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THE GEOLOGY OF THE MOBILONG MILITARY SHEET

EXPLANATION OF THE GEOLOGICAL MAP

by

R. K. Johns, M.Sc.
Senior Geologist

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PLATE 1. Fig. 1. The Bremer fault scarp from near Callington, looking east. Note level surface of uplifted block.

Fig. 2. The River Murray, near Toora. Tertiary limestones outcrop in foreground and in far cliffs.

PLATE 2. Fig. 1. Mica schists near Kanmantoo Mine. Contorted bedding marked by development of andalusite crystals.

Fig. 2. Synclinal structure on Barker Creek outlined by pyritic schists (Pyr.) enclosed by even grained greywackes.

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Fig. 2. Granite quarry, Murray Bridge. Polyzoal limestones (Tm) overlap Palaeozoic granite.

PLATE 4. Geological west-east cross sections across the eastern highlands.

PLATE 5. Fig. 1. Unconformity near Hartley. Steeply dipping Palaeozoic greywackes (€K) are here overlain by Tertiary gravels, grits, glauconitic marls and limestones (Tm).

Fig. 2. Pliocene limestones and sands, capped by kunkar, forming cliffs marginal to the River Murray at Tailem Bend.

PLATE 6. Geological cross sections of River Murray at Murray Bridge.

PLATE 7. Fig. 1. Granite quarry, Swanport.

Fig. 2. Quarry developed in Tertiary limestones, eastern bank of River Murray, Murray Bridge.

THE GEOLOGY OF THE MOBILONG MILITARY SHEET

INTRODUCTION

The Mobilong Military Sheet is situated between longitudes 139°00' and 139°30' and latitudes 35°15' and 35°00', extending over the easternmost slopes of the Mount Lofty Ranges and the flanking plains of the Murray Basin. It is bounded by the following previously published Sheets - Mannum (1957), Echunga (1954), and Alexandrina (1958). The most comprehensive work previously published and related to this sheet is that of Dickinson (1942)

Access to the area is provided by a system of good all weather roads. It is traversed by the Princes Highway - the main road connection between Adelaide and Melbourne and by the broad (5 ft. 3 in.) gauge railway linking the same capital cities. A subsidiary rail line extends from Monarto South northerly beyond Pallamana to Sedan.

Murray Bridge is the principal township having a population of 5,500. Tailem Bend is important as a rail junction. Jervois, Monteith and Swanport are small settlements on the River Murray flats where intense irrigation of fertile pastures supports dairying pursuits, while at Mypolonga irrigation area citrus and stone fruits are produced. Kanmantoo and Callington are survivals of an era of copper mining in those districts.

The average annual rainfall for the area is in the 12 to 15 inch range; figures for various recording stations being Mypolonga 12.11 in., Murray Bridge 12.21 in., Callington 13.94 in. and Tailem Bend 14.75 in.

PHYSIOGRAPHY AND DRAINAGE

The eastern Mount Lofty Ranges, in the area under review, show a general concordance of summit levels - being remnants of a Pliocene base levelled terrain. Post Pliocene earth movements along well defined north-south lineaments has resulted in a rejuvenated topography, steep stream gradients and deep gorges.

The highest point is elevated some 1,050 feet above sea level. There are no conspicuous peaks though several hills including Bremer (542 ft.), Camel (559 ft.) and Gifford (559 ft.) are prominent, marginal to the ranges proper.

The highlands forming the eastern border of the map sheet are separated by the broad valley of the River Bremer from a horst bounded by the Bremer fault on the west (Plate 1, fig. 1) and by the ~~Preamimma~~ Pallamana fault on the east. Surface elevations fall gradually in southerly and easterly directions giving way to the plains which constitute the Murray Basin.

The Murray plains are gently undulatory with elevations falling below 50 feet. Superimposed sand dunes aligned in a generally east-west direction modify the surface form.

Bisecting the plains is the most striking physiographic feature of the area - the Murray River which occupies an entrenched meandral course in a modified canyon (Plate 1, fig. 2). The stream alternates from one cliffed margin to the other being confined by artificial levees from broad alluviated flats or, in several cases, from shallow lagoons. The confined river is about 10 chains wide and it has incised a valley about one mile in width having cliffs 20-100 feet in height.

There are no surface drainage channels east of the River Murray.

