BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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Record 1979/20

A REVIEW OF PETROLEUM EXPLORATION AND PROSPECTS
IN THE GREAT AUSTRALIAN BIGHT REGION

by

C.S. Robertson, D.K. Cronk, E. Nicholas, S.J. Mayne,
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SUMMARY

Petroleum exploration carried out in the Great Australian Bight region up to December 1976 has been reviewed to provide an assessment of existing information on the region and to determine the need for further exploration.

The region reviewed lies along the southern margin of the Australian continent both onshore and offshore in Western Australia and South Australia, extending from Point d'Entrecasteaux to Cape Jaffa.

A number of Cainozoic or Mesozoic-Cainozoic sedimentary basins are recognised in the region, the development of which was dominated by the tectonic events preceding and subsequent to the onset in the Eocene of the separation of Australia from Antarctica. The basins are, from west to east, The Bremer, Great Australian Bight, Eucla, Polda, and St Vincent. Of these, in terms of plate-tectonic theory, only the wholly offshore Great Australian Bight Basin contains a complete Atlantic-margin-type sequence comprising Early Cretaceous to Early Tertiary continental to shallow-water restricted-marine clastic sediments, overlain by Tertiary holomarine carbonates. A regional unconformity representing the onset of seafloor spreading occurs in the upper part of the clastic sequence. Except for the Polda, the other basins contain Cainozoic sediments deposited after the onset of seafloor spreading. The relationship of the Polda Basin, (in which Late Jurassic and Tertiary sediments have been intersected), and particularly the offshore Elliston Graben, to the tectonic events leading to continental break-up is more speculative.

A number of intra-cratonic infra-basins also occur in the Bight region. ?Adelaidean-Early Palaeozoic sediments of the Officer Basin extend southwards beneath the Eucla Basin. Permian sediments in the Denman Basin beneath the eastern Eucla Basin possibly constitute an arm of the Arckaringa Basin, and the widespread Cretaceous sediments beneath the Eucla Basin may be an extension of the Eromanga Basin. In the Gulf St Vincent area Permian sediments of the Troubridge Basin, and Cambrian sediments of the Stansbury Basin, underlie and bound the Cainozoic St Vincent Basin.

No hydrocarbon discoveries have been made in the Great Australian Bight region and there has been no exploration activity since 1976. The data acquired up to that time is discouraging in all parts of the region except the Great Australian Bight Basin in which all the factors necessary for hydrocarbon generation and entrapment seem to be present. The three wells drilled in this basin were not optimally sited for hydrocarbon entrapment, and further drilling, particularly in the deep-water areas, is considered desirable.

