GEOLOGY AND STRUCTURE OF THE NORTHERN PORTION OF THE CAMBRAI SHEET

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Pratten RD 1952 Honours thesis
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December, 1952.

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SUMMARY

The geology of the area investigated consists of a highly folded sequence of metamorphosed sedimentary rocks.

Rock types encountered were interbedded slates, sandy and calcareous schists, sandstones, limestones, marbles and mica schists. The only representatives of igneous activity are hydrothermal quartz blows and altered dolerite dykes. Remnants of Tertiary sediments are found on the higher portions of the upfaulted Kanmantoo Series (older rocks of this area).

Special consideration was given to the structure of the area, but interpretation was rendered difficult by the lack of rock outcrop and marker horizons. However the Kanmantoo series have suffered an east-west compression which has brought about intense folding in the form of a major anticline and syncline with associated minor folds.

A tertiary fault separates the elevated Kanmantoo Series from the flat Tertiary sediments of the Murray Plains.

INTRODUCTION

Reason for Survey

The fifty square miles of mapping was carried out as part of an Honours B.Sc. course as an exercise in geological field technique and interpretation.

Locality

The area under consideration is rectangular in shape, being 1¼ miles long in the east-west direction and 3½ miles in the north-south and forms parts of the hundreds of Moorooroo, Jellicoe and Bagot which are included in the Cambrai Military sheet. The red cross-hatched portion on the attached locality map (Fig.1) represents the area studied.

Investigation Methods

Adastra aerial photographs were used both in the preliminary studies and in the actual field work. The preliminary studies included stereoscopic examination of the photographs in an attempt to determine strike trends, structure and lithological changes. From the photographs a slotted template plot was made using Military Trig stations as control. The template was then used as a control in the tracing of a "Kodatrace" master map from the air photographs.

In the field, geological fact was plotted by wax pencil directly onto the air photographs and transferred at a later date to the master map. The area of study was covered by a series of east-west traverses (across the general strike). In the eastern portion most of the traverses were confined to the creeks because rocks were better exposed and travel easier. In the west, however, the traverses were not so regular due to the paucity of rock outcrop.

Strike lines which were traced directly from the air

photographs were treated as factual and interpreted structure was shown as dashed form lines.

Previous Geological Work

The only previous published geological work is a survey by Dr. P.S. Hossfeld "The Geology of part of the North Mount Lofty Ranges". Since Hossfeld's work was of a regional nature little detailed correlation can be made with the present survey.

There are also five unpublished works dealing with areas in the southern portion of the Cambrai Sheet by Messrs. Rowley, Markham, Harms, Kaewbaidhoon and Miller. The areas studied by these investigators are marked on the locality map. The mapping carried out by the writer has been correlated, where possible, with these previous workers.

J.D. Campbell of the I.C.I. Company conducted a detailed search for marble in the Angaston district and references to his work will be found later in the text.

GEOGRAPHY

The area studied forms part of the Mount Lofty Ranges. To the east extend the broad, flat Murray Plains which, with an average rainfall of about 10 inches, are suitable for cereal cropping and sheep raising. From the Murray Plains a rise in elevation of about 600 feet to the west is brought about by a north-south fault scarp. The topography of the eastern portion of the raised block is governed by the rapid water run off from the scarp. The trellis type drainage pattern has cut deep gullies in the old peneplaned surface and produced an alluvial apron at the base of the scarp. There is very little soil cover along the eastern margin of the elevated block, the country being mainly used for sheep and cattle grazing. Further to the west the streams cut through hard and soft rock alike; the dendritic pattern being superimposed from the drainage system which existed in the now eroded Tertiary rocks. However, in places the rivers seem to be governed to some extent by the regional southerly pitch of the older rocks.

With the decreased stream activity in the west there is an increase in soil cover which is suitable for grazing, cropping orchards and vineyards.

The water divide between the trellis and dendritic type drainage approximates to a line drawn north-south through Gipps and Mons Trig stations. The actual position of the water divide is controlled by the westward advance of the headwaters of the streams that are governed by the fault movement.

The more resistant nature of the quartzites in the upper beds of the Pine Hut Formation also affects the position of the water divide. It can be noticed that a topographic high follows the outcrop of the massive sandstones and quartzites.

