DEPARTMENT OF MINES
SOUTH AUSTRALIA

GEOLOGICAL SURVEY
REGIONAL SURVEYS DIVISION

EXPLANATORY NOTES ON THE RENMARK 1:250,000 SHEET

by

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QUATERNARY STUDIES SECTION

Rept.Bk.No. 71/33

3rd March, 1971

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EXPLANATORY NOTES ON THE RENMARK 4-MILE SHEET

The Renmark 1:250,000 Sheet area is bounded by 34° and 35° South latitude and 139°30' and 141° East longitude. It includes about 5700 square miles in the south-east of South Australia, and is centrally situated in the South Australian portion of the Murray Basin. The area includes Counties Albert and Alfred and portions of Counties Buccleuch, Chandos, Eyre, Hanley, Sturt and Young. Also, the District Councils of Truro, Morgan, Waikerie, Loxton and Barmera and the Corporation of the Township of Renmark.

The Sturt Highway links Renmark in the north-east of the map area with Adelaide about 160 miles distant to the west-south-west. This highway also links Renmark to major cities in western New South Wales and western Victoria. A major road through Morgan connects with the Main North Road and with major north-south roads through the Barossa Valley. Secondary and other roads provide ready access to most parts of the map area, and to the Princess Highway, the Duke's Highway, and a major road from Adelaide to Pinnaroo, all south of the map area. The Murray River, which once provided the main access in the days of the paddle steamer, is navigable by small craft.

Pioneer contributions to the geology and geomorphology of the area were made by Sturt (1834), Tenison-Woods (1862), Tate (1885), Brown (1910), Chapman (1916), Howchin (1929) and others. The following notes are derived mainly from Firman (1969, b) and (1971, b). The earlier paper is based upon

contributions by various authors in Glaessner and Parkin (1958), the definitive works of O'Driscoll (1960) and Ludbrook (1961), and other contributions by Ludbrook, Thomson and Wopfner in Parkin (1969).

PHYSIOGRAPHY

Climate

The climate of the map area is one of hot, dry summers with relatively mild nights, and cool, but not severe winters with most rainfall during May, June, July and August. Isolines trend more or less east-west through the area. Average Annual Rainfall varies from about 14 inches in the south to about 10 inches in the north. Mean maximum temperatures vary from about 85°F in the south-west to about 90°F in the north-east. Average annual evaporation varies from about 60 inches in the south to 65 inches in the north. The southern boundary of the arid zone follows the east-west course of the Murray River along the northern boundary of the map area. The driest year in terms of rainfall was 1967. In 1914 - prior to the construction of locks - the Murray River was but a series of waterholes.

Landform

The map area is part of a great plain mainly less than 500 feet above sea level. There is a gradual rise of about 200 feet from the riverine tract, which is 100 to 150 feet above sea level, towards the Mallee Ridge in the south-east. This ridge is the surface expression of the Kosciuskan tectonic feature called the Pinnaroo Block (Firman, 1965). There are only small changes in local relief. These are due to stream incision and the formation of cliffs up to about 150 feet high along the Murray River, to undulations in old pre-

dune land surfaces up to about 100 feet, and to differences in elevation between dune crests and interdune swales. Because of the flat terrain, the absorbent nature of the surface and the generally low rainfall, the amount of surface run-off is negligible. The Marne River in the south-west is an exception.

The Murray River is the most distinctive feature. The upper or Nawait section of the river, from the South Australian border with New South Wales and Victoria to Overland Corner, occupies a valley from 2½ to 6 miles in width. In this part of its course, the river winds through extensive flats with numerous backwaters and creeks. Downstream from Overland Corner, the river flows through a narrow gorge about 1 mile in width with steep high cliffs. At the point where the river enters South Australia, river level is only about 55 feet above sea level.

The river has incised into its bed leaving vertical limestone cliffs which characterise all of its course within the map area, and particularly that part downstream of Overland Corner. O'Driscoll (1960) drew attention to a repetitive pattern of rectangular reaches jointed by sharp bends, and suggested control of the river by jointing. A later study of structural lineaments has confirmed this impression (Firman, 1970).

The evalution of the Murray River and of some of the younger geomorphic features has been briefly described in Firman (1963 and 1971b). Karst forms - mainoy sinkholes - were developed before and after the development of Middle Pleistocene calcrete. In most places, the sinkholes are now buried below younger dunes, but where they are exposed at ground surface they provide vertical connection with the groundwater surface at a depth of about 100 feet, and there is a consequent diminution in salinity together with low chloride

/carbonate ratios in the adjacent groundwater. Horizontal channels connect with the Murray River in some places. The solution features were probably developed during low stands of the Pleistocene sea.

STRATIGRAPHY

The portion of the Murray Basin within the map area contains about 1000 feet of Tertiary sediments, which overlie Cretaceous and Permian rocks in the Renmark Trough and Paringa Embayment, and lower Palaeozoic and Pre-Cambrian basement elsewhere. Sedimentary rocks older than Manoora Formation do not crop out in the map area. The Murray Basin was shaped and infilled with younger sediments during the Tertiary. Many important sequences are exposed in the Murray River cliffs.

The stratigraphy of older rocks in the basin is set down in the complementary bulletins of O'Driscoll (1960) and Ludbrook (1961). The stratigraphy of younger basin deposits is described in Firman (1969b and 1971b). Stratigraphic correlations of sediments in the South Australian portion of the basin with units elsewhere in South Australia are made in Ludbrook (1963), Harris (1966), Firman (1967b) and Parkin (1969). Relationships between stratigraphic units in the South Australian portion of the basin and elsewhere in Australia are discussed in Boutakopf (1963), Lawrence (1966), Macumber (1969), Sprigg (1967) and Ludbrook (1967).

The age, lithology, thickness and stratigraphic relationships of the rock units within the map area are set out on the accompanying stratigraphic table (Table 1).

STRUCTURE

The basin sediments of the map area are bounded on the west by the folded and metamorphosed sediments of the Adelaide Geosyncline and the Cambrian

rocks of the Kanmantoo Group. The structural boundary between these rocks and the basin sediments is west of the map area (See Firman, 1970a). On the western side of the map, basement crops out in the bed of the River Marne and has been intersected in numerous shallow bores.

A great number of hydrology bores have been put down within the basin in search of water. Some have intersected basement rocks, and it is from these and from aeromagnetic and earlier gravity work that O'Driscoll (1960, p. 17) constructed the contours showing bedrock configuration which are reproduced on the tectonic sketch. Later gravity and seismic work has better defined the region about the Remark Trough and Loxton Basin (Fig. 1 and 2). Although the shallow bores cannot be used to define bedrock configuration, they can be used to interpret warping and small scale faulting typically developed in brittle Cainozoic sediments.

A prominent north trending vertical fault, the Morgan Fault, with a throw-east block down - of about 100 feet is present immediately west of the Murray River. The Hamley Fault (see Tectonic Sketch), which is part of the Endeavour Fault zone, has been interpreted from gravity data as forming the west margin of the Remark Trough.

A well defined pattern of structural lineaments, including faults and major joints, has been developed in the Tertiary basin sediments. (Firman, 1967b, p. 170; 1970a pp. 1-3). Some lineaments parallel older faults and have throws up to a least 200 feet, others are probably major joints. On photomosaics the fractures usually occur as lineaments trending roughly north-west and north-east. They occur in several sets, and intersections from rectangular

and rhomboid blocks. The development of the lineaments throughout the late Cainozoic is associated with upwarping of the western margin of the basin, and the stranding of Tertiary and older Pleistocene sediments high in the marginal ranges. The pattern of lineaments, although developed mainly in brittle basin sediments and younger surficial deposits, reflects profound structures and tectonic elements in the crystalline basement.

The pattern of lineaments - together with spatial distribution of outcrop, some aeromagnetic trends and the thickness of sedimentary sequences revealed in bores - has been used to define the shape of the late Cainozoic Loxton Basin (See Tectonic Sketch). This basin had its origin during the late Palaeozoic block faulting which preceded Permian sedimentation in the Renmark Trough and elsewhere. Later faulting created a broader basin infilled with Cretaceous sediments. Finally, post-Miocene and Kosciuskan tectonic movement produced the structural depression in which late Cainozoic sediments of the Loxton Basin were deposited.

