

DEPARTMENT OF MINES

SOUTH AUSTRALIA

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REGIONAL GEOLOGY DIVISION

CHOWILLA 1:250 000 SHEET

EXPLANATORY NOTES

by

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EXPLANATORY NOTES FOR THE
CHOWILLA 1:250 000 GEOLOGICAL MAP

INTRODUCTION

The CHOWILLA 1:250 000 map area lies in the northwestern part of the Murray Basin, between latitudes 33° and 34°S and longitudes 139°30' and 141°E. Its eastern boundary is the South Australia-New South Wales border. The area includes portions of the Counties of Burra, Eyre, Hamley, Kimberley and Young.

The entire map area is divided into a number of medium-sized sheep stations. Several of these stations (Canopus, Hypurna, Morgan Vale and part of Oakbank) have been recently formed into the Danggali Conservation Park covering an area of about 2 500 sq.km. The nearest towns are Morgan and Renmark, 3 and 19 km south of CHOWILLA respectively.

Access by station tracks is good. The main road in the area is the Morgan Mail Road. The Murray River flows across the southeast corner of the map area.

Average annual rainfall is between 200 and 250 mm, and average annual evaporation is about 1 700 mm. The mean maximum temperature for January is about 33°C, and the mean minimum temperature for July is about 5°C.

The location and geological setting of the map area is shown on Fig. 1. Geology was annotated directly on black and white RC 5 aerial photographs at a scale of

about 1:45 000. These photos are stored at the S.A. Department of Mines, Regional Mapping Section.

PREVIOUS WORK

Ludbrook (1961) and O'Driscoll (1960) prepared complementary bulletins describing in detail the Tertiary stratigraphy and hydrology of the Murray Basin in South Australia. Pledge (1965) produced geological cross-sections for CHOWILLA based on borehole information. He also prepared a preliminary geological map of the Lindley 1:63 360 area.

Interest in the economic possibilities of the Braemar Iron 'Formation' on OLARY and CHOWILLA led to the geological mapping of the Manunda and Braemar 1:63 360 areas (Mirams, 1960; Whitten and Ker, 1961).

An aeromagnetic map of total intensity (Webb, 1965) and a Bouguer anomaly map (Hall and Gerdes, 1976) covering the CHOWILLA map sheet at a scale of 1:250 000 have been published. Reduced versions of these maps are given in Fig. 2 and Fig. 3.

Adjoining 1:250 000 geological maps which have been published are ADELAIDE (Thomson, 1969), BURRA (Mirams, 1964), MENINDEE (Rose, 1967), MILDURA (Lawrence, 1972), ORROROO (Binks, 1968) and RENMARK (Firman, 1972).

Thornton (1974a) has made a valuable synthesis of exploratory drilling and seismic surveys carried out in the Renmark area by private companies and the South Australian Department of Mines.

An interpretation of aeromagnetic and gravity data from the southern half of OLARY and the northern half of CHOWILLA was undertaken by Gerdes (1973) to resolve the regional structure and to locate the position of the Anabama-Redan Fault Zone.

Investigations for the proposed dam on the Murray River at Chowilla included detailed stratigraphy of the dam site area (Firman, 1966a; Ludbrook, 1960) and exploration for construction materials up to 80 km from the dam site (Hiern, 1963). A preliminary geological map of the Chowilla 1:63 360 area was drafted (Firman, 1966a).

Surficial deposits in the Murray Basin in South Australia have been examined in detail in recent years and the results of this work are summarized in Firman (1973a).

PHYSIOGRAPHY

The map area covers part of a great plain rising from an altitude of about 45 m above sea level in the south of the map area to about 100 m in the north. In the northwest corner, the plain slopes up to the eastern margin of the Mt. Lofty-Olary Ranges, which reaches a maximum altitude of 539 m at Boiekevie Hill.

The plain surface is gently undulating with changes in relief of up to 30 m related to calcrete-capped erosional remnants of younger Cainozoic sediments, undulations in the old pre-dune land surface, clay pan depressions, drainage features and sand dunes. In the southeast corner, the Murray River has cut a valley up to 9 km wide with a steep south bank 25 m high. At this point, about 600 km

from its mouth, the river level is only about 17 m above sea level.

Two plant associations dominate most of the area. Calcareous clayey soils support Casuarina cristata (black oak) and Kochia sedifolia (bluebush). Eucalyptus oleosa and E. gracilis (mallee) with a ground cover of Triodia irritans (porcupine grass) grow in sandy soils.

STRATIGRAPHY AND GEOLOGICAL HISTORY

The diagnostic lithologies, thicknesses and stratigraphic relationships of the various rock units are summarised in Tables 1, 2, 3, and 4. Aspects of the geological history and rock unit boundaries are discussed briefly in the text.

Proterozoic (Adelaidean) metasediments crop out in the northwest of CHOWILLA and are inferred to underlie much of the map area. Metamorphic rocks of the Proterozoic (Carpentarian) Willyama Complex and the Cambrian Kanmantoo Group may occur in the subsurface in the eastern part of CHOWILLA.

Sediments of ?Devonian, Permian and Cretaceous ages fill the Renmark Trough and Canegrass Lobe infrabasins. A more or less continuous Tertiary and Quaternary sequence of the Murray Basin covers most of the map area.

PROTEROZOIC

Carpentarian

A zone of positive gravity anomalies extending southwards from the Willyama Inlier (Thomson, 1975) suggests that rocks of the Willyama Complex (Mawson, 1912) may underlie the northeastern part of CHOWILLA, possibly as

TABLE 1
 PROTEROZOIC AND EARLY PALAEOZOIC STRATIGRAPHY

		AGE	STRATIGRAPHIC UNIT AND SYMBOL	LITHOLOGY	THICKNESS (metres)	REMARKS		
EARLY PALAEOZOIC		Ordovician	Acid intrusives (Odg)	Biotite granodiorite-adamellite; rhyolite dykes.		Emplaced during Delamerian Orogeny. Dykes intrude Wilyerpa Formation.		
		Cambrian	Kanmantoo Group (Ek)	Phyllite and slate; metagrey-wacke and gneiss.		Tentatively identified in deep bores on RENMARK and may extend under southeastern part of CHOWILLA.		
				Tectonic Discontinuity				
PROTEROZOIC	Adelaidean	Sturtian	Umberatana Group	Wilyerpa Formation (Euw)	Greenish-grey slaty laminated siltstone; quartzite; dolomite at base.	about 1000?		
				Unconformity				
			Yudnamutana Sub-group	Benda Siltstone (Eye)	Dark grey laminated siltstone and ferruginous siltstone, minor tillite; calcareous sandstone and quartzite.	0 to 730	Ferruginous beds of the Braemar Iron Formation occur throughout Benda Siltstone and the top of Pualco Tillite. Variations in thickness due to erosion prior to deposition of Wilyerpa Formation.	
				Pualco Tillite (Eyp)	Massive calcareous tillite, ferruginous at top, quartzite with minor tillite and siltstone	2 000 to 2 400		
			Unconformity					
			Burra Group (Eb)	Belair Sub-group	(?Ea)	Siltstone and shale, dolomitic in places; feldspathic quartzite beds at base.	970 to 1 600	
		Torrensian			Saddleworth Formation equivalent (Ebs)	Siltstone, shale and black slate with dolomitic and pyritic layers.	>2 170	
						?Unconformity		
				Carpentarian	Willyama Complex	High-grade metamorphic rocks; amphibolites.		May occur under the north-east part of CHOWILLA.

far south as the Hamley Fault. Thomson (1975) suggested that the gravity highs may reflect a high proportion of amphibolites in the basement.

On OLARY and in the Broken Hill area, the Willyama Complex comprises high grade gneiss, acid and minor basic intrusives, and metasediments. The original sediments are older than 1 800 million years. Isotopic dates ranging from 1 700 to 1 520 million years reflect phases of deformation, metamorphism and intrusion called the Olarian Orogeny (Thomson, in Parkin, 1969; c.f. Kimban Orogeny).

Adelaidean

Outcrops of Adelaidean rocks are restricted to the northwest of CHOWILLA, where formations belonging to the Umberatana Group unconformably overlie Burra Group rocks. The maximum thickness exposed, excluding the Wilyerpa Formation, is about 5 800 m. The sequence consists of siltstone, quartzite, tillite, shale and minor carbonates.

The lower part of the Burra Group (Thomson et al., 1964) in the Pualco Anticline and north of Mulga Hill H.S. is correlated with the Saddleworth Formation. Overlying this unit is a sequence, which is tentatively identified as the Belair Sub-group (see Forbes, 1971). Siltstone and dolomite outcropping in the core of the anticlinal structure south of Braemar H.S. may belong to this unit. The base of the Belair Sub-group is marked by a thin zone of feldspathic quartzite interbedded with siltstone. The two inliers northeast and east of Faraway Hill H.S. are designated as undifferentiated Burra Group.

The Yudnamutana Sub-group (Umberatana Group, Thomson, et.al., 1964) unconformably overlies the Belair Sub-group. The Yudnamutana Sub-group on CHOWILLA comprises two formations: Pualco Tillite and Benda Siltstone (Forbes and Cooper, 1976). The Pualco Tillite, deposited during the earlier of the two main phases of Sturtian glaciation, consists of upper and lower tillite members and a middle quartzite member. Forbes and Cooper (1976) regard the Braemar Iron 'Formation' (defined by Mirams, 1962) as a ferruginous facies of the Pualco Tillite and Benda Siltstone, and do not use it as a formal stratigraphic unit. On CHOWILLA, ferruginous beds of the Braemar Iron 'Formation' occur throughout the Benda Siltstone and in the upper tillite member of the Pualco Tillite. The Wilyerpa Formation is separated from the underlying beds by an erosional break, and for this reason is not placed in the Yudnamutana Sub-group. This discordance is especially marked on the southern part of the eastern limb of the Loch Winnoch Syncline, where the Benda Siltstone and the upper tillite member of the Pualco Tillite have been removed.