Due mainly to agricultural activities the area is not thickly vegetated, the timber being mainly large eucalypts with

some sheoaks in the lower rainfall districts. Accessibility of the region of study is good because of the agricultural clearing and well serviced roads.

The average annual rainfall (30 years 1911-1940) of the major towns in the area is

Angaston	22.15 inches
Keyneton	21.46 "
Sedan	11.65 "

GEOLOGY

General Geology and Stratigraphy

The nomenclature of the formations described in this report corresponds as nearly as possible to that introduced in previous unpublished work. Changes have been made in rock classifications but the original names have been retained where correlation has been possible.

The greater part of the area studied consists of a metamorphosed sedimentary sequence which is thought by Hossfeld to correspond to the Adelaide System (Proterozoic) while a lower Palaeozoic age has been suggested by others.

Hossfeld first named this rock sequence the "Narcoota Series", but in more recent times the name Kanmantoo Series has been generally used.

Dr. Campana of the S.A. Mines Department considers that the Angaston marble horizon corresponds stratigraphically with the Archaeocyathinae limestones of Sellick's Hill and the Rapid Bay marbles (Cambrian).

This theory would make the more arenaceous sediments which overly the limestone horizons in the Cambrai district Cambrian or younger in age.

During mapping in the Angaston-Sedan district the rock sequence has been divided on a lithological basis, into two formations -

(1) Saunders Creek Formation (older)
(2) Pine Hut Formation (younger)

The Saunders Creek Formation includes -

Marbles
Limestones
Slates
Quartzites and Sandstones
Schists.

Although many of the Saunders Creek members are arenaceous, a fairly accurate contact can be placed between this and the Pine Hut Formation which consists of sandstones, quartzites and micaceous sandstones.

Both these formations I regard as members of the Kanmantoo Series.

As for the age of the Kanmantoo Series, little information can be gained from such a limited area, but a study of previous work in the Flourier Peninsula indicates that the Kanmantoo Series lies stratigraphically above the Adelaide System.

Previous geological reports by Rowley, Harms, Markham, Kaewbaidhoon suggest three arenaceous horizons in the Kanmantoo Series as seen in the Cambrai district:-

(1) Keynes Gap sandstone
(2) Somme River micaceous quartzites
(3) Pine Hut quartzites.

Since the boundary between the Somme River micaceous quartzites and the Pine Hut quartzites is gradational and the difference in rock type vague, the writer has renamed these beds the Pine Hut Formation.

The Keynes gap sandstones which were previously thought to lie stratigraphically below the Saunders Creek Formation have now been identified as being the Pine Hut Formation. This correlation was brought about by a change in the interpretation of structure in the areas studied by Miller and the writer.

It will also be noticed that the name Saunders Creek Formation has been substituted for Saunders Creek marbles and schists; this change was considered necessary since the

descriptive name did not include all rock types associated with the marbles.

The sedimentary history of the area may be summarised as follows -

(1) Deposition of the Saunders Creek and then the Pine Hut Formations of the Kanmantoo Series. The deposition of these beds took place under shallow marine conditions in lower Palaeozoic times.

(2) After long erosion and peneplanation Tertiary marine sediments which included limestones, gravels and argillaceous beds were deposited. The Tertiary limestones are, although covered by soil, are shown by boring to be extensive in the Murray Plains. On the uplifted block all that remains of the Tertiary sedimentation are gravels which occur on some of the higher hills.

Lateritic and kaolinitic cappings are also present on some of the hills. These are considered to be remnants of the old peneplaned surface, which have, by reason of the resistant limonite, withstood erosion after the Tertiary faulting. An example of this kaolinitic laterite can be found on Barren Hill near Keyneton.

(3) Recent to present alluvium, gravel and boulder deposits are associated with the existing drainage patterns. Kunkar, is well developed over the marbles and lime rich horizons.

Saunders Creek Formation

All members of the Saunders Creek Formation are fine grained and thin bedded. Marker horizons are lacking and confusion is introduced by the lensed and discontinuous nature of some of the limestone and marble horizons.

Some of the horizons are well bedded and all contain fine grained silica in varying amounts.

