DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

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EXPLANATORY NOTES FOR THE FROME 1: 250 000 GEOLOGICAL MAP

SHEET SH/54-10 INTERNATIONAL INDEX.

GEOLOGICAL SURVEY

By

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JANUARY, 1980

D.M. No.: 538/74

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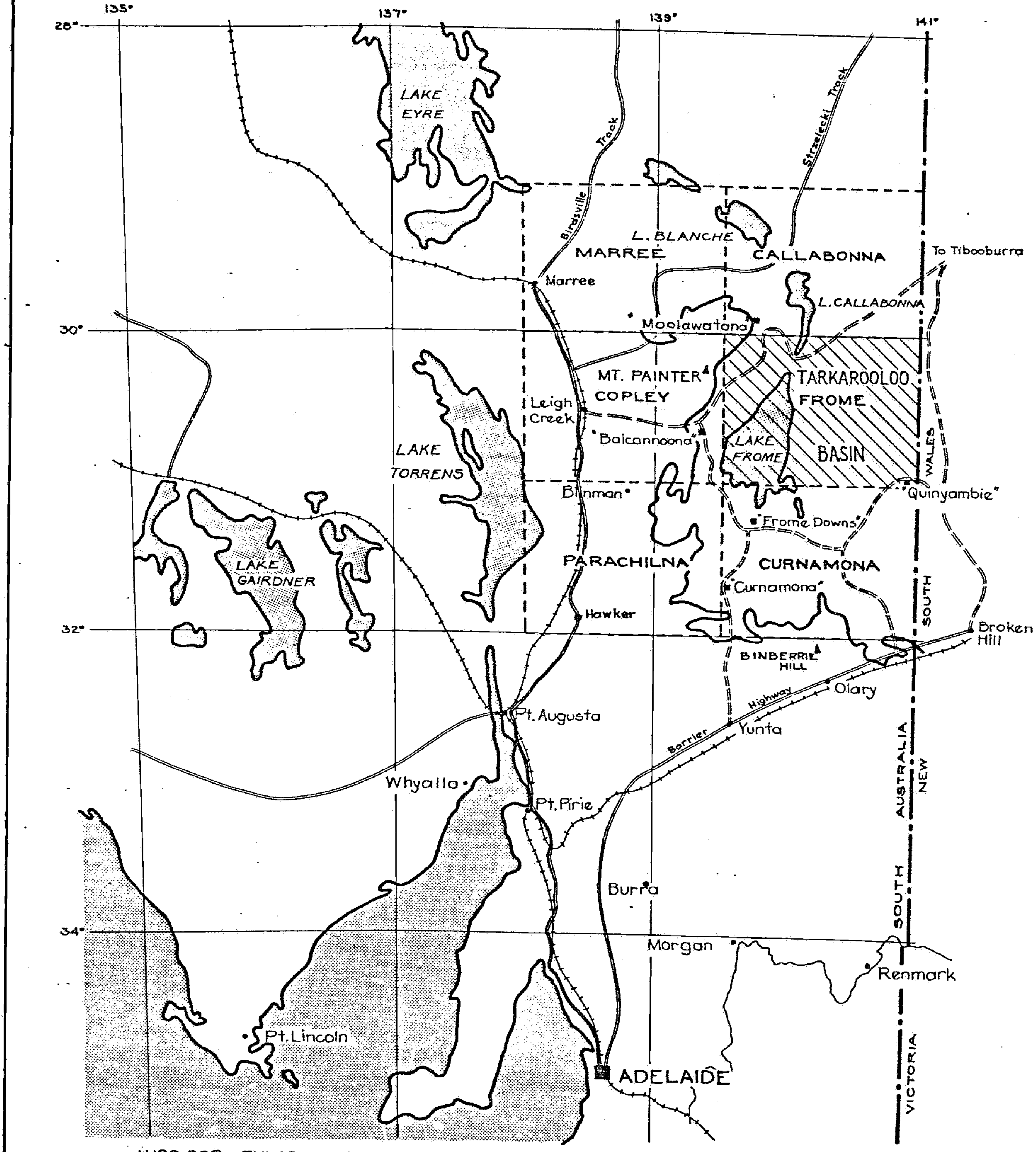
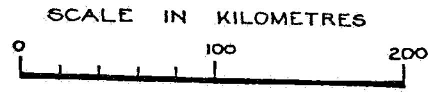


1:100,000 ENLARGEMENTS

PARALANA	*WITTAKILLA*	*AMERARKOO*
PARALANA	COOTABARLOW	COONEE
CALDINA	*PUNDALPA*	*COONEE*
	FROME	
ARKAROOLA	*ELDER*	*THURLOOKA*
FROME	COONARBINE	THURLOOKA
FROME	*COONARBINE*	*QUINYAMBIE*

1:63,360 ENLARGEMENTS



Boundary of Cainozoic Sediments
(TARKAROOLOO BASIN)

FIG.1

DEPARTMENT OF MINES – SOUTH AUSTRALIA

SCALE. 1:4,000,000

COMPILED: R. Callen

FROME 1:250,000
LOCALITY PLAN

DATE: 21ST. April 1976

DRN: A.R. CKD.

PLAN NUMBER: S12171

EXPLANATORY NOTES FOR THE FROME 1: 250 000 GEOLOGICAL MAP

Compiled by R.A. Callen

INTRODUCTION

The FROME 1: 250 000 geological sheet is located between latitudes 30° S and 31° S and longitudes 139°30' E and 141° E (Fig. 1) and covers most of the area between the northern Flinders Ranges and the New South Wales border. Its southern and northern limits approximate to the extremities of Lake Frome, which occupies most of the western portion of the sheet. A southern extension of the Strzelecki Desert covers the eastern half of the area.

Main access roads are the Barrier Highway, Port Augusta-Wilpena Pound road (which branches off through Oraparinna, thence to Wertaloona) and the Broken Hill-Tibooburra road (Fig. 1). A track along the New South Wales side of the border fence gives access to the eastern portion of the sheet, but the fence is about 50 to 100 m inside New South Wales, and hence is <u>not shown</u> on the maps. Brougham's Gate is one of the few places where one can pass through the fence into South Australia.

"Putnamutana Outstation", known locally as "Old Moolawatana", and "Quinyambie", are the only permanent habitations, being located in the northwestern and southeastern corners of the sheet respectively. "Frome Downs" is located immediately south of Lake Frome on CURNAMONA. "Balcanoona" and "Wertaloona" are situated along the foothills of the Flinders Ranges to the west of the sheet, on COPLEY. Part of the pastoral lease of "Wirrealpa" is on FROME sheet area.

The climate is dry, hot in summer, with cold winds and occasional frost in winter. Winds are dominantly from the southern quarter with a strong westerly phase during May-August and north winds in summer (Callen, 1974b). Rainfall is low and erratic (100-125 mm/yr) falling mostly in brief storms with heavier rains of 350-625 mm at 10-20 year intervals. Falls occur mainly during February, March, May, June and December, with April being the driest month. The central portion of the map area east of Lake Frome receives the lowest rainfall, while the highest and most reliable occurs near the Flinders Ranges and in the southeastern corner of the sheet.

The vegetation is sparse. Plant species most useful for geological mapping are *Eucalyptus gillii*, which occurs on the Willawortina Formation (Late Cainozoic) dolomitic sediments adjacent to the Flinders Ranges, particularly where calcrete or carbonates are exposed. *Callitris columellaris* occurs east of Lake Frome and on one island in the lake, tending to prefer the Eurinilla Formation (Quaternary) as a substrate.

The nomenclature used for basins follows Wopfner (1972): the term "Frome Embayment" (Ker 1966, Freeman 1966, Wopfner 1966) refers to the Mesozoic sedimentary basin. "Lake Frome area" refers to the region bounded by the Flinders Ranges to the west, Barrier Ranges to the east and Olary Ranges to the south. The northern limit is taken as an approximate east-west line through the southern portion of Lake Blanche on CALLABONNA. Within the Frome Embayment, the blanketing Cainozoic sediments are unconformable on the Cretaceous and relate to discrete cycle of events, hence the basin of Cainozoic deposition is named the Tarkarooloo Basin (after Lake Tarkarooloo on CURNAMONA). The Poontana Subbasin (after Poontana Ck) occupies the deeper western portion of the Tarkarooloo Basin.

The map was prepared from Department of Lands 60 chain (1: 55,000, Svy. 394,395) black and white photography supplemented by 1: 83,900 colour photography (Svy. 1209).

Landsat band 7 imagery is available (1565-0000-BW7, see Callen 1977). Petrological reports, rock samples and core are on computer file; Core and samples are shared at the SADME Core Laboratories, Frewville. Plans of drillhole distribution (Annual Report of the South Australian Department of Mines and Energy 1973/4, p 26.) and spot height data (plan 7639) are available.

1: 63 360 scale sheets are referred to thus: *Coonarbine*, and 1: 250 000 scale sheets thus: FROME.

PREVIOUS WORK

Sturt (1849) was the first to make geological observations on the remarkably parallel sand dunes which he thought were fluviatile deposits. Selwyn (1860) passed through the area in 1859 and referred on his geological map to "recent tertiary deposits on the surface". Brown (1884) made the first geological survey in 1883 of the desert east of Lake Frome, and observed Quaternary conglomerates and clays along the Pasmore River on CURNAMONA. A few years later the Engineer in-Chiefs' Department drilled artesian bores to tap the Great Artesian Basin waters.

The first geological map was published by Woolnough & David (1926). Jack (1930) published cross-sections and defined a number of groundwater basins in the Lake Frome area and described stratigraphy, rock types and basement topography. Kenny (1934) produced a summary of early work and geology in the West Darling district of New South Wales which included a portion of the Frome Embayment.

Osborne (1945) first used the term "Frome Embayment", defined as a synclinal basin bounded by the Flinders and Barrier Ranges. Evans (1946, Evans & Reeves 1948) located ferruginous Tertiary sandstone and Pleistocene outcrops, which he regarded as of Proterozoic age.

Brown (1950, 1953) recorded Cretaceous microfossils. Ludbrook (in Ker 1966) refined Brown's Cretaceous stratigraphy, and recorded probable Middle Cambrian and Eocene strata. Wopfner (1970) prepared isopach and facies maps of the Cambrian.

The geology and previous work of the Mount Painter block was discussed by Coats (Coats & Blissett 1971) and the portion of this area appearing on FROME was previously published on the Mount Painter Special geological map (Coats *et. al.* 1969). Ker (1966) completed a hydrological survey of the Frome Embayment and prepared a structure contour map of the top of the Palaeozoic strata.

These explanatory notes have been compiled from recent studies on the Frome Embayment and Tarkarooloo Basin by Callen (1974a, 1975, 1976a, 1977) and Callen & Tedford (1976). Other studies relevant to the stratigraphy were made by Firman (1970b).

Geophysical surveys in the Frome Embayment date from a reconnaissance gravity and magnetic survey undertaken on behalf of the Frome-Broken Hill Company Ltd (Kaufman & MacPhail, 1948). This was followed with further magnetic and gravity surveys by Geophysical Services International for Delhi Australian Petroleum Ltd and Santos Ltd (Harding & Geyer, 1963) and by reconnaissance gravity surveys for Delhi-Santos Ltd, conducted by Wongola Geophysical Pty Ltd, during 1964-65. Additional gravity work was completed in 1966 and 1970 (United Geophysical Corporation).

The earliest seismic survey was made by Geoseismic (Aust.) Ltd for Santos Ltd (Dennison, 1960), with more extensive investigations undertaken later by the South Australian Department of Mines (from 1962), United Geophysical Corporation (for Delhi Australian Petroleum Ltd, 1966), and United Geophysical Corporation (for Crusader Oil N.L., 1970 and 1970b).

A summary of much of the above geophysical data is presented in Figure 5, which was compiled from a plan drawn for Crusader Oil N.L. (United Geophysical Corporation, 1970b). The magnetic plan (Fig. 4) is derived from the Frome 1: 250 000 aeromagnetic sheet, an airborne survey by Adastra Hunting Geophysics under contract to the Bureau of Mineral Resources Geology and Geophysics and the South Australian Department of Mines.

Regional interpretations of geophysical data covering the Frome Embayment and adjoining areas have been compiled by Milsom (1965), Westhoff (1968), Parker (1973), and Tucker & Brown (1973).

The potential of the Cretaceous strata for oil and gas in the Great Artesian Basin has been discussed in reports by Wade (1915), Ward (1944) and Osborne (1945). Evans (1946) was the first to suggest that Cambrian rocks of the Frome Embayment might have an oil potential, while Wopfner (1966) and Freeman (1966) assessed the potential of Cambrian and Ordovician strata.

Exploratory drilling for oil in the Frome Embayment began in 1945 with the drilling of Cootabarlow 1, 2 and 3, and Lakeside 1 and Black Oak 1 bores, (the latter on CURNAMONA) by Zinc Corporation Ltd, Enterprise Exploration Ltd and Frome Broken Hill Co. Ltd. This was followed in 1968 by exploration of the Cambrian sediments, when three stratigraphic wells were completed south of Lake Frome on CURNAMONA (Delhi Australia Petroleum Ltd, 1968). Later stratigraphic drilling by the South Australian Department of Mines included the drilling on Frome of Yalkalpo 1 and 2, Mudguard 1, Wertaloona 1, Bumbarlow 1 and Wooltana 1 bores (Callen, 1972; Youngs, 1977, 1978a,b).

Uranium exploration began in 1969 by Kerr McGee Pty Ltd (Ryan 1969), and has continued since.

The South Australian Department of Mines drilled three stratigraphic bores to assist this exploration (Callen 1972, 1976a, 1975). Work has concentrated on the Tarkarooloo Basin Tertiary sediments. A list of open file reports of companies engaged in exploration is appended.

