DEPARTMENT OF MINES
SOUTH AUSTRALIA

GEOLOGICAL SURVEY
PETROLEUM DIVISION

EXPLANATORY NOTES FOR THE INNAMINCKA 1:250 000 Sheet

compiled by

I.J. Townsend
Geologist
Petroleum Exploration Section

Rept.Bk.No. 74/217
G.S. No. 5531
D.M. No. 1906/60

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- ABSTRACT — not required for publication
- INTRODUCTION
  Location, Access, Habitation, Climate, ~~Habitation~~, Mapping details.
- PREVIOUS WORK
- PHYSIOGRAPHY
  Landform & Vegetation
- STRATIGRAPHY
- STRUCTURE
- GEOLOGICAL HISTORY — could tabulate
- ECONOMIC GEOLOGY

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ENCLOSURE -- To be included in published version.

1:250 000 Geological Map - INNAMINCKA

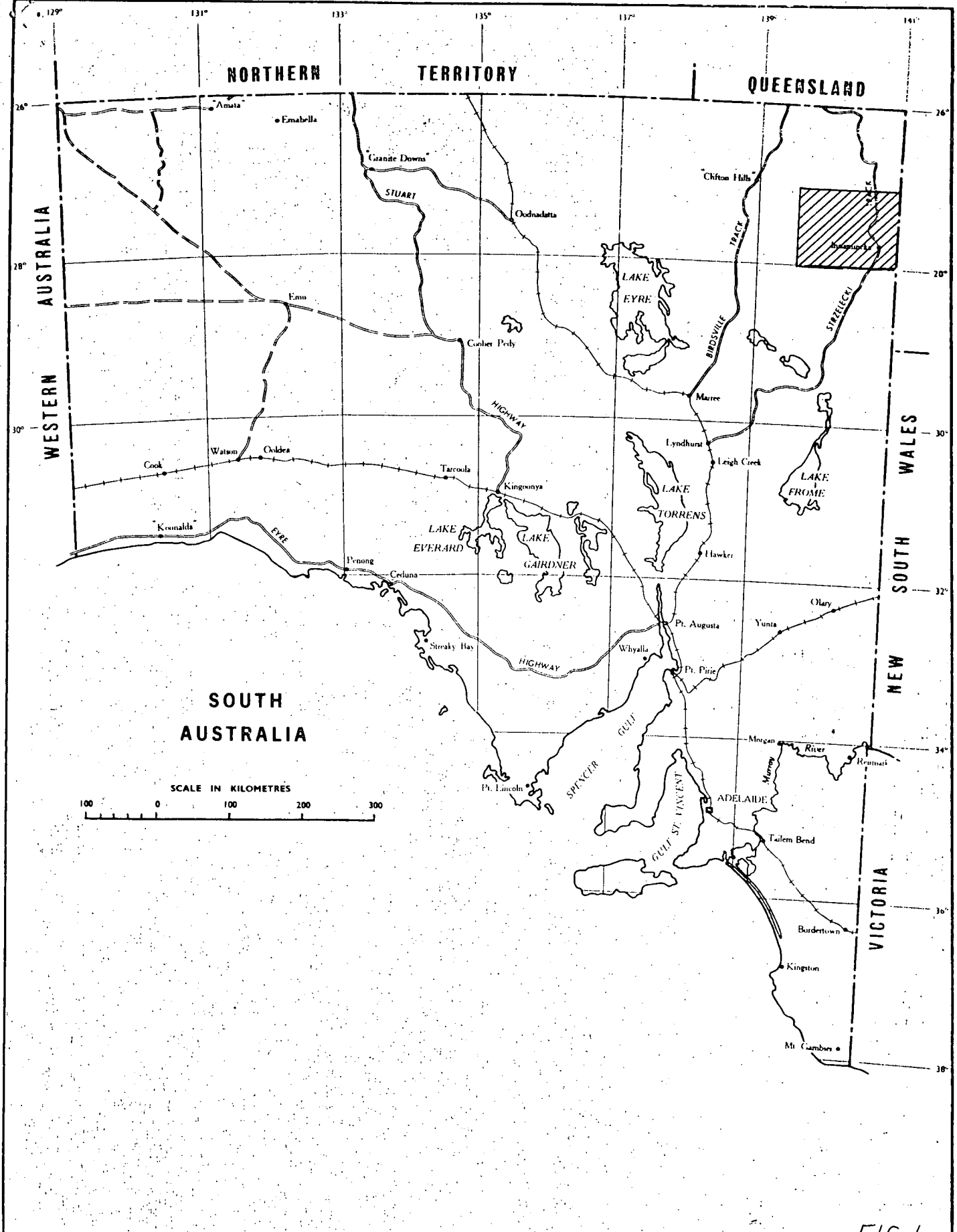

FIG. 1.