Slate and phyllite of probable Adelaidean age were encountered in drillholes in the northwest of the map area (Bryan, 1972; Wecker, 1971). Bungunna Bore (Collins Bore) bottomed in purple slate which Ludbrook (1958) identified as Adelaidean. It is likely that Adelaidean rocks extend under most of CHOWILLA, possibly as far east as the Hamley Fault. Adelaidean cover may rest on Willyama Complex metamorphics in the northeast of the map area.

EARLY PA

EARLY PALAEOZOIC

In Middle Cambrian time, the sea floor south and southeast of the Adelaide Geosyncline deepened to form the Kanmantoo Trough, which was rapidly filled with a very thick sequence of greywacke-type clastics of the Kanmantoo Group (Sprigg and Campana, 1953). Uplift of land to the west and northeast of the trough provided the source areas for sediment (Fig. 1).

Rocks belonging to the Kanmantoo Group have been tentatively identified by Thornton (1974a) in several deep drillholes on RENMARK which bottomed in metagreywacke and gneiss, and in deep wells on the eastern Paringa Embayment which encountered slate and phyllite. The Kanmantoo Group may extend through the southeastern part of CHOWILLA where the Hamley Fault may form its western boundary.

Deposition of the Kanmantoo Group ended in Late Cambrian time with the onset of the Delamerian Orogeny (Thomson in Parkin, 1969). This orogeny resulted in complex folding and faulting throughout the Adelaide Geosyncline and Kanmantoo Trough, and intense metamorphism of Kanmantoo Group rocks. The orogeny ended in Early Ordovician time with the intrusion of granitic bodies in an arc extending from Anabama to Murray Bridge.

Biotite granodiorite-adamellite intrudes Wilyerpa Formation near Bendigo H.S. on BURRA (Langsford, 1971). The intrusion is outlined by an aeromagnetic feature which extends for a short distance onto CHOWILLA. A similar aeromagnetic feature in the southeast of BURRA crosses onto CHOWILLA and may also represent a buried granitic body.

The granodiorite at Bendigo H.S. is hydrothermally altered in places, with associated copper and molybdenum mineralisation. Porphyry dykes of intermediate composition cut the granodiorite and surrounding contact-metamorphosed sediments. Rhyolite dykes intrude the Adelaidean Willyerpa Formation on CHOWILLA.

Samples of both unaltered and mineralised granodiorite from diamond drill cores were analysed for Rb/Sr ratios. Analyses of eight of these samples produced an isochron of 454 ± 84 million years. This isochron indicates the age of emplacement of the granodiorite. The later alteration did not cause the granodiorite to become an open system with respect to Rb and Sr (Webb, 1976).

MIDDLE TO LATE PALAEOZOIC

Deep drillholes on RENMARK, MILDURA and ANA BRANCH have encountered sediments of Cretaceous, Permian and possible Devonian ages. Seismic refractors in these deposits have been traced onto CHOWILLA, indicating the presence of Devonian to Cretaceous sediments in the northern Renmark Trough and Canegrass Lobe. Sediments encountered in drill-holes on the western margin of the Canegrass Lobe have been tentatively identified as Permian and Devonian.

In middle Palaeozoic time, the Renmark Trough began to form by downward movement on the Hamley and Chowilla Faults, and the Canegrass Lobe began to subside (Thornton, 1974a). The oldest sediments deposited in these basins are of possible Devonian age. Over 1 000 m of non-marine quartz sandstone interbedded with shale and siltstone were cut by Tararra - 1 on ANA BRANCH in New South Wales (Boyd and Heisler, 1967). These deposits are tentatively correlated with the Middle to

TABLE 2

MIDDLE TO LATE PALAEOZOIC AND MESOZOIC STRATIGRAPHY

(Renmark Trough and Canegrass Lobe)

	AGE	STRATIGRAPHIC UNIT AND SYMBOL	LITHOLOGY	THICKNESS (metres)	REMARKS	
MESOZOIC	Early Cretaceous	Monash Formation (Kℓ)	Sand, silt and shale; shale and siltstone with minor sand; sand- stone	100 to 650 ?	Intersected in bores on RENMARK. Divided into <u>Coombool</u> , <u>Merreti</u> and <u>Pyap</u> <u>Members</u> .	
Unconformity						
MIDDLE TO LATE PALAEOZOIC	Early Permian	Un-named unit (Pℓ)	Pale grey, well-indurated fine to medium pebbly quartz sand- stone (top only). Pebbles consist of chloritic metamorphic rock, dark brown hard calcareous mudstone, and pale grey siltstone.	200 to 850 ?	Top encountered in Minad CRC1 and CRC2 drillholes.	
	Unconformity					
	?Devonian	Un-named unit (?D) (may be equivalent to Mulga Downs Group?)	Pale grey fine sandstone with angular grains.	160 to 900	Intersected in Bungunna Bore.	

Late Devonian Mulga Downs Group, a terrestrial red-bed sequence which crops out in the Darling Depression in New South Wales. Here, the Mulga Downs Group unconformably overlies the Early Devonian marine Amphitheatre Group. Bembrick (1974) suggested that marine Early and Middle Devonian strata may underlie the terrestrial ?Devonian strata in the Tararra Trough. This stratigraphic sequence may be repeated in the Renmark Trough.

Spence (1958) suggested a Devonian age for sandstone underlying Cainozoic sediments in Bungunnia Bore.

A period of uplift and erosion followed the ?Devonian sedimentation until basin subsidence allowed the accumulation of Early Permian glacial and marine sediments in the Renmark Trough and Canegrass Lobe. Permian deposits encountered in drillholes on RENMARK consist of argillaceous diamictite, siltstone, sandstone and conglomerate.

As the Renmark Trough deepened, glaciers moved northwards and scoured out the valleys of the Paringa Embayment. Erratics dropped from melting ice rafts, and mudflows of glacial debris deposited lenses of conglomerate. Fossil leiosphaerids indicate a marginal marine environment (Evans, 1967). An assemblage of cold-water foraminifera (Ludbrook, 1967) and microflora (Harris in Grasso, 1963) from North Renmark No. 1 gives a Sakmarian to Early Artinskian age. Most of the movement on the major faults took place in Early Permian time, resulting in differing thicknesses in the Permian sequences across the faults.

Two drillholes (Minad CRC1 and CRC2) on the northwest margin of the Canegrass Lobe passed through a thin late Cainozoic sequence into a hard pebbly quartz sandstone which Gould (1975) considered to be Permian.

MESOZOIC

Uplift and erosion followed the Early Permian deposition until Early Cretaceous time when the sea advanced southwards from the Great Artesian Basin, through the Frome Embayment and Wilcannia area, and into the Renmark-Menindee and Wentworth Trough Systems.

The Cretaceous sediments of the Great Artesian Basin can be divided into three phases: an initial marine transgressive phase; a stable marine phase; and finally a marginal marine to freshwater regressive phase. In the Renmark area, these three phases are represented respectively by the Pyap, Merreti and Coombool Members of the Monash Formation (Thornton, 1972). The Cretaceous infrabasins beneath the Murray Basin were the last areas to experience marine incursion and the first to undergo regression. Consequently, Cretaceous sediments were deposited only during Aptian and Albian time. Uplift accompanied the northward departure of the sea, and a period of non-deposition set in until the Paleocene. Movement on the Hamley and Chowilla Faults probably ceased during Early Cretaceous time.

CAINOZOIC

Tertiary

The Tertiary sequence in the central Murray Basin can be divided into three phases: an initial period of freshwater deposition (Paleocene to Eocene); a transgressive period of more or less continuous marine deposition (Late Eocene to Middle Miocene); and finally, a transgressive-regressive marine to freshwater phase (Late Miocene to Pliocene). Towards the basin margins, the Late Eocene to Middle Miocene transgressive phase is not continuously

TABLE 3

TERTIARY STRATIGRAPHY

AGE	STRATIGRAPHIC UNIT AND SYMBOL	LITHOLOGY	THICKNESS (metres)	REMARKS
LATE PLIOCENE	Norwest Bend Formation (Tpn)	Pale grey, brown and yellow calcareous quartz sandstone with oyster beds.	1 to 5	Estuarine equivalent of Parilla Sand in southwest of map area.
	Parilla Sand (Tpp)	Pale grey, brown and yellow fine to medium quartz sand and clayey sand.	15 to 23	These two units have been distinguished in drillholes in the Chowilla Dam Site area. Elsewhere on CHOWILLA, non-marine sands of probable Pliocene age are designated Tp.
EARLY PLIOCENE	Loxton Sands (Tpl)	Yellow and red fine to coarse quartz sand over grey-brown clayey fine quartz sand.	55 to 60	
EARLY PLIOCENE TO ?LATE MIOCENE	Bookpurnong Beds (Tpb)	Dark grey fossiliferous glauconitic silt, sandy clay and silty sand.	12	
MIDDLE TO EARLY MIOCENE	Pata Limestone and equivalents) Morgan Limestone and equivalents (includes Cadell Marl)) (Tmm) Mannum Formation equivalents (Tmu))	Grey glauconitic sandy limestone; fossiliferous glauconitic silt and clay; black calcareous clay. Yellow bryozoal sandy limestone; grey fossiliferous calcareous sandy clay. Grey glauconitic calcareous sandy clay.	10 to 120 46	Equivalents of Pata and Morgan Limestones rest on Adelaidean rocks in drillholes in northwest of CHOWILLA.
OLIGOCENE	Ettrick Formation (Toe)	Grey glauconitic fossiliferous calcareous clay	11 to 35	Includes equivalents of <u>Gambier Limestone</u> (Tmg) and <u>Compton Conglomerate</u> (Toc)
MIDDLE OLIGOCENE TO LATE EOCENE	Buckleuch Beds (Teb)	Grey-brown fossiliferous sand	33	Found only in Bungunna Bore.
EOCENE TO PALEOCENE	Renmarks Beds (Tp-er)	Dark grey carbonaceous sand and sandy clay.	56 to greater than 132	

marine but is marked by regressive periods, particularly in Oligocene time. Evidence for these regressions has been found in deep bores in the Waikerie area (Lindsay and Bonnett, 1973).