PHYSIOGRAPHY

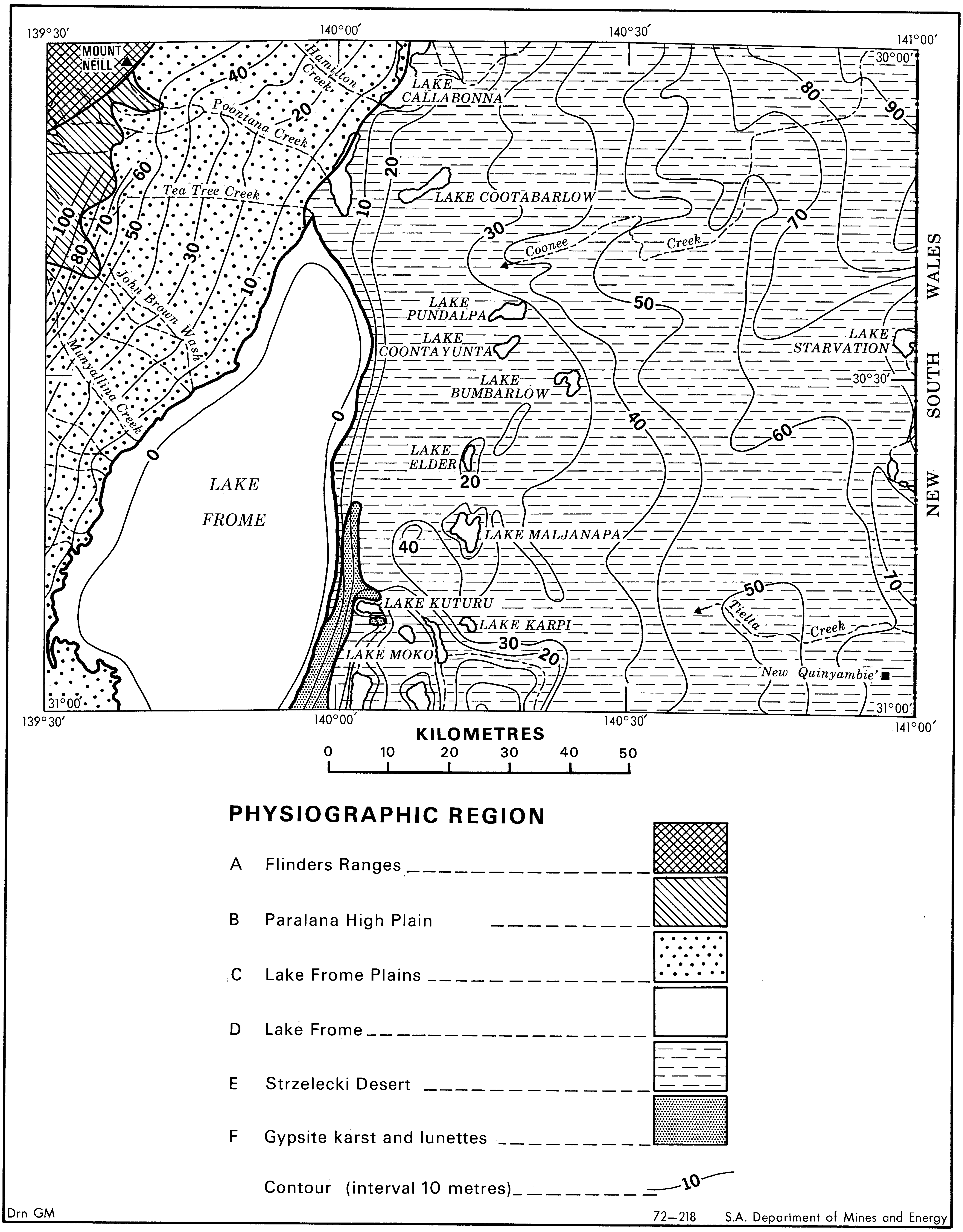
Dominant physiographic regions and topographic contours are shown in Fig. 2.

The Flinders Ranges (region A) in the northwestern corner of the sheet rise abruptly from the Lake Frome Plains (region C) to about 610 m above sea level.

Region B (The Paralana High Plain) rises gently from 100 m above sea level along its faulted eastern edge, to 155 m near the ranges. This plain was uplifted as a unit along with the Flinders Ranges, and originally formed a part of the Lake Frome Plains. The geomorphology is discussed by Twidale (1967).

The Lake Frome Plains (region C) are a complex of coalescing low angle fans, rising from 0.5 m above sea level at the edge of Lake Frome to 70 m near the ranges. They are virtually featureless, apart from occasional creeks with eucalypts, and low gravel ridges. A small area of scattered dunes is developed on *Paralana* and *Caldina* and sparse scrub clothes the area.

Lake Frome (region D) is a playa, probably with some tectonic control. Mound springs are distributed along a straight line near its eastern shore (Draper & Jensen 1976). Islands of stabilised gypsum dunes, belonging to region F, occur in the southern part of the lake. Elevation of the lake bed varies from 0.5 m above to 3.0 m below sea level. Pleistocene shoreline deposits occur sporadically along its western and southern edges. Streams, with watersheds in the Flinders Ranges, contribute detritus to fans along the western shore, where beaches, false spits and bars are developed.



139°30′
140°00′
140°30′
141°00′
30°00′
30°30′
31°00′
MOUNT NEILL
Hamilton Creek
Poontana Creek
Tea Tree Creek
John Brown Wash
Munyallina Creek
LAKE CALLABONNA
LAKE COOTABARLOW
Coonee Creek
LAKE PUNDALPA
LAKE COONTAYUNTA
LAKE BUMBARLOW
LAKE ELDER
LAKE MALJANAPA
LAKE KUTURU
LAKE KARPI
LAKE MOKO
LAKE STARVATION
LAKE FROME
Tielta Creek
'New Quinyambie'
NEW SOUTH WALES
0
10
20
30
40
50
60
70
80
90
100
KILOMETRES
0 10 20 30 40 50
PHYSIOGRAPHIC REGION
A Flinders Ranges
B Paralana High Plain
C Lake Frome Plains
D Lake Frome
E Strzelecki Desert
F Gypsite karst and lunettes
Contour (interval 10 metres)
Drn GM
72—218
S.A. Department of Mines and Energy

TABLE 1. PRECAMBRIAN AND PALAEOZOIC ROCK UNITS

Unit	Symbol	Description	Stratigraphic Relationship	Fossils	Thickness (m)	Topographic Expression	comments
COVER OF CURNAMONA CRATONIC NUCLEUS							
Unnamed Cambrian sediments	?Є	Probably Lake Frome Group - reddish brown slate, siltstone, blue grey rubbly limestone (WIRREALPA LIMESTONE) may include Lower Cambrian.		Trilobite		Subsurface, southern Frome Embayment area	Fluviatile and shallow marine
Undifferentiated Cambrian and Proterozoic	Є - P	Grey limestone, white quartzite, grey slate				Subsurface Frome Embayment area	
ADELAIDE GEOSYNCLINE & MT. PAINTER INLIER							
Bolla Bollana Formation	Pyb	Massive blue green pebbly greywacke, minor siltstone and quartzite.	Intertongues with Fitton Formation.			Moderate relief	Glacigene
Fitton Formation	Pyf	Tilloid and calc-silicate metasediments quartzites, boulder beds, pebbly arkose.	Unconformably overlies Burra Group.		2000	Low relief	Glaciomarine?
UNCONFORMITY							
Unnamed Dykes		Amphibolite (metamorphosed basaltic rocks)	Intrusive				Basic intrusive
Wywyana Formation	Pcy	Actinolitic marbles, minor amphibolite, calcsilicate hornfels and siltstones.	Tectonic contacts			Valleys	Breccia Diapiric?
UNCONFORMITY							
Terrapinna Granite	pЄt	Rapakivi - like granite, minor adamellite, augen gneiss.	Intrusive			Low hills	Acid intrusives all related.
Mount Neill Granite Porphyry	pЄn	Massive red-weathering porphyritic granite or granite porphyry. Phenocrysts dominant over matrix.	Intrusive			Rounded hills	
Unnamed Granite	pЄ2	Massive white weathering dark grey microgranite.	Intrusive				
Wattleowie Granite	pЄw	Weakly gneissic white granite and adamellite	Intrusive				
Freeling Heights Quartzite (Lower Member)	pЄf	Medium to coarse sericitic feldspathic quartzite, quartzose schist, quartz pebble conglomerate at base.	'conformable' contact Brindana Schist		600	Rugged hills, some strike ridges and valleys.	Cross bedding common, rare ripple marks.
Brindana Schist	pЄr	Quartzose schist, biotite and muscovite schists, minor garnet sericite schist, epidote quartzite, hornfels, amphibolite. garnet rock.			950+	Forms small ridge	
Pepegoona Porphyry	pЄp	Recrystallized porphyritic rhyolite(?).	Contacts may be tectonic		1 300	Low foot hills	Lava flow or near surface intrusive
Mount Adams Quartzite	pЄa	Medium grained feldspathic quartzite, minor grit.	Stratigraphic relationships uncertain.		310+	Rugged hills.	
Yagdlin Phyllite	pЄg	Laminated grey-green phyllite, lenticular quartzite, (sedimentary lamination).			400		

Note : Plan amended April 1976

FIG.3

DEPARTMENT OF MINES — SOUTH AUSTRALIA			
MOUNT PAINTER BLOCK AND LAKE FROME EMBAYMENT PRECAMBRIAN AND PALAEOZOIC			
	R.A.Callen GEOLOGIST	Drn. R.A.C.	SCALE: —
		Tcd. A.F.	74-773
		Ckd.	
Director of Mines		Exd.	DATE: SEPT. 1974

Region F has a unique undulating topography formed of old Pleistocene gypsum lunettes up to 30 m high. It has a gypsum "karst" structure of more recent origin, and lacks vegetation.

There is a prevalence of steep western shores on the lakes and claypans, whereas the eastern shores are shallow and flanked by lunettes.

STRATIGRAPHY

PRECAMBRIAN Table 1

The stratigraphy of the Precambrian is summarised in Table 1 and is derived from Coats and Blissett (1971), the basement geology on FROME being adapted from the Mount Painter Special geological sheet (Coats *et. al.* 1969). A list of unpublished University theses is given by Blight (1977), and geochronology is discussed by Webb et. al (1978).

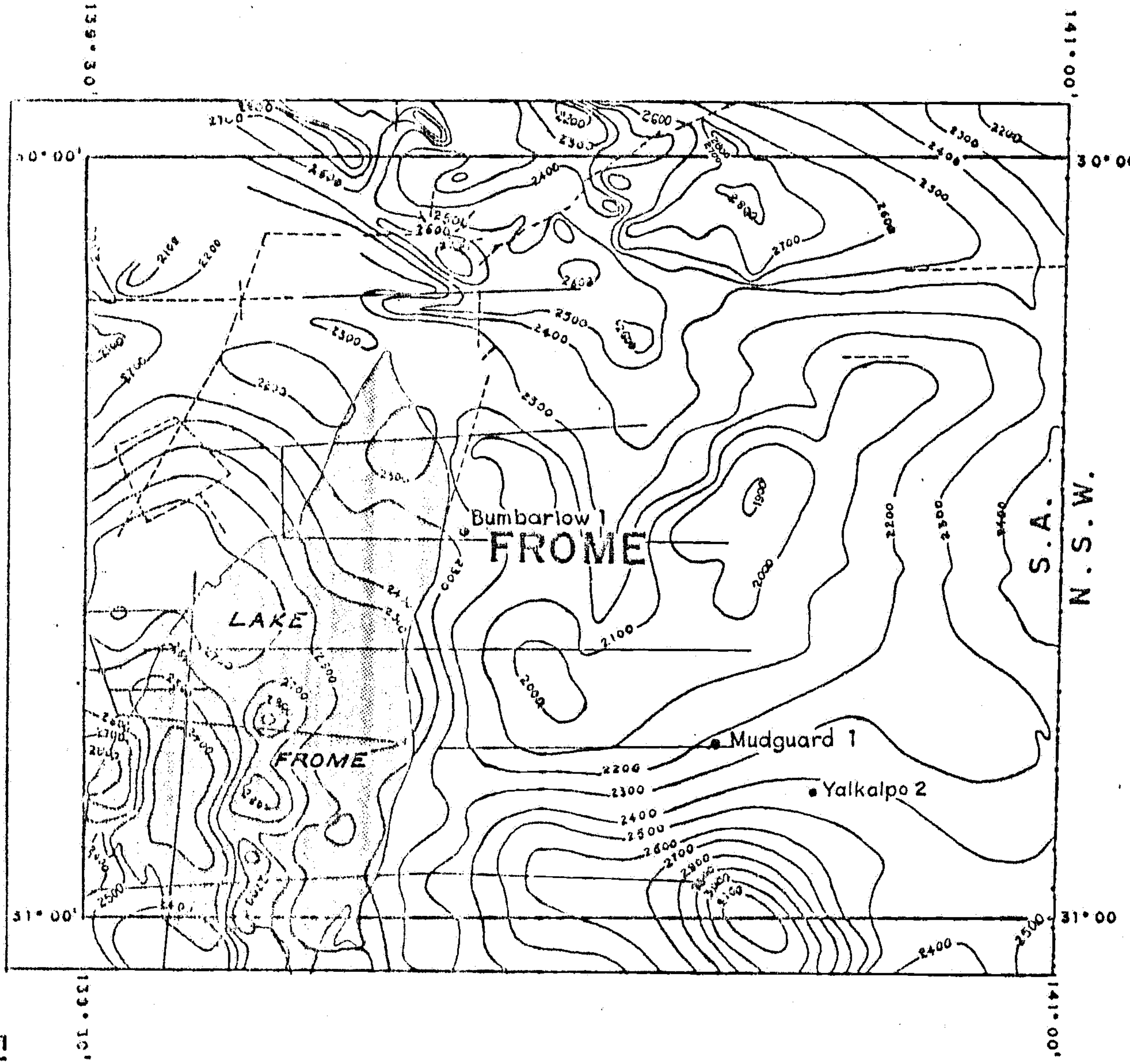
Within the Terrapinna and Wattleowie Granites, overprints have been used on FROME to differentiate bands which are considered by Coats to represent metasediments. Young (1973) discusses these rocks ("microgranites") and the contacts of the Pepagoona Porphyry.