DEPARTMENT OF MINES — SOUTH AUSTRALIA

Compiled. I.J.T.	INNAMINCKA 1:250 000 LOCALITY PLAN	Date: Dec. 1974
Drn. A.F. Ckd.		Drg. No. S11156

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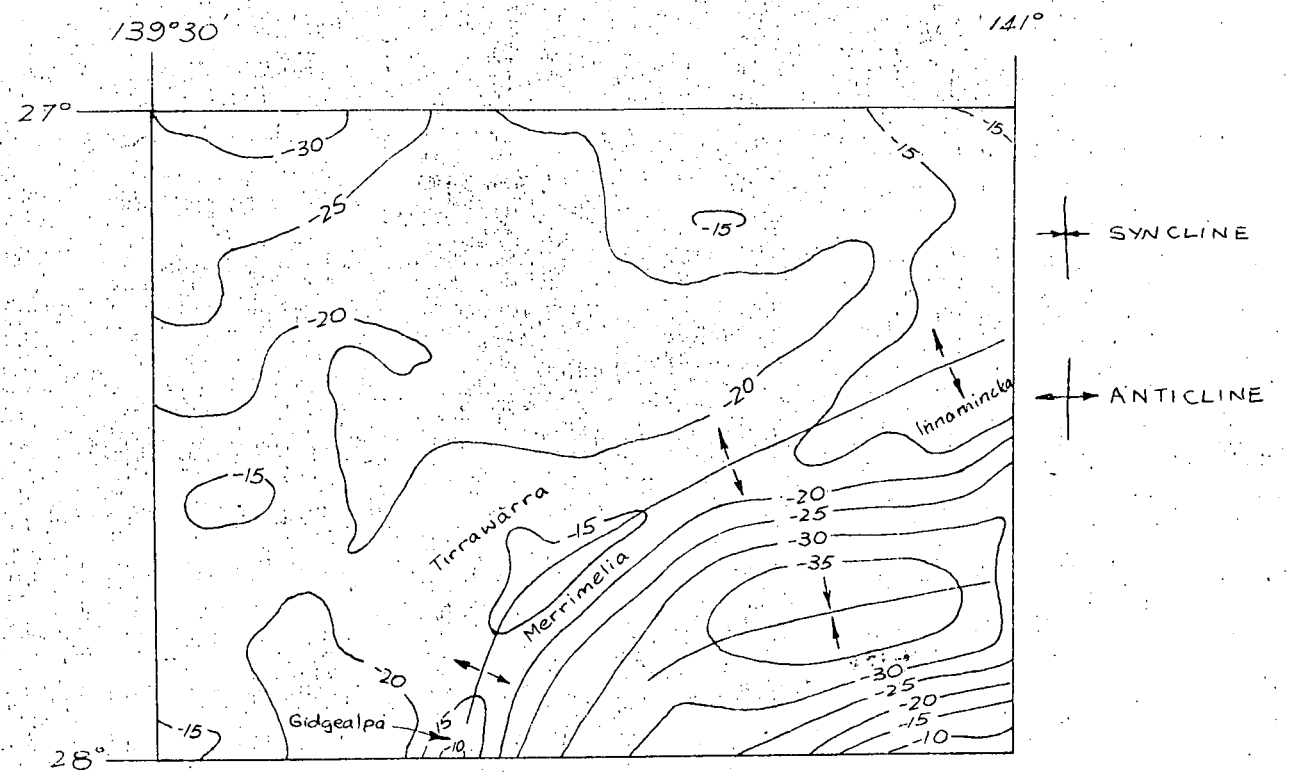

BOUGUER GRAVITY PLAN

(After Coppin Hall and Milton - 1971)

