GEOLOGICAL SURVEY

A BRIEF STUDY OF THE EUCLA BASIN WITH RECOMMENDATIONS FOR FURTHER PETROLEUM EXPLORATION

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DEPARTMENT OF MINES
SOUTH AUSTRALIA

GEOLOGICAL SURVEY
PETROLEUM EXPLORATION DIVISION

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by

BRIDGET C. YOUNGS
GEOLOGIST

26th February, 1974

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DEPARTMENT OF MINES
SOUTH AUSTRALIA

Rept.Bk.No. 780
G.S. No. 5328
S.R. No.11/5/170

A BRIEF STUDY OF THE EUCLA BASIN WITH RECOMMENDATIONS FOR FURTHER PETROLEUM EXPLORATION

INTRODUCTION

The Eucla Basin lies mainly in Western Australia with only the eastern one-third in this State. This report is confined to the onshore portion in South Australia (Fig. 1). The purpose of the report is to provide a brief summary of the geology and petroleum potential at this time of termination of P.E.L.4 and to provide a starting point for more thorough studies.

The basin is Cretaceous to Miocene in age, is underlain by Permian, presumed Cambrian and Precambrian strata, and possibly other Palaeozoic strata. It is bordered by the Lower Palaeozoic Officer Basin to the north, it may connect with the Permian Arckaringa Basin to the northeast and abuts onto the Gawler Platform in the east.

PREVIOUS WORK

Prior to 1956, the only exploration in the Eucla Basin was the drilling of twelve water bores in the southern area and one at Cook Rail Siding in the north (Crespin, 1955). The B.M.R. conducted a regional gravity survey in 1956 (Gunson and Van der Linden, 1956) and a reconnaissance gravity survey in 1958 (Quilty and Goodeve, 1958). No further exploration work was conducted until Outback Oil Company N.L. took out O.E.L. 33 (now reduced in size and designated P.E.L.4, see Fig. 1) in 1964.

During the last ten years, Cook 1, Denman 1 and Hughes 1, 2 and 3 have been drilled by Outback Oil in the vicinity of the railway (Ludbook, 1965 and 1966; Outback Oil Co., 1966) and a deep well, Mallabie 1, in the south (Fig. 1) (Scott and Speer, 1969). The only seismic survey in the area was conducted by the South Australian Department of Mines (Kendall, 1965). Two lines were shot and possible Proterozoic refractors were identified. Geosurveys (1966) carried out a gravity survey over the onshore part of the basin and this is incorporated in Fig. 2. A re-interpretation of this data (Bible, 1972) suggests that up to 3 500 m of sediments may be contained in parts of the north and northeastern onshore area. Aeromagnetic surveys conducted for Outback Oil and Exoil are incorporated in Fig. 3, and Waller et al. (1972) have recently provided additional data over the northern half of the area. The southern onshore area has been surveyed by the B.M.R. and the data is now being compiled into a map (see B.M.R. Record 1973/195, p. 11).

BASIN STRUCTURE

Figure 3 shows a broad area, trending northwesterly through the Head of the Bight and Denman, in which depths to magnetic basement exceed 1 000 m and frequently fall beneath 2 000 m. The western margin of the Gawler Platform is reflected in the shallow depths to the east of this trough and the Archaean West Australian Shield to the west. Figure 4, showing depths to a high-speed refractor (possible basement), confirms the presence of this trough which was formerly named the Denman Basin by Wopfner (1972).

The Denman Basin was described as a Permian infrabasin beneath the Eucla; it was originally believed to possibly have dimensions similar to those of the deep trough but the absence of any Permian strata in the northern wells has caused its area to be reduced to that shown in Fig. 4. The deep northwesterly trough is therefore an older feature.

A recent magnetic survey has indicated also the presence of another deep, longitudinal trough just east of Fisher (Waller et al., 1972). Depths to the magnetic basement reach 2 000 m and the trough is therefore as deep as, although narrower than, the one to the west. It is not known whether Permian sediments exist in this trough, but it could represent a connection of the Denman to the Arckaringa Basin which lies to the northeast of the area.

Figure 6 shows depths to the base of the Cretaceous and Fig. 8 depths to the base of the Tertiary. The deep Palaeozoic features were clearly only very shallow by the start of the Cretaceous.

STRATIGRAPHY

Figure 5 shows a diagrammatic stratigraphic column which has been derived from data obtained in Mallabie 1. It should be noted that lithologies of some formations in the northern areas differ from those shown on Fig. 5.

Possible Archaean rocks were intersected in the bottom of Mallabie 1 (Scott and Spear, 1969); they were dated at 1 150 m.y. (Thomson, 1970) but this probably represents the effects of the Willouran Tectonism on some rocks of the older Western Australian Shield. The gneiss in Nullarbor 7 also may be Archaean.

Mallabie 1 intersected 425 m of metamorphosed felspar porphyry overlying arkosic sandstone. The porphyry encountered in Nullarbor 3, 4 and 8 is similar and these have all been tentatively correlated with the Carpentarian Gawler Range Porphyry to the east of the basin.

Probable Cambrian sediments underlie much of the Eucla Basin and appear to be restricted to the Palaeozoic deep trough. The strata in the northern wells are red and green siltstones with thin interbedded sands and dolomites (Ludbrook, 1965 and 1966; Outback Oil Co., 1966). The latter are cherty and oolitic; they may correlate with the Observatory Hill Beds which crop out in the Officer Basin (Wopfner, 1969). Mallabie 1 encountered 480 m of an orange-red, moderately sorted, friable sandstone containing traces of gypsum and chert in parts (Scott and Speer, 1969). Nullarbor 6 contained red and green shales underlain by a ferruginous sandstone.

Lower Permian strata have been identified in Mallabie 1 and Nullarbor 8. Harris and Ludbrook (1966) proved an Artinskian (Stage 3) age for grey, non-glacial claystones in Nullarbor 8 and the sands and silts in Mallabie 1 were dated at Sakmarian (Stage 2) (Scott and Speer, 1969). The sandstones are unconsolidated, subrounded to subangular. Ludbrook (1965 and 1966) reported up to 36m of presumed Permian strata in the northern wells. The assumption was made entirely on lithological and stratigraphic grounds and more recent palynological work has proved a Lower Cretaceous age for the strata (see next paragraph).

The oldest Eucla Basin sediments are the Lower Cretaceous sands and grits which have been intersected in nearly all of the wells and bores in the basin (Figs. 9 and 10). The sediments have a constant thickness of approximately 70 m except near the margins of the Cretaceous deposition. The prominant lithology is a medium-grained, permeable sandstone containing accessory minerals such as feldspar, pyrite and glauconite. In the Hughes, Denman and Mallabie wells, a medium granule conglomerate containing moderately well-sorted quartz and minor other lithics overlies the sandstone unit. Two similar lithologies are combined in Western Australia and have been named the Loongana Sandstone (Lowry, 1970) - it is tentatively suggested that the unnamed Lower Cretaceous units in the South Australian area are lateral extensions of the Loongana Sandstone. Laws (in Outback, 1966) and Ludbrook (1966) both suggested a Palaeozoic age for the lowermost units of the Lower Cretaceous sequence; later unpublished palynological work by W.K. Harris (S.A. Geological Survey) indicated that these sands should have been included in the Cretaceous strata.