Differences in the fit of the basin shape as derived from a study of lineaments and from the pattern of the Bouger anomaly map, seems to suggest extensive modification of trough and basin margins, probably by fluvial erosion prior to successive periods of sedimentation, as suggested in Derrington and Anderson (1970).

GEOLOGICAL HISTORY

PALAEOZOIC

The Murray Basin in South Australia has on its western margin the folded sediments of the Adelaide Geosyncline and the Cambrian rocks of the Kanmantoo Group. These rocks constitute an important provenance area for sediments deposited within the basin and also form the basin floor. The rocks

crop out at one place in the bed of the Marne River on the western margin of the map area. The original sediments were mainly of greywacke type with minor developments of carbonate rocks and other clastics, which intense regional metamorphism altered to meta-greywacke, schist and gneiss during the Lower Palaeozoic Delamerian Orogeny.

A prolonged period of relative stability marked by faulting followed the Delamerian Orogeny. During this time the area was probably uplifted to form a source area for Middle Palaeozoic sediments deposited in basins to the north and east.

Early in the Permian a considerable area of the State was covered by ice. The marine, fluvio-glacial and other deposits of this time include the Permian till, sands and clays deposited in a deep basement trough which extends between Monash and Renmark. The Permian sediments in the Renmark Trough thicken from 120 feet at Loxton to 2197 feet at Nadda. The strata contain foraminifera and are believed to be of marine glacial origin.

MESOZOIC

During the Triassic and Jurassic the present land mass of the State was above sea level. Large scale down-warping of the crust began early in the Cretaceous and large areas were inundated by the sea. Basal non-marine quartz sandstones in the Murray Basin were probably laid down at this time. The marine environment persisted throughout the Lower Cretaceous. The marine beds overlying the basal sandstones consist of siltstones, followed by a dark grey marine shale of Aptian age. In late Cretaceous time most of the basins had become filled with sediments and the environment gradually changed from marine to fluvio-lacustrine. Cretaceous sediments younger than Albian are not known.

CAINOZOIC

Paleocene to Eocene

At the beginning of the Tertiary, uplift of the ranges and complementary subsidence of the present basin areas was followed by an ingression of the sea. During the early Tertiary, conditions of deposition were paralic and carbonaceous sands and silts, lignitic beds and low rank coals were laid down.

In the Murray Basin, the name "Knight Group" has been used for the undifferentiated sands, clays and siltstones of Paleocene to Eocene age near Coonalpyn. These sediments are equivalent to the Renmark Beds in the nap area. The "Knight Group" beds are overlain by the marine Bucclough Beds, a sequence about 170 feet thick which contains important faunas for correlation. The Bucclough Beds represent an incursion of the sea during the Upper Eocene which reached as far north as Waikerie.

Oligocene to Miocene

The Oligocene marine transgression is marked by equivalents of the Compton Conglomerate and by the Ettrick Formation. The Mannum Formation, which is overlain in places by Finniss Clays, is transgressive on to bedrock on the western margin of the basin. This unit, and the Morgan Limestone - which with the Cadell Marl Lens attains a thickness of 300 feet - indicates warm shallow seas. Gambier limestone in much the same stratigraphic position as Mannum Formation has been identified in Waikerie Bore No. 2. The units were deposited in a neritic to littoral environment.

Pliocene

Tectonic activity, which led to the break-up and elevation of the Tertiary basins, commenced in the late Miocene. After the early Pliocene ingression, the Hookpurnong Beds were deposited. Estuarine conditions followed

when the lower beds of Loxton Sands were laid down. Elevation of the basins continued and the upper fluvio-lacustrine beds of Loxton Sands were deposited.

A minor downwarp in the late Pliocene led to marine ingression and deposition of estuarine Norwest Bend Formation in a tract between Tailem Bend and Waikerie now occupied by the Murray River. The formation rests directly upon Morgan Limestone at Norwest Bend, elsewhere it overlies Loxton Sands with a slight discordance. The Parilla Sand is a slightly clayey and micaceous quartz sand equivalent in part to the Norwest Bend Formation, into which it grades near Kingston-on-Murray, Firman (1966d, p. 6 and 1971b). The unit overlies the upper beds of the Loxton Sands and was -probably deposited in a fluvio-lacustrine environment marginal to the narrow estuary containing Norwest Bend Formation. The unit is much more extensive than the Norwest Bend Formation.

Pleistocene

From the Paleocene to Oligocene and during the Pliocene, clay, mica and quartz sands derived directly from granitic rocks, gneiss, schist or meta-sediments or indirectly from the Permian fluvio-glacials were incorporated in sediments in the South Australian portion of the basin. This material formed the Tertiary covermass which was later re-worked and incorporated in the mainly clastic deposits formed throughout the Quaternary. Although the clastic material in many of the Quaternary deposits was derived either directly or indirectly from a provenance in the Otway Ranges, Mt. Lofty - Olary Ranges or basement highs along the Padthaway Ridge, much of it can be traced to older sediments immediately adjacent to or underlying the younger deposits.

Thin terrestrial deposits laid down at this time include a silicified cap on Parilla Sand near Chowilla, which is a Pleistocene fossil soil stratigraphically associated with the basal part of Blanchetown Clay in that area.

This feature is correlated with a silicified and foruginised cross-bedded aeolian quartz sand near Bordertown, which is probably the upper cemented portion of "Diapir Sandstone" (Lawrence, 1966, pp. 535-536).

Older Alluvial Deposits of the Murray Basin

Pleistocene sedimentation inland produced the wide-spread, thin fluvio-lacustrine Blanchetown Clay and the overlying Bungunnia Limestone. The Blanchetown Clay, which ranges in thickness from a few feet on the western edge of the depositional area to about 50 feet in the north-east near Chowilla, is widespread in the Murray Basin marginal to the Pinnaroo Block.

A time of silicification followed an interruption in deposition of the basal part of Blanchetown Clay. This event is marked by the Karoonda Surface, already described. The materials associated with this surface were re-worked to form the Chowilla Sand, a lensing sand of fluvial-lacustrine origin known to outcrop in river cliffs between Merbein in Victoria and Berri.

The Bungunnia Limestone, a thin and variable dolomitic micrite containing ostracodes, algae and oolites, was deposited during the Middle Pleistocene. In some places, loess is found between the unit and the underlying Blanchetown Clay, which indicates an important diastem. The area of distribution is similar to that of the Blanchetown Clay and serves to mark the boundary between the fluvio-lacustrine environment in which the clay was deposited and the gravelly piedmont environment of the adjoining ranges.

All deposits and other geological features were covered by or included in the limy 'B' horizons of a brown soil (Bakara Soil; the "Travertine .... in .... Solonized Brown Soils" of Crocker, 1946, p.31), which is now indurated and fossil. The oldest, hardest, thickest and most extensive of the limy horizons or pans, is the Ripon Calcrete, which marks the mid-point of the Middle Pleistocene sequence defined in South Australia. Younger moderately hard pans were developed above the Ripon Calcrete in the upper Middle Pleistocene.

A period of faulting intervened between formation of the Ripon Calcrete and younger limy pans. This can be seen on either side of the Encounter Fault at Murray Bridge and the Morgan Fault near Swan Reach, where uplift of the Cambrai Plateau relative to the riverine tract has occurred. In most places, however, the younger pans were superimposed directly on older Ripon Calcrete. The Bungunnia Limestone was laid down in Lake Bungunnia, which was probably a wide-spread system of Middle Pleistocene valley lakes. (Firman, 1965b,p.1.).

Inland Aeolian Deposits

Widespread aeolian deposition began in the Upper Pleistocene with deposition of Worrinen Formation, a pale red-brown quartz sand mixed with carbonate silt. The horizons of carbonate accumulation in the Worrinen Formation, and at the top of Pooraka Formation, west of the map area, and older units elsewhere in the Murray Basin, are recognised as soil features, and the soil profile containing these carbonates is termed Loveday Soil. The younger soil carbonates in this unit appear to be stratigraphically associated with Worrinen Formation.