The Renmark Beds (Paleocene to Eocene) were deposited in a predominantly fluvial-lacustrine environment. However, the upper part of this unit may have been laid down in paralic conditions in the south of CHOWILLA. A limited marine influence has been detected in the top part of the Renmark Beds in the Waikerie area (Lindsay and Bonnett, 1973).

The record of the Late Eocene to Middle Miocene transgressive period in the south and east of CHOWILLA is based largely on the sequence encountered in Canopus - 1 (Ludbrook, 1961). The marine Buccleuch Beds intersected in Bungunnia Bore mark an incursion of the sea which occurred in Late Eocene to Middle Oligocene time (Lindsay and Bonnett, 1973). Ettrick Formation equivalents (including equivalents of Compton Conglomerate and Gambier Limestone) record a marine transgression in Oligocene time. Equivalents of Mannum Formation and Morgan Limestone were laid down in a shallow marine shelf environment during the Early Miocene. Morgan Limestone includes the Cadell Marl at its type section, 6.5 km south of Morgan (Ludbrook, 1961). The Cadell Marl, with its distinctive fauna of warm-water molluscs, has been observed in spoil from old wells in the southwest of CHOWILLA (pers. comm. M. Buonaiuto, Univ. of Adelaide, 1976) and was also intersected in Bungunnia Bore. Finniss Clay, which occupies a stratigraphic position between Mannum Formation and Morgan Limestone, is not recorded on CHOWILLA. Marine

deposition continued into the Middle Miocene in the south-east of CHOWILLA, where fossiliferous clays equivalent to Pata Limestone are found in two stratigraphic bores (PD2 and PD81) at Chowilla dam site (Ludbrook, 1960).

On the northwest margin of the Murray Basin in South Australia, Early to Middle Miocene marine sediments rest on basement. These deposits have been recorded from drill-holes in the Oakvale (OLARY) 1:100,000 area (Lindsay and Harris, 1973), and in the South Dam area of BURRA (pers. comm. J.M. Lindsay, 1973), indicating that only the Morgan Limestone-Pata Limestone marine transgression extended into these areas. Sediments of early Tertiary age are absent and were probably never deposited.

In the northwest of CHOWILLA, grey carbonaceous fossiliferous clay and silt rest on basement in drillholes (Wecker, 1971; Bryan, 1972). Palaeontological examination indicates an Early to Middle Miocene age for these sediments. The sediments are equivalent to Morgan Limestone and Pata Limestone, and are comparable in facies to Cadell Marl (pers. comm. J.M. Lindsay, 1976).

Elevation of the Murray Basin and the resultant marine regression may have started as early as Middle Miocene time. The first evidence of this regression can be seen in Canopus 1 and Cockatoo Bore, where marginal marine black clays equivalent to Pata Limestone overlie fossiliferous and glauconitic marls equivalent to Morgan Limestone and Mannum Formation. A further period of marine deposition is marked by the Early Pliocene Bookpurnong Beds.

Generally non-marine sands of Pliocene age encountered in drillholes in the Chowilla Dam site area have been divided into the Early Pliocene Loxton Sands and the Late Pliocene Parilla Sand (Firman, 1966b). The Loxton Sands are predominantly coarser-grained than the overlying Parilla Sand. The Pliocene sands were deposited in a fluvial-lacustrine environment, except for the lower part of the Loxton Sands which is estuarine.

Elsewhere on CHOWILLA, fluviatile sands and clayey sands of Pliocene age are not differentiated and are designated Tp in bore sections. Kaolinitic and ferruginous fine to medium quartz sandstones outcropping just north of CHOWILLA on the Oakvale 1:100 000 area (Callen, 1969) probably belong to this unit.

A eustatic rise in sea level in the Late Pliocene led to marine ingression and deposition of estuarine Norwest Bend Formation in the southwest of CHOWILLA. This unit appears to extend northwards for a considerable distance along the western margin of the Murray Basin, as indicated by its presence in a well at Alexandrina O.S. (Ludbrook, 1953).

Quaternary

Sedimentary deposits

During the Early* to Middle Pleistocene, the fluvial-lacustrine Blanchetown Clay was deposited throughout most of CHOWILLA. Thin layers of Middle-Early Pleistocene Bungunnia Limestone are interbedded with the upper part of the Blanchetown Clay. The limestone is a dolomitic micrite containing oolites, ostracodes and algal remains. Bungunnia Limestone

*The terms "Early", "Middle" and "Late" Pleistocene used in these notes refer to the three-fold subdivision used by Firman (1973a) for the continental Pleistocene deposits of South Australia. These terms should not be confused with the international time subdivisions of Early and Late Pleistocene.

TABLE 4
QUATERNARY STRATIGRAPHY
(including palaeosols)

AGE	STRATIGRAPHIC UNIT AND SYMBOL	LITHOLOGY	THICKNESS (metres)	REMARKS
Holocene	Deposits of drainage channels and older floodplains (Qh)	Pale red-brown clay, silt, sand and gravel.	1 - 5	
	Deposits of claypans and Murray River lagoons (Qh1).	Pale red-brown and grey silt and clay.	1 - 2	Often associated with marginal lunette dunes of silt and clay (Qhu).
	Yamba Formation (Qhy)	Gypsiferous lacustrine clay and silt.	1 - 2	Reworked into marginal lunette dunes of seed and flour gypsum (Qhg).
	Coonambidgal Formation: lower terrace deposits (Qc2)	Pale grey clay, silt and sand.	10 - 20	Disconformably overlies <u>Monoman Formation</u> .
	Upper terrace deposits (Qc1)	Red-brown clayey sand.	up to 20	Equivalent to <u>Rufus Formation</u> .
Pleistocene	Woorinen Formation (Qpo)	Pale red-brown aeolian silty quartz sand.	3 - 6	Occurs as east-west linear dunes. Contains carbonate of <u>Loveday Soil</u> .
	Qp	Red-brown silt and sand.	1 - 5	Forms a transitional zone between areas of Woorinen Formation and areas of Pooraka Formation.
	Pooraka Formation (Qpp)	Red-brown clayey sand with gravel lenses.	1 - 5	Contains carbonate of <u>Loveday Soil</u> .
	Calcrete of Bakara and Loveday Soils (Qca)	Nodular and sheet calcrete.	about 0.5	Calcrete of Bakara Soil includes <u>Telford Gravel</u> .
	Blanchetown Clay (Qph)	Pale grey over mottled red-brown and grey sandy clay with thin beds of quartz sand; abundant concretionary carbonate; top is gypsiferous in places.	5 - 15	Thin layers of <u>Bungunna Limestone</u> interbedded at top.
	Palaeosol of Karoonda Surface	Siliceous and ferruginous duricrust.	1 - 3	Developed on Parilla Sand in Murray Valley. Duricrust on Adelaidean rocks in northwest of map area (Czsi) may be of same age.

occurs throughout CHOWILLA east of the Morgan Fault and was deposited in an ancient lake system known as Lake Bungunna. Evaporite deposits of crystalline gypsum were laid down after the deposition of Blanchetown Clay and are found at the top of this unit in places. The Blanchetown Clay often has an irregular upper surface, and appears to have been eroded shortly after deposition.

Middle Pleistocene gravel and sand (Telford Gravel) was deposited along the margin of the ranges. Telford Gravel is cemented by calcrete of the Bakara Soil, and is mapped with the calcrete (Qca) on the geological map.

Colluvial and alluvial material of the Late Pleistocene Pooraka Formation is found on the western and northern margins of the Murray Basin. Widespread aeolian deposition began in Late Pleistocene time with the laying down of Woorinen Formation in an extensive system of east-west linear dunes covering much of the map area.

A transitional unit (Qp) between areas of Pooraka Formation and areas of Woorinen Formation has been delineated on the geological map. This transitional unit probably falls within Lawrence's (1966) definition of Woorinen Formation.

The limited development of Holocene deposits on CHOWILLA is reflected by the widespread surface exposure of the Late Pleistocene Loveday Soil. Thin veneers of Holocene material derived from the underlying Late Pleistocene units are referred to as the Callabonna Clay (Firman, 1970b) and Bunyip Sand (Firman, 1973a).

The unit Qh includes bed load of the modern stream channels and the older floodplain deposits in which the modern streams are incised.

Palaeosols

A silicified cap at the top of the Parilla Sand at the Chowilla Dam site marks the Early Pleistocene fossil soil of the Karoonda Surface (Firman, 1966b). The material associated with this surface was reworked to form the Early Pleistocene Chowilla Sand.