Argillaceous members of the Saunders Creek Formation include grey and brown slates grading into calcareous and mica schists. These beds are best seen in the eastern outcrops near the Murray Range fault where metamorphism is of a low grade. Thin, fine grained sandstones and quartzites occur irregularly in the formation. Dark coloured massive biotite and muscovite schists of variable thickness form a considerable portion of the Saunders Creek Formation. Care has to be exercised in rock identification due to the increase in grade of metamorphism from east to west which is likely to bring about textural changes within a particular horizon. This change in metamorphism may be the explanation of the absence of slates in the western outcrops of the Saunders Creek Formation. It is considered that the slates have been metamorphosed to mica schist.

Calcareous beds ranging from impure limestone to pure coarsely crystalline marble are common in the Saunders Creek Formation. The calcareous beds of the eastern outcrops are mainly impure limestones including a dark massive variety and a highly sheared, partially mineralised horizon. Marble is not common in these beds although small knots can be found in structurally favourable locations. The outcrop of the impure limestone is not good and in most cases the beds were traced by

their kunkar capping and topographic depressions (brought about by their easily weathered nature).

In the highly folded western district, in which incompetent rock flowage is dominant, there are large occurrences of marble. Varieties of marble found include -

(1) Fine-grained, black marble
(2) Coarsely crystalline

white
yellow
blue marbles
pink
green

Marble outcrops are quite common in the Saunders Creek Formation. However extensive kunkar occurrences in the Angaston district suggest the presence of lime rich beds (probably marble) which do not outcrop.

Associated with these kunkar formations are secondary and leached silica deposits. Specimens of vein chalcedony were obtained from a road cutting near the Yalumba Winery. In a small marble quarry near Lindsay Park some weathered marble was found which contained bundles of fibrous blue grey asbestos of the Tremolite-Actinolite family.

The best outcrops of the Saunders Creek Formation are to be found in the deep gorges that traverse the strike of the rocks near the Murray Range fault.

In the western portions of the area the Saunders Creek beds have acted incompetently, bringing about thickening of the noses and thinning on the limbs of the folds.

Pine Hut Formation

From the predominantly argillaceous and calcareous nature of the Saunders Creek Formation there is a gradation into more arenaceous beds of a younger age. The boundary between these two rock types is by no means sharp and the division as indicated on the geological map must be accepted as approximate.

The arenaceous beds have been named the Pine Hut Formation, which corresponds to the Somme River and Pine Hut beds of previous workers.

The basal beds of the Pine Hut formation consist of sandy micaceous schist, micaceous sandstones and quartzites. These beds are dark in colour, fine grained and are often well bedded with occasional storm bedding.

The upper members of the Pine Hut Formation are massive fine-grained sandstones and quartzites. Bedding and storm bedding are well developed in places. The unweathered rock is light in colour and consists mainly of quartz with subordinate feldspar and biotite. The sandstones, on weathering, assume a red colour which is probably due to the oxidation of the iron rich accessory minerals. The upper quartzites and sandstones are much more resistant to erosion than the lower more micaceous members of the Pine Hut Formation. This differential weathering produces a ridge which coincides with the water divide.

Igneous Activity

The only evidences of igneous activity observed in the area investigated are several dolerite dykes and numerous hydrothermal quartz blows all of which occur in the highly folded portions of the Saunders Creek Formation. The dolerites appear to have a close affinity for the marble horizons, since all the dolerites found were within the marbles. One dolerite dyke occurs in a small quarry near "Lindsay Park" estate while several occur in Sibley's and I.C.I. quarries. The dolerites have suffered much alteration and may be classed as amphibolites. The feldspars have been largely altered to scapolite. Other minerals, occurring as medium grain sized crystals are hornblende, plagioclase (Andesine), apatite, biotite and magnetite. The dykes themselves are unsheared indicating that they must have been intruded in post folding times. The dolerites follow the joints in the marble with very sharp contacts and on the average are about six feet thick.

The hydrothermal quartz blows occur as milky white stocks and strike dykes and are associated with certain structural features. They occur along the noses of minor folds and in other tightly folded areas as seen at Conical Hill. Often the quartz blows from the resistant core to small hills.

The age of the igneous activity is uncertain, but the associations and structural control indicate that they must be post folding.

Post Kanmantoo Deposits

Some of the higher hills, such as Barren Hill, are capped by laterite. These cappings are typical surface deposits formed after peneplanation. The laterite consists of leached limonite with some hematite enclosing pockets of white kaolin. It seems that some portions of the original laterite must have been slightly more resistant and have survived denudation to protect the underlying sediments. Hills produced by this protective action are commonly steep sided and small in area.