Including the Recent dunes, to be described in more detail later, there were at least three well-defined times of dune formation, each marked by characteristic colours and amounts of carbonate formed during periodic soil development. From oldest to youngest, there is a shift in colour due to leaching of carbonates and, in some places, to successive removal of iron-oxide coatings on grains of quartz sand.

Recent

Deposits of the Gypsum Lakes

A large number of gypsum deposits occur in the region, particularly in the lower lying terrain near the Murray River. They have been described

by Johns (1960, pp. 45-50), Whitten (1960 pp. 25-31) and others. Many of the larger deposits are based upon crystalline gypsum of the evaporite beds which were formed after deposition of the Lower Pleistocene clays. Evaporites of this age are found at the top of Blanchetown Clay east of Blanchetown, and in the Yamba-Noora area at the top of clayey Parilla Sand. It is reasonable to assume that the formation of gypsum on the Lake floor and transfer of this material to lee-side dunes was periodic and that the process began early in the Recent, continued during the onset of a later arid phase and terminated before modern time. The gypsum deposits are referred to Yamba Formation.

Riverine and Swamp Deposits in the Murray River Tract.

The records of events after Bakara Soil time begins with incision of the river through the calcrete sheet. At swan Reach the river has cut down through Pleistocene deposits and the Tertiary Mannum and Sttrick Formations to about 170 feet below the cliff top, that is, about 60 feet below the present river level and about 50 feet below modern sea level. Steep slip-off slopes are now well upstream from meanders which are still migrating downstream.

Aggradation of the valley with the lower beds of valley fill of alluvial clays, silts and coarse sands began with the rise of the Flandrian Sea (Firman, 1966d, p.5). The course sands - revealed at the base of the riverine sequence in the Chowilla area north-east of the map area - are called Monoman Formation. This was followed by re-working of Woorinen Formation and erosion of previously exposed Tertiary sediments to form the red - brown Bunyip Sand and the yellow Molineaux Sand. The Bunyip Sand occurs at Rochka and near Swan Reach overlying sediments of an older valley fill, probably including the Partengan Beds C^{14} dated at 6020 ± 150 B.P. by Tindale (1957a, p.35).

Away from the river, decalcification of the dune sands gave rise to coarsely tabular limy accumulations within the lower phase of the Bunyip and Molineaux Sands.

The Bunyip and Molineaux Sands were later overlain by the upper beds of valley fill which have geomorphic expression and are assigned to Coonambidgal Formation. This part of the riverine sequence with geomorphic expression is found upstream from the gorge tract, and was named the "Nawait Section" by Hale and Tindale (see Fenner, 1931, pp.81-90). As Fenner puts it; "Along the Murray River, particularly in the Upper (Nawait) Section, there are extensive lakes, kidney-shaped or irregular, relics of the old river courses, and somewhat similar in origin to ox-bow lakes.....".

Modern deposits in and adjacent to the present stream channels are not differentiated from Coonambidgal Formation. The younger deposits of the lower Murray swamp lands have been described by Taylor and Poole (1931, pp.7-43).

Recent Aeolian Deposits

The Recent Bunyip Sand and Molineaux Sand were deposited at about the same time in different areas. Two phases of development are seen in the dune fields containing these units. In each case, there is an older darker coloured phase of development marked by soft calcareous pipes and a younger phase of development in which the sands contain little carbonate. Bunyip Sand is red-brown because the source material was a dark red-brown sand developed over calcrete, Molineaux Sand is yellow because it was derived from Loxton Sand, Parilla Sand, or aeolianite exposed by erosion. Molineaux Sand has also been developed from and over pale red-brown Worrinen Formation, which is due perhaps to leaching of the carbonate silt and removal of the iron oxide coating on quartz grains in the older formation.

ECONOMIC GEOLOGY

There are large reserves of gypsum in the Basin, Murray and two of the more important areas occur within the map area near Blanchetown in the west and Yamba in the east. The Cainozoic rocks yield road metal and aggregate for construction. Sandy limestones near Morgan and Waikerie formerly provided abundant building stone, but production has declined owing to the relatively high cost compared with other materials.

In general, the salinity of underground water rises from less than 3000 parts per million in the south to over 14,000 ppm. north of the River Murray. The irrigation areas depend almost exclusively upon river water.

The prospects of discovering oil or gas in the area are not rated highly. The only mineral being produced in quantity from the map area is gypsum from the deposits at Blanchetown Plain and Morgan. A considerable tonnage of rock is being quarried and crushed to provide coarse aggregate for concrete used in building, for irrigation channels, and for road-making by the Highways Department. A large quantity has been recently excavated for the embankment forming the approaches to the new bridge at Kingston.

When the construction of a dam was proposed at Chowilla, a short distance outside the north-east corner of the map area, the Department of Mines instituted a search for large volumes of rock and filling sand within a 50 mile radius. A number of new deposits were located and tested, but no large scale deposit was found and it became apparent that supplies of hard rock on the scale required for the dam could not be produced economically from the Chowilla district. Investigations showed that it would be cheaper to build a railway about seventeen miles long from Paringa to the south bank at the site and to transport granite by rail from 5 miles west of Murray Bridge at Kinchina Quarry, where large reserves of rock occur in the Monarto Granite. (Blissett, 1970). (Stapledon and Harris, 1966.

Table 2 - Economic Minerals and Rocks

Economic deposits in the area are shown on the following stratigraphic table. Units are listed in descending order of age.

		Commercial Materials
QUATERNARY		
RECENT	Aeolian gypsum sand and flour gypsum of dunes related to gypsiferous YAMBA FORMATION.	Gypsum.
	Alluvial gravels, sands, clays.	Fine aggregate (sand); clay.
	Molineaux Sand	
	Bunyip Sand	
	Yamba Formation	Gypsum; alunite
PLEISTOCENE		
	Loveday Soil	
	Fossil soil. Soft nodular and platy carbonates formed in older formations.	Coarse aggregate.
	Woorinen Formation	
	Bakara Soil	
	Fossil soil. Hard massive nodular and sheet calcrete. Ripon Calcrete at base in many places.	Coarse aggregate.
	Bungunnia Limestone	
	Thin fossiliferous dolomitic limestone.	Coarse aggregate.
	Blanchetown Clay	
	Clays, sands. Siliceous and calcareous nodules in places. Included limestone lenses.	Gypsum; Clay. Coarse aggregate.
	Chowilla Sand	

	Karoonda Surface	
	Fossil silicified soil profile on older formations. (Silicified limestone at Sugar Loaf Hill etc. may be of equivalent age.)	Coarse Aggregate.
TERTIARY		
UPPER PLIOCENE	**Parilla Sand**	Fine aggregate.
	Norwest Bend Formation	
	Estuarine "oyster" beds interbedded with sands.	Building stone; coarse aggregate.
LOWER PLIOCENE	**Loxton Sands**	Building stone; fine aggregate. Aquifer.
	Bookpurnong Beds	
MIOCENE	**Pata Limestone**	Aquifer.
	Morgan Limestone	Building stone; coarse aggregate. Aquifer.
	Manoora Formation	Building stone; coarse aggregate. Aquifer.
EOCENE	**Renmark Beds** (Concealed)	Aquifer.
MESOZOIC		
JURASSIC-CRETACEOUS	(Concealed)	Potential reservoir for hydrocarbons?
UPPER PALAEOZOIC		
PERMIAN	(Concealed)	Potential reservoir for hydrocarbons?
LOWER PALAEOZOIC		
CAMBRIAN	**Kanmantoo Group**	
	Altered siltstone and greywacke.	

BIBLIOGRAPHY

AITCHISON, D.L.J. South Australian Year Book No. 4 - 1969. Commonwealth Bureau of Census and Statistics, South Australian Office. Govt. Printer, Adelaide.