Remnants of a siliceous duricrust developed on Adelaidean rocks occur in the northwest of CHOWILLA. In places silcrete fragments are reworked into calcrete of the Bakara Soil, indicating a pre-Middle Pleistocene age for the duricrust. Silcrete and ferricrete are also developed on the sandstones of probable Pliocene age which outcrop in the southeast corner of OLARY (Callen, 1969). These areas of siliceous duricrust may be remnants of the Karoonda Surface, or of an older weathering surface.

An important feature of Pleistocene deposits of the Murray Basin is the extensive development of carbonate palaeosols. These are fossil soils containing abundant carbonate silt, and with indurated limy pans in the B horizon called calcrete. The original carbonate silt may have been transported by wind from areas of weathering of carbonate-bearing rocks.

The most prominent carbonate palaeosol is the Middle Pleistocene Bakara Soil. The older carbonate pan in the Bakara Soil is the Ripon Calcrete, a hard sheet calcrete containing fragments of dark grey carbonate. This is usually directly overlain by the younger, weaker Bakara Calcrete (informal name) which has a reworked nodular structure. Calcrete of the Bakara Soil overlies Blanchetown Clay and older units, and cements Telford Gravel.

Carbonate horizons in the Woorinen and Pooraka Formations and in the unit Qp are part of the Late Pleistocene Loveday Soil. These carbonates are usually soft and nodular, but in many places approach the Bakara Calcrete in thickness and hardness. These calcretes of the Loveday Soil are mapped with calcretes of the Bakara Soil in the unit Qca.

Deposits of the Murray River Valley

After the formation of the Bakara Soil, the Murray River began to cut through the calcrete. At Chowilla Dam site, the river has cut down into Loxton Sands to a depth of about 1.5 m below present sea level. This downcutting probably took place during the last glacial period, when the sea level was considerably lower than at present. Infilling of the valley with alluvial clay, silt and coarse sand of the Monoman Formation began with the last (Flandrian) rise in sea level. These deposits are disconformably overlain by lower terrace deposits of the fluvial Coonambidgal Formation. On the geological map, the Coonambidgal Formation is divided into upper and lower terrace deposits, designated Qc1 and Qc2 respectively. The lower terrace consists of grey alluvium of the recent channels and floodplain. The upper terrace deposits, equivalent to Pooraka Formation, are reddened and contain carbonate of the Loveday Soil. Material of the upper terrace is equivalent to the Rufus Formation of Gill (1973a), and is probably of Middle to Late Pleistocene age.

Gypsum Deposits

Gypsiferous clays and gypsum-sand mixtures of the Holocene Yamba Formation were deposited in the floors of playa lakes. The gypsum is derived from evaporite beds

found at the top of Blanchetown Clay. The gypsum in the Yamba Formation was periodically transferred to aeolian lunette dunes on the lee-side of lakes during arid periods, but this process has now ceased.

STRUCTURE AND TECTONICS

The subsurface structural features on CHOWILLA have been interpreted from gravity, aeromagnetic and seismic data. The gravity and aeromagnetic data are presented as a Bouguer anomaly map (Fig. 2) and an aeromagnetic map of total intensity (Fig. 3). Gerdes (1973) and Thornton (1974a) provide the most comprehensive accounts of the structure of the area, based on geophysical and borehole data.

Folded and faulted Adelaidean metasediments border the Murray Basin in the northwest. The Adelaidean rocks were deformed by a series of north to northeasterly-trending folds during the early Palaeozoic Delamerian Orogeny. The fold pattern is revealed on the aeromagnetic map due to the response from the magnetite-rich Braemar Iron "Formation".

The Morgan and Florieton Faults in the western part of CHOWILLA are minor structures with vertical displacements of only about 30 m. Aeromagnetic evidence suggests that the Florieton Fault continues northwards and may intersect and die out within the Anabama-Redan Fault Zone.

The northern and western areas of the Murray Basin are shallow, with only 100 to 300 m of Cainozoic sediments overlying basement. A much thicker ?Devonian, Permian, Cretaceous and Cainozoic sequence was laid down in the Renmark Trough and Canegrass Lobe.

The Renmark Trough is the most prominent structure in the map area. It is a northeast-trending graben or half-graben with a sedimentary fill reaching a maximum thickness of 3 500 m. The Hamley Fault forms the western flank and the Chowilla Fault forms part of the eastern margin. Gravity data indicate that the Renmark Trough forms part of the northeast-trending Renmark-Menindee Trough Zone and may be directly connected to the Tararra Trough in New South Wales, or, more likely, the two troughs are separated in an en echelon relationship. A system of buried Permian glacial valleys, the Paringa Embayment, slopes northwestwards into the Renmark Trough.

The two faults flanking the Renmark Trough are major structures, particularly the Hamley Fault which has a throw of about 1 500 m. On the basis of gravity data, the Chowilla Fault appears to be a secondary feature of the Hamley Fault, with a throw of similar magnitude. Movement on the faults and subsidence of the Renmark Trough commenced in middle Palaeozoic time, resulting in the accumulation of ?Devonian sediments. Most of the faulting took place in Early Permian time, and movement finally ceased during the laying down of Early Cretaceous sediments.

The Hamley Fault is probably not a single fault but is more likely to be a major shear zone containing several faults in an en echelon pattern. This zone can be traced over a distance of at least 500 km. South of CHOWILLA, it may align with the Encounter lineament. Over the remainder of its course, the fault zone can be traced as a major gravity feature flanking the Renmark-Menindee Trough Zone, on the continuation of the Darling River Lineament of

Scheibner (1976). The Hamley Fault may form the boundary between the two types of basement in the area: Adelaidean meta-sediments, and metamorphic rocks of the Willyama Complex to the west; and possible Kanmantoo Group metamorphics to the east.

The Canegrass Lobe lying to the west of the Hamley Fault is a major Palaeozoic and Cretaceous infrabasin, containing a sediment fill up to 1 400 m thick. Seismic and gravity data indicate the presence of a basement ridge, the Canopus High, between the Hamley Fault and the northeastern margin of the Canegrass Lobe. The northwestern edge of the lobe is possibly fault controlled.

Gerdes (1973) found that the subsurface basement rocks in the northeast of CHOWILLA have a magnetic susceptibility and specific gravity higher than normal for Adelaidean rocks. He suggested that these rocks are metamorphics of the Willyama Complex which have been brought close to the surface by movement on a thrust. The inferred thrust is outlined by gravity and magnetic features. From filtered gravity data, Gerdes has inferred a deep basement structure, possibly a hinge zone, running in a north-south direction through the middle of the map area.

Examination of aerial photo-mosaics has revealed a well-defined pattern of structural lineaments in Cainozoic sediments (Firman, 1970a; 1973b; 1974). These lineaments reflect structures (faults and major joints) in the underlying basement rocks. On CHOWILLA, lineaments trend in northeast-northnortheast and northwest directions, forming a pattern of rectangular and rhomboid blocks.

Spence (1958) proposed a series of monoclinal flexures to account for the gentle warping of Tertiary formations seen in the Murray River cliffs. Measurements of the

Lepidocyclina Zone in the Morgan Limestone confirm the presence of folds and occasional faults in these sediments (Lindsay and Giles, 1973).

The monoclines, like the lineaments, are probably related to basement structures which were rejuvenated in late Cainozoic time. Variations in thicknesses of late Cainozoic units can be expected across the monoclinal flexures.

ECONOMIC GEOLOGY

Iron Ore

The Adelaidean Braemar Iron 'Formation' crops out in the northwest of CHOWILLA. This unit comprises hematitic siltstone and ferruginous tillite, with interbedded shale. Iron mineralisation is in the form of euhedral magnetite crystals partly oxidised to martite, and fine flakes of hematite. Whitten (1966) suggested that the rocks were formed by the chemical precipitation of magnetite and hematite in a cold sea, with melting glaciers and ice-bergs supplying rock flour and erratics.

The Braemar Iron 'Formation' reaches a maximum thickness of 760 m at Razorback Ridge (OLARY) where logging of diamond drill holes and an adit indicates ore reserves of over 120 000 000 tonnes with an average iron content of 26%. However, the ore is difficult to concentrate economically.

The unit is much thinner (about 250 m) at Ironback Hill (CHOWILLA), where Thomas (1950) estimated ore reserves of 2.900 000 tonnes.

Base Metals

Weak copper and molybdenum mineralisation of the "porphyry copper" type occurs in quartz veins cutting altered granodiorite, near Bendigo H.S. (BURRA). Detailed geological and geochemical investigations in the area between Bendigo H.S. and Kia Ora H.S., and in the South Dam area did not reveal any mineralisation of economic grade (Langsford, 1971, 1972a, b, c, 1973; Sibenaler, 1973). An aeromagnetic anomaly suggests that the granodiorite may extend onto CHOWILLA, probably at a depth of about 100 m.

Petroleum

It is unlikely that a major oil field will be discovered in the map area. However, a minor find would be economic because of its closeness to Adelaide.

Reservoir sands occur in the ?Devonian, Early Permian and, most importantly, in the Early Cretaceous Pyap Member. Early Permian shales and mudstones appear to be the most promising source rocks (Thornton, 1974a).

The Canegrass Lobe is a likely area for structural traps west of the southern part of the Hamley Fault. Stratigraphic traps (wedge-outs) could occur around the rim. A proposal to explore the Canegrass Lobe (Thornton, 1974b) began in 1975 with a seismic reflection survey aimed at delineating basin floor structure and locating possible drilling targets. Further seismic work and a stratigraphic drillhole (Canegrass - 1) are proposed.