Contour interval = 5 milligals

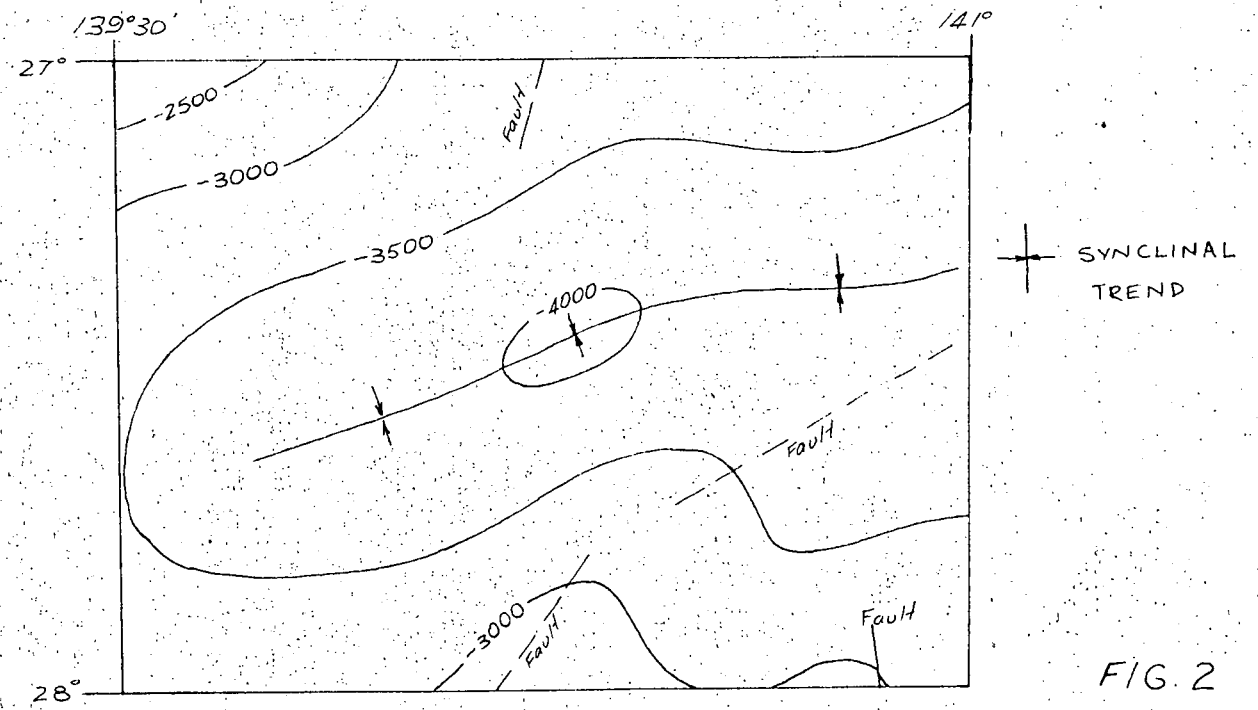

FIG. 2

INTERPRETED DEPTH TO MAGNETIC BASEMENT

(After Coppin Hall and Milton - 1972)

Contour interval = 500 metres

Compiled I.J.T.	**DEPARTMENT OF MINES — SOUTH AUSTRALIA**	Scale :
Drn. I.J.T. Ckd	INNAMINCKA 1:250 000 SHEET AREA	Date :
		Drg. No. S11155

DEPARTMENT OF MINES
SOUTH AUSTRALIA

Rept.Bk.No. 74/217
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EXPLANATORY NOTES FOR THE INNAMINCKA 1:250 000 Sheet area.

ABSTRACT

The Innamincka 1:250 000 Map area is located in the north-east of the State adjacent to the Queensland border. It lies between latitude 27°00 and 28°00 and longitudes 139°30' and 141°00. It is one of the best explored areas of the state in the subsurface and, together with STRZELECKI, contains in the subsurface the whole of South Australia's known petroleum resources.

The surface geology is dominated by Quaternary to Holocene dune sands and clays which rim the incised and eroded Tertiary Innamincka Dome exposing a Cretaceous core. A smaller dome to the south, called the Tickerna Dome has no Cretaceous exposed. The Middle Tertiary silicification on the Eyre Formation provided a silcrete cap (Tsi) which now illustrates the domal structure. Erosion of the dome provided clastics (Tmo - Doonbara Formation) which post-date Tsi and formed a Tertiary sandstone which was lateritised at the top. All exposed rocks were affected by a secondary silicification. The last main process was the gypsite process which weathered, bleached and partly ferruginised underlying strata, as previous processes did, but the last process has masked to some extent the earlier processes.

INTRODUCTION

The Innamincka 1:250 000 Map area (hereafter called INNAMINCKA) is located in the northeastern portion of the State of South Australia, between latitudes 27°00 and 28°00 and longitudes 139°30' and 141°00, and is adjacent to the Queensland border.

The area lies within the Great Artesian Basin and, together with STRZELECKI, covers the South Australian portion of the Cooper Basin, an infrabasin. The

For Intro add

Suggest PHYSIOGRAPHY

An interesting account of this is given in
- - - - by - - - - - ( ).

Omit the rest for a geological note.

drainage is dominated by Cooper Creek which enters from Queensland, flows generally in a westerly direction into vast flood plains near Tirrawarra and, on filling such floodplain areas, flows generally south and then west into Lake Eyre.

A number of permanent waterholes exist along the Cooper Creek enabling the grazing of cattle from Innamincka Homestead situated about 1 km upstream from Innamincka Township.

The Strzelecki Creek is a distributary of Cooper Creek and is a system of channels which flow generally south-southwest during intense flooding into Lake Callabonna about 250 km south of Innamincka.

Rock exposure is restricted to the eastern third of the Sheet area on the Innamincka Dome and again about 20 km to the south in the Tickerna area. The remaining area is generally covered by Recent sand dunes and interdune deposits of silt and clay.

PREVIOUS WORK

what year?

The first expedition to the Innamincka area was the notable but fateful pioneering of Burke and Wills in their epic journey to the Gulf of Carpentaria and return to the Cooper Creek depot with two assistants, King and Grey.

King was the only person to survive this journey and was found by Howitt's search party months later, living with the local natives. The location of the depot was just east of the map area on Cooper Creek near what is now Nappamerrie Homestead. Provisions were left buried at the spot now known as the "Dig Tree" by Brahe who had left only seven hours prior to Burke's return to the depot. Brahe had already stayed two months longer than

interesting but hardly relevant

Any geological conclusions in this work? If so, state them.

The first detailed geological work on INNAMINCKA was carried out by Wopfner (1957, 1958) for Geosurveys of Aust Std during the early years of petroleum exploration in (South) Australia. This project, which included the preparation of the first geological map of the area, outlined a number of domes in southwest Queensland and northeast South Australia. Since then Wopfner and others have refined this earlier work and defined or described a number of units, notably the Cainozoic units, used in the present published maps (Wopfner & Twidale 1967; W C H 1974; Wopfner 1974). — perhaps refer to historic drilling of Innamincka No[illegible]

From the early 1960s the pace of petroleum exploration in the Cooper basin quickened and the detailed seismic and drilling programs of Delhi International and other companies have greatly increased the knowledge of subsurface geology, including that of INNAMINCKA. Most attention has focussed on the gas and oil-bearing Permian succession but aspects of the Mesozoic and the pre-Permian geology as well as of the basin generally have been published (see Bibliography).

and the continuing assessment of data by the SA MD Petrol Expl. Division

Geophysical Surveys

Aeromagnetic —

Gravity —

Burke requested, and with provisions at a minimum had left for Menindie.