A few small outcrops of the "Younger Granite Suite", included in the area of brecciated Wywyana Formation, are not differentiated on FROME.

In the subsurface, little information is available. Crystalline basement rocks of the Curnamona Cratonic Nucleus (Thomson 1974, Thomson *et. al.* 1976) probably occupy most of the map area and are most likely continuous with the Mount Painter Block (see also Sprigg's "Paralania" , Sprigg *et al*, 1958). An extensive porphyry body occupies at least the southern part of the Benagerie Ridge on FROME and is best represented in Mudgard 1 bore (Youngs 1977). The porphyry is not reflected by features in the magnetic or gravity maps (Figs. 3, 4) but is represented by

TOTAL MAGNETIC INTENSITY

(From FROME 1:250000 aeromagnetic map and selected seismic lines).



Magnetic intensity at 100γ intervals.. 2200

CRUSADER OIL N.L. ......

S.A. Dept. Mines ....

S.A. Dept. of Mines and Energy bores drilled since publication of the map. . . . .

Scale in Kilometres

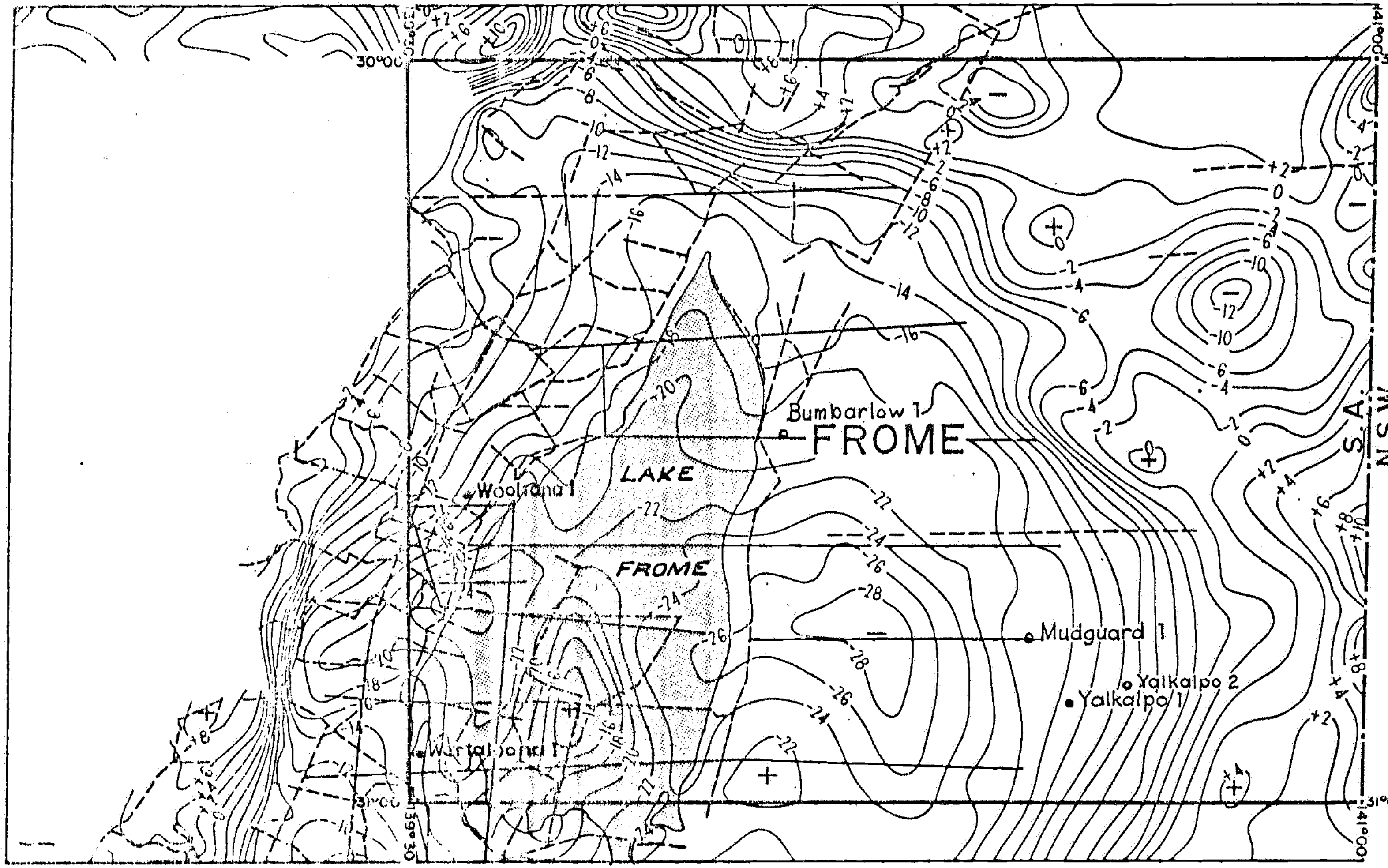
10 0 10 20 30 40

FIG.3

FIG.3
S12011

R.A. CALLEN — Geologist

S.A. DEPT. of MINES



BOUGUER GRAVITY AND SEISMIC LINES

(Compiled from plan drawn by United Geophysical Corporation for Crusader Oil N.L., open file envelope 1275(v) Dept. of Mines and Energy.)

Bouguer gravity contour (interval 2 milligals) .... -6-

Crusader Oil N.L. .... ———

S.A. Dept. of Mines .... – – – –

S.A. Dept. of Mines and Energy bores

Drilled prior to publication of map ..... •

Drilled since publication of map ..... ○

SCALE IN KILOMETRES

10 0 10 20 30 40 50

R. A. Callen — Geologist

FIG. 4

S 12010

S.A. Dept. of Mines

a characteristic lack of reflections in seismic profiles. Thomson (1966, p. 216) noted similarities to the Gawler Range Volcanics (Blissett 1975), but ages are younger (1160-1500 Ma) and similar to basaltic volcanics in Bumbarlow 1 bore (Youngs 1978b).

Depths to magnetic basement, interpreted as crystalline basement by Tucker and Brown (1973), permit a thin Adelaidean sequence of 500-600 m over the southwestern portion of FROME. Bumbarlow 1 bore intersected 300 m of Precambrian basaltic lava flows, interbedded with red and green shale, sandstone and conglomerate. Clasts include metamorphic and volcanic rocks. Below this 18 m of grey laminated shales. Youngs (1978b) suspects the contact with the shales is unconformable.

Unmetamorphosed purple cross-bedded coarse sandstones, cut by thin quartz veins, are located on the New South Wales border fence at latitude 31°40' (Callen, 1974b). These are probably Adelaidean.

Thus a thin relatively undeformed platform cover of Proterozoic, (?)Adelaidean rocks exists on FROME.

PALAEOZOIC (Table 1).

There is no exposure of Palaeozoic rocks, records being limited to two stratigraphic bores, Yalkalpo 1 (Callen 1972) and 2, (Youngs 1977, 1978a,b), east of the Benagerie Ridge. Yalkalpo 1 bore intersected a few metres of Lower Cambrian (personal communication, B. Daily, University of Adelaide, 1975) grey limestone above the Precambrian porphyry, whereas Yalkalpo 2 bore, intersected 540 m of Lower and Middle Cambrian red-beds and blue-grey limestone, without reaching basement. The absence of Cambrian in Bumbarlow 1 bore suggests the Arrowie Basin (Wopfner 1970a,b) is probably restricted by the Benagerie Ridge to the west of Lake Frome. The Cambrian sequence east of the Benagerie Ridge can probably be regarded as a separate basin.

TABLE 2 LAKE FROME AREA - MESOZOIC ROCK UNITS

	ROCK UNIT	SYMBOL	LITHOLOGY	FOSSILS	THICKNESS (METRES)	COMMENTS
CRETACEOUS	MARREE SUB-GROUP (MARREE FORMATION) (OODNADATTA FORMATION AND BULLDOG SHALE equivalent)	K1m	Monotonous sequence of dull greenish grey micaceous shale and siltstone, intraformational breccia, minor pebble beds.	Burrows, leaf impressions & carbonaceous material. Spores. Foraminafera	150-275	Often pyritic or ferruginous. Present in most deep bores, outcropping in small areas along Flinders Ranges. Sand beds may be Attraction Hill Sandstone in part. Could include some Winton Formation at top (non-marine). The Oodnadatta & Bulldog shale are lithologically indistinguishable on present evidence.
CRETACEOUS / JURASSIC	?CADNA-OWIE FORMATION, formerly (Pelican Well Formation)	K1c	Sandstone, micaceous, medium grained and subangular; interbedded with dull greenish-grey micaceous shale and silty shale; pebble and boulder beds common, some limestones.	Leaf and stem detritus, spores.	52 max.	Identified in Cootabarlow No. 2, Coonee Ck., Arbcola, Lakeside No. 1, Black Oak, and Curraworra Bores and Yalkalpo No. 1. Basal part Jurassic and partly equivalent to the Algebuckina Sandstone.
JURASSIC	UNNAMED CONGLOMERATE	K11	Marine boulder bed of granitic rock types, rhyolite porphyry and grey slate. Low percentage grey slate matrix.		2·4 min.	Probably Jurassic, derived from Benagerie Ridge. Porphyry locally derived.

DEPARTMENT OF MINES—SOUTH AUSTRALIA

COMPILED: R. A Callen
DRN:
CKD.

LAKE FROME AREA
MESOZOIC ROCK UNITS

SCALE. (Chart)
DATE: 5TH APRIL 1976
PLAN NUMBER: S12170

Delhi-Santos Lake Frome 1, 2 and 3 bores were drilled on CURNAMONA along the southern edge of Lake Frome. They intersected 780 m of Middle Cambrian strata, and by comparison with exposed sections on PARACHILNA, almost penetrated the base of this sequence. Other bores on CURNAMONA also intersected Cambrian rocks (see open file envelopes listed in the appendix, for the western part of the sheet area). These thick Cambrian sections west of the Benagerie Ridge on CURNAMONA presumably extend onto FROME. The "base of Mesozoic" on the tectonic sketch, was determined from seismic data, and does not fully accord with more recent private company drilling west of Lake Frome.

A gravity low in the southeastern portion of FROME suggests some low density sediments, possibly Cambrian, are present. Wopfner (1966), showed that Ordovician strata might underlie the eastern margin of FROME. Later Palaeozoic sediments are unknown.

MESOZOIC (Table 2).

Terminology for the Mesozoic of the Frome Embayment was first introduced by Forbes (1966). The following information is from subsurface data, there being no outcrop.

The oldest Mesozoic unit on FROME is the unnamed ?Jurassic conglomerate in Yalkalpo 1 bore, resting on the Lower Cambrian ?Parara Limestone. This has a very small proportion of grey silty shale matrix, identical to the overlying Cadna-owie Formation equivalent. Clasts are porphyry, granite and various metamorphic rocks derived from the Benagerie Ridge (Section A-A'on map).

The Cadna-owie Formation (Wopfner 1969, Wopfner *et. al.* 1970, now used in preference to Pelican Well Formation in the Frome Embayment), is gradational with the Marree Formation. However, in Yalkalpo 1 bore it can be identified using the petrophysical logs.

The Cadna-owie Formation on FROME is shale, sand, and silt with lenses of coarse clasts ranging in size from pebbles to large boulders. Sandy beds are common, especially near the base. Clasts include white quartzite and sandstone, reddish brown porphyry, and fine siliceous shale. Some of these may have been reworked from Permian sediments, which have mostly been stripped. The work of R. Morgan (personal communication 1974, Geological Survey of New South Wales) indicated the basal Cadna-owie Formation was deposited during the Late Jurassic.

The Marree Formation (Bumbarlow 1, Cootabarlow 1 bores) constitutes a monotonous sequence of dull greenish grey to bluish-grey finely micaceous shale and siltstone, laminated beds, intraformational breccia and minor polymictic conglomerate. Much plant leaf and stem material and numerous invertebrate burrows or traces are present. Bivalves, foraminifera and microflora are common. No weathering horizon is developed on the Cretaceous in subsurface. Morgan deduced from palynological evidence that the upper part of the Marree Formation had been eroded in Yalkalpo 1 bore. Unlike some other areas (e.g. Oodnadatta region) the Marree Formation in the Frome Embayment cannot be subdivided at present.

The Cretaceous Winton Formation has not been positively identified on FROME. Ludbrook (in Ker, 1966) shows the Cenomanian is absent from the sequence south of Tilcha Bore on CALLABONNA. However, thin Winton Formation may occur in the extreme north of the sheet area (Muloowurtina and Poontana bores). A brownish sandy sequence in Cootabarlow 1 bore and sandy beds at the top of Poontana bore may represent the unit, but have not been distinguished as such on the bore logs or sections.