In the ranges the prominent fault scarps exert a strong control on surface drainage. The Bremer River, a consequent intermittent stream, is the principal one, receiving large accessions from the Mt. Barker Creek system which drains the terrain east of the Kohunga - Meadows divide, and empties ultimately into Lake Alexandrina. Preamimma Creek and Rocky Gully empty into the Murray near Murray Bridge but other channels which discharge onto the Murray plains in this region are soon dissipated.

GEOLOGY

Basement rocks are Palaeozoic sediments which have undergone intense folding, regional metamorphism and migmatisation which culminated in mobilisation and granite intrusion. These are overlapped by a generally undisturbed sequence of Tertiary limestones whose thickness here is seldom more than 200 feet. The greater part of the area is veneered by Quaternary drift. Recent alluvial materials are related to the present drainage system.

Kanmantoo Group (Palaeozoic)

The oldest rocks exposed are of Cambrian age being members of the Kanmantoo Group as defined by Sprigg and Campana (1953) and whose relation to the underlying Adelaide System (Proterozoic) have been discussed more recently by Kleeman and Skinner (1959) and by Horwitz et al. (1959).

A thickness of over 40,000 feet of characteristic "flysch" facies consisting of greywackes, mica schists, micaceous quartzites, siltstones and phyllites are exposed in the area. Several more or less distinct units within the exposed Kanmantoo Group have been recognised and mapped.

The lowermost unit is now represented by a belt of migmatites which outcrop along the easternmost flanks of the ranges where they are truncated by the ~~Preamimma~~ Pallamana fault. These beds are at least 8,000 feet in thickness and consist principally of quartz plagioclase biotite schists carrying quartzo-felspathic veinlets and incipient pegmatites. Biotite schists, occasionally with crystals of fluorapatite are sparse while actinolite and anthophyllite schists are common. Discordant tourmaline bearing pegmatites are common in this belt. The sequence is best studied along Rocky Gully; petrographic features of selected rocks from here have been described by Johns and Kruger (1949).

The succeeding sediments over 20,000 feet in thickness form a monotonous sequence of drab grey coloured, even, fine grained greywackes and siltstones, being now represented largely by fine grained quartz-felspar mica schists. A shale interval has been differentiated and this is readily traceable in the Kanmantoo-Callington region though the upper and lower boundaries are not sharply defined and are somewhat arbitrary in nature. The limits of this unit are more poorly defined east of the Bremer Fault where there is a change to coarser facies while in the keel of the synclinal structure between Monarto and Monarto South they were not recognised. The shales have been transformed to phyllites and schists consisting essentially of micas with felspar, quartz, andalusite and staurolite. The andalusite bearing schists are mostly conspicuous rocks and contain crystals or knots of andalusite up to an inch in length - for these rocks Woolnough (1908) coined the term 'paringite'. These are illustrated in Plate 2, fig. 1, where andalusite crystals stand out as prominent knots or nodules with marked development along bedding planes thereby preserving sedimentary structures which intense metamorphism has commonly destroyed elsewhere.

Pyritic schists occur at a number of levels within the Group. There are at least ten separate horizons, all being superficially identical in composition and texture and lenticular in form. Though they are useful in tracing out the structure (Plate 2, fig. 2) in several areas they are too discontinuous to make good horizon markers. The beds have a characteristic outcrop and may be traced by the leached boxworks in the generally yellow or red weathered and iron stained outcrops. Micas and fine graphite are often abundant while sillimanite is a sporadic accessory and garnet is sometimes discernible. Outcrops are generally smooth and rounded in contrast with the blocky outcrops of the enclosing greywackes. Fresh unweathered sulphides are rarely seen but they are exposed in a roadside excavation 3 miles east of Monarto. Individual beds vary considerably in width up to several hundred feet, the thickest and most persistent beds being those of the Rockleigh locality and though no direct correlation can be made they appear to be either equivalent or slightly higher in the succession than the bedded Nairne (Brukunga) pyrite deposits.

Metamorphism and Igneous Activity

The Kanmantoo greywacke type sediments appear to have been folded, deeply buried and to have undergone regional metamorphism which gave rise to phyllites and mica schists locally of sillimanite grade. The region mapped is portion of a wider belt of metamorphic rocks extending along the eastern flank of the Mt. Lofty Ranges and which are invaded at isolated centres by mobilised cones of granite (e.g. Victor Harbour, Palmer and Murray Bridge) and at other centres enclose concordant bodies of granitic rock derived from granitization of sediments in situ (e.g. Palmer and Monarto).