R. Lockhart Jack was the first person to record the Innamincka Dome. He noted in 1915 on a trip to Cordillo Downs that the Innamincka area showed "Desert Sandstone" dipping gently westwards. Later (1925) he discussed the geology of the Innamincka area and included a section of Innamincka Hill.

The first geological map of the area was produced by H. Wopfner for Geosurveys of Australia Ltd. in a project outlining a number of domes in southwest Queensland and northeast of South Australia as part of a petroleum search by Santos Limited.

The units have been described previously by Wopfner and again recently in the mapping of CORDILLO (preliminary map completed) by Wopfner.

~~Other~~ The sheet areas ~~surrounding~~ adjoining INNAMINCKA in South Australia have all been mapped by BMR ~~and are at various stages of preparation for publication~~. The Bureau of Mineral Resources has produced a geological map and explanatory notes of the Queensland portion of the Innamincka Dome which is situated on DURHAM DOWNS.

Because of the intense exploration for petroleum in the Cooper Basin, INNAMINCKA and STRZELECKI have the greatest density of seismic coverage and petroleum wells of any sheets in the State.

GEOPHYSICAL SURVEYS — incorp. in PREVIOUS WORK.

AEROMAGNETIC SURVEY

INNAMINCKA has been completely covered by an aeromagnetic survey flown at 1 500 feet above mean sea level (A.M.S.L.) on an E-W grid of 5 mile spacing. It was flown by Delhi International Oil Corporation in 1961-2 to cover the joint Oil Exploration Licences OEL 20 and 21, (now P.E.L.'s 5 and 6). These data were interpreted by the Bureau of Mineral Resources. The map shows only one main feature, a broad depression now known as the Cooper Basin covering a large portion of INNAMINCKA (Figure 2). This figure is part of a 1:1 000 000 aeromagnetic map covering the Great Artesian Basin produced in 1972 by the Seismic Section of the S.A. Department of Mines (S.A.D.M.).

and Santos and Farmee & suspect.

Ref?

→ to STRUCTURE

GRAVITY SURVEYS

Delhi International Oil Corporation conducted gravity surveys over their joint licence area with Santos Ltd. between 1963 and 1965. Various other companies have contributed more detailed work to small areas of the Cooper Basin in their farm-out areas. This work together with gravity surveys by the Bureau of Mineral Resources and S.A.D.M. has been co-ordinated by the Seismic Section of the S.A.D.M. The resulting 1972 publication is a 1:1 000 000 Bouguer gravity map of 5 milligal intervals covering the Great Artesian Basin, part of which is shown in Fig. 2.

not discussed

PHYSIOGRAPHY AND CLIMATE

The topography on INNAMINCKA is controlled by the Innamincka Dome and the smaller Tickerna structure to the south. The dome's highest region stands about 100 m above plain level. The plains contain the floodplains of the Cooper Creek and are generally modified by recent sand ridges encroaching from the south and west. As the Innamincka Dome is approached the sand dunes give way to gibber plains and eventually the gibber soil-covered dipslopes of Lockhart Jack's "Desert Sandstone" (Eyre Formation) which form cuestas and mesas of silcrete towards the centre of the dome. Bleached material adds contrast to the darker overlying silcrete, and this along with multi-coloured pastel shades of ferruginisation, creates a very picturesque area.

Vegetation is quite dense on the watercourses especially along the permanent waterholes of Cooper Creek and ephemeral waterholes of Strzelecki Creek. Numerous eucalypts and red mulga dominate the watercourse. Elsewhere sparse mulga and small bushes occur. Canegrass and spinifex are the prominent vegetation in sand dune areas and Mitchell grass on the gibber plains. ~~To the west~~ In the western part where clayey and sandy soils occur, the area comes alive with young vegetation after rains but within weeks is reduced to barren plains.

TABLE 1

STRATIGRAPHY OF OUTCROPPING UNITS

AGE	STRATIGRAPHIC UNIT	THICKNESS	SYMBOL	LITHOLOGY	REMARKS	CORRELATION OUTSIDE SHEET AREA
RECENT	STRZELECKI ~~DESERT~~		Qrs	Dune sands & sheet sands		Simpson Sand
	STURTS ~~STONEY DESERT~~	0–10 m	Qrt	Gibbers on gypsiferous brown clayey and sandy soils.		Callabonna Clay
	Lake deposits alluvium		Qrl Qra	Saline/silty claypan dep. Flood plain creek silts and clays.		
PLEIST-OCENE	UNNAMED	0–3 m	(T–Q)	Gypsiferous sandy soil forming a surface (possibly gypcrete) Sandstones clays and conglomerates	Gypsite surface (Wopfner --) (Qpt) Possible Tingana Clay Restricted to Creek banks -otherwise covered by Qrt.	Possible Telford Gravel equivalent
? PLIOCENE	'Hamga' silcrete			~~SECOND SILICIFICATION~~	It is a process not a rock unit.	
TERT-IARY	CADELGA LIME-STONE	0–1 m	Tma	Fresh water Limestones with chert capping	Often ~~left~~ occurs as cherty limestone lag pebbles	?Mangatitja limestone
MIOCENE TO ?PLIOCENE	DOONBARA FORM.	0–3 m	Tmo	Ferruginous flat patchy pisolitic drk. red s'stone white sands, grits and conglomerates containing silcrete boulders & pebbles	Both Tma & Tmo are best exposed in Candradecka Ck. and Rocky Crossing	
OLIGOCENE	SILCRETE OF THE CORDILLO SURFACE ~~SILCRETE~~		Tsi	HORIZON	"Duricrust" "greybilly"	(fossil palaeosol)
EOCENE PALAEOCENE-	EYRE FORM.	0–150 m	Tee	White to offwhite and ferruginised, in part cross-bedded kaolinitic (minor) quartz sandstones	Contains distinctive basal pebble band with reddish agate and black fossil wood	~~MURNPEOWIE FORMATION~~ on M Mundp Fm on MORRIS Macumba Fm ~ OODNA D.