ARMSTRONG, A.T., 1950 - Building Stone Deposits, Hundred Cadell. S.Aust. Min. Geol. Surv. Rept. Bk. No. 28/126. (unpub.)

ARMSTRONG, A.T., 1951 - Overland Corner Limestone Quarry. S.Aust. Dept. Geol. Surv. Rept. Bk. No. 31/46. (Unpub.)

ANON - 1956 - General Notes: Tripoli Occurrence - Hundred Martho. Min. Rev. 100: 6-8

BARNES, T.A., 1951 - Underground Water Survey of Portion of the Murray Basin (Counties Albert and Alfred). Geol. Surv. S.Aust. Bull. 25.

BARNES, T.A., 1946a - Overland Corner Quarry. S.Aust. Dept. Min. Geol. Surv. Rept. Bk. No. 22/61. (unpub.)

BARNES, T.A., 1946b - Report on Building Stone in Waikerie - Renmark - Loxton Area.
S. Aust. Dept. Min. Geol. Surv. Rept. Bk. No. 22/95 (unpub.)

BLISSETT, A.H., 1970. Mineral Resources of the Upper Murray Planning Area. S.Aust. Dept. Min. Geol. Surv. Rept. Bk. No. 70/146 (Unpub.)

BROWN, H.Y.L., 1908 - Record of the Mines of South Australia. (Fourth Edn. compiled by L.C.E. Gee) Govt. Printer, Adelaide, p. 160.

BROWN, H.Y.L., 1910 - Report on the Geology of the Country south and east of the Murray River. Parl. Paper 90, pp. 1-7.

CHAPMAN, F., 1916 - Cainozoic Geology of the Mallee and other Victorian Bores. Records of the Geol. Surv. Vict. III (4).

CRAWFORD, A.R., 1955 - Geological Survey of Renmark Area for New Quarry for Renmark Irrigation Trust. S.Aust. Min. Geol. Surv. Rept. Bk. No. 41/80 (unpub.)

CRAWFORD, G., and O'DRISCOLL, E.P., 1962 - Field Permeability Testing of the Murray Basin Limestone Aquifer - Numbi Experimental Station, South Australia. S.Aust. Dept. Min. Geol. Surv. Rept. Inves. 20.

CROCKER, R.L., 1946 - Post-Miocene Climatic and Geological History and its Significance in Relation to the Genesis of the Major Soil Types of South Australia. Counc. Sci. Industr. Res. Aust. Bull. No. 193: p. 31, pp. 27-38.

DAVID, T.E.W., 1952 - Explanatory Notes to Accompany A New Geological Map of the Commonwealth of Australia. Australasian Medical Publishing Company, Sydney, p. 175.

DAVID, Sir, T.W. EDGEWORTH, 1950 - The Geology of the Commonwealth of Australia (Brown, W.R. Ed.) Edward Arnold, London 2. p. 614.

DERRINGTON, S.S. and ANDERSON, J.C., 1970 - Well Completion Report A.A.O. Sunset No. 1, A.A.O. Merkalla No. 1, A.A.O. Nadda No. 1. Mines Administration Pty. Ltd., 31 Charlotte St., BRISBANE. (unpub.)

FENNER, CHARLES, 1931 - South Australia, a Geographical Study. Whitcombe and Tombs, Melbourne: 81-90.

FIRMAN, J.B., 1963 - Quaternary Geological Events near Swan Reach in the Murray Basin, South Australia. S.Aust. Dept. Min. Geol. Surv. Quart. Notes, 5.

FIRMAN, J.B., 1965 - Late Cainozoic Lacustrine Deposits in the Murray Basin, South Australia. S.Aust. Dept. Min. Geol. Surv. S.Aust. Quart. geol. Notes, 16: p.1.

FIRMAN, J.B., 1966d - Stratigraphy of the Chowilla Area in the Murray Basin. S.Aust. Dept. Min. Geol. Surv. Quart. geol. Notes, 20.

FIRMAN, J.B., 1967b - Stratigraphy of Late Cainozoic Deposits in South Australia. Trans. R. Soc. S.Aust. 91.

FIRMAN, J.B., 1968 - Soil Distribution - A stratigraphic Approach. Trans. 9th Int. Cong. Soil Sc. Adelaide, Aust. 1968. Vol. 4, Angus and Robertson, Sydney, 569-576.

FIRMAN, J.B., 1969a - Quaternary Period in Handbook of South Australian Geology (Parkin, L.W. Ed). Govt. Printer, Adelaide: 204-233.

FIRMAN, J.B., 1969b - An Introduction to the Structure and Stratigraphy of the Murray Basin and the Gambier Embayment in Geological Excursions Handbook, ANZAAS 41st Cong. Adelaide, 1969. Section 3, (Brian Daily Ed.) pp. 41-48.

FIRMAN, J.B., 1970a - Structural Lineaments in the Murray Basin of South Australia. S.Aust. Dept. Min. Geol. Surv. Quart. geol. Notes, 35: pp. 1-3.

FIRMAN, J.B., 1970b - Paleosols - A stratigraphic Definition (in press).

FIRMAN, J.B., 1971a - Calcrete and Related Materials in the Murray Basin and Gambier Embayment, South Australia. (in prep.)

FIRMAN, J.B., 1971b - Regional Stratigraphy of Surifical Deposits in the Murray Basin and Gambier Embayment, S.A. S.Aust. Dept. Min. Geol. Surv. Rept. Bk. No. 71/1 (unpub.).

FORBES, B.G., 1959 - Clay Deposit, Overland Corner (Mineral Claim 2439, Hd. Parcoola). S.Aust. Dept. Min. Geol. Surv. Rept. Bk. No. 48/127 (unpub.).

GLAESSNER, M.F., and PARKIN, L.W., (Editors) 1958 - The Geology of South Australia in J. Geol. Aust. 5(2): 163.

GRASSO, R., 1963 - A.O.C. North Renmark No. 1 Well Completion Report. P.S.S.A. No. 52 (unpub.)

HARRIS, W.K., New and Redefined Names in South Australian Lower Tertiary Stratigraphy. S. Aust. Dept. Min. Geol. Surv. Quart. Notes. 20.

HIERN, M.N., 1963 - Chowilla Dam Site - Geological Investigations Materials of Construction - Supplementary Report. Min. Rev. Adelaide, 115 pp. 117-129.

HIERN, M.N., 1965 - Occurrence of Activable Clay in South Australia. Second Report. Min. Rev. Adelaide. 188, pp. 44-52.

HILLWOOD, E.R., 1963 - Siliceous Limestone Deposit - Sugar Leaf Hill. Min. Rev. Adelaide, 115, pp. 130-133.

HOWCHIN, PROF. W., 1929 - Notes on the Geology of the Great Pyap Bend (Loxton), River Murray Basin and Renmark. Trans. Roy. Soc. S.Aust. 1. 53, pp. 167-195.

JACK, R. LOCKHARD, 1921a - The Salt and Gypsum Resources of South Australia. S.Aust. Dept. Min. Geol. Surv. Bull. 8.

JACK, R. LOCKHARD, 1921c - Gypsum west-south-west of Ral Ral house, S.Aust. Dept. Min. Geol. Surv. Rept. Bk. No. 8/35 (unpub.)

JACK, R. LOCKHARD, 1926a - Clay and Cement in South Australia. S.Aust. Dept. Min. Geol. Surv. S. Aust. Bull 12, p. 86.

JOHNS, R.K., 1955 - Gypsum Deposits at Retten Lake in the Renmark District. Min. Rev. Adelaide, 94, pp. 5255.

JOHNS, R.K., 1954a - Gypsum Deposits south - east of Renmark. Min. Rev. Adelaide 96, pp. 45-48.

JOHNS, R.K., 1954b - Gypsum Deposits - Blanchetown Plain. Min. Rev. Adelaide, 96,pp. 48-50.

JOHNS, R.K., 1962b - South Australian Rock Phosphate Deposits. Min. Rev. Adelaide, 114, pp. 2230.