Spores and microplankton have been studied by Dettman (1963), Dettman & Playford (1969, especially pages 182-192, tables 9.1,

TABLE 5 LAKE FROME AREA - CAINOZOIC - TERTIARY

AGE	ROCK UNIT	SYMBOL	LITHOLOGY	SEDIMENTARY STRUCTURES	CRITERIA FOR CORRELATION	FOSSILS	GEOMETRY	GEOMORPHIC EXPRESSION	SECONDARY WEATHERING EFFECTS
Uncertain LATE MIOCENE-PLIOCENE possibly to EARLY PLEISTOCENE. From relationship to NAMBA FORMATION	WILLAWORTINA FORMATION	Czw	Extremely to very poorly sorted bouldery to pebbly silt clay or sand clay with numerous greenish carbonate nodules enveloping matrix and skeleton grains in southern areas. Lenses and sheets of pale greenish white dolomite, with scattered pebbles, bouldery dolomite near ranges. Lenses of pebbles to large boulders common near Flinders Ranges, sand beds further east. 2.5-7YR5-8/1-8, 5-7Y6-8/1-8.	Crude wavy and lenticular horizontal lamination. Well defined medium scale cross-beds. Beds 0.5 - 1 m thick. Fining upwards cycles in lower part.	Greenish clays with very poorly sorted sand to boulder content, usually matrix supported framework. Greenish silty carbonates. Red brown mottling common.	Rare vertebrates	Wedge shaped mass, thinning east, between Lake Frome and Flinders Ranges, and to south. (0-150m)	Forms basic landscape of uplifted "high plain" flanking Flinders Ranges, where it supports growth of Eucalyptus gillii. Crops out as vertical or overhanging cliffs along creeks. Cliffs along Pasmore River and south shore of Lake Frome.	Well developed massive white hard carbonate developed in long cylindroids or horizontal sheets, pisolitic structures. Hard buff groundwater calcrete cements porous sediment. Massive crusts of gypsum rosettes. Red-green mottling, green colour increasing with depth, black patch stain on fractures.
		CZsi	Brown silcrete and iron oxide cement		Colour, petrology		Thin sheets	Capping on sands of Tmb and Tee	
Medial MIOCENE (BATESFORDIAN-BALCOMBIAN) from plant spores and pollen, to ? Late Miocene.	NAMBA FORMATION	Tmb	Alternating fine to medium poorly sorted sands, silt and clay, thin dolomite and limy dolomite beds, often oolitic. Sands generally angular, of high sphericity, but may also be polished and subrounded with low sphericity. Clays may be black (ferrous ion) and tough with characteristic irregular shiny-surfaced fractures, (unit Tmb_2) or pale green or grey. Sands and clays may be carbonaceous. Dolomites often have nodular structure, and are penetrated by branching pores lined with manganese. Rare charales limestone. 1-10Y2-9/0.25-6, N0-N9, 10YR2-7/1-2, rarely 5B5-7/1, 5-10R3-3.5/3-4, 5GY4-7/0.5-1 and 5G6/1.	Horizontal lamination common, especially in silt and very fine sand. Very small to medium scale cross-bedding common in silts and sands. Irregular oolitns in carbonates, often rod shaped. Intraformational brecciation, quick flow structures common. Bioturbation common. Rare shrinkage (?subaqueous) cracks and slumps. Cyclic deposition in unit Tmb_1.	Pale grey green clays and fine silts and sands, dolomites, tough black clay with irregular fractures. Fish spines in lower beds. Vertebrates - lung fish teeth.	Ostracoda (Cyprididis), Charales oogonia and stem moulds, Potamopyrgus s.l., Aves, Cetacea, Dipnoi, Teleosti, Chelonia, Crocodilia, Monotremata, Marsupialia. Plant spores - Nothofagus, Dacrydium, Podocarpus, Eucalyptus, GRAMINEAE, RESTIONACEAE, CUPANIEAE, Pediastrum	Thin widespread blanket and shallow basins (20-250 m)	Sloping cliffs, often capped by dolomite, gypcrete or secondary carbonate cemented younger units, along edges of dry lakes and creeks, east and south-east of Lake Frome. Less commonly as dipping sequences upfaulted along western margin of Flinders Ranges. Mainly subsurface.	Sometimes capped by ferruginous yellow-brown orthoquartzite silcrete. (CZsi) Alunite soil-like horizons associated with uppermost black clay. Massive gypsum crust. Reddish mottling (weakly developed). Also capped by puddingstone opaline and chalcedonic silcrete.
PALEOCENE AND EOCENE from plant spores + pollen	EYRE FORMATION	Tee	Moderate to poorly sorted sands, grain size ranging from fine to small pebbles, often polished, subrounded and of low sphericity. Polish greater for larger sizes. Characteristic basal pebble beds with milky, clear or smoky quartz, grey quartzite, black chert, red jasper, agate, may be very micaceous. Brown to grey colour common from presence of carbonaceous matter. Dark brown to black carbonaceous clay, silty, soft. EOCENE beds tend to be silty and carbonaceous, PALEOCENE coarser grained. 5YR2/1, 10YR6/2, N1-N8, 4Y6/0.45, 5B8/1, 5BG-7/2.	Medium scale and small scale trough cross-stratification and planar cross-stratification. Lamination. Tool marks. Fining upwards sequences.	Polished basal pebble bed. Essentially sands, often carbonaceous, black clays are soft and silty with much carbonaceous matter.	Spores pollen, dinoflagellates, arthropods (rare), leaf, stem and fruit moulds. Plants include fragments carbonized wood. Podocarpus, Dacrydium, Nothofagus, PROTEACEAE, CASUARINACEAE, GRAMINEAE, RESTIONACEAE, CUPANIEAE, MALVACEAE, SANTALACEAE, MYRTACEAE, HALORAGIS	Thin widespread blankets (10-75m)	Silicified outcrop upfaulted on margins of basin. Isolated outcrop on state border. Usually moderately to steeply dipping.	Often ferruginized and capped by massive microcrystalline quartz silcrete with botryoidal or columnar structure. (Tsi & CZsi) Frequently silicifies the sediment itself.

After H. Wopfner et. al. (1974), Callen & Tedford (in press)

FIG. 7

Note: Plan amended April 1976

DEPARTMENT OF MINES — SOUTH AUSTRALIA

LAKE FROME AREA — CAINOZOIC TERTIARY

	R.A. Callen GEOLOGIST	Drn. R.A.C.	SCALE: —
		Tcd. A.F	74-769
		Ckd.	
Director of Mines		Exd.	DATE: SEPT. 1974

9.3, 9.4), Cookson & Eisenack (1958) and Eisenack & Cookson (1960), Evans (1966). Cootabarlow 2 bore is the reference section for the *Crybelosporites stylosus* zone of Dettman.

(N.B. On the bore log for LC1A (in northwestern part of map area), the thickness for the Cretaceous (K) should read 120 m. The basal conglomerate and lower part of the Cadna-owie Formation are Jurassic not Cretaceous as shown in the map legend).

CAINOZOIC

Several new names have been used for rock units in the eastern side of the Flinders Ranges, north of the Olary Block. These units are defined elsewhere (Wopfner *et. al.* 1974, Callen & Tedford 1976). Suggested equivalents are given in Table 5.

Tertiary (Table 3 and section D-D' on map).

The new name TARKAROOLOO BASIN is given to the Cainozoic sediments deposited in the Lake Frome area. The northern limits of the basin are at present undefined. These continental deposits form a thinner and more extensive cover than the Frome Embayment Mesozoic sequence. Sedimentation was initiated by a different series of tectonic events than for the Mesozoic rocks and the locus of deposition is nearer the Flinders Ranges. There are considerable differences in the tectonic history of the Palaeogene strata here compared with those of the Neogene.

Palaeocene-Eocene

Deposition during these epochs is represented by the EYRE FORMATION (Wopfner *et. al.* 1974, formerly Murnpeowie Formation of Forbes 1966), recognised over a wide area of the Great Artesian Basin, and well-developed in the Lake Frome area. Supplementary reference sections for the Eyre Formation in the Tarkarooloo Basin are Mines Administration LC1A bore on *Paralana* (FROME) and the Reedy Springs section on MARREE (Wopfner *et. al.*

1974). Yalkalpo 1 bore is a third important section, representative of the reduced sequence on the Benagerie Ridge.

The lithology of the Eyre Formation is consistent over the whole FROME 1: 250 000 sheet, with fine to very coarse-grained (medium dominating) sub-mature to mature sands, moderately to poorly sorted and frequently bimodal. The sands are often pyritic and carbonaceous, becoming micaceous, kaolinitic and angular towards the Olary Ranges. Quartz grains are subrounded and original crystal faces often visible. Matrix is usually dominated by kaolinite, with accessory montmorillonite and illite. A characteristic pebble bed is present at the base, with black chert (both fibrous chalcedony and micro-crystalline quartz), fossil wood, red 'jasper', and quartz of milky, grey, yellow or no colour. The grains are characterised by high polish. Lenses of black carbonaceous silt occur.

The Eyre Formation reaches its maximum thickness in the Poontana Sub-basin, thinning over the "high" in the eastern part of the sheet. The base of the Tertiary was contoured for the tectonic sketch using sparse bore data. A structure contour map using a selection of extensive company drilling is included in plan 76/6.

In the Lake Frome area there is excellent biostratigraphic control (Harris *in* Wopfner *et. al.* 1974), discussed in detail for the Mooloowatana-Reedy Springs area by Callen (1975, Fig. 15). A disconformity may occur within the unit, the late Palaeocene being unrepresented. The Eocene is typically finer grained and of a characteristic dark brown colour, with leaf remains, in contrast to the coarse sandy Palaeocene deposits with black carbonaceous matter.

Conglomerate which crops out on the New South Wales border may be the only exposure on FROME *(Thurlooka)*. It represents basal Eyre Formation.

In subsurface, the contact with the Cretaceous strata is well defined: coarse polished quartz sand with chert pebbles overlies dull green grey silty shale of the Marree Formation. The upper contact may be difficult to identify because sands may occur in the overlying Namba Formation (Callen & Tedford 1976 a,c, Callen 1976a) as in Yalkalpo 1 bore. In general, the first sands encountered below the black clays or carbonate horizons of the Namba Formation are those of the Eyre Formation. Eyre Formation sands are usually coarser grained, more highly polished, with higher roundness and lower sphericity than those of the Namba Formation.

Both the lower and upper contacts show regional disconformable relationships. Channelling is poorly developed or absent at the lower contact on FROME (see Wopfner *et. al.* 1974), though channel sands of the Namba Formation may cut into the Eyre Formation.

Deposition of the Eyre Formation ceased during the Upper Eocene, leaving a widespread sand blanket.

Oligocene - Early Pliocene

Silcrete and bleaching of ?Oligocene age, occur to a limited degree on dipping sequences around the margins of the Tarkarooloo Basin, although they do not occur on FROME itself. Incipient silicification and some silcrete ?pebbles are present in Yalkalpo 1 bore.

The Namba Formation (Callen & Tedford 1976) was deposited essentially during the Early to Medial Miocene although it may extend into the Late Miocene. The name is derived from Lake

Namba (new name*) on CURNAMONA. The type section is in Yalkalpo 1 bore on *Quinyambie*, and an important supplementary section is located at Wooltana 1 bore on *Arkaroola*. The outcrop supplementary section is in a cliff on the central western shore of Lake Tarkarooloo* (CURNAMONA). The unit is the time equivalent of the Etadunna Formation (Stirton *et. al.* 1961), as shown by similarity in certain characteristic fossil-vertebrates, and comparable microflora (Harris 1972).

A Medial Miocene age (?Balcombian-Batesfordian) was determined palynologically (Harris, personal communications 1972, 1973), the flora being comparable with that of the Munno Para Clay Member (Lindsay & Shepherd 1966, Lindsay 1969) of the St. Vincent Basin. The Miocene microflora was found in Cootabarlow 2, Wooltana 1, LC1A, F22/26, and Glenmore 1 (on BROKEN HILL, see Brunker 1967) bores, and in Lake Eyre 20 bore in the Lake Eyre Basin. The Lake Eyre bore microflora is very similar to that of Wooltana 1 bore. Correlation with foraminiferal zones of the Murray Basin and southern Victoria has been obtained through Tricentrol Aust. Ltd bore near Mutooroo, OLARY (Lindsay & Harris 1973). Vertebrate fossils of considerable evolutionary and palaeogeographical significance are described by Tedford *et. al.* (1977). Although the possible age range of the Namba Formation is Late Oligocene to Late Miocene the unit was probably deposited in a relatively short time interval in the Early to Medial Miocene.

The Namba Formation is divided into two units on the map, though in Wooltana 1 bore it may be divided into six (Callen & Tedford 1976) using geophysical and litholog-data. The regional two-fold subdivision is based on the occurrence of dark grey, tough clays with a characteristic irregular shiny fracture

*Names formalised by the Geographical Names Board, South Australia, 1973. Detailed list in Callen (1974b).

pattern in the lower unit (Tmb_2). This unit is dominated by clays rich in smectite, and typified by rather poorly defined cyclic deposition involving black clay, cross-bedded sand, finely laminated silt and thin carbonates. The upper unit (Tmb_1), also containing carbonates, is dominated by fine laminated silt and cross-bedded fine sand with prominent bioturbation. Muds are dominated by illite and are light green grey or olive. The numbering for the two members (Tmb_1, Tmb_2) has been revised to the correct sequence in Callen & Tedford (1976), Tmb_1 being the older member and Tmb_2 the younger.

The carbonates (dolomite) alternate regularly with clays, and are rich in palygorskite at the base of each major carbonate horizon. Clay mineralogy was determined by Brown (see list of Brown's work in Callen 1975, Appendix 2), and is discussed in Callen & Tedford (1976) and Callen, (1977).

A distinctive carbonaceous laminated dark green to black fissile claystone is restricted to the Poontana Sub-basin (Wooltana 1 bore Central Pacific Minerals Pty Ltd bores see Schindlmayr 1970). It contains gastropods (M. Buonaiuto pers. comm. 1978), fish remains, ostracods and microflora.