TABLE 1 (CONTINUED)

AGE	STRATIGRAPHIC UNIT	THICKNESS	SYMBOL	LITHOLOGY	REMARKS	CORRELATION OUTSIDE SHEET AREA
Upper CRETACEOUS	MT. HOWIE SANDSTONE	0-5 m	Kuh	White to offwhite kaolinitic pebbly, cross bedded, weathered sandstone pebbles of shale up to 15 cm.	Often has salt and pepper appearance. Contains leaf impressions (minor).	-
CRETACEOUS	WINTON FORMATION		Kw	White to grey shales, silts, and salt and pepper kaolinitic sandstones	Shales display distinctive conchoidal fracturing.	WINTON FORMATION (Qld)
	BETOOTA LIMESTONE		Kub	Limestones.	Green-black with leaf impressions (abundant).	Betoota L.S.

TABLE II

STRATIGRAPHY OF SUB ~~CROPPING~~ SURFACE UNITS (DOWN TO EARLY PERMIAN)

AGE	STRATIGRAPHIC UNIT	THICKNESS	SYMBOL	LITHOLOGY	REMARKS	CORRELATION
CRETACEOUS	OODNADATTA FORMATION (Wooldridge Limestone Mbr	400 m 10 m	Klo	Silty shale		Tambo ALLARU MUDSTONE (Toolebuc Limestone).
	COORIKIANA S.S.MBR.	30 m	Klc	Sandstone on G.A.B. margin. Shaley away from SW margin		? Part of Roma
	BULLDOG SHALE	370 m	Klb	Marine shales - uniform grey		Roma WALLUMBILLA FM.
	CADNA-OWIE FORMATION	100 m	Klc	Siltstones with minor sandstones and some coals in the upper sections	Transitional unit from terrestrial sandstones toward marine silts and shales	TRANSITION BEDS This terminology is superseded.
	ALGEBUCKINA SANDSTONE	300 m	Jua	Fine to coarse, white to offwhite sandstones with minor clays	aquifer	MOOGA Mooga Westbourne Adori
JURASSIC	BIRKHEAD	100 m	Jmb	Shales and siltstones with traces of sandstones and lignitic coals	aquiclude	BIRKHEAD ~~FORMATION~~ Walloon
	HUTTON	180 m	Jlh	fine to coarse off-white sandstones poorly sorted and minor shales and coals.	aquifer	HUTTON SANDSTONE
E.TRIAS	NAPPA MERRIE	450 m	Kln	Interbedded s'stones siltstones & shales	Caprock to the hydrocarbon-bearing Toolachee Formation	

TABLE II CONTINUED

AGE	STRATIGRAPHIC UNIT	THICKNESS	SYMBOL	LITHOLOGY	REMARKS	CORRELATION
PERMIAN	GIDGEALPA GP. (see table IV)	~1000m	PG	Sandstones shales and coals	Reservoirs for oil and gas	~~PEDIRKA & ARCKARINGA BASINS~~ Permi and ~~Crown Point~~ Fms of Pedirka Basin equiv to lower Gidgealpa Gp.
	MERRIMELIA	40 m	~~P/m~~ Plme	Conglomerates, sandstones	~~Assumed deposited in glacial times but no evidence~~ conclusive glacial deposit	(BOORTHANNA FM.) of Arckaringa Basin (Lower Part) & Crown Point Fm of Pedirka Basin.

TABLE III

STRATIGRAPHY OF PRE-PERMIAN ~~SUB-CROPPING~~ SURFACE UNITS ~~(CONTINUED)~~

AGE	SYMBOL	LITHOLOGY & NAME	AGE REASONING
?DEVONIAN OR (?CAMBRIAN)	D	"Innamincka Red Beds"	Inarticulate Brachiopod Lingula found in Innamincka No. 1 - Tentatively dated as Devonian by Ludbrook (1960) who also points out the possibility of a Cambrian age as Lingula ranges from Camb. to Rec. and the rocks have similar lithologies to the Lake Frome Group (Middle to Late Cambrian).
ORDOVICIAN	O	Unnamed	
		Pyritic shales Black shales Quartzites Siltstones (most are only assumed to be Ordovician by lithological correlation)	Biserial graptolites found in Dullingari No.1 Well. (Middle to Early Ordovician) and also fragments of uniserial graptolites lower down (Early Ord).
CAMBRIAN	€	~~Volcanics~~ ..... ~~Rock Relationships~~	
		~~Carbonates~~ ..... Many trilobite fragments indicating lower and middle Cambrian and also lithological similarity to Lake Frome Group of sediments.
		Unnamed carbonates, siltstones, shales and ~~interbedded volcanics~~	
Cambrian or older	?€	Unnamed Volcanics	Red and green tuffs, dolomitic in part; minor rhyolite and trachyte.

date

10

Precambrian

Spencer (Ludbrook)

However Ludbrook also pointed out that a Cambrian age was possible as the Lingula ranges are free from C to Recent and "the Inaamincka Red Beds resemble, lithologically, the Middle to Late C Lake Frome Group.