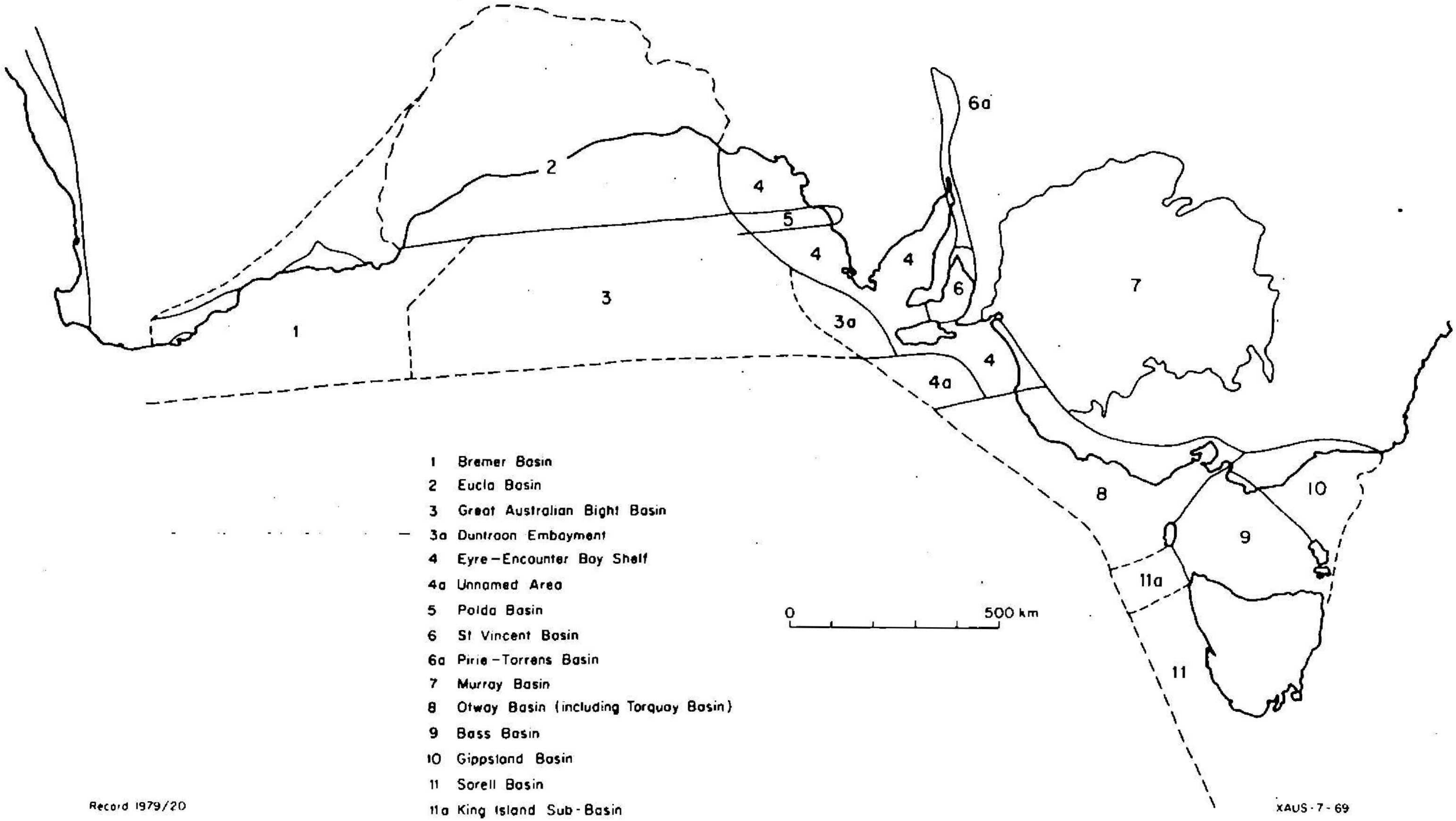


Fig. 1 Basins of southern Australia

1. INTRODUCTION

This Record is a summary of petroleum exploration and prospects in the whole of the region extending from the western boundary of the Bremer Basin in the west to the eastern end of the Eyre-Encounter Bay Shelf in the east (Fig. 1). Although in broad terms the basins further east share a common tectonic history with the Bight region it has been convenient to consider them in separate reviews, since the Otway and Gippsland Basins in particular involve a very large amount of exploration data.

In addition to the basins named in Figure 1, the Bight region contains a number of infra-basins which are generally of low prospectivity for petroleum but for completeness are included in the review.

Onshore, geological mapping by the respective State Surveys has resulted in the publication of 1:250 000 scale Geological Series maps for the three sheets covering the Bremer Basin, for all the Western Australian part of the Eucla Basin and one sheet area of the South Australian part, and for the Gulf St Vincent area.

The geology of the region has been described by Lowry (1970), Playford and others (1975a & b), Pattinson and others (1976), and in Parkin (1969). The subsurface data has largely resulted from petroleum exploration.

This summary is based mainly on information available to the Bureau of Mineral Resources, Geology and Geophysics (BMR) up to December 1977. Much of the petroleum exploration carried out onshore by industry in the region up to 1974 was subsidised by the Australian Government under the terms of the Petroleum Search Subsidy Act (PSSA). Final reports on subsidised wells and subsidised geophysical surveys containing both basic and interpretative data, are available to the public. Subsidised operations are identified as such in Appendices 1 and 2.

Reports on surveys carried out by BMR and the State Geological Surveys are also publicly available.