The ?Loongana Sandstone is overlain by up to 120 m of soft grey clays and fissile claystones. The sequence is glauconitic, carbonaceous and pyritic throughout. Maximum thicknesses occur in the western parts of the South Australian portion of the basin (Fig. 7), i.e. near to the central basin areas in Western Australia (see Lowry, 1970, for isopach plan). This clay sequence is probably the eastern extension of the Madura Formation in Western Australia, which is Campanian to Senonian in age there (Lowry, 1970).

Figure 8 shows depths to the base of the Tertiary. The Tertiary Eucla Group comprises a basal sandstone and overlying limestones. The Middle Eocene Hampton Sandstone is a medium to coarse grained, quartz sandstone with limonite staining of the grains. The maximum thickness attained is 36 m and the unit occurs in all but the southeastern bores of the basin.

Figure 10 shows the Pidinga Formation, consisting of carbonaceous and pyritic clays, silts and minor sands, in Nullabor 6 and 7 bores. The maximum thickness of the formation is 25 m. Ludbrook (in Parkin, 1969) assigns it a Middle Eocene age and suggests it is either the same age in part or older than the Hampton Sandstone.

The Upper Eocene Wilson Bluff Limestone conformably overlies the Hampton Sandstone and is present throughout the basin, although it is thin in the east along the basin margins. The formation is a white, compact chalk composed of bryozoal fragments in a micrite groundmass. Porosity is very high but permeability is probably low owing to the micrite sealing cavities within individual bryozoa. Chert nodules, and occasionally larger pods, occur in all but the uppermost 12 m of the formation. Maximum thicknesses of over 100 m occur in the southern part of the onshore area and the Wilson Bluff Limestone crops out in the cliffs at the Head of the Bight.

The youngest formation in the Eucla Group is the Lower Miocene Nullarbor Limestone which crops out over all of the present basin area. This carbonate is a hard and dense, white biosparite composed mainly of algae and foraminiferal tests. Thicknesses are generally aroung 50 m but are less at the basin margins.

Quaternary aeolianites cover the Nullarbor Limestone in the area of the Head of the Bight. Elsewhere superficial deposits are rare.

GEOLOGICAL HISTORY

The sediments of the area are underlain by Archaean rocks of the Western Australian Shield and the Gawler Platform. Granite gneisses encountered at total depth in Mallabie 1 and Nullarbor 7 represent the basement in the region.

Before, and possibly during, the Proterozoic, the basement was tectonically deformed along north-northwesterly trends thus enabling the large thickness of Adelaidean sediments and volcanics, like those encountered in Mallabie 1, to be deposited in the deep basement troughs described on an earlier page (see page 3). Scott and Speer (1969) postulate a shallow marine origin for the sandstone overlying basement in Mallabie 1.

Probable Cambrian strata were deposited throughout the central trough area. In the north over 300 m of sandstones, shales and dolomites were deposited in what may have been an alternately shallow to moderately deep marine environment as the shelf area gradually sunk to accomodate the strata. The possible Cambrian sediments in the south also suggest deposition in a shallow marine environment with a certain amount of dehydration during the early stages.

The Ordovician to Carboniferous history of the area is unknown at present. No sediments of this age have been found but it is entirely possible that the Ordovician and Devonian depositional areas in the Officer and Arckaringa Basins could have spread into the region. If sedimentation did occur, extensive uplift and erosion will have taken place and remnants may have been left only in the deep Palaeozoic troughs.

Permian sediments may have been more extensive than they are at present and it is possible that a connection from the Canning Basin in the northwest to the Arckaringa Basin in the northeast may have existed by way of the Palaeozoic troughs underlying the Eucla Basin. The Permian strata in the Denman Basin were deposited in a marginal marine environment after the Late Carboniferous-Permian glaciation (Harris and Ludbrook, 1966).

During most of the Mesozoic era the region was possibly subject to erosion and non-deposition resulting in a relatively flat land surface onto which the Cretaceous sediments were laid. The Cretaceous transgression is believed to have been initiated by the parting of Antarctica and Australia during the late Jurassic or early Cretaceous.

A marine transgression entered the Eucla Basin from the south and west during the early Cretaceous and the glauconitic shales and silts of the Madura Formation were preceeded by non-marine deposition of the basal sands and conglomerates. Deposition ceased during the Upper Cretaceous and subsequent erosion was probably not significant.

Gentle downwarping of the Eucla Basin commenced in the Eocene and sedimentation started with the marine Hampton Sandstone in the west and the restricted terrestrial Pidinga Formation in the southeast. As the seas spread, the Wilson Bluff Limestone was deposited in quiet seas.

The Oligocene was a period of even erosion and weathering of the Wilson Bluff Limestone. Another marine transgression occurred during the early Miocene and the Nullarbor Limestone was deposited over large areas of the shelf in open seas with good circulation and currents.

Since the Middle Miocene, the Eucla Basin has been gently tilted towards the southeast, uplifted above sea-level and has developed an immature karst topography with only rare aeolian deposits near to the present coastline.

RECOMMENDATIONS FOR FURTHER WORK

The Tertiary carbonates of the Eucla Basin do not offer suitable targets for petroleum exploration but all the formations beneath them should be considered, at least during the early stages of future exploration in the basin. The Eocene and Cretaceous sands and clays could provide suitable reservoirs and cap rocks in the form of both structural and stratighaphic traps; lignitic beds encountered in these beds offer encouragement as potential source rocks. The Lower Permian strata in Mallabie 1 and Nullarbor 8 are sands and siltstones and the Lower Cretaceous in the northern wells is mainly sandstone also; areas of thicker Permian development could contain younger beds similar to the Mt. Toondina Beds of the Arckaringa Basin (Townsend, 1973). The ?Cambrian strata offer possible carbonate reservoirs in the northern wells and more arenaceous beds in Mallabie 1 in the south. It is possible that Ordovician and Devonian rocks, which occur in the Officer and Arckaringa Basins, could exist under unexplored area of the Eucla Basin.

A recommended programme of future work is as follows:

1. Seismic surveys over selected areas of interest (Fig.3) -
   A. the northwestern end of the Palaeozoic trough in the vicinity of Hughes and Denman.
   B. the longitudinal trough which crosses the railway between Fisher and Watson (Waller et al., 1972).

C. the Denman Basin (Permian and older targets).

D. the "low" near the S.A.-W.A. border.

2. Drilling of structures which seismic results suggest contain thick Palaeozoic and/or Cretaceous-Eocene sediments. The Palaeozoic targets being Permian cyclic sands, shales and coals similar to those in the Cooper Basin, Cambrian sands and carbonates and possibly also Ordovician and Devonian arenites if they exist in this region.

3. At least one stratigraphic well to test for the presence of Permian rocks between Cook and Maralinga (Ludbrook, 1961) and hence to locate a possible link between the Arckaringa and Denman Basins.

4. The increase of geological and geophysical knowledge coming from the above exploration programme could lead to other later exploration including the drilling of stratigraphic as well as structural targets. Suitable areas might exist around the margins of the deep Palaeozoic troughs and also along the northern and eastern edges of the Eucla Basin.