Previous investigators report the finding of gravels (Tertiary) underlying the laterite. However, none was found in the particular area studied by the writer. Surface travertine deposits of a much younger age than the laterites overly the Kanmantoo Series especially in the Angaston district. There is a close association between the travertine and the marble-limestone horizons of the Saunders Creek Formation. There is also extensive travertine covering the Tertiary sediments of the Murray Plain, to the east of the fault scarp, which were not studied by the writer.

Soil cover is abundant in regions to the east of the Somme River, being particularly thick in the vicinity of "Lindsay Park" and "Collingrove" estates and Angaston.

STRUCTURE

Under conditions of deep burial, the rocks of the Kanmantoo Series underwent deformation by the action of a strong east-west compressional force. Conditions of folding were such that even the quartzites and sandstones of the Pine Hut Series, as evidenced by drag folding and contortion, responded incompetently. The Saunders Creek beds yielded to the compressional force in a highly incompetent manner bringing about great complexities of structure.

There are two main structural units in the area studied, one is a north pitching (average of 20°) syncline whose axial direction is approximately north-south and the other a south pitching (20°-30°) anticline of the same axial direction. The change of plunge between these two structural units takes place in a zone of shear (within the Saunders Creek Formation) that runs in the axial direction through "Keyneton Estate". For the purposes of this report this shear will be referred to as the Somme River Shear.

There is little surface evidence of the zone of shear except the abrupt change in pitch of the sediments on either side. The movement of the shear must have been of the hinge type, that is the eastern block was tilted to the north whereas the western tilted to the south. It is the writer's opinion that the movement was not taken up by any particular horizon but rather by the highly incompetent Saunders Creek Formation as a whole. Previous investigators have noted the change of pitch between the major syncline and anticline, but did not offer any explanation apart from the inclusion of a suspected fault which coincides with the zone of shearing suggested by the author.

Although it has been stated that the main structural features are a western anticline and an eastern syncline, the picture is much more complicated. The limbs of these major folds have suffered much minor drag folding, even the sandstones and quartzites of the Pine Hut Formation have been drag folded and crumpled to a high degree.

The axis of the major syncline has a direction of 5° west of north and is located ¾ mile east of Gipps trig station. On the east limb of the syncline occurs the Saunders Creek Formation forming part of the Murray Range fault scarp. These beds have undergone minor folding which is not so severe as encountered in the nose of the western anticline. A minor syncline with associated drag folding and contortion was identified in the field but it is possible that a minor anticline also exists.

As stated previously, limestones and lime-rich beds have been mapped in this region, but due to the lower grade of regional metamorphism, there are no major occurrences of marble. Between the two limbs of the Saunders Creek Formation in the synclinal trough the Pine Hut Formation is found to be tightly folded. To the west of the synclinal axis two minor synclines and one minor anticline were mapped. The noses of these minor folds are highly contorted and it is impossible to map all of the structure that occurs along the axes of the folds.

It will be noticed that the west limb of the Pine Hut Formation is considerably thicker than the east limb. An axial plane fault (corresponding to the axis of a minor anticline) has been postulated to explain this discrepancy. The movement of the fault was east side up. The only mineralisation in the district is associated with this fault, which is not considered to be associated with the Tertiary movements, but of a rather earlier age.

Steep dips are almost universal in the synclinal region. The average dip angle lies between 60°-80°. However, dips on the west limbs of folds are generally lower than those on the east indicating asymmetry of folding, that is the fold axial plane dips to the west. Due to the high angle of the majority of dips and the severity of the folding dip, readings are not always reliable and care has to be exercised in interpreting structure from them.

Measurements of dip and strike of rock jointing were taken and it was found that, within a range of up to 20°, the joints could be grouped, although in any one locality not all the joint directions were developed.

Axial plane bearing 170°
Tension joint bearing 75°-90°
Shear direction joints bearing 40°-60°
120°-140°

The diagram (fig. 2) indicates the grouping of these joints in relation to the strain ellipsoid. Some of the variations in joint strike can be explained by different rock types responding differently to stress.

The Saunders Creek Formation, which appears on the west limb of the main syncline, swings in a series of tight minor folds to the west to form the nose of the south pitching anticline.