(1) Murray Bridge granite

This granite is undoubtedly comagmatic with those of Victor Harbour and Palmer. It has all the characters of an originally mobile magma and is considered to form part of the batholythic mass traceable in a south easterly direction through Cold and Wet to beyond Mount Monster (Mawson and Segnit 1946 etc.)

It is a coarse grained reddish brown coloured rock composed of brown microcline, vitreous smoky quartz and subordinate white plagioclase (andesine) - {in some cases plagioclase mantles the potash felspar crystals}. Biotite is a common constituent while accessories include fluorite, magnetite, zircon, sphene and apatite. Petrographic characters have been discussed by Kleeman (1934) and Johns and Kruger (op. cit.)

Xenoliths are sparsely distributed, the most noteworthy being exposed in the old quarry in Sturt Reserve at Murray Bridge.

(2) Monarto Granite

The Monarto "granite" is typically a light grey coloured rock of fine and even grain but it varies in texture and grain size and occasionally displays a gneissose structure. It is of adamellite composition consisting of grey-white coloured felspars, including oligoclase and microcline, biotite and muscovite with accessory zircon and apatite.

The granite (Plate 3, fig. 1) is considered to be a concordant body generated _in situ_ by granitization of pre-existing greywackes. Contacts with host rocks where observable in its northernmost extremity are quite sharp though somewhat irregular in plan, whereas along its eastern aspect they are diffuse and ill defined.

(3) _Pegmatites_

Discordant pegmatites are common in the migmatite belt flanking the eastern scarp of the range and possibly represent crystallized residual liquors from the Murray Bridge granite magma. The principal constituents are quartz, microcline, muscovite and tourmaline.

(4) _Basic Dykes_

Two discordant meta dolerite dykes have been noted in the bed of Rocky Gully.

Geological Structure of the Basement

The major faults and their effects on surface drainage etc. have been described in a preceding chapter. The Bremer fault is traceable north into the Mannum (1957) map sheet as a broad zone of brecciation. On the Mobilong Sheet the rocks adjacent to the fault zone are somewhat broken but cannot be described as brecciated. Vertical movement on the fault is inferred (Plate 4) to be small. The Bremer Scarp is a prominent physiographic feature (Plate 1, Fig. 1), throughout its length to the Bremer trig vicinity whence it plunges below the Murray plain.

Precise vertical movement on the Palmana fault is indeterminate but it is possibly 200-300 ft. Its southwestern prolongation is discussed in a succeeding chapter.

The basement sediments have been folded in a complex manner with the fold axes being more or less meridional and attended by intensely crumpled drag folds which are developed on all scales of magnitude.

The geological structure west of the Bremer fault is generally synclinal, with a major synclinal axis paralleling the western border of the sheet. The sediments in the northern extremities are here steeply inclined and often overturned but bedding dips moderate southwards, the overall pitch of the fold structures being directed southerly.

The above structure is separated from a generally open syncline occupying the greater part of the Bremer horst by a highly attenuated anticlinal structure whose axis is traceable from near Monarto South northwards where it converges on the Bremer fault.

Minor crenulations developed on the major structures add complexity to t e fold pattern.

Tertiary Sediments

1. Marine Sediments

(a) Miocene

Ludbrook (1918) has described the Mannum Formation which is so well exposed in the cliffs of the River Murray as the most markedly transgressive element of the Murray Group of Tertiary sediments. The base of the formation is observable in this area at a number of places; at Murray Bridge the limestones are in direct contact with granite (Plate 3, Fig. 2), near Monarto South with Monarto granite and schists, and along the course of the Bremer River in the Hartley locality with greywackes.

In the cliffs of the Murray River t e formation is typically composed of calcarceus sandstones and sandy limestones crowded with Lovenia "forbesi" and other echinoids. Near Murray Bridge township a number of quarries expose dense calcarenites which are in this locality typical of the formation.

The basal beds between Monarto South and Kinchina R.S. incorporate large blocks of granite and pebble beds. Near Hartley the basal beds consist of grits and gravels and these are succeeded by glauconitic marls, sands and sandy limestones (Plate 5, fig. 1).