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26th February, 1974
BCY:JL

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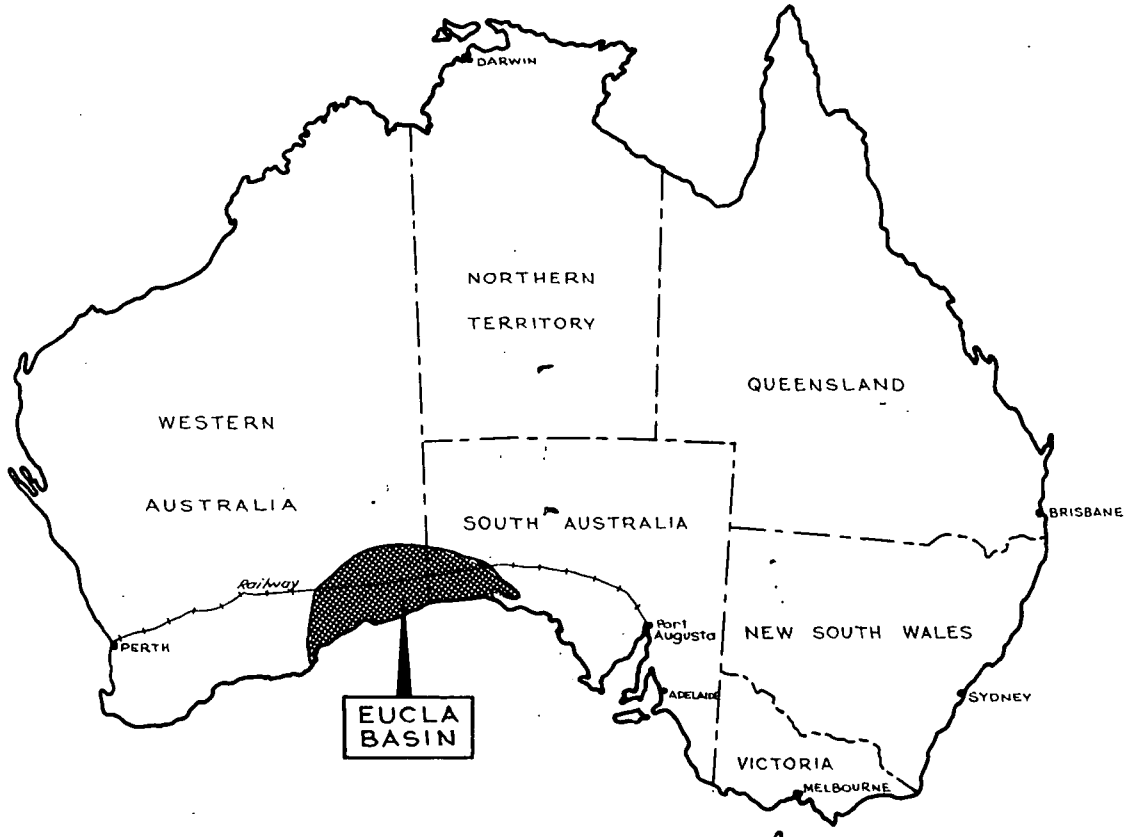

SCALE

0 1000

KILOMETRES

PETROLEUM TENEMENTS

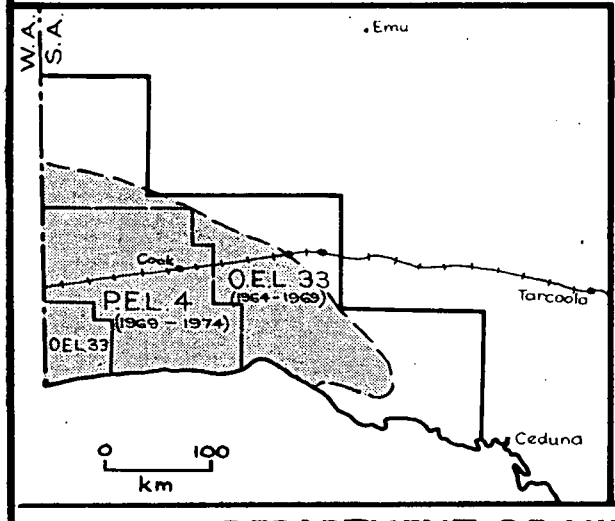

FIG. 1

DEPARTMENT OF MINES — SOUTH AUSTRALIA

PETROLEUM GEOLOGY SECTION	Drn.	ONSHORE EUCLA BASIN—S.A.	SCALE: 1:30 000 000
	Tod. A.F.	LOCALITY PLAN	S 10660
	Ckd.		A+D
	Exd.		DATE: JANUARY 1974