Coal

Low-grade brown coal (lignite) occurs in the early Cainozoic Renmark Beds. Canopus - 2 passed through 9 m of lignite at a depth of 270 m.

Several holes drilled by Mines Administration Pty. Ltd. encountered lignite in sediments of Miocene age. Analyses of two samples from a lignite interval nearly 2 m thick gave average values of 26% fixed carbon, 37% volatiles, 21% moisture and 16% ash (Bryan, 1972).

Two holes were drilled by Mines Administration Pty. Ltd. on the northwest margin of the Canegrass Lobe to determine if coal is present in Permian sediments (Gould, 1975). Probable Permian sandstone was encountered in both holes but proved too hard for deeper drilling and testing for coal deposits.

Dolomite

Four samples of Adelaidean siliceous dolomite from the "Braemar" H.S. area gave values of 34-39% CaCO_3 and 25-29% MgCO_3 (Johns, 1963).

Gypsum

Deposits in the map area occur in Holocene gypsiferous lake sediments (Yamba Formation) and adjacent aeolian gypsum dunes. The gypsum is probably derived from gypsiferous layers in Blanchetown Clay. Three deposits have been investigated:

Morgan Deposit: Drilling and trenching in the western half of the claypan indicate reserves of 100 000 tonnes of crystalline gypsum (Whitten, 1962). Drilling on the adjacent dune indicates reserves of 1 500 000 tonnes of seed and flour gypsum (Olliver, 1967). This is the only mineral deposit being worked in the map area, and in the period 1960-1975 four operators have quarried 30 400 tonnes of gypsum valued at \$54 000.

Parcoola Deposits: Geological investigations have shown reserves of 10 000 000 tonnes of seed gypsum in dunes and 5 000 000 tonnes of crystalline gypsum in the claypans. Purity ranges from 60% to 70%. The claypan deposits contain possibly up to 20% alunite (Hiern, 1971).

Rotten Lake: About 800 000 tonnes of seed gypsum, varying in grade from 60% to over 80%, occur in the lake bed with associated crystalline and flour gypsum (Miles, 1951; Johns, 1953).

Construction Materials

Extensive exploration for construction materials was carried out within a radius of 80 km from the Chowilla Dam site (Hiern, 1963). No large deposit of hard rock was found in the area. The following notes summarise the materials investigated, and additional information.

Calcrete of the Bakara and Loveday Soils has been obtained from numerous small roadside quarries in the map area and used for surfacing dirt roads.

Calcrete at Tilmy Flats was investigated by trenching (Trudinger, 1966). The material consists of massive calcrete with varying proportions of nodular calcrete. Between 50% and 70% of the stone was found to be suitable for rip-rap on the proposed dam, but the presence of a chalky film makes it unsuitable for concrete aggregate. Reserves of material suitable for embankments are estimated at nearly 10 550 000 tonnes.

Bungunnia Limestone is a hard, dense fine-grained dolomitic limestone suitable for concrete aggregate. Small quantities are used for surfacing dirt roads, but the sharp

edges are not a desirable feature for road aggregate. The beds are generally too thin to be worthwhile exploiting.

A silicified sandstone up to 1.5 m thick (Pleistocene Karoonda Surface) caps Parilla Sand in the cliffs near the Chowilla Dam site. This material is generally too friable for construction purposes.

Fine aggregate for concrete and earthworks may be obtained from the Parilla Sand and alluvial sands of the Murray Valley.

Some parts of the Blanchetown Clay may be suitable for the manufacture of bricks, pipes and tiles. Clay from Lake Werta Werta might be suitable for making lightweight aggregate (Blissett, 1970). Blanchetown Clay from Tilmy Dam has an activity of 61% relative to Fuller's Earth Standard (Hiern, 1965).

Uranium

Exploration for sedimentary uranium has been carried out in the north of CHOWILLA by Mines Administration Pty. Ltd. (Wecker, 1971; Bryan, 1972) and Sedimentary Uranium N.L. (Hall, Relph and Associates Pty. Ltd., 1971).

Mines Administration Pty. Ltd. did most of the work which comprised an aerial scintillometer survey, drilling, and analyses of bore water samples. The aerial survey showed low-level radiometric anomalies (1.5 to 2 times background) over some claypans. Water samples from four bores all had U_3O_8 contents below the normal background value of 5 mg/l.

Radiometric logging of drillholes gave peaks of up to 430 counts per second (6 times background) in dark grey clay equivalent to the Morgan Limestone-Pata Limestone interval. One drillhole (Minad P-5) intersected lignite at the top of this unit with a U_3O_8 content of 0.22 kg/tonne over an interval of 1.8 m. Further drilling showed that the lignite is in a shallow restricted Tertiary basin, with no likelihood of economic uranium deposits in sands downdip from the lignite.

Sedimentary Uranium N.L. drilled 7 holes in the north of CHOWILLA but found no anomalous radioactivity.

Phosphate

A survey of Tertiary borehole samples from the Murray Basin in South Australia for sedimentary phosphate included three bores on CHOWILLA (Lindsay, 1965). Chemical analyses of four samples from Canopus - 1 gave P_2O_5 contents ranging from 0.24% to 0.61% with the highest value from the Renmark Beds.

Diatomite

A sequence, 4 m thick, of very fine-grained low-density white siliceous rock with interbeds of gypsiferous clay overlies Parilla Sand in a cliff section near Chowilla Dam site. The siliceous rock has been termed diatomite by Stapledon and Trudinger (1964).

Groundwater

Sands of the Renmark Beds contain water which is unusable or of poor stock quality. Salinities range from 10 000 to 21 400 mg/l (mainly chlorides).

Water in the Miocene and Pliocene sediments tends to be more saline than in the Renmark Beds and is usually unsuitable for stock use. Near the basin margin, shallower waters in sands and sandy clays may in places have a lower salinity, due to recharge from watercourses. In particular, areas adjacent to the Mt. Lofty-Olary Ranges should have good quality stock water at depths of 100 m. or less.

Most stock water is obtained from surface water draining into earth dams.

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BIBLIOGRAPHY

- Associated Australian Oilfields N.L., 1968. Hamley seismic and gravity survey by Mines Administration Pty. Ltd., and Namco Geophysical Co. S. Aust. Dept. Mines open file Env. 824 - unpublished.
- Baker, G., 1968. Australites from northnortheast of Morgan, South Australia. Mem. Nat. Mus. Vict., 28, pp.39-76.
- Barker, S., 1970. Quondong Station, South Australia: a field context for applied rangeland research. Trans. roy. Soc. S. Aust., 94, pp. 179-190.
- Barker, S. and Lange, R.T., 1969. Occurrence of polygonal patterned ground in the arid zone of South Australia. Trans. roy. Soc. S. Aust., 93, pp. 153-155.
- Bembrick, C.S., 1974. Murray Basin, in Markham, N.L. and Basden, H. (ed.). The Mineral Deposits of New South Wales, pp. 557-568. Geol. Surv. N.S.W.
- Binks, P.J., 1968. ORROROO map sheet, Geological Atlas of South Australia, 1:250 000 series, geol. Surv. S. Aust.
- Blissett, A.H., 1970. Mineral Resources of the Upper Murray Planning Area. S. Aust. Dept. Mines unpub. rept. RB70/146.
- Blumer, J.M. and Webb, J.E., 1965. Final report on gravity survey of E.P.L. 36, South Australia. S. Aust. Dept. Mines open file Env. 498 - unpublished.
- Boucaut, W.R.P., 1966. Chowilla project - reservoir. Geological Investigations, Progress Report No. 1, S. Aust. Dept. Mines unpub. Rept. RB63/107.
- Boucaut, W.R.P., 1967. Chowilla project - saline water disposal, Tilmy Flat. Geological Investigations - Progress Report No. 2. S. Aust. Dept. Mines unpub. Rept. RB64/10.

- Boyd, B. and Heisler, H.H., 1967. A.O.G. Tararra No. 1 well, N.S.W. Well completion report. S. Aust. Dept. Mines open File Env. 1658 - unpublished.
- Boyd, D., 1971. Interpretation of the Aeromagnetic data published by South Australian Mines Department over S.M.L.550 and adjacent ground. S. Aust. Dept. Mines open file Env. 1695 - unpublished.
- Bryan, R., 1972. Final report, S.M.L.416 (Postmark), Mines Administration Pty. Ltd., S. Aust. Dept. Mines open file Env. 1403 - unpublished.
- Callen, R.A., 1969. Preliminary Notes on the Oakvale 1:63 360 sheet. S. Aust. Dept. Mines unpub. Rept. RB69/1.
- Campbell, J.H.B., 1965. Renmark area seismic survey O.E.L.35, South Australia, for Tasman Oil Pty. Ltd. S. Aust. Dept. Mines open file Env. 532 - unpublished.
- Cookson, I.C., undated. The microspore content of certain Tertiary sediments in a bore at Canopus Station, South Australia. S. Aust. Dept. Mines unpub. Rept. RB37/83.
- Crocker, R.L., 1946. Post-Miocene climatic and geologic history and its significance in relation to the genesis of the major soil types of South Australia. Bull. Comm. Scient. ind. Res., 193.
- Douglas, J.G., and Ferguson, J.A. (eds.), 1976. Geology of Victoria. Geol. Soc. Aust. Spec. Publ. 5.
- Drew, M.F., Paten, R.J. and Gray, H.D., 1969. Final report in the Sunset seismic survey. P.E.L.3, South Australia, P.E.P.64, Victoria. S. Aust. Dept. Mines open file Env. 1198 - unpublished.