Note on ?€ volcanics

STRATIGRAPHY

A. Subsurface

Cambrian

The oldest sediments intersected in the Cooper Basin are ~~Cambrian~~ limestones, ~~Limestones~~ of confirmed Cambrian age (Ref) with interbedded volcanics. These deposits which are known ~~are present~~ in a number of the early Gidgealpa wells. ~~Cambrian sediments~~ almost certainly underlie the whole of the sheet area (Devine and Youngs, 1975 ~~in press~~) although most wells have not drilled deep enough to penetrate them.

?Ordovician

Ordovician sediments have been confirmed by palaeontologic evidence in cores from Dullingari No. 1 south of INNAMINCKA and from Pandieburra No. 1 west of INNAMINCKA (Ref). Quartzite and shales in other wells such as Coonatie No. 1 and Tirrawarra No. 1 are probably also of Ordovician age.

? Devonian - Carboniferous

Innamincka Nos. 1 and 2 intersected red beds ~~of assumed Devonian to Carboniferous age~~ in the very early exploration period, and later so did Packsaddle No. 1. An age of Devonian to Carboniferous was suggested for these beds which (Ludbrook, 1960) based on the presence of Lingula.

The fossil Lingula has a time range from Cambrian to Recent ~~so~~ a Cambrian age should not be ~~ignored in that, lithologically~~ ruled out especially as the Innamincka "Red Beds" resemble lithologically the Middle to ~~Upper~~ Late Cambrian Lake Frome Group, Ludbrook (1960). was recovered from these beds in ———. Therefore

Permian

The Cooper Basin is a Permo-Triassic basin which resulted from the Kanimblan Orogeny dated at 320 million years, (Middle Carboniferous). Deposition commenced with the Early Permian

Reference to
Mapimelia Formation

a bit missing?

Merrimelia Formation which consists of sandstones and conglomerates. The pebbles are somewhat rounded and it is assumed that the formation may have had a glacial origin, but fluvial transport and deposition. The Gidgealpa Group unconformably overlies the Merrimelia Formation and its lithology consists of non-marine sandstones, siltstones, carbonaceous shales, and coals indicating back swamp and alluvial floodplain conditions through the Early Permian. Structural movements occurred during the Early Permian as shown by greater structural relief on the lower Gidgealpa Group than in the Upper Gidgealpa. An unconformity occurs between the Late and Early Permian. The Gidgealpa Group includes the following tabulated formations.

What does this mean?

not stratigraphy

TABLE IV . THE GIDGEALPA GROUP - ~~(after Gatehouse 1972)~~

FORMATION	STAGE	AGE
TOOLACHEE	P. reticulatus Assembl. UPPER STAGE 5	Late Permian
Daralingie Beds	UPPER LOWER STAGE 5	
ROSENEATH SHALE	LOWER STAGE 5	
EPSILON FORMATION	UPPER-UPPER STAGE 4	Early Permain
MURTEREE SHALE	UPPER STAGE 4	
PATCHAWARRA FORMATION.	LOWER STAGE 4	
TIRRAWARRA SANDSTONE.	STAGE 3	
MERRIMELIA FORMATION.	STAGE 2	?Carboniferous to Early Permian

Triassic

The Lower Triassic Nappamerrie Formation conformably overlies the Permian sediments. The lithology consists of sandstones with interbeds of siltstones and shales, the latter being most important in that they form the cap rock for the Permian hydrocarbons. No oil or gas has been found where the Triassic caprock is absent or thin.

Jurassic

Unconformably overlying the Triassic Napparmerrie Formation are Jurassic rocks which are dominantly sandstones and include, from oldest to youngest, in the Southwest Queensland region, the Hutton Sandstone, Birkhead Formation, Adori Sandstone, Westbourne Formation and Mooga Sandstone. These last three are correlated with the Algebuckina Sandstone of the western basin margin. The Algebuckina Sandstone or Mooga Sandstone is the main artesian aquifer of the Great Artesian Basin. The Hutton sandstone is an important aquifer also and may merge with the Mooga Sandstone towards the basin margin. The Mooga sandstone is fairly uniform over much of the Great Artesian Basin and produces generally potable artesian water wherever intersected.

The environment of deposition was fluvial and lacustrine for the Mooga or Algebuckina Sandstone and at the end of the Jurassic there was a transition towards marine deposition.

Cretaceous

~~CRETACEOUS~~.

During the transitional period from a non-marine to a marine environment, deposition of the Cadna-owie Formation (or "Transition Beds") occurred. This unit is generally a white

(bleached) to grey porous sandstone, clayey and carbonaceous in parts, with calcareous sandy interbeds. The formation is also capable of producing good water in much of the western portion of the Great Artesian Basin. A widespread marine transgression covering all of the Great Artesian Basin produced a blanket of shale units known as the Bulldog Shale (often called the "Roma") and the Oodnadatta Formation ("Tambo"). The regression which followed, trended north to northeast and resulted in fluviatile sands and alluvial silts and clays. This formation is known as the Winton Formation and is present through much of South Australia and Queensland. Its maximum thickness is 600 metres in the region of the deeper parts of the Cooper Basin. The top of the Winton Formation is an erosional surface so true thicknesses are not known.