500—2.69 665

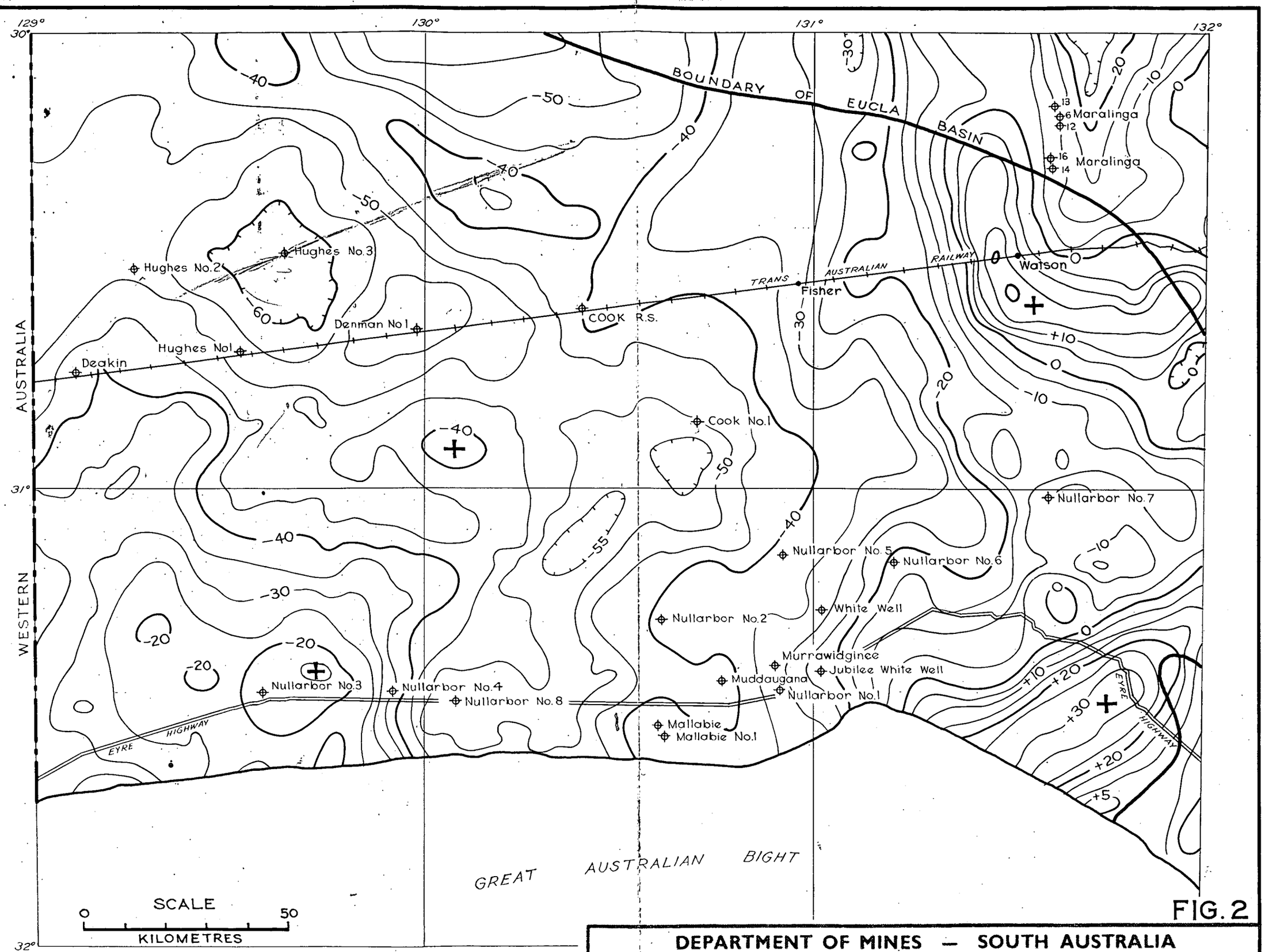

FIG. 2

LEGEND

-20 Gravity contour, value in milligals

\+ Gravity high

-60 Gravity low

Taken from State Gravity Map (1:1000000) Plan No. 71-684 D

DEPARTMENT OF MINES — SOUTH AUSTRALIA

ONSHORE EUCLA BASIN — S.A.

BOUGUER GRAVITY ANOMALIES

PETROLEUM GEOLOGY SECTION	B.C. Youngs GEOLOGIST	Drn. B.C.Y.	SCALE : 1 : 1000 000
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		Ckd.	
Director of Mines	SEN. GEOLOGIST	Exd.	DATE : JANUARY 1974

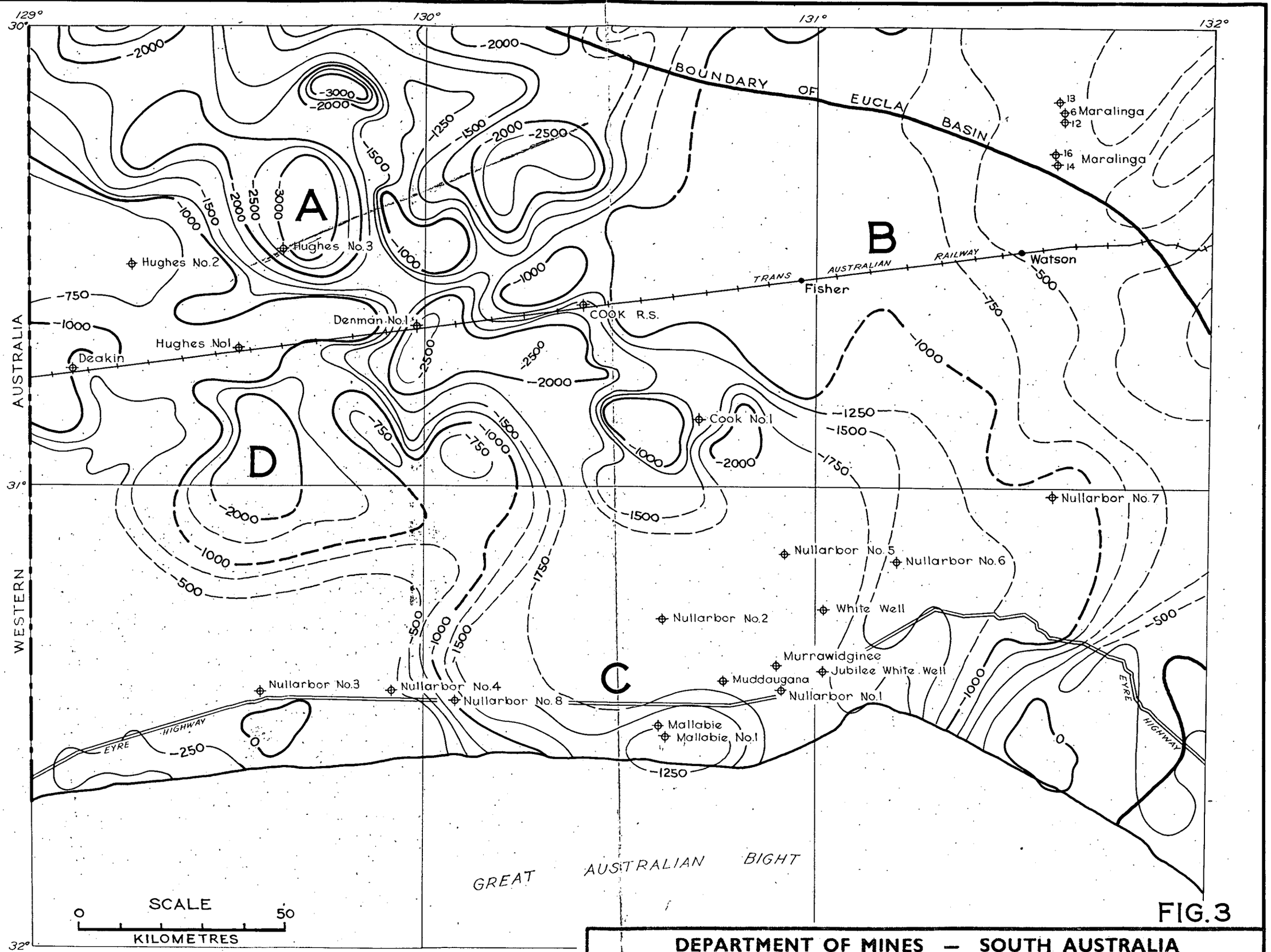

FIG.3

LEGEND

-500- Contour showing interpreted depth to magnetic basement in metres

A, B Refer to areas mentioned in "Recommendations for further work."

Taken from State 1:1000000 Depth to Magnetic Basement 73-143D

DEPARTMENT OF MINES — SOUTH AUSTRALIA

ONSHORE EUCLA BASIN — S.A.

DEPTHS TO MAGNETIC BASEMENT

PETROLEUM GEOLOGY SECTION	B.C. Youngs GEOLOGIST	Drn. B.C.Y.	SCALE: 1:1000 000
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Director of Mines	SEN. GEOLOGIST	Exd.	DATE: JANUARY 1974