(b) Pliocene

The cliffs marginal to Bell Swamp and extending southerly beyond Tailem Bend on the eastern side of the Murray are composed of fine yellow and white unfossiliferous sands, in part micaceous and containing very little clay, with interbedded green, grey and brown clays.

At Tailem Bend (Plate 5, fig. 2) these are succeeded by fine calcareous loosely coherent sands and limestones carrying abundant Marginopora vertebralis - the North West Bend Formation described previously by Ludbrook (1959).

2. Terrestrial Sediments

Remnants of late Tertiary ferruginous grits and laterites are preserved at several localities and mark traces of an old (?)Pliocene peneplained surface. The best exposures are at Lucernbrae where several feet of flat lying ferruginous grit mantle greywackes. Elsewhere the cappings have been largely removed by erosion and only scattered fragments remain.

Quaternary Deposits

The land surface of the Murray Plains is generally blanketed by siliceous sand and/or travertine limestone which with clays overlie the Tertiary limestones; these are assigned a Pleistocene age. The sediments are of varying thickness and attain at least 55 ft.

De Mooy (1959) rejects Crocker's (1946) "hypothesis of formation of the present aeolian topography during a Recent Arid Period (Flandrian transgression)", and postulates "redistribution of sands by aeolian activity .... in Pleistocene arid cycles". He classifies the soils of these areas as part of the Seymour Combination which "may be regarded as portion of the Mallee country extending eastward across the Victorian border .... The materials are predominantly coarse textured, redistributed by aeolian activity, and commonly travertinized near the surface. West of the River Murray the plains extend .... to the foot of a range which it is suspected represents a former coastal dune range." The approximate position of this suggested stranded shoreline is determined by the 200 ft. contour to the west and south west of Murray Bridge.

There is a distinct possibility, however, that this line marks the trace of the buried Palmona scarp southerly from near Gifford Hill to "Loydella" and beyond. The cover of Tertiary strata on this horst block is generally thinly distributed over basement and in several places it has been completely stripped. Mica schists outcrop on the southern boundary of the map area while near Brinkley, a short distance east of the presumed position of the fault, a bore penetrated 323 ft. of Cainozoic sediments before entering basement.

Sprigg (1959) in a study of the sand dune association of the Upper South East has plotted the principal dunes, of which this area forms part of a "white sand-dune complex". The main source of sand is considered by him to have been introduced by the River Murray with lesser amounts from coastal erosion in Encounter Bay and from submarine outcrops of granite and/or pre Tertiary and Tertiary sedimentary rocks and subsequent distribution by dominantly westerly winds. The importance of large contributions of sand derived from resorting of Permian glacial materials appears to have been inadequately stressed.

Periods of low sea level during the Quaternary and undoubtedly related to Pleistocene glaciation are reflected in the bed of the River Murray at Murray Bridge where the mean water level of the river is about 8 feet above lower water Port Adelaide; the present bed is 50 feet below this datum. Boring undertaken prior to bridge construction shows that there are up to over 110 ft. of silts, clays and sands below water and resting on an old granite floor which makes the old true bed of the river 120 ft. below base level. Plate 6, summarising these data shows an undulatory granite floor overlain by a lenticular sequence comprising sandy clays, sand, clays and silt with peat. The rise which separates the two well defined channels emerges further downstream as Long Island (inadvertently shown as Tertiary on the Mobilong Map).

Drilling on the river flats at the site of the present railway bridge shows a more extensive bed of sand (up to 30 ft. in thickness) below silts, clays and a bed of peat; these pass downwards into sands and gravels at the base. These deposits mantle Tertiary limestones which are here separated from granite basement by 20-25 ft. of gravelly clays.

The implication that the river formerly ran on a higher grade, when the deeper erosion was effected was first discussed by Howchin (1929) and more recently by Sprigg (1952) and Gibson (1958).

The shallow alluvial deposits of creek channels and flood plains in and adjacent to the ranges are related to the present cycle of erosion.

MINERAL AND ROCK DEPOSITS

(1) Copper

The copper deposits of the Callington - Kanmantoo district have been exhaustively dealt with by Dickinson (1942). Mines, in order of importance, described include the Bremer (workings to 600 ft.) the Kanmantoo (to 200 ft.) and the Paringa (to 250 ft.). The West Kanmantoo, Wheal Friendship, Wheal Prosper and Wheal Maria were small producers.