JOHNS, R.K., 1963 - Limestone, Dolomite and Magnetite Resources of South Australia. S.Aust. Dept. Min. Geol. Surv. Bull 38.

JOHNSON, W., HIERN, M.N., and STEEL, R.D., 1960 - Chowilla Dam Site - Geological Investigations. Preliminary Report. S.Aust. Dept. Min. Surv. Rept. Bk. No. 41/136 (unpub.)

KING. D., 1957b- Building Stone Deposits near Morgan. Min. Rev. Adelaide 104,pp.50-53.

LAWRENCE, C.R., 1966 - Cainozoic Stratigraphy and Structure of the Mallee Region, Victoria. Trans. R. Soc. Vict. 79.

LINDSAY, J.M., 1965 - River Murray Drainage Investigation. Progress Report No. 2. Stratigraphy and Micropalaeontology of Bores and Surface Sections. S.Aust. Min. Dept. Srv. Rept. Bk. No. 60/111 (unpub.).

LUDBROOK, N.H., 1961 - Stratigraphy of the Murray Basin in South Australia. S.Aust. Dept. Min. Sur. Bull 36: 96.

LUDBROOK, N.H., 1969a- Tertiary Period in Handbook of South Australian Geology (L.W. Parkin Ed.) Govt. Printer, Adelaide, 172-203.

MACUMBER, P.G., 1969 - The Inland Limits of the Murravian Mutine Transgression in Victoria. Aust. J. Sci. Vol. 32, No. 4. pp. 165-166.

MILES, K.R., 1951 - Notes on Preliminary Inspection of Gypsum Deposits in Berri- Barmera District. S.Aust. Dept. Min. Rept. Bk. No. 31/116 (unpub.)

MILLER, P.G., 1964 - Report on Reconnaissance Survey - Quaternary Sedimentary Succession and Sub-Surface Drainage, Murray River Irrigation Areas. S.Aust. Dept. Min. Rept. Bk. No. 58/5 (unpub.)

MILLER, P.G., 1965 - Phosphate Reconnaissance Survey, Mid and Upper Tertiary Sediments, Murray River Cliffs. S.Aust. Dept. Min. Rept. Bk. No. 60/69 (unpub.)

NIXON, L.G.B., 1961 - Cooltong Plain Clay Deposit. Min. Rev. Adelaide, 111 p. 43-55.

O'DRISCOLL, E.P.D., 1960 - The Hydrology of the Murray Basin Province in South Australia. S.Aust. Dept. Min. Geol. Surv. Bull 35: 138-24.

PARKIN, L.W., (Ed) 1969 - Handbook of South Australian Geology. Govt. Printer, Adelaide, 268p.

ROBERTS, G.T., 1965a - Progress Report No. 1 - River Murray Drainage Investigation. S.Aust. Dept. Min. Geol. Surv. Rept. Bk. No. 60/36 (unpub.)

ROBERTS, G.T., 1965b - River Murray Drainage Investigation. Progress Report No. 3. S.Aust. Dept. of Mines Geol. Rept. Bk. No. 61/86 (unpub.)

ROBERTS, G.T., 1968a - Features of the Blanchetown Clay in the Waikerie District. S.Aust. Dept. Min. Geol. Surv. Quart. geol. Notes 28, pp.4-6.

ROBERTS, G.T., 1968b - Report on Groundwater Hydrology Adjacent to the River Murray inSouth Australia. Progress Report No. 4. S.Aust. Dept. Min. Rept. Bk. No. 67/82 (unpub.)

ROBERTS, G.T., 1969 - Review of Groundwater Hydrology Adjacent to the River Murray in South Australia. Min. Rev. Adelaide, 127, pp. 9-18.

RUSSELL, R.T., 1964 - Report on an Investigation of the Tertiary Succession, Murray Basin, South-eastern South Australia, for Sedimentary Phosphate. Rept. to Mines Exploration Pty. Ltd. Env. 418, DM.1711/64 (unpub.)

SPENCE, J., 1958 - The Geology of the Murray Basin. Frome-Broken Hill Co. Pty. Ltd., Rept. No. 7500-G 27 (unpub.)

STAPLEDON, D.H., and TRUDINGER, J.P., 1964a - Chowilla Dam. Embankment Materials Investigation. Sand for Dam Shoulders. S.Aust. Dept. of Mines. Rept. Rept. Bk. No. 59/95 (unpub.)

STAPLEDON, D.H., and TRUDINGER, J.P., 1964b - Chowilla Dam. Embankment Materials. Rip-rap Investigation Progress Geological Reports, November, 1964. S.Aust. Dept. Mines Rept. Bk. No. 59/124 (unpub.)

STAPLEDON, D.H., and TRUDINGER, J.P., 1965 - Chowilla Dam. Rip-rap Investigation. Lowbank Quarry Site. Progress Geological Report. February, 1965. S.Aust. Dept. of Mines Rept. Bk. No. 60/26 (unpub.)

STURT, CAPT. CHARLES, 1954 - Two expeditions into the Interior of South Australia. 2 Vols.

TATE, PROF. R., 1885 - Notes on the Physical and Geological Features of the Basin of the Lower Murray River. Trans. R. Soc. S.Aust. VII: pp. 24-46.

TENISON-WOODS, J.B., 1862 - Geological Observations in South Australia. London: Melbourne.

TINDALE, N.B., 1947 - Subdivision of Pleistocene Time in South Australia. Rec. S.Aust. Muse. 8(4): p. 654.

TRUDINGER, J.P., 1966b - Chowilla Project - Materials Investigation. Petrographic Examination of Sand from Possible Concrete Sand Sources. S.Aust. Dept. of Mines Rept. Bk. No. 62/61 (unpub.)

TRUDINGER, J.P., 1966c - Chowilla Project. Geological Investigations - Calcrete Deposit - Tilmy Flat. S.Aust. Dept. Min. Geol. Surv. Rept. Bk. No. 63/59 (unpub.)

TRUDINGER, J.P., and MASON, M.G., 1965 - Chowilla Dam, Embankment Materials. Rip-rap Investigation - Moora Quarry Site. S.Aust. Dept. Min. Geol. Surv. Rept. Bk. No. 60/53 (unpub.)

WALTER, M.R., 1965 - B.P.N.L. Monash No. 1 Well Completion Report. Beach Petroleum No. 1965/35 (unpub.)

WARD, L.K., 1918 - Report on the Occurrence of Stone suitable for making Concrete on the Upper Reaches of the River Murray. S.Aust. Dept. Min. Geol. Surv. Rept. Bk. No. 6/193 (unpub.)

HARD, L.K., 1921a - Control of Gypsum deposits near the River Murray. S.Aust. Dept. Min. Geol. Surv. Rept. Bk. No. 8/79 (unpub.)

HARD, L.K., 1921b - Reserving of gypsum deposits near the River Murray. S.Aust. Dept. Min. Geol. Surv. Rept. Bk. No. 8/89 (unpub.)

WHITTEN, G.F., 1959 - Diamond Drilling of Limestone for Building Stone - Near Morgan. Min. Rev. Adelaide, 107, pp.102-109.

WILLINGTON, C.M., 1962 - Gypsum Resources of South Australia. Min. Rev. Adelaide, 92, pp. 167-192.