The sediments reach their maximum thickness in the Poontana Sub-basin, and appear to retain the same thickness up to the marginal fault system of the Flinders Ranges. There is little information on the Tertiary close to the ranges, west of the Poontana structure. Holes drilled for Exoil and Western Nuclear (Aust.) Ltd suggest unit Tmb_1 is missing (cross-section A-A') in the outer rim of the Paralana High Plains (region B, Fig. 2).

The outcrop of FROME is mainly of unit Tmb_2, black clay or silicified sands. Most outcrop occurs on *Eurinilla* and

Siccus on the northern edge of CURNAMONA, where unit Tmb_1 is also present and a sharp undulating contact with Tmb_2 can be locally observed.

An alunite horizon, developed in the upper part of unit Tmb_2 is widespread in the western high plains on COPLEY and east of Lake Frome at Lakes Starvation and Bumbarlow. Its structure suggests it is related to a weathering horizon or soil profile, thus indicating an hiatus.

Late Tertiary to Early Quaternary

Late Miocene - Early Pleistocene.

There is a ferruginous horizon resembling the Karoonda Surface (Firman 1971) developed on the Namba Formation. This is included with unit CzSi on the map, and is probably equivalent to the ferruginous and silicified paleosol complex of ?Pliocene age recognised by Firman (pers. comm. 1979).

Upon the Namba Formation clays is developed a siliceous horizon, consisting of microcrystalline quartz, with numerous cavities of pedogenic origin infilled by opal and chalcedony. On sandstones of the same unit this is represented by quartz overgrowths on the detrital grains or microcrystalline quartz cement, producing massive "grey billy". This silicification came after ferruginisation, hence the silcrete duricrust generally has a red and white mottled appearance. Its frequent association with alunite suggests it is older than or equivalent to the Willawortina Formation.

The Willawortina Formation constitutes a wedge shaped deposit, thickest near the Flinders Ranges on COPLEY, of poorly sorted conglomerates, nodular to massive carbonates, and red and green mottled clays, interpreted as flood plain and stream deposits. On FROME it is restricted to the Poontana Sub-basin. Its type section is WC2 bore on the Paralan High Plains with an outcrop supplementary section, south of "Wertaloona" on *Balcanoona* (COPLEY). Another supplementary section is Wooltana 1 bore. The Willawortina Formation intertongues with the upper member of the Namba Formation (Tmb_1). The base of the unit is well defined by petrophysical logs in the southern portion of the basin, but in the northern area, where secondary carbonate cementation is absent, it is less distinctive. The boundary with the older Tertiary sequence has been mapped by Leeson (1967, see also Coats *et. al.* 1973) on *Balcanoona* (COPLEY). A thick sequence of conglomerate and clay of the Willawortina Formation overlies clastics of the Namba Formation with no apparent evidence for an unconformity in the Beverley area (Paralana High Plain).

The Willawortina Formation was referred to the Avondale Clay (Firman 1967) on the adjoining COPLEY sheet.

In the area flanking the northwestern shore of Lake Frome, drilling has intersected hard red-brown calcareous and green-grey clays (Schindlmayr, 1970). These are probably fine grained equivalents of the Willawortina Formation which grade into the Namba Formation unit Tmb_1.

The Millyera Beds (Qp_6) comprise laminated light green to bluish green clay with thin fine sand beds and thin charophyte-stem limestone and gypsum laminae. They are locally disconformable on the Namba Formation. Abundant ostracods, charophytes, gastropods, bivalves (M. Buonaiuto, personal communication, 1978), and worm burrows are present. The Beds were named after Lake Millyera on *Siccus* (CURNAMONA), where they are best exposed. When unweathered they are finely laminated and contain abundant ostracods, and lenses of sand, rich in charophyte oogonia. The clays have a characteristic sub-conchoidal fracture, distinguishing them from the Miocene sequence, and often have a distinctive finely laminated charophyte limestone or gypsum bed at the top.

In Lake Callabonna, clays similar to those of the Millyera Beds contain vertebrate remains of Plio-Pleistocene age: these are the "*Diprotodon*-bearing beds" of Tedford (1973).

Unit 'Qp_5' crops out in two widely separated areas: along the northeastern shore of Lake Millyera and on the northern shores at the junction of Lake Frome with Lake Callabonna. Unit Qp_5 invariably occurs directly overlying the green clays of the Millyera Beds, and its type area is on the southeastern shore of Lake Millyera. Lithologically it is fine to coarse fossiliferous sand. Fine cross-bedding and wavy horizontal bedding is typical, and abundant charophyte stem fragments and oogonia occur. Bright reddish orange gypsum-impregnated silt lenses are present, closely resembling the Eurinilla Formation (described below).

The Millyera Formation of Callen & Tedford (1976) constitutes the Millyera Beds (Qp_6) and unit Qp_5 combined, though recent work suggests the original practise of separating them is probably correct, and a disconformity may exist between.

The next youngest unit is the unnamed conglomerate Qp_7, consisting of extensive sheets of planar cross-bedded conglomerate and sand, exposed along the southern shore of Lake Frome and the Pasmore River. The unit is solidly cemented with secondary white or buff carbonate. It contains boulders and pebbles derived from the Olary and southern Flinders Ranges, with a local admixture of carbonate nodules derived from the Willawortina Formation. The Willawortina Formation contains numerous similar lenses of conglomerate, also cemented, which may be difficult to distinguish from unit Qp_7 in isolated outcrops. The unnamed conglomerate may be equivalent to unit Qp_5, by comparison with a similar sequence in Lake Tarkarooloo on CURNAMONA, which grades into unit Qp_5 northwards along the outcrops on the lake floor.

TABLE 5

CAINOZOIC UNITS OF FROME AND POSSIBLE EQUIVALENTS

TIME UNIT	TARKAROOLOO BASIN AFTER CALLEN & TEDFORD (1977): SYMBOL	TARKAROOLOO BASIN AFTER CALLEN & TEDFORD (1977): NAME	EQUIVALENTS IN OTHER BASINS AND ADJACENT MAP SHEETS: FIRMAN 1971 'FROME EMBAYMENT' AREA	COATS et. al., (1973) COPLEY	STIRTON et. al., 1961 LAKE EYRE
HOLOCENE (RECENT)	Qra		Qra	Qra	
	Qrl	Unnamed lake deposits	Qrl	Qrl	
	Qrs	SIMPSON SAND	SIMPSON SAND	Qrs	
	Qrb	Unnamed clays & sands	TINGANA CLAY CALLABONNA CLAY	ARROWIE FORMATION / Qrl	
LATE PLEISTOCENE TO HOLOCENE	Qcc1	Unnamed soils	LOVEDAY SOIL	ARROWIE FORMATION	
	Qp1	COONARBINE FORMATION + Older Holocene fan deposits	POORAKA FORMATION	POORAKA FORMATION	
	Qp2	Unnamed gypsum lunettes			
MEDIAL TO LATE PLEISTOCENE	Qcc2	Unnamed soil	LOVEDAY SOIL		
	Qp3	Unnamed beach deposits			
	Qc5	Gypsum in Eurinilla Formation	Qcs	Qcs	
	Qp4	EURINILLA FORMATION	POORAKA FORMATION + TELFORD GRAVEL	POORAKA FORMATION	KATIPIRI SAND & TIRARI FORMATION
	Qca	Unnamed calcrete	BAKARA SOIL + (RIPON CALCRETE) Includes groundwater calcrete in basal Eurinilla Formation.	Qca Includes groundwater calcrete	
	Op6 + Qp5	MILLYERA FORMATION (MILLYERA BEOS + unit Qp5)			MAMPUWORDU SAND
	Qp7	Unnamed Conglomerate (Equiv. MILLYERA FORMATION)	TELFORD GRAVEL	TELFORD GRAVEL	
LATE MIOCENE TO EARLY PLEISTOCENE	CZw	WILLAWORTINA FORMATION	AVONDALE CLAY & "Conglomerate at Lyndhurst"	BUNGUNNIA LIMESTONE Equiv., AVONDALE CLAY, "T-Q"	
	CZsi	Ferruginous horizon & Silcrete (Relationship to Willawortina Formation, uncertain)	Ferruginous horizon of the KAROONDA SOIL	Not recognised	
MEDIAL TO LATE MIOCENE	Tmb	NAMBA FORMATION	AVONDALE CLAY	BUNGUNNIA LIMESTONE AVONDALE CLAY	WIPAJIRI FORMATION ETADUNNA FORMATION
OLIGOCENE ?	Tsi	Not represented	Tsi	Tsi	
EARLY PALEOCENE TO LATE EOCENE	Tee	EYRE FORMATION	EYRE FORMATION	EYRE FORMATION	

Mound Spring Deposits (Qra to Qp4) ?

COMPILED : R.A. Callen	DEPARTMENT OF MINES—SOUTH AUSTRALIA	SCALE: —
DRN : A.R. CKD.	LAKE FROME AREA — CAINOZOIC CORRELATION CHART	DATE:
		PLAN NUMBER: S12169