"Copper was the chief economic mineral of the district and it was obtained from small hypogene quartz veins in the form of metallic sulphides or their oxidised derivatives. Other economic minerals including lead, silver, zinc, arsenic and gold were produced also but only in small or negligible quantities". (Dickinson, 1942).

The mineral deposits are described as being numerous, small in size and having a chaotic areal distribution. Dickinson further states that "the principal ores worked were primary copper sulphide ores which, ... assayed 8-12% Cu. The metalliferous minerals comprised chalcopyrite, pyrite and bornite in a gangue composed chiefly of quartz with some calcite and micaceous minerals .... The copper minerals, particularly in the Bremer Mine are reported to have been somewhat contaminated with bismuth which decreased their potential value.

"The ore deposits comprise numerous small ore bodies which may be classified into two broad structural types (i) pipes and (ii) tabular veins. Both are localized by intersecting sets of fractures which appear to be concentrated in restricted zones elongated parallel to the regional trend."

"............. The veins are transverse or oblique to the crumpled stratification and have been formed in irregular interlacing fractures. In general the ore-shoots are pipelike in form and attitude (steep pitch). They do not have pitches comparable to those of adjacent sediments but cross cut the bedding along the lines of intersection of the steeply inclined fractures. The Bremer Mine ore shoots have a tabular form and are thus contrasts to the general type. In this mine the ore shoots appear to occupy stronger and more persistent fractures in contra distinction to the intricately woven breaks at Kanmantoo and elsewhere."

Summarising, he says the "total copper output of the district came mainly from two mines, the Bremer and the Kanmantoo. It amounted to roughly about 5,000 tons and was produced principally between the years 1846 and 1875.

"....... No known ore reserves are present in any of the mines. .... The failure of past operations to produce the above small tonnage, which was chiefly derived from shallow workings in oxidised or enriched sulphide ores, on a profitable basis, together with geological experience lead to the conclusion that the deposits are of no present economic importance and that no encouragement can be given to further exploration schemes".

(2) <u>Gold</u>

Gold production was limited to the workings of the Pioneer, Lady Jane and Great Gun mines. The Pioneer workings were less than 100 ft. deep in ore containing copper, arsenic and gold. The recorded production amounts to 80 tons of ore containing 8 dwts. gold/ton.

The Lady Jane Mine was in operation in 1902 and for a short period in 1927. There were two main shafts, one to 110 ft., which were connected by a drive. The lode was reported to be thin

(Pearson, J.L., 1927, Min. Rev. 46, pp. 67-70).

(3) Arsenic

The ore from a number of mines of this area contained arsenic but the Preamimma was the most important.

This mine was first opened in 1854 and reopened for short periods in 1862, 1899, 1907 and 1924. Copper ores and later arsenical ores were mined from several shafts (the deepest is reported to be 300 ft.) and from drives at four separate levels. Winton, L.J. (1924, Min. Rev. 41, p. 73 and 1926, Min. Rev. 44, p. 53) reported on the property and records that 300 tons of 40% arsenical ore were sold.

(4) Pyrite

Bedded pyritic schists, apparently similar in grade to the Nairne pyritic ore, occur at a number of stratigraphic levels within the Kanmantoo Group. The material having the coarsest grain and highest grade of unleached pyrite close to the surface occurs in a road side quarry 2½ miles east of Monarto. At the outcrop the bed is here less than 100 feet in width though in a trial of electromagnetic equipment an anomalous zone 500 feet in width and having three peaks was indicated.

These beds elsewhere are strongly leached and oxidised, the depth of weathering being unknown.

(5) Building and monumental stone

This area provides several varieties of attractive stone which are utilised in the building and monumental trades.

(a) Granite

The Murray Bridge and Swanport granites are of very uniform, coarse even grain and attractive in both the rough dressed and polished forms; they are classed in the trade as 'red' granites. They have been quarried from several deposits; formerly at Murray Bridge near Sturt Reserve and currently from both sides of the River Murray near Swanport (Plate 7, fig. 1) where the reserves are large. Their current use is confined to ornamental facings, in base courses, as a building stone and to monumental purposes. Their hardness makes them suitable for kerb construction and paving blocks and they have been used extensively in the City of Adelaide for this purpose.