Data from unsubsidised company operations may or may not be available to the public. Under the provisions of the Petroleum (Submerged Lands) Act (P(SL)A), which applies to operations in offshore areas since 1968, the Designated Authority for the State in question may publicly release basic (non-interpretative) data from exploration operations five years or more after their receipt, or after the operator has relinquished title to the areas in which the operations were carried out. Therefore, some of the data from unsubsidised company operations mentioned in this review may not yet be available to the public.

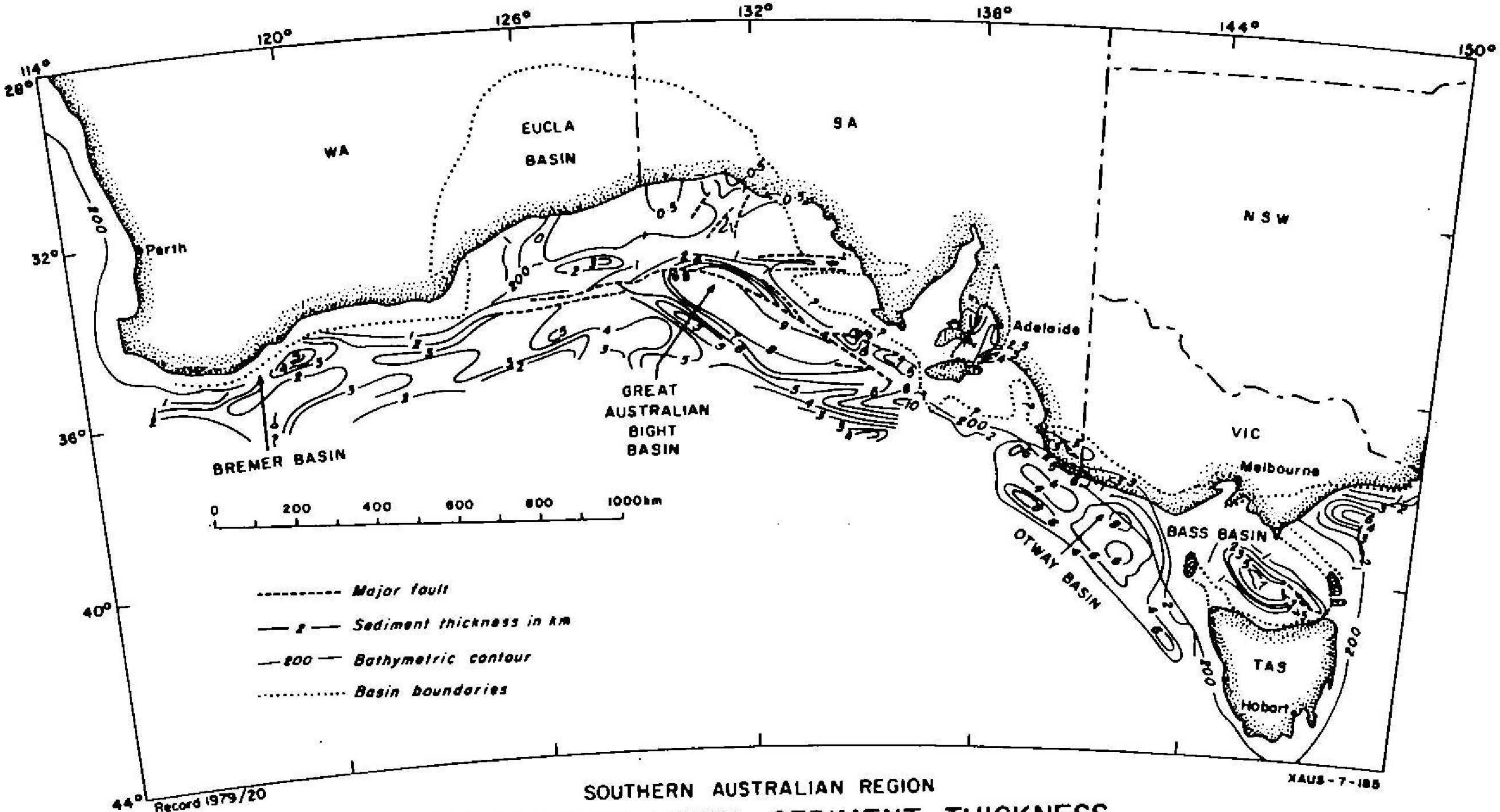
2. REGIONAL TECTONIC SETTING

Broadly speaking, the geologic framework of the area under review (Pls. 1, 7) consists of the southern part of the Archaean Australian Shield, i.e. the Yilgarn Block of Western Australia and the Gawler Block of South Australia separated by a depressed region wherein sediments of no great total thickness have accumulated at intervals from Proterozoic times onwards. On the eastern edge of the Gawler Block the Adelaide Fold Belt, including the Kanmantoo Trough, consists of sediments of from Adelaidean (Late Proterozoic) to Cambrian age that were variably modified by tectonic events that culminated in the Delamerian Orogeny of the Ordovician. Elsewhere in the Great Australian Bight region limited thicknesses of Palaeozoic sediments occur in poorly explored infra-basins, and very little is known about their tectonic history.

The tectonic history of the region during the post-Triassic period in which the bulk of the sediments of interest to petroleum exploration were deposited, is dominated by the tectonic events which resulted in the separation of Australia from Antarctica. It will therefore be helpful to outline the main sequence of these events here.

The separation of Australia from Antarctica has been interpreted in terms of plate-tectonic theory by Griffiths (1971) and Boeuf and Doust (1975). Considering the southern margin of Australia as an aseismic Atlantic-type continental margin (Falvey, 1974), a number of stages in its development according to the Atlantic model can be recognised in the region reviewed (Pl. 9). There are indications that the first, taphrogenic stage was initiated in the Late Jurassic, some 150 million years B.P. Minor faulting took place and old faults were reactivated, especially in the Adelaide Fold Belt and the Polda Basin. Fluviatile-lacustrine sediments were deposited in topographically low areas. There was crustal subsidence in areas adjacent to the taphrogenic zone, possibly because of the lateral movement of subcrustal material. Gentle downwarps developed in the Eucla Basin and Murray Basin areas, allowing shallow marine conditions to develop by intermittent incursions from the 'Eromanga Sea' to the north, and from a Baltic-type depression to the south.