TABLE 4

ROCK UNIT	MAP SYMBOL	LITHOLOGY	SEDIMENTARY STRUCTURES	CRITERIA FOR CORRELATION	FOSSILS	AGE	GEOMETRY	GEOMORPHIC EXPRESSION	SOIL DEVELOPMENT
STREAM DEPOSITS	Qra	Pebbles, sand, minor clay of modern stream bed. Silt and clay of low angle fans along western shore of Lake Frome, lower part may include fans of Coonarbine Formation age.	Fine to medium scale cross-bedding, ripple marks, horizontal lamination, imbricated pebbles, etc. in streams.			Recent	Linear (stream channels) - Thin wedge (fans) (0-4m)	Bedload of streams, low-angle fans along west shore of Lake Frome.	
LAKE DEPOSITS	Qrl	Sand, silt, clay, salt. Black to green and brown	Unbedded or laminated, salt shows pressure ridges and blister structure.	Essentially continuous with Qrb clays.		Sub-Recent	Thin spread (A few cms)	Windblown sand in lake bed, salt crust, silts and clays of mound springs.	?
UNNAMED SANDS	Qrs	Fine to medium sands. Bright red brown.	Aeolian cross-bedding - very large scale.	Unconsolidated, red-brown colour. Youngest unit in landscape.	Rare - Insect carapaces, seeds. Charales oogonia.	Sub-Recent	Thin Linear (0-6m)	Modern windrift dunes of Strzelecki Desert.	?
SANDS	Qrb	Fine brown quartz sand. Blue green, brown and black structureless semi-liquid clay.	Sub horizontal bedding in sands.		Ostracods Charophytes (some reworked)	RECENT	Bench-Linear (0-4m)	Forms low benches around islands in Lake Frome and along eastern shore. False spits and bars of west shore may be equivalent.	?
DISCONFORMITY									
COONARBINE FORMATION — CALCAREOUS PALEOSOL	Qcc_1	Cylindroids and patches of soft white carbonate, sometimes oriented in horizontal and vertical tubules or cylindroids. Usually poorly developed.		Generally less well developed than Qcc_2		PLEISTOCENE -RECENT? From Radiocarbon Dating	Bench-linear	Caps benches	Probably the Bca horizon of a fossil soil
COONARBINE FORMATION	Qp_1	Sand to silty or clayey sand, poorly to moderately sorted, usually fine-grained, with subangular to subrounded grains. 2.5-10YR3-8/4-6	Weak horizontal lamination, lenses, large scale cross-bedding (rarely well-defined)	Weakly developed bedding, moderate sorting, light brown colour, absence of gypcrete and large carbonate nodules. Locally abundant land snails. Typical soil horizon at top.	Snail shells, emu shell, aboriginal artifacts. Charales oogonia (rare). Rare vertebrate Burrows.	PLEISTOCENE -RECENT ?	Thin blanket (0-2m)	Flat low-lying plains, dominates landscape of planes and seif dunes. Crops out in creeks as vertical faces with columnar jointing.	Weakly developed carbonate cylindroids, weathering as hard granules. Discontinuous. Rectangular blocky structure forming columns of sediment.
COONARBINE FORMATION	Qp_2	Gypsum sand, coarse to very coarse, interbedded clay pellet layers. Lime biscuits and shell in basal layers.	Large scale cross bed sets. Complex fine scale cross-lamination.	Gypsum sand, moderate angle cross-stratification.	Charales oogonia Rare gastropods		Wedge shaped (0-5m)	Cliffs along southeastern shore of Lake Frome and islands in the lake.	Powdery gypsum crust with columnar jointing, which may persist into EURINILLA FORMATION. Qcc_1
DISCONFORMITY									
CALCAREOUS PALEOSOL	Qcc_2	Soft white carbonate cylindroids tubules blotches and lumps in several layers, weather out as hard granules or crusts.				Pleistocene? From Radiocarbon Dating	Soil horizon		Probably the Bca horizon of a fossil soil.
UNNAMED GRAVEL	Qp_3	Cobble and pebble deposits.	Imbricated flat pebbles in some localities.	Level (10-15m) same as Qp_5	Shells for QP_5	Radiocarbon Dating & Relation to Qp_5	Linear Strandlines (0.5-2m)	Ridges parallel to western shore of Lake Frome	Weak carbonate cementation Qcc_1
GYPCRETE	Qcs	Gypsum crusts, of rosettes of disc-shaped crystals. Developed in various layers according to porosity. Includes calcareous cement in basal Eurinilla Formation.				Associated with lower part of EURINILLA FORMATION	Discontinuous tabular masses	Often forms massive cap, causing underlying strata to form in cliffs.	Groundwater origin - part same origin as younger Qca unit, with which it is associated in same horizon.
EURINILLA FORMATION	Qp_4	Clay-sand to sand, with interbeds of silt and clay in upper part, lower part sand, often with pebbles. Very poorly sorted, grains may be moderately rounded, but rough and pitted, or rounded, and frosted. Upper part 2.5-5YR4-9/4-7 Sandy lower part 7-10YR5-7.5/2-6 Clays 5Y7/1-2.	None or crude horizontal stratification well-developed horizontal lamination (2-10 cm). Sometimes developed into large scale low angle sets. Basal sands trough or planar cross-bedded on medium scale. Rarely lower part horizontal wavy laminae with load casts.	Poor sorting, fine upper part, coarse lower part. Upper part lacks bedding or more rarely has well-defined sub-horizontal cross-stratification, lower part cross-bedded. Upper part reddish-brown, lower yellowish brown. Typical soil horizons, ground water calcrete and gypcrete (in basal part).	Insect burrows and nests. Vertebrates in basal channels, including Diprotodon, Procoptodon sp. Basal layer of gastropods and lamellibranchs (Coxiella, etc) near edge L. Frome Numerous charales oogonia, especially in coarse sand.	UPPER PLEISTOCENE (Macropus)	Thin tabular widespread sand sheets, fills hollows (0-20m)	Flat low-lying plains, cropping out as low slopes around depression and watercourses. Lower part often cemented by gypcrete or calcrete, producing bench or massive cap to cliff. Frequently basal channels approximate present clay drainage.	Several well developed horizons of carbonate and gypsum cylindroids may be present at top, soft large nodules in some areas. Frequently weather out as granules or sheets on surface. Lower sand cemented with crystalline white calcrete, weakly to strongly. Also with massive or layered gypsum rosettes. Mottled in shades of red-brown and white. Qcc_2, Qcs, Qca?
FOSSILIFEROUS SAND (NOW MILLYERA FORMATION WITH UNIT CZm)	Qp_5	Pale greenish fine sands with wavy green clay laminae and coarse sand lenses. Thin basal lenses of bright orange brown sand. White sands at base of Eurinilla Formation. Cappel by chara oogonia and shell hash limestone.	Small to medium scale cross-bedding. Clasts of clay.	Foraminifera, fish bones, greenish sand.	Charales stem moulds, oogonia, fish vertebrae and spines, Coxiella. Foraminifera	PLIOCENE or PLEISTOCENE, or on boundary (from relationships to other units)	Thin discontinuous sand sheets Bench & Beach	Forms white benches near base of cliff profiles.	Affected by carbonate mottles patches in northern areas. Qcc_2, Qcc_1
CALCRETE	Qca	White to pale brown secondary carbonate cement developed in coarse grained beds, also greenish carbonate with large cylindroids and tubules of carbonate. Black manganese staining in sands of topographic lows.		May include two calcretes Black stain may be related to older bed, not younger calcrete, younger calcrete equivalent to gypcrete.		Developed on Millyera Beds and Willawortina Formation	sometimes effects Namba Formation	Bold outcrop, causes cemented units to stand out as prominent benches.	Groundwater calcrete,
UNDIFFERENTIATED CONGLOMERATE	Qp_6	Undifferentiated conglomerate, grading to coarse sand. Intertongues with greenish brown silty clay in some areas.	Planar cross-bedding, trough cross-bedding, crude lenticular bedding.	Constitutes several different units - conglomerates of Willawortina Formation, unnamed conglomerate Qp7, and conglomerate associated with Eurinilla Formation (Telford Gravel equivalent)		Conglomerate associated with EURINILLA FORMATION is PLEISTOCENE	Discontinuous linear (1-5m)	Bold outcrop capping cliffs, or as ridges projecting above Lake Frome Plains.	Massive hard or soft, white, calcrete; cements coarser layers. Qca
DISCONFORMITY									
MILLYERA BEDS * (NOW MILLYERA FORMATION, WITH UNIT Qp5)	CZm	Pale green laminated clay, conchoidal fracture with thin Charales limestone (5Y9/1) laminae at top, interbedded with fine well-sorted sand (2Y7/4, 5Y7/2). Bedding absent in clay in Lake Frome. Limestone may grade to thin ripple-marked gypsum beds. Sand grains angular. Reddish to white fine sand with basal pebble beds and interbedded hard thin Charales limestone beds. Coarse loose white to greenish sands, subrounded grains. Algal limestone of mound springs Clay: 10YR5/2, 5Y5/6, 5Y8-9/1-4, Fine sand: white to 2-5Y7/2-4. Channel sand: 5-10Y6-8/2, 5-10YR5-8/4-7.	Fine horizontal lamination in clays and limestone, asymmetric small scale ripples in gypsum, oriented Charales tubules, botryoidal blister structure on gypsum. Trough cross-bedded channel sands.	Charales tubule limestone, greenish ostracod-bearing clay, fine sand with Charales oogonia.	Charales stem moulds and oogonia. Spiral gastropods (Coxiella sp.), worm burrows (spiral, along bedding planes), silicified wood (pebbles, and tree-trunks): Coniferales. Ostracods Vertebrates in mound springs.	Uncertain: LATE MIOCENE -EARLY PLEISTOCENE (From position relative to other units).	Shallow basin, discontinuous linear deposits. (5 m+)	In bed of Lake Frome and cropping out around edge; occupying old deeply eroded stream channels, now represented by linear lakes associated with Billeroo - Eurinilla Creek System. Mound spring limestone.	Massive white groundwater calcrete in sands, bright orange stain in basal coarse sands. Qca
DISCONFORMITY									
UNNAMED CONGLOMERATE	Qp_7	Massive calcareous conglomerate, calcareous sandstone. Basal cross-bedded light grey sand. Pinkish brown sand grains.	Planar cross-bedding, crude lenticular bedding.	Reworked carbonate nodules from Willawortina Formation. Interbedded yellowish brown clayey sand with greenish carbonate nodules.		Pliocene to late Pleistocene (From relationship to other units)	Discontinuous linear. (1-10 m)	Bold outcrop capping cliff tops, particularly along Sicus - Pasmore River system and southwestern shores of Lake Frome.	Massive white groundwater calcrete, often vughy and crystalline - cements coarser beds. Qca

Note: Plan amended April 1976

FIG.8

DEPARTMENT OF MINES — SOUTH AUSTRALIA

LAKE FROME AREA – CAINOZOIC QUATERNARY

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	Ckd.		
Director of Mines	Exd.	DATE: SEPT '74	

Unit Qp_7 is possibly equivalent to the Telford Gravel of Firman (1963).

Upon these units is developed the calcrete horizon Qca, a white to pinkish massive carbonate which cements unit Qp_5 or sands of the Namba and Willawortina Formations. Iron and manganese oxide crusts, forming pipe-like structures and spherical bodies or sheets, are associated. The material is best developed east of Lake Frome.

Quaternary (Table 4, and large scale section D-D' on map).

The works of Williams (1971), Wasson (1979) and Callen & Tedford (1970) are useful for an understanding of the Quaternary discussed here.

Pleistocene

The Eurinilla Formation (Qp_4, Callen & Tedford 1976) has its type section at Lake Moko on *Coonarbine* (CURNAMONA) with supplementary sections at Lakes Millyera and Koorka. It is of late Pleistocene age, and contains basal channel sands with *Diprotodon sp., Procoptodon goliah,* and other species similar to those of the "Callabonna fauna". It is regarded as at least partly equivalent to the Tirari Formation (Stirton *et. al.* 1961).

The formation consists of fine to medium clayey poorly sorted sands, of orange brown colour, impregnated with gypsum at the base, and with interbedded green clays and silty clays. The upper portion often lacks sedimentary structures, or is horizontally laminated, whereas the lower portion is trough cross-bedded.

Excellent exposures are visible in extensive cliffs along the south side of Yandama Creek near its junction with Lake Callabonna, where the unit is overlain by the Coonarbine Formation. These are not shown on the map, having been discovered since its publication.

The unit has a strongly disconformable contact with the underlying units. East of Lake Frome it is generally cut into the Namba Formation or Millyera Formation and, west and south of the Lake, into the Willawortina Formation or unit Qp_7.

On FROME, undifferentiated gravels on the Lake Frome Plains which are included in unit Qp_6 occupy ridges in the landscape, though they are older than the surrounding sands (Qp_1, etc.). The reverse topography results from differential compaction and erosion. Most of the gravels may belong to the Qp_7 channel deposits, or unit Qp_4.

Old beach ridges (Qp_3), developed along the northwestern shore of Lake Frome, consist of gravel deposits and rare patches of material resembling unit Qp_5. The deposits are overlapped by the Coonarbine Formation sands. Recent evidence suggests the older (upper) ridges correlate with the unit Qp_5.

The next youngest unit is gypcrete (Qcs, map section D-D'), which forms massive to nodular crystalline sheets of wedge-shaped crystals or fibrous gypsum; it is present in the basal Eurinilla Formation or older units and is related to old land surfaces. Gypcrete frequently forms hard caps, permitting the development of finely patterned indented marginal cliffs along lake and watercourse edges which is readily distinguished from silcrete and usually also from calcrete.

Unit Qcc_2 a calcareous paleosol horizon, is typically developed on the Eurinilla Formation as widely developed horizons of soft white carbonate tubules and lumps, hard when weathered. Orange, brown and black ochreous mottling is associated. The unit appears as white patches on aerial photographs, difficult to distinguish from gypcrete.

Pleistocene - Holocene

The Coonarbine Formation (Qp_1, Callen & Tedford 1976) sediments are moderately sorted sands, forming a thin widespread blanket east of Lake Frome. Cross bedding is present in some sections. Several mottled white carbonate paleosol horizons (Qcc_1) are present, weaker in development than the paleosol on the Eurinilla Formation (Qcc_2). The uppermost of these paleosols is frequently absent. A characteristic large scale rectangular jointing or pedality products a columnar weathering pattern. Locally, characteristic shells of the land snail *Thersites* (Buonaiuto *op. cit.*) are present. Radiocarbon dating of the paleosols demonstrates an age range from *c.* 30,000 to 7,000 yrs B.P., so that the unit extends back into the Pleistocene. Each paleosol is developed on an aeolian phase, the youngest of these ing longitudinal dunes, which comprise the indurated cores of the Strzelecki Desert dunes. Loose sandy crests comprise the modern dunes (Qrs). Excellent outcrops, discovered since publication of the map, are present in the gully cut by overflow of Cootabarlow 3 bore.

Along the eastern shore of Lake Frome, and on its islands, are extensive gypsum/clay pellet lunettes (Qp_2, see Bowler 1977). These discomformably overlie the Eurinilla Formation. Their extent is now known to be greater than recognised at the time of mapping - much of the material shown as Qp_4 around Lake Maljanappa is unit Qp_2, and the lunettes along the edge of Lake Frome extend further north. Further east, each lake is flanked by a sandy leeside mound on its eastern margin, much of which is material of the same age as the gypsum lunettes. These have not been distinguished on FROME.

As mapped, the Coonarbine Formation includes some younger material of similar aspect, but without calcareous paleosol development. The paleosols may be absent in the upper unit of the Coonarbine Formation, and hence are indistinguishable from these deposits at the scale of mapping (lithology is otherwise identical).

West of Lake Frome are extensive fluviatile sediments of very low angle fans and sheet deposits, which overlie the Eurinilla Formation. As they contain *Thersites* and have a similar appearance and weathering pattern to the Coonarbine Formation, they are included in this unit. They generally crop out as blocky 'breakaways' along creek edges. Calcareous soil is usually absent. Further work is needed to demonstrate their relationship to such units as the Mundi Mundi Unit of Wasson (1979).

On COPLEY and OLARY the units mapped as Pooraka Formation are essentially Coonarbine Formation. The Pooraka Formation as shown on adjacent maps constitutes the Coonarbine Formation and Eurinilla Formation combined.

The Coonarbine Formation has not been distinguished from unit Qrs east of Lake Frome (Thus the largest area shown as Qp_1 on the map is the alluvial material discussed above, and which recent evidence suggests should probably not be regarded as part of the Coonarbine Formation.

The Arrowie Formation (Coats 1973) on the Paralana High Plain constitutes brown sand with reworked cobbles, occasionally merging into thick cobble deposits derived from weathered Willa-wortina Formation, in which are land snails similar to those of the Coonarbine Formation. Some Eurinilla Formation is included, and also at least two phases of younger fans.

The Holocene dunefield (Qrs) of the Strzelecki Desert and part of the Lake Frome Plains consists of red brown loose sands and longitudinal dunes (Qrs, Simpson Sand of Firman 1970b in part). These have been largely reworked from the Coonarbine Formation dunes and Eurinilla Formation, and are partly active today. They have steep north faces, and are linked to transverse dunes along pan and lake edges. The unit dominates the eastern half of FROME. As mapped, Qrs includes residuals of older Tertiary deposits, exposed in interdune areas, and the Coonarbine Formation. Eurinilla Formation is present along the water-courses.

Holocene beach deposits (Qrb) have been recognised, related to the present shoreline, and suggest a more active lake phase. False spits and bars are developed along the western shore, but are absent on the eastern side. They result from wind action on waters flooding into the lake from the Flinders Ranges. The deposits are probably related to the younger beach sands, and therefore are included in unit Qrb. Semi-liquid blue-green to brown and black clays of Holocene age (Qrl, Draper & Jensen 1976, Bowler 1977) form the uppermost playa sediments. They are distinguished from the Millyera Formation clays by absence of lamination. Low angle fans (Qra) occur along the western margin at creek outlets. A thin crust of salt is developed on the southern part of the lake (dashed line on map, Draper & Jensen 1976).

Since deposition of unit Qp_2, a gypsum karst structure has developed on the larger mounds along the eastern edge of Lake Frome. Modern gypsum/sand lunettes of small size are accumulating along the eastern edge of the present lake shore, and on some of the smaller lake shores.

STRUCTURE

Mt. Painter Inlier

The structural geology of the Mt. Painter Inlier has been described by Coats (Coats & Blissett 1971).