Examples of their use are the base courses of Adelaide Railway Station, the Savings Bank of South Australia and the base pedestal of the South African War Memorial.

The Monarto granite has been quarried in the past for use in kerbing and as a building stone. It is typically a fine grained light grey stone, hard, and displaying a weak gneissose structure.

Examples may be seen in the base of Colonel Light's Statue at Montefiore Hill and in the steps of St. Peter's Cathedral.

(b) Murray Bridge Freestone

Tertiary polyzoal calcarenites have been formerly quarried from the cliffs of the River Murray near Murray Bridge and also a small quantity from near Mypolonga.

The freestone used is a fine grained dense facies of the Mannum Formation containing occasional layer shell fragments that weather slightly more slowly than the matrix. Durability is good but the chief disabilities are the presence of cavities which result from solution and clay pocketing and require stopping, and the high proportion of waste to be removed in quarrying operations.

It is of light buff to yellow brown colour, fairly hard but capable of being readily sawn and carved. It has a high compressive strength but is somewhat brittle when transversely loaded.

It has been used largely in the district for building and in Adelaide as a structural material for many public buildings. It was used in the G.P.O., the Museum, Art Gallery and the superstructure of St. Peter's Cathedral.

(c) "Travertine"

Limestone was used almost exclusively for dwellings and farm buildings in those areas veneered by "travertine" (kunkar) because of its ready availability and ease of working. It is a white to buff coloured amorphous stone, of variable hardness and irregular fracture.

(d) Greywacke

Farm buildings and dwellings situated in the hilly areas underlain by greywackes are largely constructed of this type of stone. It breaks generally along well defined fractures into easily workable stone suited to walling construction.

(6) Ballast etc.

Ballast, road construction materials and aggregate for civil construction projects are derived from the Palaeozoic rocks and from Tertiary limestones. Quarries located in the Kanmantoo Group of sediments provide coarse aggregate for base courses and finer material for sealing of roads with bitumen in areas where they are required.

Tertiary limestones are being actively quarried for road works near Murray Bridge. Plate 7, Fig. 2 shows one of a number of quarries producing aggregate from the cliffs of the Murray River.

(7) Clays and shales for brickmaking

The suitability of local alluvial clays and deeply weathered bedrock shales for brickmaking is being investigated. Preliminary work indicates that a blend of these raw materials may be satisfactory for the establishment of a local industry providing reserves of these materials are adequate.

HYDROLOGY AND WATER SUPPLY

Large supplies of water are drawn from the River Murray for township use, irrigation of pastures, orchards etc. on the river flats and adjacent lands and for reticulation through a system of mains to nearby farms.

Most of the farming community, however, is dependent on underground sources of supply augmented in areas where catchment and permeability are adequate by the storage of surface waters in dams.

In the ranges stock waters are drawn from shallow wells constructed in gravels and alluvium of stream channels and from deeper bores drilled into basement rocks. Those supplies are generally small . Salinities of underground waters here are very variable and they range from good stock waters to brackish and, in areas of poor recharge, salt water.

In that part of the Murray Basin west of the River Murray bores, which provide windmill supplies, range in depth from 150 to 350 ft. depending on surface elevation and depth of bedrock. The salinities of these waters range from 200 to 500 grains/gallon while several bores yield water too saline for stock.

The main aquifer is the porous Tertiary limestone which is generally obscured by a thickness of Quaternary strata up to 50 ft. in thickness. The limestones form a thin mantle over the basement rocks of the Bremer horst and deepening southwards to at least 278 ft. near Brinkley in the section immediately east of the Pallamana Fault. From the Murray Bridge - Swanport locality where granite outcrops or lies at shallow depth the Tertiary limestones thicken both northwards and southwards to possibly 200 ft.

East of the River Murray bores sited near the river are generally 100 ft. in depth but depth to the aquifer increases to the east to almost 250 ft. Granite outcrops sporadically and forms an undulating impermeable floor to water bearing Tertiary sediments which thicken generally in an easterly direction; the greatest recorded thickness being 262 ft. penetrated in a bore situated 2 miles north of Tailem Bend.

Salinities of 400-500 grains/gallon in bores marginal to the river are common but deteriorating to salt (over 1000 grains/gallon) in the Bartlett trig locality in an area where there are a number of granite outcrops.

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