The next stage was marked by major faulting and rift valley formation across the whole of the region under review. The main axis of the rift valley system is indicated by the Outer Continental Margin Ridge (Plates 1, 7, and 9) which today is situated approximately along the 36th parallel. Cuesta-like fault blocks dipped away from the axial zone of rift formation, the most significant blocks being those that formed the Great Australian Bight Ridge and



SOUTHERN AUSTRALIAN REGION

Fig. 1a GENERALISED TOTAL SEDIMENT THICKNESS

Sediment thicknesses are based on seismic data obtained and interpreted by petroleum exploration companies and BMR the Outer Continental Margin Ridge. The Early Cretaceous sediments of the Eucla Basin area consist of shallow marine sediments grading southwards into fluvio-lacustrine sediments which are believed to have an erosional contact with basement rocks of the Great Australian Bight Ridge and to pinch out against the Outer Continental Margin Ridge. Volcanism, which was widespread in basins to the east of the region (Otway, Bass, Gippsland - Plate 8) has not hitherto been proven in the Great Australian Bight region, apart from Jurassic and Tertiary basalts on Kangaroo Island.

During the Late Cretaceous, subsidence continued along the rift valley adjacent to the present continental margin of southern Australia. The absence of Late Cretaceous sediments in some areas may be explained as the result of non-deposition or of post-depositional erosion along an uplifted portion of the rift valley axis (Boeuf and Doust, 1975).

Seafloor spreading between Australia and Antarctica seems to have begun at some time between the Late Paleocene and the mid-Eocene: the oldest seafloor magnetic anomaly is Anomaly 22 (Weissel and Hayes, 1972) which is dated 45-46 m.y. ago (Tarling & Mitchell, 1976) i.e. mid-Eocene, or 55 m.y. ago (Heirtzler and others, 1968) i.e. Late Paleocene. Data from D.S.D.P. Site 282 off the west coast of Tasmania (where Late Paleocene oceanic clay rests on basalt), and the fact that major faulting ended in early Tertiary times, can be interpreted as supporting the estimated time of initiation of seafloor spreading. However a restricted sea, on continental crust, similar to the present Baltic Sea probably existed from at least Early Cretaceous times.