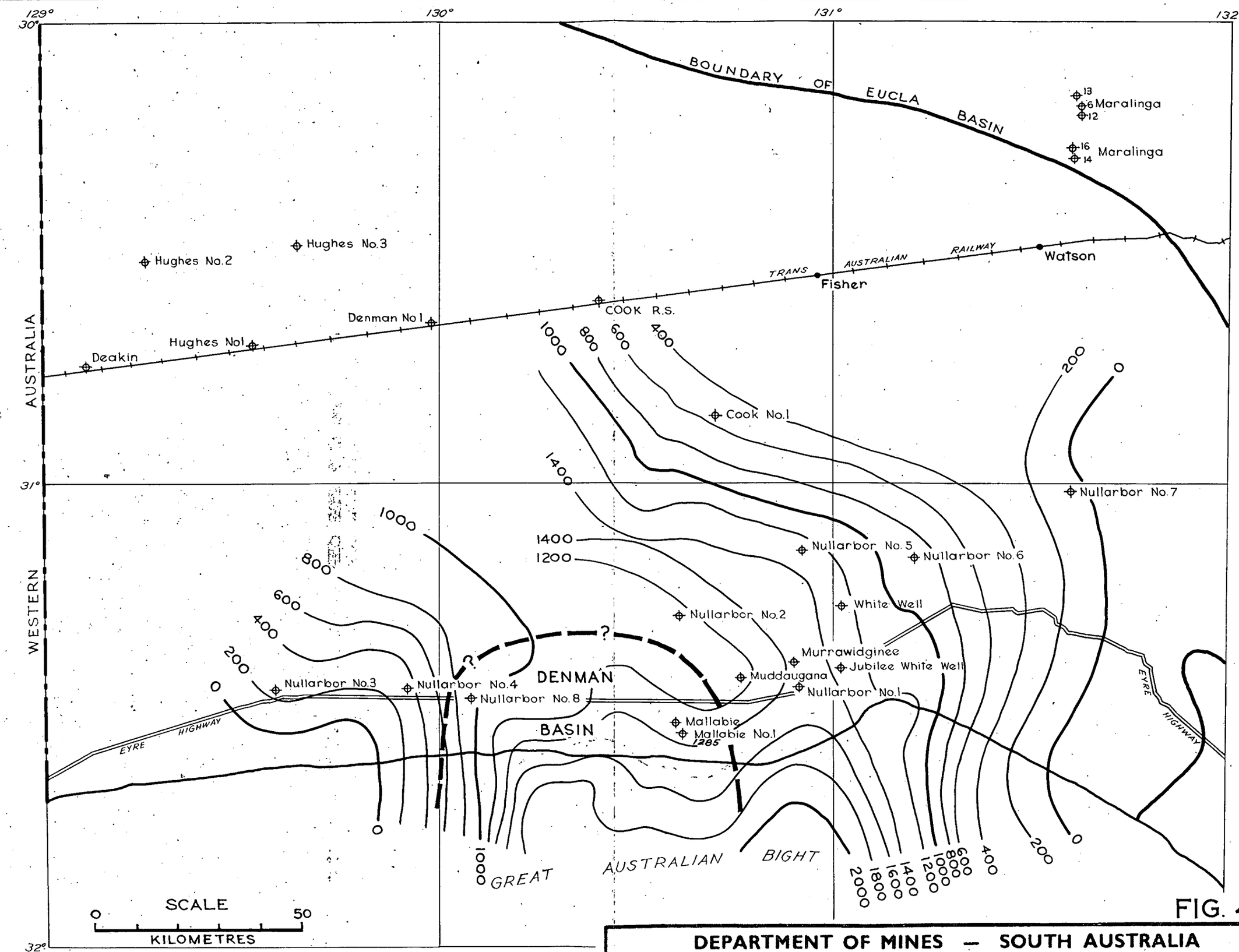

FIG. 4

LEGEND

200 Depth in metres below sea level to a high speed refractor

Taken from Scott and Speer 1969

DEPARTMENT OF MINES — SOUTH AUSTRALIA

ONSHORE EUCLA BASIN — S.A.

DEPTHS TO A HIGH SPEED REFRACTOR (PROBABLE PROTEROZOIC)

PETROLEUM GEOLOGY SECTION	B.C. Youngs GEOLOGIST	Drn. B.C.Y.	SCALE: 1:1000 000
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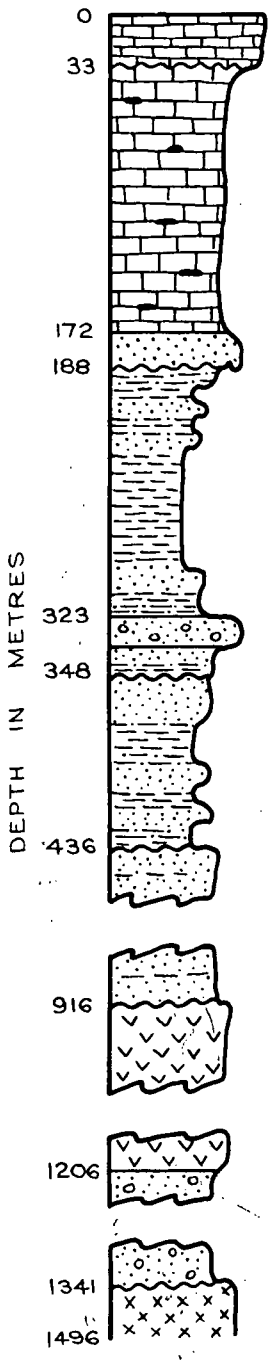
		Ckd.	
Director of Mines	SEN. GEOLOGIST	Exd.	DATE: JANUARY 1974



LOWER MIOCENE	Nullarbor Limestone	— White - cream, hard, crystalline biosparite.
UPPER EOCENE	Wilson Bluff Limestone	— White, compact, chalk containing chert and bryoza.
MIDDLE EOCENE	Hampton Sandstone	— Medium - coarse, quartz sandstone.
LOWER - ? UPPER CRETACEOUS	Madura Formation Equivalent	— Soft grey clays with minor sands and silts.
LOWER CRETACEOUS	Loongana Sandstone	— Granule conglomerate overlying glauconitic, pyritic sandstone. (NB. Possible lateral equiv. of Pidinga Fmn.).
LOWER PERMIAN	Unnamed	Sands, silts and grey claystones. Coarser elements occasionally at base
?CAMBRIAN	?Observatory Hill Beds	— Red - brown, fine - medium, sandstone with silty layers. Traces of gypsum. Some chert. (N.B. Red - green shales & dolomites in northern wells).
?PROTEROZOIC	?Gawler Range Volcanics	— Felspar porphyry.
	Unnamed	— Red - brown - white, medium granular sandstone.
?ARCHAEAN	Unnamed	— Granitic gneiss.