TABLE 1 STRATIGRAPHY OF THE REMARK 1:250,000 Area

AGE	ROCK UNIT	LITHOLOGY AND FOSSILS	THICKNESS	STRATIGRAPHIC RELATIONS	REMARKS
Recent. Shell from Layer C above river level in the Tertengan Beds near Swan Reach is C14 dated at 6020 ± 150 BP. (Tindale, 1957).	COONGBRIG L FORMATION After Coonambidgal Creek New South Wales.	Clays, silts and sands, light grey alluvium. H. tamalensis and fresh-water mussels.	At least 50 feet	Deposits of modern streams not differentiated. Overlies Monoman Formation. Tertengan Beds of Tindale (1957) cropping out at ground surface near Swan Reach not differentiated.	Upper Valley Fill. As used herein, restricted to riverine deposits with geomorphic expression in the Murray River tract and adjacent stranded deposits once connected.
Recent	HALINEMUX SANDS After the Hundred of Halinemux, County Buccleuch. South Australia.	Quartz sand. Pale yellow upper layers overlie dark yellow lower layers with soft columnar carbonate nodules.	About 20-30 feet in jumbled (parabolic) dunes, but veneers old erosional surfaces with local relief of a 100 feet or more.	Veneered by pale grey leached sands in many places, not separately identified. Overlies LOVEDAY SOIL. Woorinen Formation and older units. Stratigraphic position similar to Bunyip Sand	Found in the Murray Basin and other southern basins between the aeolian Semaphore Sands of the southern coastal margin and the red brown inland aeolian dunes. Occurs as longitudinal dunes trending west-east, and north-west-south-east, as jumbled dunes, or as a capping on Woorinen Formation.
Recent. The sand is being actively reworked in places at the present time.	BUNYIP SAND After Bunyip Reach near Chowilla Homestead. County Hawdon, Firman (1966,p.5,1967,p.175).	Light red-brown and red-brown quartz sand. Two phases occur; the older contains soft rosy or columnar carbonate nodules in some places. Remains of aboriginal man common here and in the underlying Woorinen Formation.	Variable, but up to about 15 feet.	Overlies LOVEDAY SOIL. Woorinen Formation and older units. Stratigraphic position similar to Halinemux Sand.	Found in the Murray Basin adjacent to the Murray River, and north and east of the Pinnaroo Block. Occurs as dunes or as a veneer on Woorinen Formation and older units.
Recent. Age of base uncertain. Sub-fossil wood from near the contact of Coonambidgal Formation and Monoman Formation at Chowilla is C14 dated at 4080 ± 100 B.P. (Firman,1967).	MONOMAN FORMATION After Monoman Creek in the Murray River tract near Chowilla, South Australia.	Coarse-grained quartz sand. Ferruginous Loxton Sands in the type area. Sub-fossil plant material. Notothorium sp.	About 50 feet near Chowilla.	Underlies Coonambidgal Formation. Unconformably overlies Loxton Sands near Chowilla and older sediments downstream.	Lower valley fill.
Recent.	YAMBA FORMATION After Yamba Railway Siding on the Murray Bridge - Remark Railway.	Gypsiferous clays and gypsum-quartz sand mixtures, associated with crystalline "sand" gypsum and off-white powdery "flour" gypsum of the semphire flats and bordering dunes.	Up to 25 feet in dunes	Older than the saline crust of the ephemeral lakes. Yamba Formation is correlated with St. Kilda Formation on the coastal margin. Aeolian layers are inter-bedded with quartz sand at the top of Woorinen Formation in some places. Some inland deposits are derived from older crystalline gypsum formed at the end of Blanchetown Clay time.	Occupies playa lakes marking old stream courses running through the lowlands north-west, north and north-east of the Pinnaroo Block. Aeolian gypsum sand and off-white weakly cemented flour gypsum of the dunes overlies or is marginal to gypsiferous beds of Yamba Formation
Upper Pleistocene	WOORINEN FORMATION After the township of Woorinen in the Hundred of Parilla, County Chandos.	Pale reddish-brown quartz sand with carbonate occurs as soil layers in most places.	40 to 20 feet	Overlies Bakara Soil and older units. Probably near top of Pooraka Formation on the western margin of the basin.	In the Murray Basin, and in a similar inland position in other southern basins. Occurs as east-west longitudinal dunes.
Middle Pleistocene	**BUNGUNNIA LIMESTONE** After Bungunnia Homestead about 10 miles north of Morgan on the Murray River.	**Thin-bedded or flaggy "limestones" or "marl" (Micrite-flaggy or bedded, semicrite, calithic algal biolithite, calcilutite, ?dolomitic and containing ostracodes (Firman 1966, p.5).**	**Variable up to about 10 feet.**	**Overlies loess, bedded gypsum, Blanchetown Clay and older units. Overlain by most younger units, except Murray River sediments.**	**Occurs east of the Cambrai Plateau, that is, east of the Morgan Fault line scarpe, and west, north and north-east of th Pinnaroo Block.**
Lower Pleistocene	BLANCHETOWN CLAY After Blanchetown on the Murray River. The name follows the informal usage of Spence (1959).	In the Chowilla-Morgan area, the Upper Member is greenish grey sandy clay with some thin micrite lenses and thin beds of quartz sand. Siliceous septarian nodules are found in some places. The Lower Member is a red-brown and green mottled sandy clay. The sequence is more variable in Victoria and New South Wales. Fresh-water fauna.	Up to about 70 feet in South Australia. Thins to the west and thickens to the east.	Overlies late Pliocene deposits and other Tertiary sediments. Underlies Middle Pleistocene calcareous deposits including loess. Bungunnia Limestone and calcrete pans.	Thickest sequences are east of the Pinaroo Block, particularly in the Loxton Basin.
Upper Pliocene	NORWEST BEND FORMATION After Norwest Sand on the River Murray. Described by Tate (1880, p. 34) at Norwest Bend Station.	Pale grey, brown and yellow quartz sand, calcareous, fossiliferous in places and containing oyster beds which characterize the deposit.	About 20 feet, but top eroded.	Overlies Morgan Limestone and Mannum Formation, disconformably on the western margin of the basin. Overlain by Pleistocene to Recent deposits, mainly Blanchetown Clay.	Occurs in the Murray River tract, and on the western margin of the map area as far east at Waikerie.
Upper Pliocene Age given is for areas described in this report.	PARILLA SAND After the town of Parilla in the Hundred of Parilla, County Chandos.	Light grey, pale brown and pale yellow fine to medium-grained clayey quartz sand with thin beds of olive sandy clay near the top.	About 50 feet in the type locality.	Overlain by Blanchetown Clay and younger units. Underlain by Loxton Sands and older units in South Australia. Grades laterally into Norwest Bend Formation near Kingston-on-Murray and is equivalent in part to that formation.	Widespread in the Murray Basin. Can be traced in cliff sections as far upstream as Nyah in Victoria. Thickest sequence occurs in the Loxton Basin.
Lower Pliocene	LOXTON SANDS After the township of Loxton in County Alfred, Section 118, Hd. Gordon.	Red and yellow coarse-grained micaceous quartz sand over fine to medium-grained micaceous quartz sand, calcareous, fossiliferous with shell beds near the base.	50 feet in the type section at Section 118, Hd. of Gordon. Over 400ft in the east, less than 50ft in the northwest.	Overlies Morgan Limestone in the west of the map area, Bookpurnong Beds in the north-east.	More-or-less continuous in the eastern part of the map area, but thin and discontinuous in the west.
Lower Pliocene	BOOKPURNONG BEDS First described by Howchin (1929, p.168). Section 377 Hd. of Gordon.	Carbonaceous and glauconitic marls and micaceous sands. Richly fossiliferous with abundant molluscs.	About 12 feet in type section, but about 50ft. elsewhere.	Overlies Pata Limestone. Underlies Loxton Sands.	Occurs sub-surface in the south-east quadrant of the map area.
Middle Miocene	PATA LIMESTONE Section 377, Hd. of Gordon.	Pale grey bryozoal limestone, fossiliferous with abundant worm tubes.	About 50 feet.	Underlain by Morgan Limestone. A glauconitic marl seperates these beds in places.	Sub-surface in the south-east quadrant of the map area.
Lower Miocene	MORGAN LIMESTONE After the township of Morgan. Described by Tate (1885). Type section 4 miles downstream from Morgan on the E. bank of the Murray River.	Yellow bryozoal limestone. (Hard yellow banded with calleperas, and soft bryozoal members have been described). Fossiliferous with a rich microfauna.	Greater than 94 ft. in the type section. More than 50 ft. thick near Nadda.	Conformably overlies the Finniss Clay with which the base of the limestone is interbedded in the type section.	Occurs throughout the map area: Crops out in the west, sub-surface in the east. Has a marly lens (Gadsdil Marl Lens) about 120ft thick by 300 yards long in the type section.
Lower Miocene	**FINNIS CLAY** After the Hundred of Finnis. Type section is in Section 519, Hd. of Finnis.	**Grey-green and brown clays, peary fossiliferous.**	**1 - 15 feet thick in type section.**	**Overlies Mannum Formation with a pronounced break. Underlies Morgan Limestone conformably.**	**Crops out in the Hundred of Finnis.**
Lower Miocene	MANNUM FORMATION After the township of Mannum. Type section, Hd. of Finnis, Section 519.	Fossiliferous calcareous quartz sandstones and sandy limestones	About 100 feet	Overlain by Finnis Clay with a marked break in sedimentation underlain by Ettrick Formation.	Well developed in the south-west of the Murray Basin proper. Transgressive onto Kanmantoo Group rocks.
Middle Miocene to Upper Eocene	GAMBIER LIMESTONE Named after the township of Mt. Gambier. Type section near Town Hall. First described by Tenison Woods (1860, p.256; 1862, p.75).	White to cream bryozoal limestone with echinoids, brachiopods, and with abundant microfauna.	20 feet in Waikerie No. 2	Diachronous. Near Waikerie overlies Ettrick Formation and underlies Morgan Limestone.	Represented in the map area by light grey fossiliferous calcarenite with minor claystone near Waikerie.
Oligocene	ETTRICK FORMATION After Hundred of Ettrick Type section is in No. 2 Bore, section 21, Hundred of Ettrick.	Glauconitic and calcarenitic marls and limestones.	75 feet in the type section. Possibly 100 feet in the Loxton Basin.	Partly equivalent to Gambier Limestone. Gradual faunal transition upwards into Mannum Formation. Overlies Renmark Beds.	Occurs sub-surface throughout the map area.
Oligocene	COMPTON CONGLOMERATE	Quartz and ironstone gravel.	About 100 feet in a bore in the east side of the map area.	Passes upward into Gambier Limestone in type section at Ralphs Quarry. Overlies basement and underlies Morgan Limestone in the map area.	Found in a bore west of Swan Reach.
Eocene	BUCCLEUCH BEDS After County Buccleuch. Type section Bore 304/55, Cecealgyn.	Shelly sand, carbonaceous clay.	About 170 feet thick in type section, 124ft. near Waikerie and 40ft. near Caurnamont.	Overlain by Ettrick Formation. Underlain by Renmark Beds.	Known only from bores near Caurnamont and Waikerie.
Eocene to Paleocene	RENMARK BEDS	Sand with carbonaceous clay and lignite.	094ft. thick in A.O.C. Nth. Renmark No.1, 715ft in B.P.N.L. Loxton No.2	Underlies Ettrick Formation. Overlies Lower Cretaceous sediments.	Found sub-surface throughout the map area.
Lower Cretaceous		Sandstone and shale.	445ft. in A.O.C. Nth. Renmark No.1, 545 in B.P.N.L. Loxton No.2	Underlies Renmark Beds. Overlies Lower Permian sediments within the Renmark Trough and Paringa Embayment.	Found in the Renmark Trough and Paringa Embayment.
Lower Permian		Shale and sandstone, conglomerate in part.	+297ft. thick in A.A.O Nadda No.1 420ft. thick in B.P.N.L. Loxton No.2	Underlies Lower Cretaceous sediments. Overlies ?Cambrian basement rocks.	Found in the Renmark Trough and Paringa Embayment.
Lower Cambrian	KANMANTOO GROUP	Meta-greywacke and siltstone. Marble and calc-silicate rocks, phyllites and sediments intruded by granite.			Basement underlying basin sediments. Crops out on the western margin of the map area in the bed of the River Marne.