As Australia moved northwards away from the spreading ridge, downwarping occurred on the continental margin, possibly as a result of cooling and thermal contraction (Falvey, 1974), allowing the accumulation of a considerable wedge of Tertiary carbonates on the shelf and slope.

From Plate 8 it may be seen that carbonate deposition began much earlier in the west than in the east, and was possibly due to the depletion in the supply of clastic sediments, as peneplanation of the continent became more advanced.

3. DEFINITION OF BASINS

The following is a brief description of the various basins or groups of basins occurring in the region. They are considered in detail in later chapters.

3.1 Eucla Basin area

The term 'Eucla Basin' has been applied by various authors to sediments of different age ranges. BMR (1969) restricted the term to the Tertiary strata. To provide the most comprehensive coverage, this review will deal under the heading 'Eucla Basin area' with both the Tertiary sediments and the underlying older Phanerozoic sediments.

Officer Basin The Officer Basin is the oldest sedimentary basin in the area. It outcrops over a wide area to the north of the Eucla Basin but little is known about it where it disappears beneath younger sediments in the south. A map in the 1972-73 Annual Report of the South Australian Mines Department shows the Officer Basin as extending for a full degree of latitude south of the southern limit of its exposure and for another degree still further south along the Mallabie Depression (see below). Some wells in the Eucla Basin have penetrated strata of pre-Permian age: these have been assumed to belong to the Officer Basin.

Denman Basin This term was coined (Wopfner, 1969) for Permian sediments encountered in the Mallabie Depression in the east of the Eucla Basin area (Pls. 1, 7, 11). This depression, first indicated by geophysics in the Head of Bight region, appears to be a broad valley extending northwards from near the coast and filled with Phanerozoic sediments. However, the Denman gravity 'low', from which the Denman Basin derives its name, coincides only approximately with the sedimentary infill of the Mallabie Depression. The South Australian Mines Department map mentioned previously shows these Permian rocks as constituting an elongate arm of the Arckaringa Basin. Consequently a more suitable term for them might be the 'Denman Lobe' of the Arckaringa Basin.

'Wylie Lobe' of the Eromanga Basin Well data indicate that Neocomian to Senonian Cretaceous beds, including marine strata, are widespread beneath the Tertiary Eucla Basin (Pls. 1, 9, 10). The micro-fauna in these beds has some similarity to that of the Eromanga Basin, and scattered remnants of Cretaceous rocks north of the Gawler Block support the notion of a Cretaceous sea connexion between the two areas. The name 'Wylie Lobe' is here used for this previously unnamed sequence. The long axis of the lobe appears to be approximately along the Transcontinental Railway and its sediments are probably thickest in the Mallabie and Madura Depressions. This latter term refers to a depression in

Precambrian basement indicated by seismic work near the coast west of the South Australian-Western Australian border and verified by the Madura No. 1 and Eyre No. 1 wells. The depression is similar to the Mallabie Depression on the other side of the Bight. It is possible that the 'Wylie Lobe' was connected to a Baltic Sea-type extension of the Indian Ocean as well as to the 'Eromanga Sea' (Pl. 9).

Eucla Basin The Eucla Basin is, in common usage, 'The artesian basin underlying the Nullarbor Plain, with highly mineralised water obtained in bores along the railway' - Learmonth's Encyclopaedia of Australia, 1968. Lowry (1970) has given a detailed account of the geology of the Eucla Basin in Western Australia, and the following definition stems in part from that work.

The Eucla Basin is that sequence of Cainozoic strata whose northern limits (Pls. 1, 7) are in the Great Victoria Desert in approximately latitude 29°30'S and whose southern limit is the Great Australian Bight Ridge in latitude 33°20'S. Its western limits trend from near Lake Gidgi in the north to Israelite Bay in the south, and its eastern limits, in South Australia, extend from near Lake Maurice through Fowlers Bay to the edge of the continental shelf (Pl. 1). The basin is thus about 800 km from east to west, and 450 km from north to south. The basal beds are of Eocene age and rest disconformably upon older Phanerozoic rocks and nonconformably upon crystalline basement.

Lowry, however, included the underlying Permian and Cretaceous sediments in the Eucla Basin.