- Evans, P.R., 1967. Upper Carboniferous and Permian palynological stages and their distribution in eastern Australia. Rec. Bur. Miner. Resour. Geol. Geophys. Aust., 1967/99 - unpublished.
- Firman, J.B., 1963. Quaternary geological events near Swan Reach in the Murray Basin, South Australia. Quart. Geol. Notes, Geol. Surv. S. Aust., 5.
- Firman, J.B., 1964. The Bakara Soil and other stratigraphic units of late Cainozoic age in the Murray Basin, South Australia. Quart. Geol. Notes, Geol. Surv. S. Aust., 10, pp 2-5.
- Firman, J.B., 1965. Late Cainozoic lacustrine deposits in the Murray Basin, South Australia. Quart. Geol. Notes, Geol. Surv. S. Aust. 16, pp 1-2.
- Firman, J.B., 1966a. Stratigraphy of the Chowilla area, South Australia. S. Aust. Dept. Mines unpub. Rept. RB63/64.
- Firman, J.B., 1966b. Stratigraphy of the Chowilla area in the Murray Basin. Quart. Geol. Notes, Geol. Surv. S. Aust., 20, pp 3-7.
- Firman, J.B., 1967a. Stratigraphy of late Cainozoic deposits in South Australia. Trans. roy. Soc. S. Aust., 91 pp. 165-178.
- Firman, J.B., 1967b. Late Cainozoic stratigraphic units in South Australia. Quart. Geol. Notes, Geol. Surv. S. Aust., 22, pp. 4-8.
- Firman, J.B., 1969. 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. Quart. Geol. Notes., Geol. Surv. S. Aust., 35, pp 1-3.
- Firman, J.B., 1970b. Late Cainozoic Stratigraphic Units in the Great Artesian Basin, South Australia. Quart. Geol. Notes, Geol. Surv. S. Aust., 36, pp 1-4.
- Firman, J.B., 1971. Riverine and swamp deposits in the River Murray tract, South Australia. Quart. Geol. Notes, Geol. Surv. S. Aust., 40 pp 1-4.
- Firman, J.B., 1972. Explanatory Notes on the RENMARK 1:250 000 geological map. Geol. Surv. S. Aust.
- Firman, J.B., 1973a. Regional stratigraphy of surficial deposits in the Murray Basin and Gambier Embayment. Rept. Invest. Geol. Surv. S. Aust., 39.
- Firman, J.B., 1973b. Structural lineaments in South Australia. A study of particular linear features on photo-mosaics. S. Aust. Dept. Mines unpub. Rept. RB73/145.
- Firman, J.B., 1974. Structural lineaments in South Australia. Trans. roy. Soc. S. Aust., 98, pp. 153-172.
- Forbes, B.G., 1970. Benda Siltstones. Quart. Geol. Notes, Geol. Surv. S. Aust., 33, pp. 1-2.
- Forbes, B.G., 1971. A table of Adelaidean and Cambrian stratigraphic names. Quart. Geol. Notes, Geol. Surv. S. Aust., 38.
- Forbes, B.G. and Cooper, R.S., 1976. The Pualco Tillite of the Olary Region, South Australia. Quart. Geol. Notes, Geol. Surv. S. Aust., 60.
- Gerdes, R.A., 1973. Anabama Fault Project. S.A. Dept. Mines unpub. Rept. RB73/75.
- Gill, E.D., 1973a. Geology and geomorphology of the Murray River Region between Mildura and Renmark, Australia. Mem. Nat. Mus. Victoria, 34 pp. 1-97.

- Gill, E.D., 1973b. Palaeopedology of the Murray River R gion between Mildura and Renmark, Australia. Mem. Nat. Mus. Victoria, 34, pp. 241-252.
- Gould, W.B., 1975. Report on Investigation for Coal - Exploration Licence 182. S. Aust. Dept. Mines open file Env. 2553 - unpublished.
- Grasso, R., 1963. North Renmark No. 1 well, South Australia, final well report. Australian Oil Corp. S. Aust. Dept. Mines open file Env. 307 - unpublished.
- Hall, J. McG. and Gerdes, R.A., 1976. CHOWILLA map sheet, Bouguer Anomaly Map, 1:250 000. Geol. Surv. S. Aust.
- Hall, Relph and Associates Pty. Ltd., 1971. Fourth Quarterly Report S.M.L.393, Sedimentary Uranium N.L. S. Aust. D pt. Mines open file Env. 1348 - unpublished.
- Harris, W.K., 1966. New and redefined names in South Australian Lower Tertiary stratigraphy. Quart. geol. Notes, Geol. Surv. S. Aust., 20, pp 1-3.
- Hiern, M.N., 1960. Survey of stone deposits for the proposed River Murray storage - progress report. S. Aust. Dept. Mines unpub. Rept. RB 51/52.
- Hiern, M.N., 1963. Chowilla Dam site - geological investigations Min. Rev., Adelaide, 115, pp. 117-129.
- Hiern, M.N., 1965. Occurrence of activable clay in South Australia - second report. Min. Rev., Adelaide 118, pp. 44-52.
- Hiern, M.N., 1969. Preliminary Report - Redcliffe Gypsum Deposit. S. Aust. Dept. Mines unpub. rept. RB68/97.
- Hiern, M.N., 1971. Parcoola Gypsum Deposit. Mineral Resources Rev. S. Aust., 130, pp. 157-161.
- Johns, R.K., 1953. Gypsum Deposits at Rotten Lake in the Renmark district. Min. Rev., Adelaide 94, pp52-55.

- Johns, R.K., 1963. Limestone, Dolomite and Magnesite resources of South Australia. Bull. Geol. Surv. S. Aust., 38.
- Johnson, W., Hiern, M.N., and Steel, R.D., 1960. Chowilla Dam site - Geological investigations. Preliminary report. S. Aust. Dept. Mines unpub. Rept. RB 51/136.
- Kendall, G.W., 1965. Report on a seismic refraction and reflection survey in the northern portion of the Murray Basin in South Australia. S. Aust. Dept. Mines unpub. Rept. RB61/112.
- Kendall, G.W., and Seedsman, K.R., 1967. Reconnaissance seismic refraction and gravity surveys in the northern portion of the Murray Basin in South Australia - 1963. Min. Rev., Adelaide 120, pp. 5-16.
- Langsford, N.R., 1971. The Investigation of the Bendigo copper and molybdenum prospect - Report No. 1. S. Aust. Dept. Mines unpub. Rept. RB 71/129.
- Langsford, N.R., 1972a. The investigation of the Bendigo copper and molybdenum prospect - Report No. 2. S. Aust. Dept. Mines unpub. Rept. RB 72/2.
- Langsford, N.R., 1972b. The investigation of the Bendigo copper and molybdenum prospect - Report No. 3. S. Aust. Dept. Mines unpub. Rept. RB 72/1.
- Langsford, N.R., 1972c. Kia Ora-South Dam Project - reconnaissance drilling. S. Aust. Dept. Mines unpub. Rept. RB 72/131.
- Langsford, N.R., 1973. The investigation of the Bendigo copper and molybdenum prospect - Report No. 4. S. Aust. Dept. Mines unpub. Rept. RB 73/63.

- Lawrence, C.R., 1966. Cainozoic stratigraphy and structure of the mallee region, Victoria. Trans. roy. Soc. Vict. 79/2, pp 517-553.
- Lawrence, C.R., 1972. MILDURA 1:250 000 geological map. Geol. Surv. Victoria.
- Lawrence, C.R., 1975. Geology, Hydrodynamics and Hydro-chemistry of the southern Murray Basin. Geol. Surv. Victoria, Memoir 30.
- Lindsay, J.M., 1965. Examination of bore samples for sedimentary phosphate, Murray Basin and Gambier Embayment of the Otway Basin. S. Aust. Dept. Mines unpub. Rept. RB 60/11.
- Lindsay, J.M., 1972. River Murray Salinity geomorphology Investigation, Lake Victoria area, N.S.W. Stratigraphic and palaeontological notes with reference to the Chowilla area, S.A. S. Aust. Dept. Mines unpub. Rept. RB 72/149.
- Lindsay, J.M. and Bonnett, J.E., 1973. Tertiary stratigraphy of three deep bores in the Waikerie area of the Murray Basin. Rep. Invest., Geol. Surv. S. Aust., 38.
- Lindsay, J.M. and Giles, S.D., 1973. Notes on the Lepidocyclina Zone in Morgan Limestone along the Murray River, South Australia. Quart. Geol. Notes, Geol. Surv. S. Aust., 45 pp 1-7.
- Lindsay, J.M. and Harris, W.K., 1973. Miocene marine transgressions on Mutooroo, OLARY, at the northern margin of the Murray Basin. S. Aust. Dept. Mines unpub. Rept. RB 779.
- Ludbrook, N.H., 1953. S. Aust. Dept. Mines unpub. Paleontological Report F 118/53.
- Ludbrook, N.H., 1957. A reference column for the Tertiary sediments of the South Australian portion of the Murray Basin. Journ. Proc. roy. Soc. N.S.W., 90, pp. 174-180.