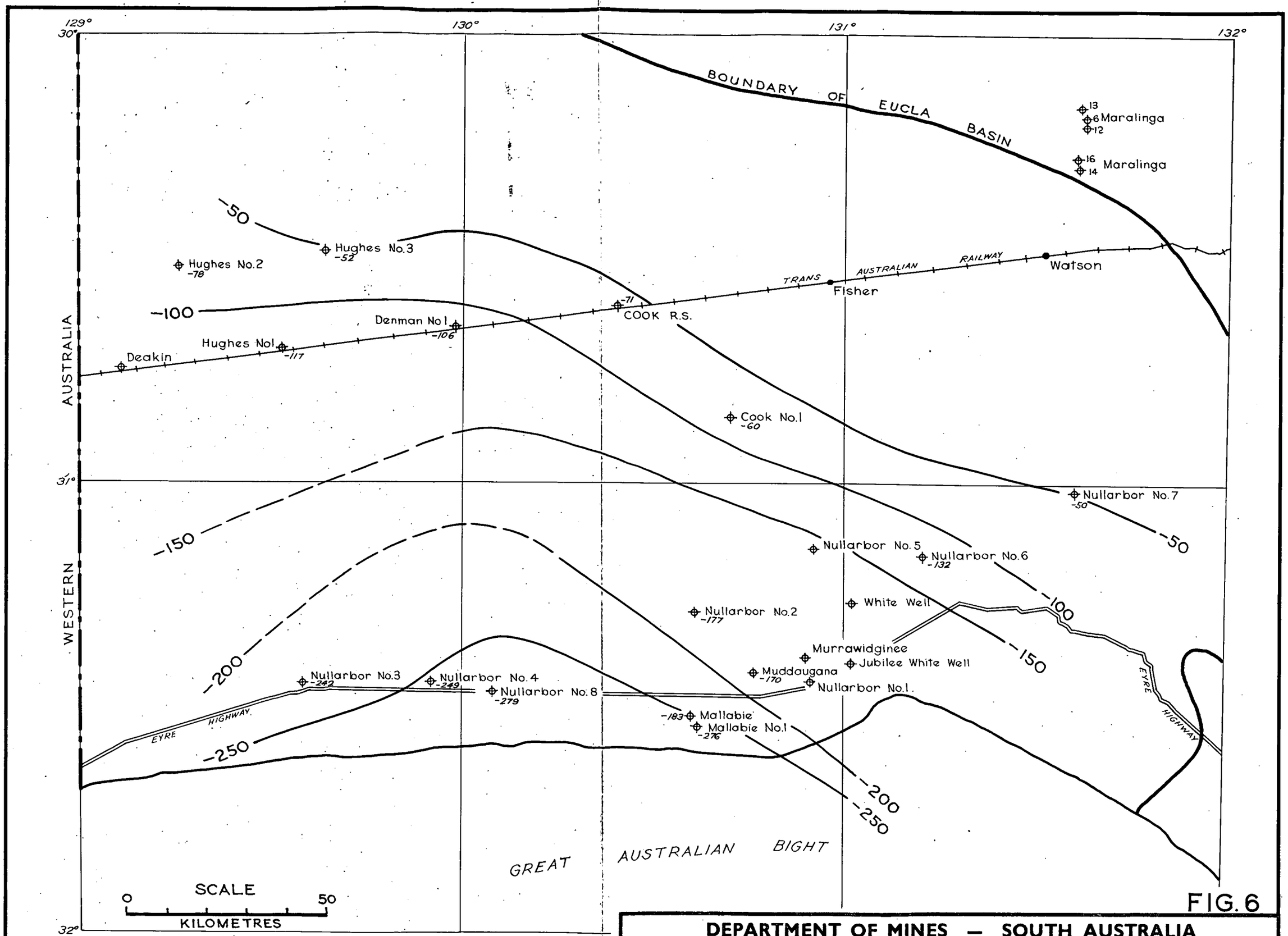
Data from Scott and Speer, 1969

FIG. 5

DEPARTMENT OF MINES — SOUTH AUSTRALIA

PETROLEUM GEOLOGY SECTION	Drn. B.Y.	ONSHORE EUCLA BASIN — S.A.	SCALE: 1:4000 (Approx)
	Tcd. A.F.	STRATIGRAPHIC COLUMN (MALLABIE NO. 1)	S 10712 A+D
	Ckd.		
	Exd.		DATE: JANUARY 1974

500-2,69 665



LEGEND

-100 Contour showing depth to base of Cretaceous in metres.

FIG. 6

DEPARTMENT OF MINES — SOUTH AUSTRALIA

ONSHORE EUCLA BASIN — S.A.

DEPTHS TO BASE OF CRETACEOUS

PETROLEUM GEOLOGY SECTION	B.C. Youngs GEOLOGIST	*Drn.* B.C.Y.	**SCALE:** 1:1000 000
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		Ckd.	
Director of Mines	SEN. GEOLOGIST	*Exd.*	**DATE:** JANUARY 1974

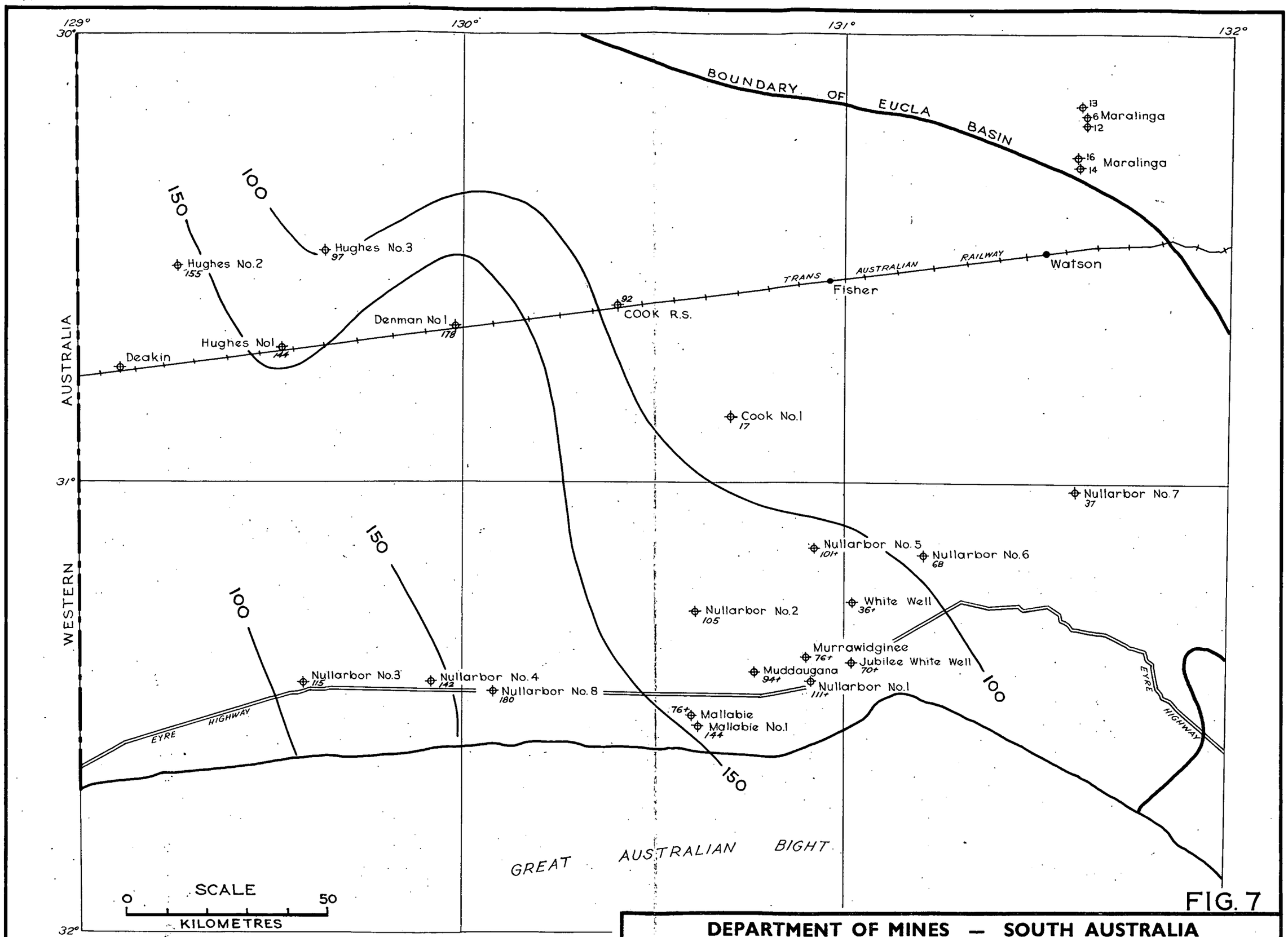

FIG. 7

LEGEND

100 — Cretaceous isopach (value in metres)

DEPARTMENT OF MINES — SOUTH AUSTRALIA

ONSHORE EUCLA BASIN — S.A.