3.2 Great Australian Bight Basin

The Great Australian Bight Basin is wholly an offshore basin containing Cretaceous and Cainozoic sediments which rest on continental crust seawards of about the 200 m isobath across most of the Bight. It extends under the Eyre Terrace and the Ceduna Terrace (Pl. 7), and under the continental rise south of the terraces, from about 124° to 136°E. The northern limits of the basin are defined by a basement ridge, the Great Australian Bight Ridge (Boeuf and Doust, 1975), which separates it from the Eucla Basin (Pls. 1, 7, 9). Upper Cretaceous sediments in the basin wedge out against this ridge, and Lower Cretaceous sediments either wedge out or are in faulted contact with it. The ridge is part of a stable basement platform which dips gently to the south and southwest, and which further into the basin is bounded on the southern margin by a system of major faults trending west-east to northwest-southeast with considerable down-to-the-basin throw.

A wedge of Mesozoic and Tertiary sediments unconformably overlies the block-faulted and collapsed continental basement. The sediments reach a maximum thickness of up to 10 km in the deeper part of the basin, usually below the continental shelf and slope, and thin to the north against shallow basement (Boeuf and Doust, 1975).

The southern boundary of the Great Australian Bight Basin has not so far been clearly defined but for the purpose of this study is taken as the Diamantina Fracture Zone in the west of the basin area (Willcox, 1978) and the outer edge of the continental rise in the east.

The Duntroon Embayment ('Duntroon Basin' of Smith and Kamerling, 1969) lies at the eastern end of the Great Australian Bight Basin on the edge of the continental shelf south of Eyre Peninsula and west of Kangaroo Island. It extends over an area of some 24 000 km^2, being restricted to the north and northeast by an en-echelon system of northwesterly and westerly-trending major faults, to the east by a system of fault-bounded, westerly-plunging basement blocks, and to the south (during at least part of the Mesozoic) by an area of elevated magnetic basement on the continental slope. Results of the BMR Continental Margin survey indicate that the western side of the embayment probably extends from the upper continental slope northwards across the Ceduna Terrace. The sedimentary section is up to 6 km thick. Almost half of the sediments (over 2500 m) are Early Cretaceous in age, and overlie down-faulted basement with angular unconformity.

3.3 Bremer Basin

The Bremer Basin, south of the Yilgarn Block in Western Australia, occupies the westernmost part of the area of Cretaceous-Cainozoic sedimentation that was inaugurated by the separation of Australia from Antarctica. The basin includes onshore Eocene beds west of the general area of the Archipelago of the Recherche, and offshore sediments to the bottom of the continental slope.

In the east-west direction the basin extends from the southern end of the Darling Fault near Point d'Entrecasteaux to the western corner of the Great Australian Bight near the Archipelago of the Recherche. The onshore limits are highly irregular, since the basin sediments occur as several discrete and isolated outliers on crystalline basement as far as 150 km from the coast. The offshore part of the basin is by far the larger, but about a half of this is within an area of shallow basement, with high areas of crystalline rock actually occurring as islands, e.g. the Archipelago of the Recherche.

3.4 Polda Basin

In this report the term 'Polda Basin' is used for that tectono-sedimentary feature shown on the Tectonic Map of Australia (Geological Society of Australia, 1971) on the east side of the Bight as the 'Polda Trough', but referred to in the literature by a variety of names. In order to compromise with various usages, the Polda Basin is herein considered to consist of two parts, the Polda hydrologic basin, and the Elliston Graben (Pls. 1, 7). The Polda hydrologic basin is that unit to which the name 'Polda Basin' was originally applied by J.T. Miller in 1928 when he described the hydrologic basin on Eyre Peninsula. This basin, originally described but not named in 1912 by Jack, was clearly envisaged by these early authors as an erosional depression in the Precambrian rocks infilled with young water-bearing deposits.

The Elliston Graben has been defined by geophysics. It extends westwards from Anxious Bay on Eyre Peninsula to about 132°E where it debouches onto the continental slope, whilst it extends onshore for about 15 km to terminate against a basement ridge which apparently separates the graben from the Polda Hydrologic Basin to the southeast. The east-trending graben is about 30 km wide by about 300 km long. The small onshore part of the graben is called the Talia Lobe.