TABLE 2

STRATIGRAPHIC ROCK UNITS OF THE RENMARK 1:250,000 AREA

Age	*Rock Unit*	*Lithology and fossils*	*Thickness*	*Stratigraphic relationships*	*Remarks*
RECENT Shell from layer C above river level in the Tartangan Beds near Swan Reach is C14 dated at 6020 ± 150 BP. (Tindale, 1957)	*Coonambidgal Formation* After Coonambidgal Creek, New South Wales	Clays, silts and sands, light grey alluvium. *E. camaldulensis* and fresh-water mussels	At least 15 m	Deposits of modern streams not differentiated. Overlies Monoman Formation. Tartangan Beds of Tindale (1957) cropping out at ground surface near Swan Reach not differentiated	Upper valley fill. As used herein, restricted to riverine deposits with geomorphic expression in the Murray River tract and adjacent stranded deposits once connected
RECENT	*Molineaux Sands* After the hundred of Molineux, county Buccleuch, South Australia	Quartz sand. Pale yellow upper layers overlie dark yellow lower layers with soft columnar carbonate nodules	About 6-9 m in jumbled (parabolic) dunes, but veneers old erosional surfaces with local relief of 30 m or more	Veneered by pale grey leached sands in many places, not separately identified. Overlies Loveday Soil, Woorinen Formation and older units. Stratigraphic position similar to Bunyip Sand	Found in the Murray Basin and other southern basins between the aeolian Semaphore Sands of the southern coastal margin and the red brown inland aeolian dunes. Occurs as longitudinal dunes trending west-east, and northwest-southeast, as jumbled dunes, or as a capping on Woorinen Formation
RECENT The sand is being actively reworked in places at the present time	*Bunyip Sand* After Bunyip Reach, near Chowilla homestead, county Hamley. Firman (1966, p. 5, 1967, p. 175)	Light red-brown quartz sand. Two phases occur; the older contains soft ropy or columnar carbonate nodules in some places. Remains of aboriginal man common here and in the underlying Woorinen Formation	Variable, but up to about 5 m	Overlies Loveday soil Woorinen Formation and older units. Stratigraphic position similar to Molineaux Sand	Found in the Murray Basin adjacent to the Murray River and north and east of the Pinnaroo Block. Occurs as dunes or as a veneer on Woorinen Formation and older units
RECENT Age of base uncertain. Sub-fossil wood from near the contact of Coonambidgal Formation and Monoman Formation at Chowilla is C14 dated at 4080 ± 100 BP. (Firman, 1967)	*Monoman Formation* After Monoman Creek in the Murray River tract near Chowilla, South Australia	Coarse-grained quartz sand. ?Reworked Loxton Sands in the type area. Sub-fossil plant material. *Nototherium* sp.	About 15 m near Chowilla	Underlies Coonambidgal Formation. Unconformably overlies Loxton Sands near Chowilla and older sediments downstream	Lower valley fill
RECENT	*Yamba Formation* After Yamba railway siding on the Murray Bridge-Renmark railway	Gypsiferous clays and gypsum-quartz sand mixtures, associated with crystalline "seed" gypsum and off-white powdery "flour" gypsum of the samphire flats and bordering dunes	Up to 8 m in dunes	Older than the saline crust of the ephemeral lakes. Yamba Formation is correlated with St. Kilda Formation on the coastal margin. Aeolian layers are inter-bedded with quartz sand at the top of Woorinen Formation in some places. Some inland deposits are derived from older crystalline gypsum formed at the end of Blanchetown Clay time	Occupies playa lakes marking old stream courses running through the lowlands northwest, north and northeast of the Pinnaroo Block. Aeolian gypsum sand and off-white weakly cemented flour gypsum of the dunes overlies or is marginal to gypsiferous beds of Yamba Formation
UPPER PLEISTOCENE	*Woorinen Formation* After the township of Woorinen in the hundred of Parilla county Chandos	Pale reddish-brown quartz sand with carbonate occurs as soil layers in most places	3 to 6 m	Overlies Bakara Soil and older units. Probably near top of Pooraka Formation on the western margin of the basin	In the Murray Basin, and in a similar inland position in other southern basins. Occurs as east-west longitudinal dunes
MIDDLE PLEISTOCENE	*Bungunnia Limestone* After Bungunnia homestead about 16 km north of Morgan on the Murray River	Thin-bedded or flaggy "limestones" or "marl" (micrite-flaggy or banded), oomicrite, oolithic algal biolithite, calcilutite, ?dolomitic and containing ostracodes (Firman 1966, p. 5)	Variable up to about 3 m	Overlies loess, bedded gypsum, Blanchetown Clay and older units. Overlain by most younger units, except Murray River sediments	Occurs east of the Cambrai Plateau, that is, east of the Morgan Fault line scarps, and west, north and northeast of the Pinnaroo Block
LOWER PLEISTOCENE	*Blanchetown Clay* After Blanchetown on the Murray River. The name follows the informal usage of Spence (1959)	In the Chowilla-Morgan area, the Upper Member is greenish-grey sandy clay with some thin micrite lenses and thin beds of quartz sand. Siliceous septarian nodules are found in some places. The Lower Member is a red-brown and green mottled sandy clay. The sequence is more variable in Victoria and New South Wales. Fresh-water fauna	Up to about 21 m in South Australia. Thins to the west and thickens to the east	Overlies late Pliocene deposits and other Tertiary sediments. Underlies Middle Pleistocene calcareous deposits including loess, Bungunnia Limestone and calcrete pans	Thickest sequences are east of the Pinnaroo Block, particularly in the Loxton Basin
UPPER PLIOCENE	*Norwest Bend Formation* After Norwest Bend on the Murray River. Described by Tate (1885, p. 34) at Norwest Bend Station	Pale grey, brown and yellow quartz sand, calcareous, fossiliferous in places and containing oyster beds which characterize the deposit.	About 6 m, but top eroded	Overlies Morgan Limestone and Mannum Formation, disconformably on the western margin of the basin. Overlain by Pleistocene to Recent deposits, mainly Blanchetown Clay	Occurs in the Murray River tract, and on the western margin of the map area as far east as Waikerie