CRETACEOUS ISOPACHS

PETROLEUM GEOLOGY SECTION	B.C. Youngs GEOLOGIST	*Drn.* B.C.Y.	**SCALE:** 1 : 1000 000
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		Ckd.	
Director of Mines	SEN. GEOLOGIST	*Exd.*	**DATE:** JANUARY 1974

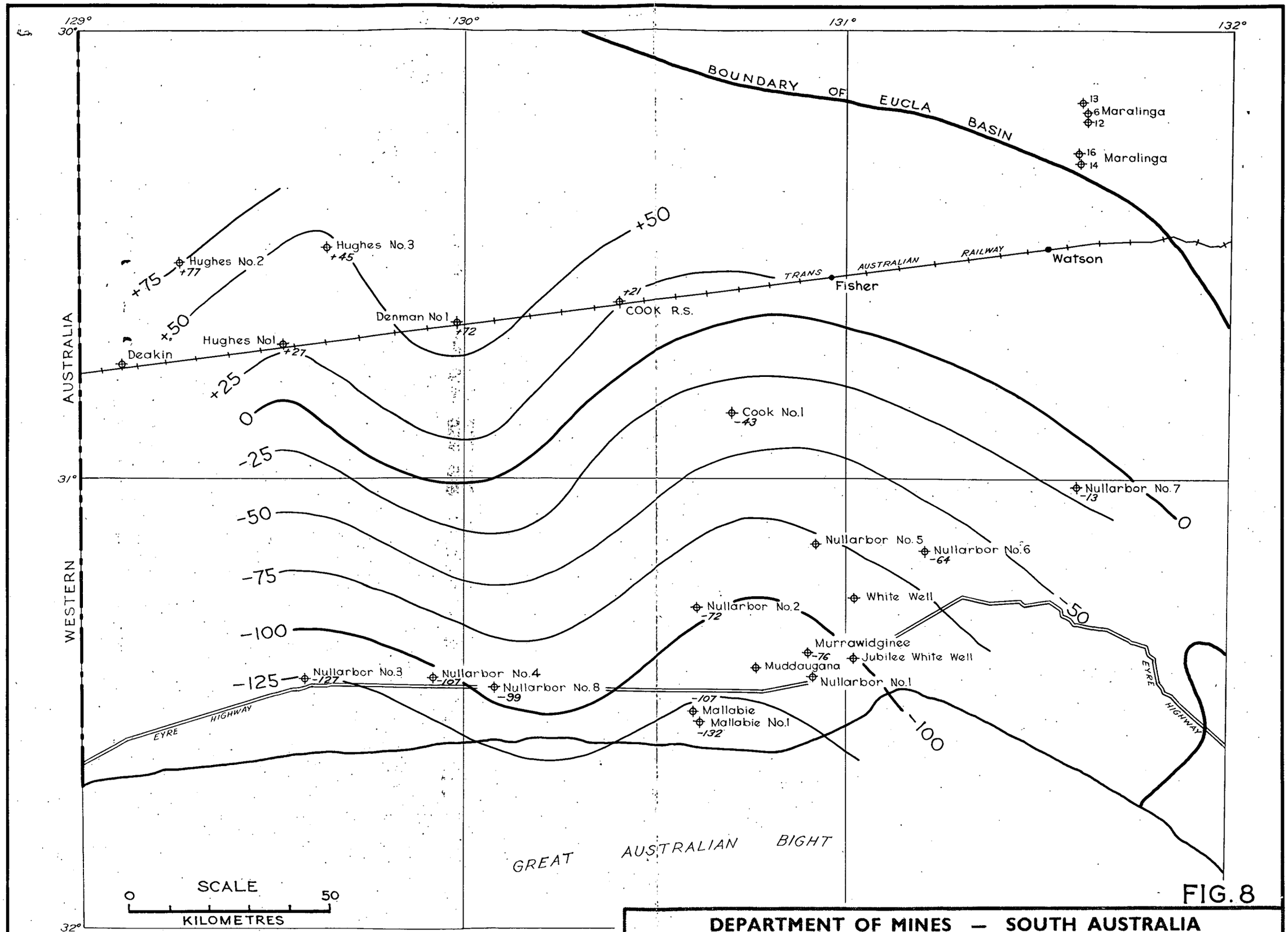


FIG. 8

LEGEND

-50 Depth to base of Tertiary in metres below sea level.