The Winton Formation is the oldest formation exposed on INNAMINCKA. The best exposure is in the centre of the eroded Innamincka dome. The Winton Formation does not crop out in the small Tickerna structure to the south.

B. ~~Surface Exposure~~ Exposed

The oldest member of the Winton Formation observed in the Innamincka area is the Betoota Limestone, a dark green sandy limestone which contains plant fragments. Samples collected from both Innamincka and Betoota Domes are lithologically similar and according to Wopfner (1958) are from the same formation. This limestone band has an exposed thickness of about 1 m ~~exposed~~ on INNAMINCKA. It is the lowest part of the Winton Formation exposed in the area and is approximately 60 m below the eroded ?top of the Cretaceous. The sediments of this upper section

extract from here

Cenozoic

Silents of the Cadillo Sandstone
(Tsc)

of Winton include shales with some sandstones and minor siltstones.

The Mount Howie Sandstone unconformably overlies the Winton and shows cut and fill structures into the bleached Winton. It is a medium to coarse grained kaolinitic sandstone showing large scale crossbedding and generally includes clay galls, and clay pebbles up to 15 cm. Most of the Cretaceous sediments on INNAMINCKA are deeply weathered and some display multi-coloured picturesque patterns resulting from preferential ferruginisation on the bleached profile.

At least three periods of deep weathering have modified the Cretaceous sediments on INNAMINCKA and each of these was accompanied by ferruginisation and bleaching processes. The first process was associated with silcrete formation, the second with a laterite soil formation and secondary silicification, and the third with the gypsite surface. Unconformably overlying the Cretaceous sediments is the Eyre Formation, a sequence of pebbly sandstone grits, torrentially bedded sandstones and siltstones with minor interbedded shales. Throughout the Innamincka Dome the base of this formation is represented by a pebbly sandstone band or series of bands which in places on the southern limb reach a thickness of 3-5 metres. These sediments are Early Tertiary in age and again have been modified by the three processes mentioned ~~in the previous section~~ above. This basal pebble conglomerate contains pebbles of vein quartz (by far the most abundant), fossil wood (assumed to be of Jurassic age) and agate. The presence of agate and fossil wood make this horizon and ideal marker bed for the greater part ~~of the~~ exposed Cretaceous-Tertiary contact on INNAMINCKA.

Silification of the uppermost part of these sediments occurred during middle Tertiary times (Oligocene to Early Miocene) as part

of, or immediately following deep weathering. This silicification process affected the exposed rocks of much of South Australia but in the Innamincka area appears to be restricted to the Eyre Formation with only minor silicification of the Winton where the Eyre Formation was very thin. To the west of the Great Australian Artesian Basin, contemporaenous silcrete occurs on much older rocks indicating that the process operated on the existing eroded land surface at the end of Early Tertiary (Eocene) time.

The silcrete (previously referred to as "duricrust") is a resistant caprock which has been partially to completely silicified in a soil profile. It caps most of the Innamincka Dome periphery and has almost formed a pound which resulted from the eroded centre of an anticlinal structure. A few mesas and buttes remain in the centre of the dome, however, showing the structure of the gently folded silcrete. Unconformably on the eroded structure is the Doonbara Formation, a sequence of conglomerates and sandstones derived in part from the silcrete and the Eyre Formation. The top of this formation has been greatly ferruginised to form a laterite surface with accompanying bleaching below. Pisoliths were formed in many of the ferruginous sandstones which when analysed showed iron, silica, minor aluminium, and a small amount of manganese.

The Cadelga Limestone is less than 2 m thick on INNAMINCKA and developed apparently conformably on top of the ferruginous sandstone. Reworking, almost in situ, in the basal portions of the limestone is often observed. Angular fragements of ferruginous sandstone ranging from 1 to 20 mm are cemented in a grey to offwhite or pink limestone. This gives way to a purer lime-

~~Post Doon boundary fault~~ 'Younger' silcrete

Relate to legend.

Separate off the gypsite surface into the next paragraph

stone (offwhite to grey) which almost always contains chert in the uppermost part. Only one location of in situ limestone was found on INNAMINCKA and this is near Rocky Crossing.

A second silicification occurred possibly after the Tertiary deposition and it silcreted the Eyre Formation again and some of the Doonbara Formation. Pleistocene clay and conglomerate are the next youngest units and these were deposited unconformably on the eroded Tertiary surface. Outcrops are minor and are restricted to banks of creeks where more recent erosion has exposed them. One cut-and-fill structure was observed showing a broad shallow feature cut into clay. The base of the cut is lined with large gibbers forming a basal conglomerate which is overlain by a sequence of conglomerate and sand. It is assumed that between the completion of the deposition and the conglomerate, however, the land surface again reached stability and the sediments below were subjected to deep weathering and ferruginisation. This surface, now known as the gypsite surface, or Warrina Surface, modified all of the Great Artesian Basin (G.A.B.) sediments exposed at that time and its presence has been observed over much of South Australia including areas outside of the G.A.B. In some localities a thick gypcrete crust was formed as an evaporitic layer in conditions similar to Lake Eyre today. In other locations, higher topographically than the Pleistocene surface, erosion would have prevented the processes associated with the gypsite surface from leaving their mark.