Rocks comprising the Mount Painter Complex form two discrete structural units, the Mount Babbage Block and Mount Painter Block. The Mount Painter Block was deformed prior to the Adelaidean into a series of easterly and northeasterly trending folds. Fold styles reflect competence of the rocks. Adelaidean easterly trending domes and basins during an early Palaeozoic phase of tectonism. Faulting took place along pre-existing lines of weakness. The Mt. Adams Fault complex is a major structure, and is associated with breccia consisting mainly of Wywyana Formation. This and the marginal faults of the ranges were reactivated in late Cainozoic times. Some Mesozoic strata have been overthrust by Precambrian basement near Parabarana on CALLABONNA.

Concealed pre-Mesozoic rocks.

The Benagerie Ridge coincides with a magnetic high, and is continuous with the well-defined structure on CURNAMONA (Jack 1930, Callen 1976a). In the southern part of the sheet, magnetic basement is interpreted at depths of 2-6km (Parker 1973, Tucker & Brown 1973). Tucker suggested that the Palaeozoic and Adelaidean sediments are not magnetic enough to account for the anomalies, which are better explained as intra-basement features. However, Bumbarlow 1 bore intersected red-beds and basalts of possible pre-Adelaidean age. The Mesozoic and lower Cainozoic strata (see cross sections) thin out over the Benagerie Ridge; Bumbarlow 1 and Mudguard 1 and private company uranium exploration drilling on *Eurinilla* (CURNAMONA), show the Middle Cambrian to be absent on top of this ridge.

A small coincident magnetic and gravity high along the eastern side of the Poontana structure in Lake Frome (Figs. 3, 4) is probably an intra-basement feature (pre-Adelaidean).

Seismic work by the South Australian Department of Mines and Crusader Oil N.L. indicates gentle folding in the Middle Cambrian rocks, with an overall westerly dip in the western third of the map area. Crusader's work indicates a narrow horst-like fault structure, encompassing probable Cambrian rocks, called the Poontana Structure (Coats *et. al.* 1969). This feature is not well-defined in the vicinity of Wooltana 1 bore. Topographic features and drilling in the Cainozoic indicate it continues to the north where it forms the edge of the Paralana High Plain. This structure has been more accurately defined since publication of the Mt. Painter Special map, (Coats *et. al.* 1969) where it is shown as a fault or monocline to the west of its location on FROME. A similar narrow horst-like structure also marks the edge of the Balcanoona Highplain (COPLEY - see discussion and Fig. 3, Callen & Tedford 1977).

Frome Embayment and Tarkarooloo Basin

Configuration of the Mesozoic and Cainozoic basins differed. The Cretaceous basin has its axis beneath the eastern portion of Lake Frome (United Geophysical Corp. 1966), but during the Tertiary the locus of thickest accumulation moved westwards, closer to the edge of the present Flinders Ranges, resulting in the formation of the Poontana Sub-basin (unpublished Department of Mines and Energy plan 76/116 is available, showing contours for the base of the Cainozoic). This is illustrated on section A-A' on the map. In the Tarkarooloo Basin, fine grained sediments of the Namba Formation abut the bounding fault of the Flinders Ranges. At "Wertaloona" on COPLEY the Miocene sequence is represented by thin coarser sediments, and in the Munyallina Valley probable equivalents above the silicified Eyre Formation are coarse and feldspathic. This suggests the Flinders Ranges were present at the time, though of reduced height. Fan deposits must have ceased abruptly at the margins of the ranges. Intermontane basins were present, and have largely been stripped, but lacustrine sediments probably did not extend across the ranges. At the time, the ranges were probably thickly mantled with soil.

The Mesozoic and Cainozoic strata are virtually flat lying, though a westerly dip of 1-2^{o} west and south of L. Frome is inferred from drilling results; this is consistent with the dip on the Mesozoic-Palaeozoic unconformity calculated by Horwitz (1958).

The Mesozoic and Cainozoic strata have a fault contact with the Adelaide "Geosyncline" sediments and Mount Painter Inlier igneous and metamorphic rocks lying to the west. The bounding fault system constitutes high angle reverse and possibly thrust faults, and coincides closely with the abrupt eastern margin of the Flinders Ranges.

Other structures

On the New South Wales border, steeply dipping quartz-veined ?Adelaidean (or ?Palaeozoic) rocks are exposed, implying that a basement structure affects the Cainozoic sediments.

Another structure is suggested by the alignment of mound springs along the eastern side of Lake Frome. Some of these may derive water from the Great Australian Basin (Draper & Jensen 1976). Sections AA',BB' illustrate a thickening and deepening of the Tertiary sequence west of this line.

The possible fault indicated at $140^{\circ}33'$, crossing the southern border of the FROME map onto CURNAMONA, is interpreted from a ridge of silcreted Tertiary sediments, which has probably been upfaulted. The structure also corresponds approximately to the edge of a major magnetic feature on CURNAMONA separating a magnetic pattern typical of Willyama Inlier crystalline basement to the west from a linear northerly oriented magnetic low to the east. The latter is possibly the effect of gently folded Cambrian rocks. Extended north, the trend of the magnetic feature and fault passes between Mudguard 1 and Yalkalpo 1 bores. A thick sequence of Cambrian rocks lies to the east, and shallow Precambrian rocks to the west.

Draper & Jensen (1976) have suggested Lake Frome, like Lake Eyre (Johns & Ludbrook 1963, Dulhunty 1978), is tilted to the south.

SEQUENCE OF EVENTS

1. In the Mt. Painter-Mt. Adams area, deposition of a thick sequence (6 100 m on COPLEY) of sediments began at least 2000 MY ago. This has since been metamorphosed to produce the Radium Creek Metamorphics. Widespread occurrence of porphyritic acid volcanics suggests a stable basement block prior to deposition of the Adelaidean System.

2. The sequence was folded, faulted and uplifted.

3. After prolonged erosion, the sediments of the Adelaide 'Geosyncline' were deposited. The Wywyana Formation marble indicates a phase of carbonate deposition, later involved in diapiric intrusions during early Sturtian and later times. The Fitton Formation and Bolla Bollana Formation represent a possible glacial interval. The remainder of the Adelaidean sequence is not represented on FROME.

The major portion of the Lake Frome area probably persisted as a stable cratonic block during deposition of the Adelaidean, as there is evidence for a thin undeformed Adelaidean and Cambrian cover. Here, the Precambrian is represented by shales, red-beds and conglomerates with interbedded basaltic lavas. There were extensive rhyolitic porphyry flows.

Lower Cambrian marine carbonate sedimentation took place, at least flanking the southern part of the Benagerie Ridge. During Middle Cambrian times a sequence of redbeds accumulated, directly related to those of the central Flinders Ranges. These are essentially continental fluviatile and deltaic deposits, with a marine transgression represented by the Wirrealpa Limestone.

4. During Middle Cambrian to Ordovician time the Adelaidean and Cambrian rocks of the mobile belt were folded and intruded by granites along the western margin of the sheet area as a result of the Delamarian Orogony (Thomson, 1969). Further east the basement acted as a stable cratonic nucleus (the Curnamona Cratonic Nucleus), where Delamarian folding is effectively absent.

5. The next depositional event was in Early Jurassic times, when epeirogenic movements initiated formation of the Great Australian Basin of which the Frome Embayment is a part. The Embayment comprises a lobe of sediments open to the main basin to the north. Crystalline basement areas were exposed in the Mount Painter area and along the Benagerie Ridge (Callen 1975).

Wopfner (1969) regarded the Parabarana Sandstone (on CALLABONNA, see Ludbrook, 1965) as representing the beginning of the Lower Cretaceous marine transgression following non marine Jurassic conditions. The Cadna-Owie Formation is thought to represent a nearshore facies, which intertongues with the lower part of the Marree Formation at the basin margins.

6. During the Late Cretaceous there was a major regression.

7. In the Early Palaeocene, renewed uplift initiated erosion of the regressive sediments of the Late Cretaceous. A new phase of non-marine sedimentation took place. A widespread sand blanket, the Eyre Formation, was laid down by braided and, subsequently meandering streams, over much of the Great Australian Basin. The basin had an outlet to the sea, and constant reworking and high rainfall caused the abundant fines eroded from the Cretaceous sediments to be flushed out. High rainfall and humid conditions are indicated by the floral content. Forests grew in the vicinity. Polished pebbles of fossil wood, chert and porphyry

originated from the Mesozoic strata.

The fine, brown, carbonaceous silts of the Eocene represent swampy or lacustrine conditions with meandering streams, indicating decrease in stream gradient as adjacent upland was eroded.

8. Widespread stable conditions then prevailed during the Oligocene, which was essentially a period of nondeposition. Silcrete developed sporadically along the margins of the Flinders and Barrier Ranges as a result of peculiarities in groundwater composition and climate, but is rare on FROME, which is in the centre of the Tarkarooloo basin.

9. In Medial Miocene times the Poontana trough began forming west of Lake Frome, and was the site of deposition of very finely laminated fissile carbonaceous clays of the lowermost Namba Formation, in a probable freshwater lake environment. The vertebrates and microflora indicate permanent water and high rainfall. Warm conditions are suggested from foraminiferal evidence in equivalent marine strata of the Murray Basin. High in the Miocene sequence, vertebrates are present. The taxonomic content implies a large body of permanent water with forested shores, in agreement with the high rainfall suggested from floral evidence.

Abundant smectite in the lower Namba Formation was formed under conditions of restricted leaching, though much was probably also inherited from the Marree Formation. An estuarine environment, or alkaline lake with internal drainage was present, and the palygorskite-dolomite sequence developed during times of seasonal aridity. Intermittent exposure of the lake sediments to weathering is recorded by incipient soil formation.

10. During deposition of the upper Namba Formation (unit Tmb_1), with its illiterich claymineral suite, a marked change in conditions occurred. This resulted from uplift of the Flinders Ranges in Upper Tertiary to Pliocene times, and imposition of a more seasonal, possibly cooler climate. Such uplift was first suggested by Howchin (1913). Binks (1972) records a similar history for the Ediacara area (see also Callen & Tedford 1976 for discussion). The lakes were swamped with detritus, and extensive alluvial fans of the Willawortina Formation formed. Meandering streams dominated the lower part of the fan environment whilst mud flow and streamflood deposits built up near the ranges. These sediments were accommodated by the Poontana Subbasin. There is evidence for uplift, and weathering of high areas upon which alunite developed, before the Willawortina Formation was deposited.

11. In Late Tertiary times, after deposition of the Namba Formation, there was a period of extensive ferruginisation and silicification (CzSi).

12. This was followed by vigorous uplift of the Flinders Ranges, and to lesser degree, the Barrier Ranges and Olary Ranges.

13. Deposition of the Millyera Formation lacustrine, fluviatile and beach deposits followed. In the Pasmore River region, extensive conglomerates (Qp_7) probably represent the ancient river system feeding this lake. The channels roughly coincided with present day rivers. Rainfall must have been higher than at present as the lake was much larger and extended

towards the New South Wales border. Channel deposits were extensive. Evaporation was high toward the end of this phase.

14. Calcrete and mottled ferruginous paleosol developed.

15. The Eurinilla Formation records an essentially fluviatile environment, dominated by meandering streams, closely coincident with present drainage. Lake Frome decreased to something approaching its present size. Large marsupials lived in the vicinity. The higher beach deposits west of Lake Frome were probably formed about this time (?*c.*50,000 years B.P.)

16. A calcareous paleosol then formed over a wide area.

17. In Late Pleistocene to Early Holocene times, a new phase of deposition set in, represented by the Coonarbine Formation, which is essentially aeolian. An extensive system of seif dunes and gypsum lunettes developed, in at least three phases. During the major Quaternary aridity (*c.*25 000 to 18 000 B.P.), lunettes formed in and adjacent to the eastern side of Lake Frome, and smaller lakes to the east. Dry cold westerly winds prevailed. Carbonate paleosol horizons are intercolated between the aeolian phases. Fan deposition occurred west of Lake Frome, but it is not known whether this coincided with dune development; it is most likely to have alternated with or postdated the major aeolian phases, perhaps coiciding with interglacials. Younger beach deposits are now known from the western shore of Lake Frome.

During Late Pleistocene times the Flinders Ranges and flanking High Plains continued to be uplifted, whilst the Olary and Barrier Ranges were comparatively stable. Lacustrine sediments continued to be deposited in Lake Frome.

ECONOMIC GEOLOGY

Metallic Minerals

The mineral resources of the Mount Painter Province have been discussed by Blissett (Coats & Blissett 1971). Potential for copper and uranium mineralisation is considered to exist along the Mount Adams fault system. The Gunsight Prospect lies on this structure at the northern margin of the sheet.

Reserves of 15,900 tonnes of uranium oxide have been proved at the Beverley by Western Nuclear Aust. Ltd. in joint venture with the Transoil-Petromin-Oilmin group. The uranium occurs in medium grained fluviatile sands in the uppermost part of Member 2 of the Namba Formation. The Poontana structure controls sedimentation, and has channelled the uraniferous groundwaters which led to deposition of the uranium. On CURNAMONA, small prospects occur in channels of the Eyre Formation but as yet no uranium has been found in this unit on FROME. Economic aspects of this geology are discussed by Callen (1974a, 1976a), Brunt (1978) and Haynes (1976) and extractive leaching by Lackey (1974).

Heavy minerals with a high percentage of titanium occur in the Eurinilla Formation on the western shore of Lake Frome. Other deposits containing 70% zircon and 2.8% rutile in the heavy fraction were found in surface deposits at Lake Cootabarlow (Stillwell 1949). The sands of the Eyre Formation, particularly on CURNAMONA, contain up to 5% rutile, zircon and other heavy minerals.

Rare manganese "wad" that occurs as massive layers in the Miocene sands is related to groundwater movements in the ?Plio-Pleistocene. Outcrop of this material has been prospected along Tielta Creek.