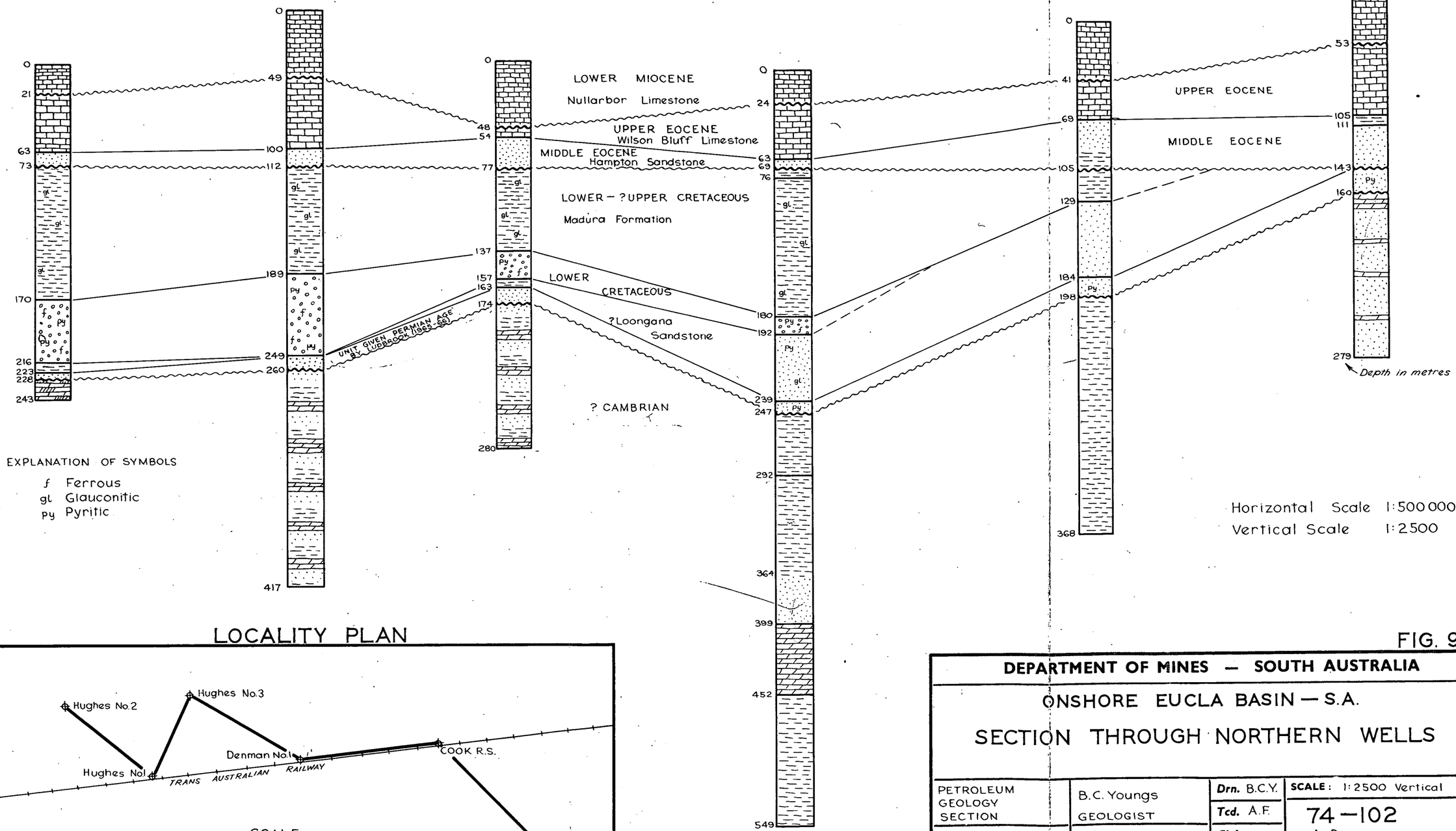
DEPARTMENT OF MINES — SOUTH AUSTRALIA

ONSHORE EUCLA BASIN — S.A.

DEPTHS TO BASE OF TERTIARY

PETROLEUM GEOLOGY SECTION	B.C. Youngs GEOLOGIST	Drn. B.C.Y.	SCALE : 1 : 1000 000
		Tcd. A.F.	74 — 47 A+D
		Ckd.	
Director of Mines	SEN. GEOLOGIST	Exd.	DATE : JANUARY 1974

HUGHES NO.2 | HUGHES NO.1 | HUGHES NO.3 | DENMAN NO.1 | COOK R.S. | COOK NO.1



EXPLANATION OF SYMBOLS

f Ferrous
gl Glauconitic
py Pyritic

Horizontal Scale 1:500 000
Vertical Scale 1:2500

LOCALITY PLAN

FIG. 9

DEPARTMENT OF MINES — SOUTH AUSTRALIA

ONSHORE EUCLA BASIN — S.A.

SECTION THROUGH NORTHERN WELLS

PETROLEUM GEOLOGY SECTION	B.C. Youngs GEOLOGIST	Drn. B.C.Y.	SCALE: 1:2500 Vertical
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Director of Mines		Ckd.	
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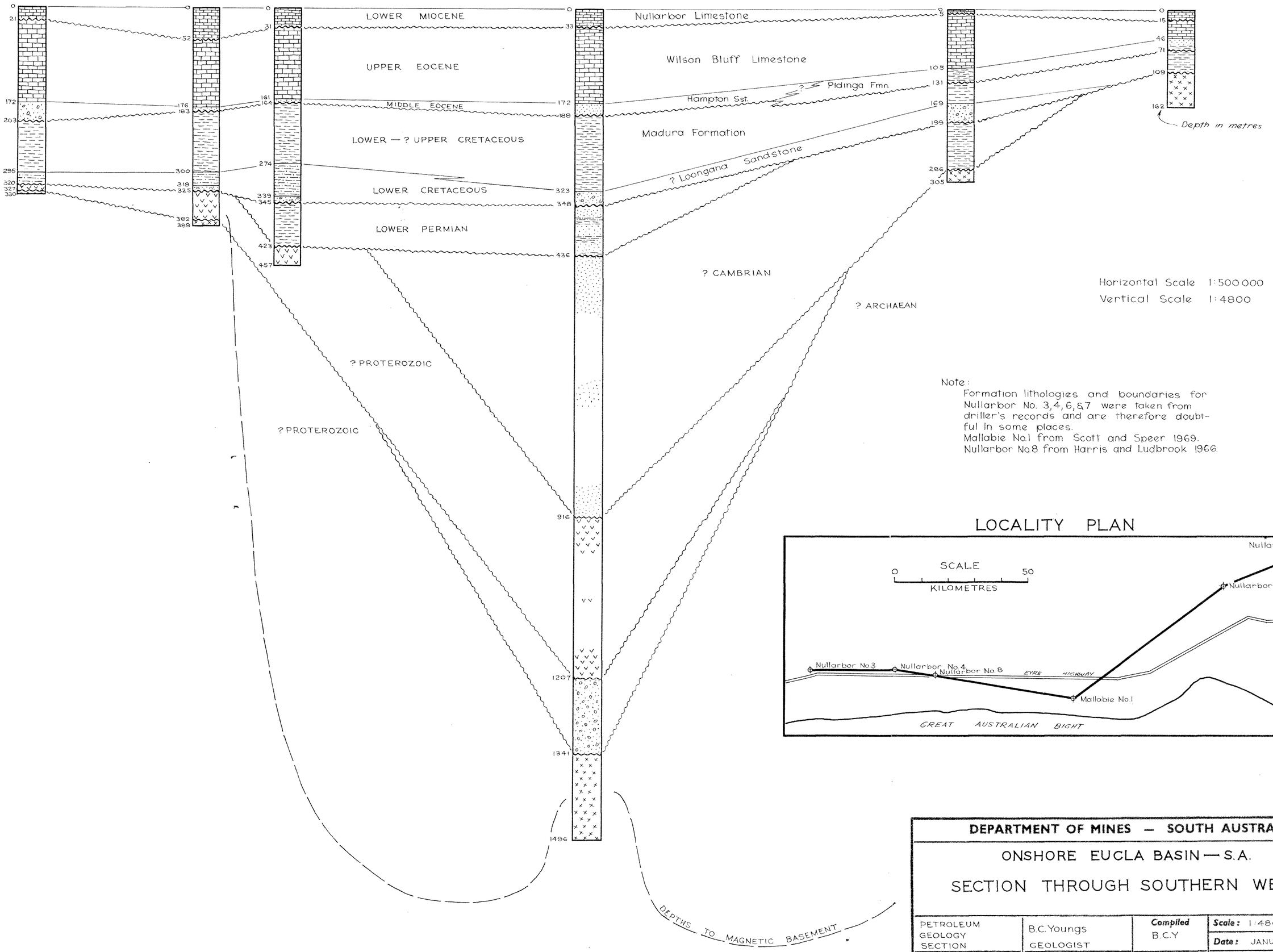

Note:
Formation lithologies and boundaries for Nullarbor No. 3,4,6,&7 were taken from driller's records and are therefore doubtful in some places.
Mallabie No.1 from Scott and Speer 1969.
Nullarbor No.8 from Harris and Ludbrook 1966.

LOCALITY PLAN

FIG. 10

DEPARTMENT OF MINES — SOUTH AUSTRALIA

ONSHORE EUCLA BASIN — S.A.

SECTION THROUGH SOUTHERN WELLS.

PETROLEUM GEOLOGY SECTION	B.C. Youngs GEOLOGIST	Compiled B.C.Y	Scale: 1:4800 Vertical
			Date: JANUARY 1974
Director of Mines		Drn. A.F. Ckd.	Drg. No. 74—103 A+D

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