tracing beds, which correspond to our Saunder's Creek group, into a tillite horizon both north and east of Dutton. In the absence of any evidence to refute this claim, my colleagues and I feel that the Kanmantoo Series must be taken to be of Adelaide System age.

Sprigg has suggested that the Kanmantoo Series may be of post-Proterozoic age, representing the eugeosynclinal phase of the miogeosynclinal Adelaide System. The more intense metamorphism of these supposedly younger rocks could be accounted for by the eventual collapse of the geosyncline. The relatively coarse, shallow water nature of the sediments, the entire lack of fossils, and Hossfeld's findings described above, deprive this suggestion of any supporting evidence.

The only other possibility - that the Series is of pre-Adelaide System age - while supported by the advanced state of its metamorphism and granitization, is not considered to be very likely.

Assuming the beds to be of Adelaide System (Mid to Late Proterozoic) age, the folding is, by analogy with that in the Flinders Ranges, of post-midCambrian age, and may have continued on a minor scale after the Palaeozoic up to the Mesozoic.

ECONOMIC GEOLOGY

Workable mineral deposits have been rare in this area, and production has been small.

(a) Base Metal Deposits.

The only metallic sulphides observed in the area were pyrite and possibly pyrrhotite and chalcocite. No sulphides occur in important quantities outside the North Rhine Copper Mine deposit.

Copper mineralization on a small scale is widespread in the eastern part of the area. The mineralization, with one exception, is limited to beds of the Saunder's Creek Marbles and Schists. The following occurrences have been noted.

1. North Rhine Copper Mine. This deposit is situated just north of the Pine Hut road, on sections 563 and 570, Hundred of Jellicoe. The dumps and shafts can be seen on Photo 13-26 Run 6.

Traces of copper, and ironstained quartz gossan, occur over a wide area. The copper occurs as azurite and malachite impregnations in a white soft sandstone, and also in pyrite-quartz veins. There are two main lodes, which strike approximately North-south, and dip

75° west. Four shafts, and several small pits have been sunk to prospect the deposit. The main shaft is surmounted by a stone tower and a chimney about fifty feet high, and appears to be timbered. At present water fills this shaft to within 15 feet of the surface. A large volume of broken rock present around the shaft indicates that a considerable amount of work has been done underground. Pyrite, possibly chalcocite, and copper carbonates, are present in a few specimens of rock - usually quartz veins in sandstone but the bulk of the material appears to be barren rock. Garnet is sometimes observed. The country rock is poorly bedded and poorly exposed in the region of the deposit, but appears to strike at about 320° and dip eastward at angles as low as 30°. Folding may be present, but cannot be proved.

From old mining records it has been ascertained that one shaft attained a depth of 260 feet and that the lode in this shaft was driven on for 420 feet. The lode, although 3 to 6 feet wide, contained too much pyrite to be economically worked. The "engine shaft" presumably a different shaft immediately adjacent to the preceding, attained a depth of 360', and a drive followed the lode for 300'. The lode was not payable, but contained "black sulphuret" (presumably partly decomposed pyrite with some copper, possibly chalcocite) throughout.

Up to August 1854 the mine had produced over 100 tons of approximately 20% ore. The mine has been closed for over 90 years.

There is no obvious reason as to why the lodes are situated where they are; there seems to be no obvious structural control, and it appears that the sandstones and quartzites would present little chemical favourability.

2. <u>Old Shaft. Photo 13-42 Run 7.</u> Here a shaft about 25' deep has been sunk to reveal traces of copper carbonates disseminated in schist. Quartz tourmaline veins outcrop nearby, and may be genetically connected.

3. <u>Pine Hut Road Photo 13-41 Run 7, northwest corner</u>.

Immediately south of the road several shallow shafts and a series of pits have prospected copper bearing rock. The copper appears to occur as staining in schist and knotted schist, and appears to be associated with quartz tourmaline veins which occur nearby and may be intersected in the shafts. Some minor shattering of the schists was observed. The prospecting was unsuccessful.

4. Shaft, near creek, Photo 13-30 Run 6. A shallow shaft has been sunk on a quartz vein showing copper carbonate staining. Malachite and azurite are also present in the biotite schist country rock. The quartz vein occupies a minor shatter zone in the schists. Production appears to have been negligible.