Non Metallic Minerals & Fossil Fuels

Swelling clays of the palygorskite group (a variety of Fuller's Earth) and degraded ?montmorillonite type occur in association with dolomite, in outcrops around many of the small lakes. Demand for palygorskite for use as industrial absorbants and catalysts is such that exploration has begun on CURNAMONA immediately southeast of Lake Frome (Barnes & Olliver 1978). Thick white kaolinite deposits are associated with sands of the Eyre Formation particularly adjacent to granitic source areas, and have been investigated in the Paralana High Plains on COPLEY.

Extensive impure gypsum is present, usually mixed with clay and sand in aeolian lunettes, and also as thin sheets in Lake Frome. The Namba Formation has some similarities with the Green River Formation, and hence has potential for evaporites, exploration by Comalco Exp. Corp. is proceeding.

Alunite, occurs over a wide area in the upper part of the Namba Formation, but is often impure, being mixed with clays. Outcrop occurs at Lakes Bumbarlow and Starvation, and has been recorded in bores elsewhere.

The Eyre Formation contains large fragments of coalified wood (e.g. Yalkalpo 1 bore) and methane gas has been detected from bores in the eastern side of the lake, but no significant fossil fuels are known. From her studies of the Wirrealpa and Aroona Creek Limestone, Youngs (1978c) has shown the Arrowie Basin has potential for hydrocarbons north and northeast of Lake Frome (Youngs 1978a,b).

Hydrogeology

Several workers have studied the hydrogeology, the most recent being Ker (1966). Underground water supplies are available over most of the area; artesian supplies are provided from the basal Great Australian Basin sediments where these are present.

West of Lake Frome, water of variable quality is obtained from several sources including stream gravels of the Eurinilla and "Coonarbine Formation", unconsolidated sands of the Willawortina Formation channels in the northern part of the area, and blanket Tertiary sands which provide moderate stock quality sub-artesian water.

East of Lake Frome, the Tertiary aquifers provide good supplies (Brown 1950, who misidentified the Eyre Formation aquifer as Cretaceous). The major aquifer, the Cadna-Owie Formation or Algebuckina Sandstone (Interstate Conference on Artesian Water 1929), has not been used west of Lake Frome. Springs situated along the western shore of Lake Frome and the mound springs within the lake are too saline for stock.

Flow from the eastern artesian bores (Boucaut & Beal, 1977) is essentially uncontrolled and local graziers have noted a reduction of 25-50% during the past 40 years.

RAC:GU

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APPENDIX

OPEN FILE COMPANY REPORTS HELD IN THE ENVELOPE SYSTEM,
DEPARTMENT OF MINES AND ENERGY, SOUTH AUSTRALIA

Company	Date	Locality & map sheet, minerals	LEASE	ENV.	Rock strat. units
Afmeco Pty. Ltd.	1972	Lake Frome, SH54-10, 6837-3, U	SML634	2016	C
Afmeco " "	1973	Lake Frome, SH54-10, 6837, 6937, U	EL19	2176	C
Afmeco " "	1973	Beverley Area, SH54-10, 6837-4, U	EL64	2535	C
Oilmin NL., Transoil NL., Petromin NL., & Afmeco Pty. Ltd.	1977	Poontana Sub-basin, SH54-10, SH54-9, 6937-3, 4, 6737-3,4, 6837-2, U.	EL176	2535	T
Anaconda Australia Inc.	1966	Paralana Springs, SH54-9, SH54-10, SH54-6, SH54-5, 6737-1,4, 6837-4, 6838-2, 6738-2,3, Base metals.	SML112	633	B (stream sed.)
Central Pacific Minerals NL., & Magellan Petroleum (N.Y.) Pty. Ltd.	1971	Lake Frome, SH54-10, 6837, 6937, U	SML462	1746	C
Central Pacific Minerals NL., & Magellan Petroleum (N.Y.) Pty. Ltd.	1971	Lake Frome SH54-10, SH54-9, 6937-3,4, 6737-2. U	SML240	1408	C,M
Chevron Exploration Corporation	1972	Quinyambie Prospect, SH54-10, 7036 7037-2,3, U	SML663	2100	T
Chevron Exploration "	1973	Quinyambie Prospect, Sh54-10, 7037-2,3 7036, U	EL40	2257	T
Delhi International Oil Corp., Santos Ltd. & Vamgas N.L.	1970	Frome Downs SH54-5, SH54-6, SH54-9, SH54-10, SH54-14, SH54-14, 6738, 6838, 6938, 7038, 6737, 6735. Petroleum	PEL5/6	1124	M.C. Cam. (Wirrealpa L/S)
Delhi International Oil Corp., Santos Ltd. & Vamgas NL.	1971	Frome Downs, SH54-10, SH54-13, SH54-9 SH54-5, SH54-14, 6735, 6736, 6737, 6738, 6835, 6935. Petroleum.	PEL5/6	1275	M Cam. (Wirrealpa L/S)

Company	Date	Locality & map sheet, minerals	LEASE	ENV.	Rock strat. units
Delhi International Oil Corp., Santos Ltd., Vamgas N.L.	1971	Frome Downs SH54-10, SH54-13, SH54-14, Sh54-6, 6735, 6736, 6835 6935, 6838, 7035. Petroleum	PEL5/6	1566	M,C. Cam. (Wirrealpa L/S)
Delhi Australian Petroleum Ltd. & Santos Ltd.	1963	Lake Frome, SH54-9, SH54-10, SH54-13 SH54-14, 6736-2,3, 6836, 6735, 6835-34, Oil, Gas.	OEL20/21	287	K-Cam.
Delhi Australian Petroleum Ltd. Santos Ltd.	1963	Lake Frome, SH54-13, SH54-9, SH54-14 SH54-10, SH54-6, 6635, 6735, 6736, 6737-1, 6835, 6836. Petroleum.	OEL20/21	305	
Delhi Australian Petroleum Ltd. & Santos Ltd.	1963	SH54-13, SH54-9, SH54-10, SH54-6, SH54-14, 6735, 6736, 6837, 6937, 6836, 6737-2. Petroleum.	OEL20/21	306	
Delhi Australian Petroleum Ltd. & Santos Ltd.	1963	Lake Frome, SH54-13, SH54-9, SH54-5 SH54-14, SH54-10, 6735, 6736, 6737 6738, 6835, 6837, Petroleum.	OEL20/21	335	
Delhi Australian Petroleum Ltd. & Santos Ltd.	1965	Strzelecki Desert. SH54-10, SH54-13 SH54-14, SH54-2, SH54-10, SH54-9, SH54-1. Petroleum.	OEL20/21	569	
Delhi Australian Petroleum Ltd. & Santos Ltd.	1965	Frome Embayment, SH54-10, SH54-13 SH54-14, SH54-1, SH54-2, SH54-5, SH54-5, SH54-10, Petroleum.	OEL20/21	510	
Delhi Australian Petroleum Ltd. & Santos Ltd.	1966	Eromanga, Cooper Basin, SH54-13 SH54-14, SH54-9, SH54-10, SH54-6, SH54-5, SH54-1, SH54-2, SH54-15, SH54-10, 6735, 6835, 6736, 6836, 6739, 6740, Oil, gas.	OEL20/21	556	P
Kerr McGee Australia Ltd.	1969	Mt. Painter area, SH54-10, SH54-6, 6837-1,4 6838-2,4, U.	SML218	986	C

Company	Date	Locality & map sheet, minerals	SML	ENV.	Rock strat. units
Mines Administration Pty. Ltd.	1970	Lake Callabona. SH54-6, SH54-10, 6837, U	SML431	1440	T
Mines Administration " "	1971	Lake Frome, SH54-10, SH54-14, 6835, 6836, U.	SML531	1622	C,M.
Mines Administration " "	1972	Lake Callabonna, SH54-10, SH54-6, 6837-1, 6838-1,2, 6937-4, 6938-3, U.	SML596	1800	T
North Flinders Mines N.L.	1970, 1971	Coup Prospect, Arkaroola, Wooltana SH54-10, 6837-2,3, Cu, Zn	SML294	1226	B(Blue Mine Conglo-merate, Wywyana F., Ulupa Siltstone, Wooltama Volcanics, Opaninda F., Human-ity Seat F., Wortup Quartzite, Skilloga ee Dolomite)
North Flinders Mines N.L.	1969	Willigan Hill, Parabarana, Mt. Adams, Mt. Fitton, SH54-9, Sh54-10, SH54-5 SH54-6, 6737-1, 6837-4, 6738-2, 6838-3, Cu, U	SML291	1224	B
North Flinders Mines N.L.	1969, 1970, 1971	O'Donoghues Castle, Wooltana, Mcleashes Mine, SH54-10, SH54-6, 6837-2,3. 6838-3 Cu, Pb, Zn.	SML294	1226	B (Woodnamoka phyll ite, Callanna Beds) (stream sediment & soil samples) Adel-aidean (Burra Group Blue Mine Conglomer ate, Skillogalee Dolomite).
North Flinders Mines N.L.	1971	Pinnacles, Mine, Yudnamutana Mine,	SML558	1369	Adelaidean, B.
North Flinders Mines N.L.	1970, 1971	Mt. Adams SH54-10, SH54-6, 6837-4, 6838-3. Parabarana, U, Cu, Pb, Zn.	SML296	1220	B (soil sampling)
North Flinders Mines N.L.	1971	Freeling Heights, SH54-9, SH54-10, 6737-1, 6837-4, base metals	SML558	1639	B (stream sed.)
North Flinders Mines N.L	1971	Moolawatana, SH54-5, SH54-6, SH54-9, SH54-10, 6738, 6838, 6737, 6837, Cu, Zn, Pb.	SML444	1442	B (stream sed.)

Company	Date	Locality & map sheet, minerals	~~SML/EL~~ LEASE	ENV.	Rock strat. units
North Flinders Mines Ltd.	1971 1972	Pinnacles Mine, Yudnamutana Mine, SH54-5, SH54-6, SH54-9, SH54-10 6738-1,2, 6838-3,4, 6737-1, 6837-4 Metalliferous Minerals, Cu, U.	SML558	1369	Adelaidean, B. (stream sediment an soil samples) Fitto F., Carpentarian, Terrapinna Granite.
North Flinders Mines Ltd.	1972	Mt. Painter Province, Gunsight, Carthew, Brindana Mine, Pinnacles Mine, Mt. Neil, SH54-10, SH54-6, 6837-4, 6838-3. Cu, U.	SML558	1369	B (Rock chip sampl-ing)
North Flinders Mines Ltd.	1972, 1973, 1974	Gunsight, Mt. Neil, Mt. Babbage, Mt. Painter Province, Carthew, Mt. Adams, Pinnacles, SH54-6, SH54-9. SH54-10, 6737-1,4, 6838-3, 6837-4. Base metals and U, Cu, Zn, Pb, Fe.	SML704, 588	2034	B (stream sed., etc
Billy Springs Pty. Ltd.	1968	Mt. Adams, SH54-10, 6837-4, base metals	SML194	1038	B
Oilmin N.L., Transoil N.L. & Petromin N.L.	1979	Lake Yalkalpo, SH54-10, 6936-2. U.	EL386	3315	C
Delhi Australian Petroleum Ltd. & Santos Ltd.	1959	Frome Embayment, SH54-6m SH54-10 Oil, Gas.	OEL20/21	69	M
Delhi Australian Petroleum Ltd. & Santos Ltd.	1960	Frome Embayment SH54-10, 7037 Oil, Gas.	OEL20/21	65	J
Sedimentary Uranium N.L.	1972	Lake Frome, SH54-10, 6936, U.	SML630	1827	T?
Southern Ventures Pty. Ltd.	1974	Lake Carnanto, SH54-10, 7036-2,3. U.	EL105	2377	C
Southern Ventures " "	1974	Lake Yalkalpo SH54-10, SH54-14, U.	EL90	2467	C,K
Southern Ventures " "	1974	Lake Carnanto, SH54-10, U.	EL105	2468	C,K
Southern Ventures " "	1974	Lake Yalkalpo, SH54-14, SH54-10, 7035, 7036-3,4. U.	EL90	2327	
Southern Ventures " "	1976	Lake Carnanto, SH54-10, SH54-14, 7036, U.	EL178	2584	T

Company	Date	Locality & map sheet, minerals	~~EL~~ LEASE	ENV.	Rock strat. units
Southern Ventures Pty. Ltd.	1977	Quinyambie, SH54-10, SH54-14, 7036-2,3, 7035-1,4. U.	EL334	3058	T
Tricentrol Australia Ltd.	1974	Lake Elder Area, SH54-10, 6936-2,3, U.	EL34	2392	T,M.
Tricentrol " "	1974	Lake Elder, SH54-10, 6936, U.	EL34	2211	T.
Tricentrol " "	1975	Lake Coonarbine, SH54-10, SH54-14, 6936-2,3, 6935-1,4, U.	EL127, (69,34)	2432	T.
Union Corporation (Australia) Pty. Ltd.	1973	Frome Embayment, SH54-10, 6937, 7037, U.	EL5/6	2338	T,K.
Union Corporation (Australia) Pty. Ltd.	1973	Quinyambie, SH54-10, 6937, U.	EL6	2146/2338	C,K.
Union Corporation (Australia) Pty. Ltd.	1973	Lake Pundalpa SH54-10, 6937-2,3, 7037-2,3. U.	EL5	2145/2338	T
Western Mining Corp. Ltd.	1978	Wittakilla SH54-6, SH54-10, 6838 6938, 6837, 6937, base metals	EL364	3153	T,K. B not interested

Note: Symbols used under column Rock Strat. Units.

B = Crystalline basement
C = Cainozoic
K = Cretaceous
M = Mesozoic
Cam = Cambrian
J = Jurassic
T = Tertiary
P = Permian