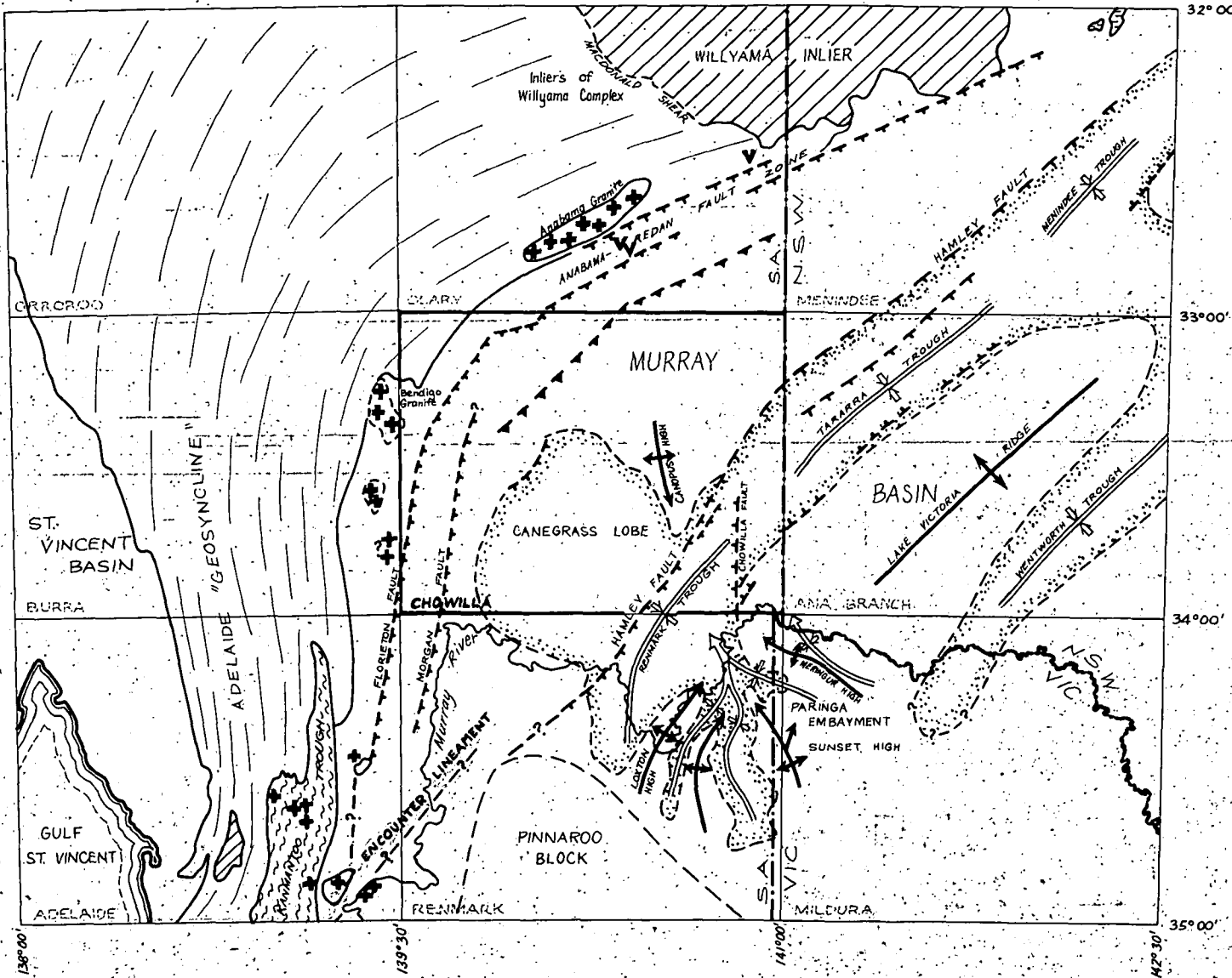
- Ludbrook, N.H., 1958. The Murray Basin in South Australia in Glaessner, M.F., and Parkin, L.W. eds. The Geology of South Australia. Jour. geol. Soc. Aust. 5/2, pp.102-114.
- Ludbrook, N.H., 1960. Chowilla Dam site, River Murray - Stratigraphy and Micropalaeontology. S. Aust. Dept. Mines unpub. Rept. RB 51/121.
- Ludbrook, N.H., 1961. Stratigraphy of the Murray Basin in South Australia. Bull. Geol. Surv. S. Aust., 36.
- Ludbrook, N.H., 1967. Permian deposits of South Australia and their fauna. Trans. roy. Soc. S. Aust., 91, pp 65-87.
- Lukk, G.E., 1974. A review of available seismic data over the Murray Basin covered by P.E.L. 14, South Australia, P.E.L. 201, N.S.W., and P.E.P. 85, Vic. S. Aust Dept. Mines open file Env. 2397 - unpublished.
- Marshall, L.G., 1973. Fossil vertebrate faunas from the Lake Victoria region, S.W. New South Wales, Australia. Mem. Nat. Mus. Victoria, 34, pp. 151-171.
- Mawson, D., 1912. Geological investigations in the Broken Hill area. Mem. roy. Soc. S. Aust., 4/4, pp. 211-319.
- Meyers, N.A., 1974. Geological evaluation of the Murray Basin. S. Aust. Dept. Mines open file Env. 2397 - unpublished.
- Miles, K.R., 1951. Notes on preliminary inspection of gypsum deposits in Berri-Barmera district. S. Aust. Dept. Mines unpub. Rept. RB 31/116.
- Mirams, R.C., 1958. Progress report No. 1 on Braemar ironstone deposits. S. Aust. Dept. Mines unpub. Rept. RB 47/81.

- Mirams, R.C., 1960. Manunda map sheet, Geological Atlas of South Australia, 1:63 360 series. Geol. Surv. S. Aust.
- Mirams, R.C., 1962. The geology of the Manunda military sheet. Rept. Invest., Geol. Surv. S. Aust., 19.
- Mirams, R.C. 1964. BURRA map sheet, geological Atlas of South Australia, 1:250 000 series. Geol. Surv. S. Aust.
- O'Driscoll, E.P.D., 1960. The Hydrology of the Murray Basin province in South Australia. Bull. Geol. Surv., S. Aust., 35.
- Olliver, J.G., 1967. Gypsum deposit - Blocks Q and N, Hundred of Stuart. Min. Rev., Adelaide, 120, pp. 75-80.
- Parkin, L.W., (ed.), 1969. Handbook of South Australian Geology. Geol. Surv., S. Aust.
- Pels, S., 1969. The Murray Basin, in The Geology of New South Wales, ed. G.H. Packham, pp. 499-511. Geol. Soc. Aust.
- Pledge, N.S., 1965. CHOWILLA 4-mile sheet - preliminary report. S. Aust. Dept. Mines unpub. Rept. RB 60/10.
- Roberts, G.T., 1966. Chowilla Project - saline water disposal, Tilmy Flat, County Hamley. Geological investigation - progress report No. 1. S. Aust. Dept. Mines unpub. Rept. RB 62/98.
- Roberts, G.T., 1968. Features in the Blanchetown Clay in the Waikerie district. Quart. Geol. Notes, Geol. Surv. S. Aust., 28, pp. 4-6.
- Rose, G., 1967. MENINDEE 1:250 000 geological map, Geol. Surv. N.S.W.








- Scheibner, E., 1976. Explanatory Notes on the Tectonic Map of New South Wales. Geol. Surv. N.S.W.
- Seedsman, K.R., 1964. Geophysical Exploration in the South Australian portion of the Murray Basin. Jour. Aust. Petrol. Explor. Ass. pp. 90-98.
- Sibenaler, X.P., 1973. Kia Ora-South Dam project. Rotary drilling - report no. 2. S. Aust. Dept. Mines unpub. Rept. RB 73/164.
- Spence, J., 1958. The geology of the Murray Basin. S. Aust. Dept. Mines open file Env. 144 - unpublished.
- Sprigg, R.C. and Campana, B., 1953. The age and facies of the Kanmantoo Group. Aust. Jour. Sci., 16, pp. 12-14.
- Stackler, W.F. and Yakunin, A., 1962. Report on a gravity/seismic survey - Loxton area (portion of O.E.L.23), South Australia, for Beach Petroleum N.L. S. Aust. Dept. Mines, open file Env. 280 - unpublished.
- Stapledon, D.H. and Trudinger, J.P., 1964. Chowilla dam, embankment materials investigation - sand for dam shoulders. Interim geological report. S. Aust. Dept. Mines unpub. Rept. RB 59/95.
- Steel, T.M., 1968. Chowilla Project. Saline water disposal - Tilmy Flat. Geological Investigation, Progress report No. 3. S. Aust. Dept. Mines unpub. Rept. RB 66/60.
- Swindon, V.G., 1966. A review of the Renmark-Canegrass area, Murray Basin, South Australia. S. Aust. Dept. Mines open file Env. 746 - unpublished.
- Thomas, W.M., 1950. Investigation of the Braemar ironstone deposits. S. Aust. Dept. Mines unpub. Rept. RB 27/99.