In the Cooper Creek area of Innamincka Dome the second silicification can be observed at Innamincka Hill and eastwards along the Creek. The silicification preceded the gypsite processes and is generally at a lower level than the protruding silcrete (Tsi) capped mesas. The introduction of gypsum and the

formation of the gypsite surface followed. The ferruginisation and intense bleaching associated with the gypsite surface appears to have been widespread and must have erased many features of previous processes, or at least masked them. The indicators of the gypsite weathering include colours of yellow ochre to brown limonite, and pastel colours of yellow, orange, pink and purple. The main feature is an almost pure white weathered profile with abundant kaolin and gypsum, a backdrop on to which the pale colours of ferruginisation are sparsely introduced.

These colours contrast markedly with the dull dark browns and reds of the ferruginisation of the silcrete profile and the brighter brick reds of the laterite soil profile.

It is obvious that some sediments must have undergone two or three of the weathering and ferruginisation processes and the last must certainly leave the greatest mark although indications of earlier ones can be seen in many locations.

Epeirogenic movements after the formation of the gypsite surface would have raised the erosion energy level. The sediments between protruding silcrete mesas would have been soft gypseous clays and soils which would have allowed rapid erosion. The drainage pattern would quickly be controlled to main channels previously cut through the silcrete and it is assumed that a very similar drainage pattern occurred in Late Tertiary and Late Pleistocene times. The general drainage pattern is thought to be the same as that present today.

The rapid erosion produced basal conglomerates and these filled many channels cut into the underlying clays. The cycle was completed with declining energy levels which produced sands and in turn clays (?Tingana Clay).

Minor movements may have rejuvenated the system and produced the Recent gibber conglomerates and gypseous gibber and sandy soils (Callabonna Clay).

Recent dune sands, claypan or lake deposits and alluvium complete the sedimentary cycle on Innamincka.

ECONOMIC GEOLOGY

Water

Water can be won from many horizons in the northeast part of the State. From youngest to oldest the aquifers include the following:-

1. The Late Tertiary Doonbara Formation, particularly to the north of INNAMINCKA on CORDILLO is used extensively for stock. A number of wells on the northern limb of Innamincka Dome produce at shallow depth from Doonbara Formation sands. Natural seepages are occasionally developed such as Nilpie Springs on CORDILLO and the eastern end of Callamurra water hole on INNAMINCKA, (Wopfner 1961).

2. The Tertiary Eyre Formation is an aquifer with a catchment area around the Innamincka Dome. Many water bores, including a number drilled to supply water for oil exploration wells produce from the Tertiary Eyre Formation.

3. The Cretaceous Winton Formation sandstones are proven water producers in southwest Queensland and northeastern South Australia. Early this century a number of wells were dug into the kaolinitic spotted "salt and pepper" sandstone and water won for the purpose of watering stock in these areas.

4. Many water bores of the Great Artesian Basin produce from the Cadna-owie Formation (Transition Beds) particularly close to the basin margin where numerous natural springs occur.

5. The main aquifer of the Great Artesian Basin is the Algebuckina sandstone (Mooga Sandstone) the uppermost unit of Jurassic sediments. It produces very good quality artesian water over much of the Great Artesian Basin from depths down to about 1500 metres. The intake beds crop out in N.E. Queensland. Some areas are more saline because of reduced flow and partial stagnation but generally the water is potable. Consequently it has opened much of arid South Australia and Queensland for purposes of grazing cattle and furnishing the main stock routes with plentiful supplies. This aquifer also supplies towns such as Oodnadatta and Birdsville.

6. The Hutton Sandstone is also an aquifer. ~~and this is the lowermost formation of Jurassic age.~~ It is not used however because of the Artesian aquifer above it.

b. ~~Hydrocarbons~~ Petroleum

~~Hydrocarbons~~ Petroleum have so far been recovered from four formations in the Permian Cooper Basin, three of which are major potential producers. The Toolachee Formation is Late Permian in age whereas the Daralingie Beds (minor), the Epsilon Formation (minor), the Patchawarra Formation, and the Tirrawarra Sandstone are all of Early Permian age.

The first discovery of petroleum in the Cooper Basin was made on INNAMINCKA at Gidgealpa No. 2 on December 31st, 1963. This well was drilled higher up on the structure than the unproductive Gidgealpa No.1 and produced gas from both the Toolachee and Patchawarra formations. Since the Gidgealpa discovery 22 more fields have been found, four of them in Queensland. Many of the fields are on STRZELECKI, immediately south of INNAMINCKA. Only three fields contain oil and these all produce from the Tirrawarra Sandstone. Together these two

Sheet areas in the subsurface hold the whole of South Australia's known petroleum resources. The only other producing gas well is Caroline No. 1 in the southeast of S.A. which is tapped only for carbon dioxide.

I.J. Townsend.

I.J. TOWNSEND
GEOLOGIST
PETROLEUM EXPLORATION DIVISION

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10. Moorari No. 1 - Bridge Oil International
11. Packsaddle No. 1 - Alliance Oil Dev. Co.
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