The form lines (dashed lines on geological map) are meant to give an indication of the type of structure only. It is the writer's opinion that the structure within the Saunders Creek Formation is much more complicated than indicated by the form lines. Due to the lack of outcrop, marker horizons and the complexity of structure it was found impossible to trace every

minor fold. However, enough information was gained to indicate that the Saunders Creek beds acted incompetently. Plastic flowage caused thickening in the noses of the minor folds and thinning on the flanks.

Although there are differences of interpretation, the writer is inclined to agree with J.D. Campbell's theories of the type of folding in the Angaston area.

Apart from the Somme River shear and the East Limb fault there is the Murray Range fault. This fault strikes north-south and is situated about a mile west of Towitta. Movement, of the normal type, is considered to have taken place in early Tertiary times and its parallelism to the axial plane direction of earlier folding is explained by a pre-existing structural weakness. Due to the mantle of rock waste from the elevated block deposited in the fault zone, little evidence of the movement can be found apart from the topographic effects. In placing the Murray Range Fault on the geological map the first occurrences of Kanmantoo rocks encountered in east-west traverses from the Murray Plains were taken as indicating the fault's approximate position.

Previous investigators, working on the southern portions of the Cambrai Military Sheet, considered that the structure consisted of a major syncline and gentle folding in the western areas. The writer's interpretation agrees with the major eastern syncline but discounts the possibility of gentle folding to the west. This variation of ideas is produced mainly by differing opinions regarding stratigraphy and regional pitch. The stratigraphy as suggested in previous reports becomes intolerable if the change in pitch across the Somme River shear is taken into consideration.

METAMORPHISM

From a consideration of the mineral assemblages of the rocks it is evident that the area studied has been affected by a regional metamorphism of the albite, epidote, amphibolite facies (sub-facies chlorite, almandine). Previous reports indicate that there is an increase in the grade of regional metamorphism to the south, bringing about granitisation and scapolitisation. In the area investigated there is also a metamorphic gradient from east to west which is indicated by the more schistose nature of the western outcrops of the Saunders Creek Formation.

ECONOMIC GEOLOGY

Along a highly sheared limestone horizon associated with the East Limb fault, several small mine workings were found. Although there were no surface indications of mineralisation, samples were taken from the dumps and the following minerals were identified:-

Galena
Pyrites
Sphalerite
Malachite
Azurite

together with:-

transported limonite
Kaolin
Sheared limestone
Quartz
Siderite
Mica

The copper staining was only found in one mine dump and it was inferred that work had ceased within the oxidised zone since no primary copper minerals were found and the shaft was devoid of water.

None of the mine workings investigated were of economic importance, either having been abandoned or worked on a part time basis by private individuals.

The most important economic mineral in the Angaston district is marble. Two major marble quarries are worked in

the area; they are -

(1) I.C.I. Quarry

Large reserves of high grade stone are available. The quality of the stone is affected to a minor degree by dolerite dykes, shearing and surface weathering.

Large scale developments have been made in recent times to produce stone for cement manufacture, and to a smaller degree for the chemical industry.

(2) Sibley's Quarry

This smaller marble deposit is worked by a number of companies for monumental stone.

GEOLOGICAL HISTORY

(1) Deposition of the Saunders Creek Formation under shallow marine conditions in lower Palaeozoic times (Cambrian?)

(2) Deposition of Pine Hut Formation conformably on the Saunders Creek formation under marine conditions in lower Palaeozoic times.

(3) Deep burial of above formations.

(4) East-west compressional force resulting in tight folding and lines of weakness being developed.

(5) Regional metamorphism of the chlorite almandine sub-facies at the same time as, or later than, the folding.

(6) Movement on the East Limb fault and Somme River shear, possibly a later stage expression of the compressive force.

(7) Long erosion and peneplanation.

(8) Deposition of early Tertiary sediments.

(9) Movement along pre-existing axial plane lines of weakness, giving rise to the Murray Range block fault. The west block moved upward relative to east block.

(10) Further Tertiary marine sedimentation on the downthrow block.

(11) Formation of recent and present soils, alluvium and surface deposits.

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ACKNOWLEDGEMENTS

The writer wishes to thank Professor Rudd, Dr. Campana and Mr. P.G. Miller for assistance given during the production of this report.

TABLE OF PLANS AND SECTIONS.