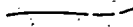
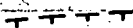


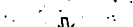
- Thomson, B.P., 1975. Tectonics and regional geology of the Willyama, Mount Paiter and Denison Inlier areas in Knight, C.L. (Ed.) Economic Geology of Australia and Papua New Guinea. Vol. 1, pp. 469-476. Aust. Inst. Min. Met.
- Thomson, B.P., Coats, R.P., Mirams, R.C., Forbes, B.G., Dalgarno, C.R., and Johnson, J.E., 1964. Precambrian rock groups in the Adelaide Geosyncline. A new subdivision. Quart. Geol. Notes, Geol. Surv. S. Aust., 9, pp. 1-19.
- Thornton, R.C.N., 1972. Lower Cretaceous sedimentary units beneath the western Murray Basin. Quart. Geol. Notes, Geol. Surv. S. Aust., 44, pp. 5-11.
- Thornton, R.C.N., 1974a. Hydrocarbon potential of western Murray Basin and infrabasins. Rept. Invest. Geol. Surv. S. Aust., 41.
- Thornton, R.C.N., 1974b. A proposal to explore the Canegrass Lobe, western Murray Basin. S. Aust. Dept. Mines unpub. Rept. RB 74/156.
- Trudinger, J.P., 1966. Chowilla project - geological investigations. Calcrete deposit - Tilmy Flat. S. Aust. Dept. Mines unpub. Rept. RB 63/59.
- Webb, A.W., 1976. Geochronology of the granitic rocks of southeastern South Australia. Amdel Report No. 1138.
- Webb, J.E., 1965. CHOWILLA map sheet, aeromagnetic map of total intensity, 1:250 000. Geol. Surv. S. Aust.
- Wecker, R., 1971. Final report, S.M.L.569 (Pine Valley) Mines Administration Pty. Ltd., S. Aust. Dept. Mines open file Env. 1696 - unpublished.
- Whitten, G.F., 1962. Gypsum deposit - Blocks Q and N, Hundred of Stuart. Min. Rev., Adelaide, 113, pp. 25-31.

- Whitten, G.F., 1965. The use of aeromagnetic maps in geological regional mapping. Quart. Geol. Notes, Geol. Surv. S. Aust., 15, pp. 1-5.
- Whitten, G.F., 1966. Suggested correlation of iron ore deposits within South Australia. Quart. Geol. Notes, Geol. Surv. S. Aust., 18, pp 7-11.
- Whitten, G.F., 1970. The investigation and exploitation of the Razorback Ridge iron deposit. Rep. Invest. Geol. Surv. S. Aust., 33.
- Whitten, G.F. and Ker, D.S., 1961. Braemar map sheet. Geological Atlas of South Australia 1:63 360 series. Geol. Surv. S. Aust.
- Youles, I.P., 1972. Final report on S.M.L.550 (Bendigo) Exoil N.L. and Transoil N.L. S. Aust. Dept. Mines open file Env. 1695 - unpublished.
- Young, G.A., 1963. Chowilla airborne magnetic and radiometric survey, S.A., 1961. Bur. Min. Res. Geol. and Geophys. Record No. 1963/25.



LEGEND

-  Cainozoic sediments of Murray and St Vincent Basins
-  Permian and ?Devonian infrabasins
-  Ordovician Scopes Range Beds
-  Cambrian-Ordovician granite and acid volcanics
-  Cambrian Kanmantoo Group
-  Upper Proterozoic Adelaide System
-  Lower Proterozoic Willyama Complex and Upper Proterozoic Barossa Complex

-  Geological boundary
-  Fault
-  Inferred thrust
-  Axis of basement high
-  Axis of Permian - ?Devonian trough

Structure of Renmark Area from Thornton (1974 a).
 Structure of N.S.W. portion from Scheibner, E., 1974.
 Tectonic Map of N.S.W. 1:1 000 000. Geol. Survey N.S.W.

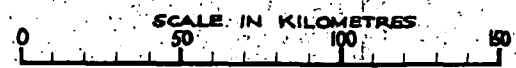
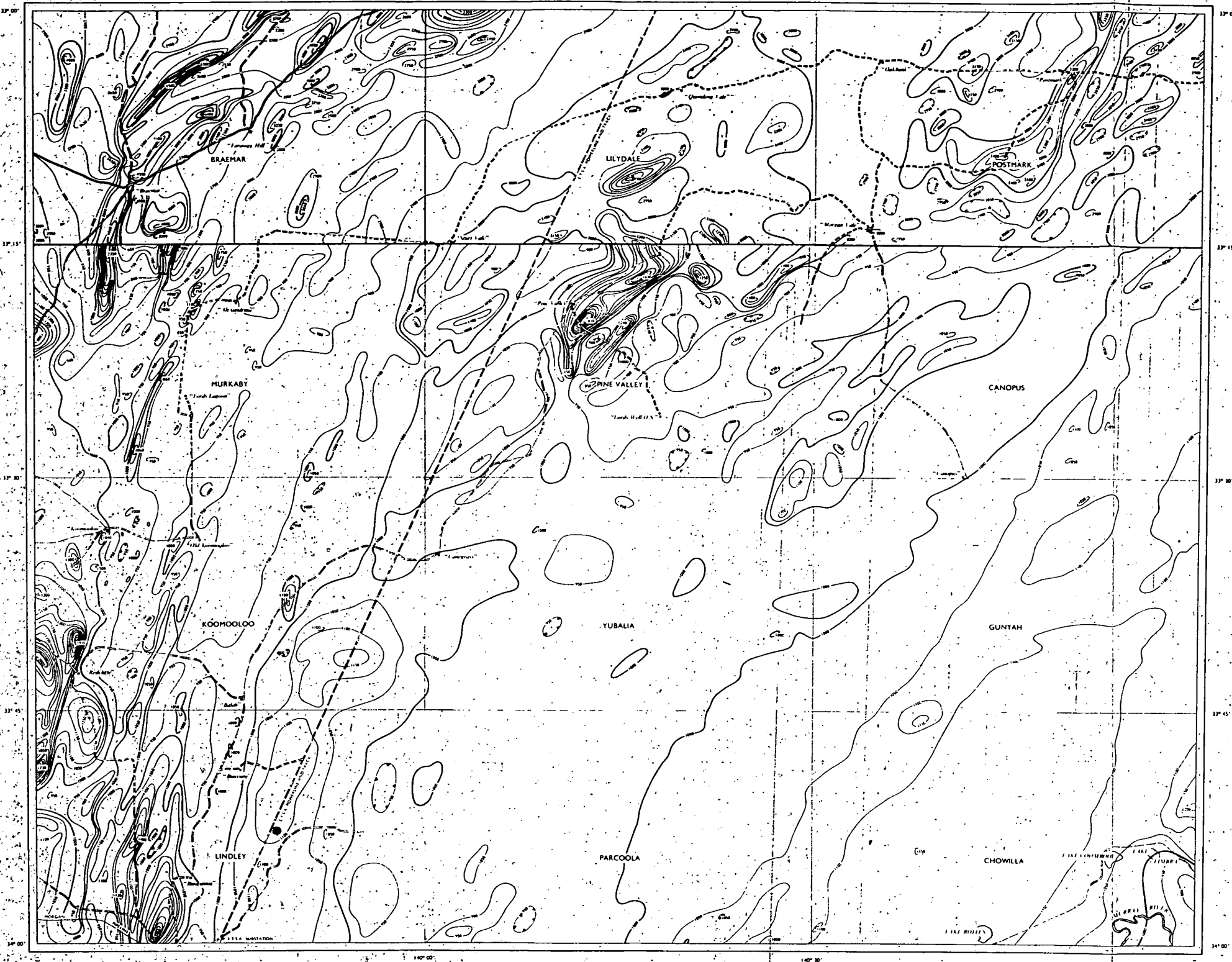


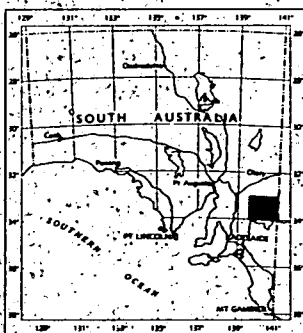
FIG. 1

DEPARTMENT OF MINES - SOUTH AUSTRALIA			
LOCATION AND GEOLOGICAL SETTING OF CHOWILLA 1:250 000 MAP AREA - FOR EXPLANATORY NOTES			
	Compiled	Scale 1	
	R.H. Rogers	Date: 19-10-76	
	Drn.		
	Clk.	Dr. No. 76-858	
Director of Mines			

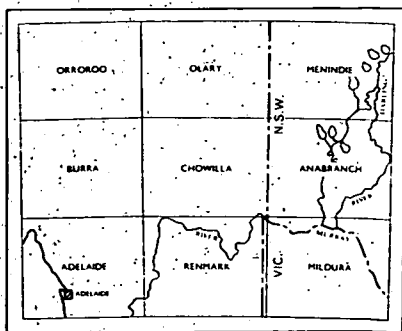
FIG 1



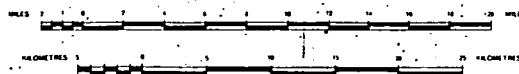
LOCALITY



INDEX TO ADJOINING SHEETS



SCALE



**AEROMAGNETIC MAP
OF TOTAL INTENSITY**

Published 1963.

NOTE

This map is compiled from aeromagnetic surveys conducted by Bureau of Mineral Resources on behalf of the S.A. Dept. of Mines.
The total magnetic intensity at 500 ft. above ground level was measured continuously. The contours are derived for normal regional gradient. Uncorrected photo magnetic contours were used to improve detail based on a spacing of one meter and corrected base maps. The aeromagnetic contours are recorded on photographs taken with a 35 mm. camera.
Results reduced by Geophysics Section, S.A. Dept. of Mines, 21 Webb St., 25.5 A.M. Senior Geophysicist Campbell under the direction of S. B. Barrett, M.Sc., Geophysicist, Geophysics Section.
Issued under the Authority of the Honorable Sir A. (1962) M.C. & L.C.
The one inch sheets of BRAEMAR, LILYDALE and POSTMARK are part of a survey completed in 1955. The balance of the sheets are part of a survey completed in 1962.

LEGEND

Magnetic Contours (values in gammas)

Roads shown thus:



This 1:250,000 map reduced by the S.A. Dept. of Mines from published 1:62,500 sheets