TABLE 2

STRATIGRAPHIC ROCK UNITS OF THE RENMARK 1: 250,000 AREA—*continued*

Age	*Rock Unit*	*Lithology and fossils*	*Thickness*	*Stratigraphic relationships*	*Remarks*
UPPER PLIOCENE Age given is for area described in this report	*Parilla Sand* After the town of Parilla, in the hundred of Parilla, county Chandos	Light grey, pale brown and pale yellow fine to medium-grained clayey quartz sand with thin beds of olive sandy clay near the top	About 15 m in the type locality	Overlain by Blanchetown Clay and younger units. Underlain by Loxton Sands and older units in South Australia. Grades laterally into Norwest Bend Formation near Kingston-on-Murray and is equivalent in part to that formation	Widespread in the Murray Basin. Can be traced in cliff sections as far upstream as Hyah in Victoria. Thickest sequence occurs in the Loxton Basin
LOWER PLIOCENE	*Loxton Sands* After the township of Loxton in section 118, hundred of Gordon, county Alfred	Red and yellow coarse-grained micaceous quartz sand over fine to medium-grained micaceous quartz sand, calcareous and fossiliferous with shell beds near the base	15 m in the type section at section 118, hundred of Gordon. Over 30 m in the east, less than 15 m in the northwest	Overlies Morgan Limestone in the west of the map area, Bookpurnong Beds in the northeast	More-or-less continuous in the eastern part of the map area, but thin and discontinuous in the west
LOWER PLIOCENE	*Bookpurnong Beds* First described by Howchin (1929, p. 168). Section 377, hundred of Gordon	Carbonaceous and glauconitic marls and micaceous sands. Richly fossiliferous with abundant mollusca	About 3.6 m in type section, but about 15 m elsewhere	Overlies Pata Limestone. Underlies Loxton Sands	Occurs subsurface in the southeast quadrant of the map area
MIDDLE MIOCENE	*Pata Limestone* Section 377, hundred of Gordon	Pale grey bryozoal limestone, fossiliferous with abundant worm tubes	About 15 m	Underlain by Morgan Limestone. A glauconitic marl separates these beds in places	Subsurface in the southeast quadrant of the map area
LOWER MIOCENE	*Morgan Limestone* After the township of Morgan. Described by Tate (1885). Type section 6 km downstream from Morgan on the east bank of the Murray River	Yellow bryozoal limestone. (Hard yellow banded with *Cellepora*, and soft bryozoal members have been described). Fossiliferous with a rich microfauna	Greater than 28 m in the type section. More than 15 m thick near Nadda	Conformably overlies the Finniss Clay with which the base of the limestone is interbedded in the type section	Occurs throughout the map area: Crops out in the west, subsurface in the east. Has a marly lens (Cadell Marl Lens) about 36 m thick by 275 m long in the type section
LOWER MIOCENE	*Finniss Clay* After the hundred of Finniss. Type section is in section 519, hundred of Finniss	Grey-green and brown clays, poorly fossiliferous	1-5 m thick in type section	Overlies Mannum Formation with a pronounced break. Underlies Morgan Limestone conformably	Crops out in the hundred of Finniss
LOWER MIOCENE	*Mannum Formation* After the township of Mannum. Type section, section 519, hundred of Finniss	Fossiliferous calcareous quartz sandstones and sandy limestones	About 30 m	Overlain by Finniss Clay with a marked break in sedimentation; underlain by Ettrick Formation	Well developed in the southwest of the Murray Basin proper. Transgressive onto Kanmantoo Group rocks
MIDDLE MIOCENE TO UPPER EOCENE	*Gambier Limestone* Named after the township of Mount Gambier. Type section near Town Hall. First described by Tenison Woods (1860, p. 256: 1862, p. 75)	White to cream byrozoal limestone with echinoids, brachiopods, and with abundant microfauna	6 m in Waikerie No. 2	Diachronous. Near Waikerie, overlies Ettrick Formation and underlies Morgan Limestone	Represented in the map area by light grey fossiliferous calcarenite with minor claystone near Waikerie
OLIGOCENE	*Ettrick Formation* After hundred of Ettrick. Type section is in No. 2 bore, section 21, hundred of Ettrick	Glauconitic and calcarenitic marls and limestones	23 m in the type section. Possibly 30 m in the Loxton Basin	Partly equivalent to Gambier Limestone. Gradual faunal transition upwards into Mannum Formation. Overlies Renmark Beds	Occurs subsurface throughout the map area
OLIGOCENE	*Compton Conglomerate*	Quartz and ironstone gravel	About 30 m in a bore in the west side of the map area	Passes upward into Gambier Limestone in type section at Knights Quarry. Overlies basement and underlies Morgan Limestone in the map area	Found in a bore west of Swan Reach
EOCENE	*Buccleuch Beds* After county Buccleuch. Type section, Coonalpyn township bore-section 56, hundred Concy [illegible]	Shelly sand, carbonaceous clay	About 52 m thick in type section, 37 m near Waikerie and 12 m near Caurnamont	Overlain by Ettrick Formation. Underlain by Renmark Beds	Known only from bores near Caurnamont and Waikerie
EOCENE TO PALEOCENE	*Renmark Beds*	Sand with carbonaceous clay and lignite	334 m thick in A.O.G. North Renmark No. 1, 216 m in B.P.N.L. Loxton No. 2	Underlies Ettrick Formation. Overlies Lower Cretaceous sediments	Found subsurface throughout the map area
LOWER CRETACEOUS		Sandstone and shale	440 m in A.O.G. North Renmark No. 1, 96 m in B.P.N.L. Loxton No. 2	Underlies Renmark Beds. Overlies Lower Permian sediments within the Renmark Trough and Paringa Embayment	Found in the Renmark Trough and Paringa Embayment
LOWER PERMIAN		Shale and sandstone, conglomerate in part	396 m thick in A.A.O. Nadda No. 1, 36 m thick in B.P.N.L. Loxton No. 2	Underlies Lower Cretaceous sediments. Overlies ?Cambrian basement rocks	Found in the Renmark Trough and Paringa Embayment
LOWER CAMBRIAN	*Kanmantoo Group*	Meta-greywacke and siltstone. Marble and calc-silicate rocks, phyllites and sediments intruded by granite			Basement underlying basin sediments. Crops out on the western margin of the map area in the bed of the River Marne