5. It is considered that minor copper mineralization of no industrial importance may be associated with quartz tourmaline "lodes" occurring in the schists on Photos 13-30 Run 6, and 13-42, Run 7. So far these lodes have not been prospected, and surface indications are not encouraging.

(b) NON METALLIC DEPOSITS

1. Kunkar Small pits have been opened in the kunkar derived from marbles on the roadways in Photos 13-47 Run 7 and 13-25 Run 6.

In several places on the Murray Plain small pits have been opened in surface travertine. The material has been used as roadmetal.

2. "Aplitic Granite" A small quarry along the main Eden Valley-Angaston road (Photo 13-52 Run 7) has exploited this material for roadmetal.

3. Sheared Quartz rock. This crumbly material has been quarried for roadmetal near Keyne's Trig.

4. Residual leached material has been used as roadmetal from small pits north east of Eden Valley.

5. Gravel. Tertiary gravel beds have been worked near the main Eden Valley - Angaston road (Photo 13-19 Run 6) and in the north of Photo 13-25 Run 6, off the Keyneton Road. The latter deposit is quite extensive and is still being worked.

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LIST OF ACCOMPANYING PLANS ETC.

1. Ethulon Fact Sheet. Scale 4"=1mile
2. Composite Interpreted Geological Sheet. Scale 4"= 1 mile.
3. Locality Map (attached)
4. One Mile Cambrai Military Map, showing approximate outcrop of Saunder's Creek and Penrice marble beds.
5. Slotted template plot of Runs 6 and 7
6. Slotted template plot of Runs 6-7-8-9
7. Cross sections along lines shown on 2.
8. Hand Specimens and thin sections as listed.

HAND SPECIMENS AND SLIDES

	Spec. No.	Slide No.	Locality	Photo
Pine Hut Quartzites				
Banded Quartzite	1	1	13-29	Run 6
Impure Quartzite	2	-	13-45	Run 7
Weathered quartzite	3	-	13-45	Run 7
Somme River Micac. Quartzites				
Micac. Quartzite, garnet bearing	4	-	13-47	Run 7
Saunder's Creek Marbles & Schists				
Impure banded marble	5	-	13-43	Run 7
Impure sideritic marble	6	2	13-25	Run 6
Marble	7	-	13-47	Run 7
Schist with garnets	8	-	13-47	Run 7
Schist	9	3	13-43	Run 7
Pyritic Schist	10	-	13-31	Run 6
Keyne's Gap Sandstones				
Sandstone	11	-	13-49	Run 7
Sandstone with anthophyllite	12	-	13-49	Run 7
Banded Qtz-Epidote-Amphibolite rock	12A	5	13-23	Run 6
Eden Valley Schists				
Schist	13	-	13-51	Run 7
Sandy Schist	14	6	13-49	Run 7
Schist	15	-	13-21	Run 6
Silicified Sediment ? tuff	15 A.	-	13-21	Run 6
Igneous				
Tonalite	16	7	13-51	Run 7
Porphyritic Dolerite (Amphibolite)	18	-	13-43	Run 7
Dolerite (")	17	8	13-23	Run 6
Dolerite (")	19	)	13-49	Run 7.

Granitised Sediments	Spec. No.	Slide No.	Locality	Photo
Keyne's Hill Gneiss	20	9	13-49	Run 7
Silicified Sandstone	21	4	13-49	Run 7
Aplitic Rock	22	10	13-51	Run 7
Economic and Miscellaneous				
Tourmaline vein	23	-	13-45	Run 7
Tourmaline Quartz vein	24	-	13-31	Run 6
Leached part of end stage of (24)	25	-	13-31	Run 6
Garnets - alteration zone around (25)	26	)	13-31	Run 6.
North Rhine Copper Mine				
Sulphide lode matter	27	-	13-45	Run 7
Copper staining in Sandstone	28	-	13-45	Run 7
Quartz vein in sandstone	29	-	13-45	Run 7
Leached cappings				
Peggy's Hill laterite	30, 31	-	13-21	Run 6
Keyne's Trig. laterite	32	-	13-49	Run 7
Surface Material, ? Gossans				
Boxwork and quartz crystals	33	-	13-19	Run 6
Quartz crystals, and boxwork	34	-	13-19	Run 6
Quartz with quartz crystals in cavities	35	-	13-53	Run 7

Note. The precise specimen localities are shown on the Ethulon fact map (Scale 4" = 1 mile) in red ink