3.5 Eyre-Encounter Bay Shelf

The Eyre-Encounter Bay Shelf extends as an area of shallow basement along the eastern margin of the Bight, around Eyre Peninsula and Kangaroo Island and offshore from the coast between Encounter Bay and Cape Jaffa. Spencer Gulf is included in the Shelf, but not Gulf St Vincent. It is thought that only thin Cainozoic sediments blanket the Shelf, the seaward edge of which is generally the edge of the continental shelf at 200 m. As already indicated, the Duntroon Embayment immediately west of Kangaroo Island is considered to be a part of the Great Australian Bight Basin.

3.6 Gulf St Vincent area

The Gulf St Vincent area is here considered to be, broadly, that area around the Gulf between the Gawler Block on the west and the Flinders Ranges-Fleurieu Peninsula on the east. The following basins are recognised in the area:

1. Stansbury Basin
2. Troubridge Basin
3. St Vincent Basin (and its northern extension, the Pirie-Torrens Basin)

Stansbury Basin   The Stansbury Basin is a sequence of Cambrian sediments occurring on Yorke and Fleurieu Peninsulas, Kangaroo Island and, it is assumed, beneath the waters of Gulf St Vincent (Pl. 1). It is mentioned by Wopfner (1969), but Crawford (1965) referred to the Cambrian sediments as the Dalrymple Basin.

Troubridge Basin   The Troubridge Basin (Wopfner, 1969) covers very much the same area as the Stansbury Basin. The beds are Early Permian in age, and consist of glacigenic sediments. Permian beds are also known from the Encounter Bay-Coorong area, and these may represent an extension of the Troubridge Basin from the Fleurieu Peninsula southeastwards.

St Vincent Basin   The St Vincent Basin is a sequence of Cainozoic sediments very largely submerged beneath the waters of Gulf St Vincent, but occurring onshore in restricted areas along the eastern and western shores and somewhat more extensively along the northern shore of the Gulf. Some boundaries of the basin are erosional-depositional contacts between the Cainozoic sediments and Adelaidean or Permian basement, whilst others are faults of the South Australian Rift Valley (see Chapter 8, Tectonic history and structure). The southwestern boundary is an arbitrarily drawn line between the 'sole' of Yorke Peninsula and Kangaroo Island. The St Vincent Basin constitutes only the southern end of a Cainozoic structural and depositional basin that extends sinusoidally from Investigator Strait to the northern end of Lake Torrens.

4. EUCLA BASIN AREA

4.1 Tectonic history and structure

Officer Basin   Little is known about the structure of the Officer Basin sediments beneath the Eucla Basin. It seems probable that they are little disturbed tectonically and that they show a gentle regional dip towards the Officer Basin depocentre to the north.

<u>Denman Basin</u> In the Eucla Basin area Permian sediments have been encountered only in a few wells in the Mallabie Depression. This feature is, on the evidence of gravity data, assumed to be a broad shallow valley (Pl. 10) leading northwards to the thick depositional basin south of the Musgrave Block. It is not known whether this valley is developed in crystalline basement or in Officer Basin sediments. The Permian sediments are attributed to glacial action and have been laid down in a shallow sea, perhaps an arm of the 'Arckaringa Basin sea' that extended into the Mallabie Depression. There is nothing to suggest that the Denman Basin sediments are other than flat-lying. They are expected to have suffered nothing but the mildest tectonism, if indeed any at all.

<u>'Wylie Lobe' of the Eromanga Basin</u> The Early Cretaceous sediments of the Eucla Basin area have been linked with the Eromanga Basin on the evidence of the marine micro-fossils they contain. The basal Cretaceous beds are interpreted as marginal marine swamp deposits and shoreline clastics laid down over a pene-plained surface cut in the older rocks. There would probably have been original slight dips towards the centre of the marine embayment - northwards from the Great Australian Bight Ridge area, southwards from the Musgrave Block direction. The Cretaceous beds have, however, a regional dip to the south imposed upon them as a result of Cainozoic sagging towards the developing Southern Ocean. The shallow-marine regimen of Early to Middle Cretaceous times would have been ended by quite slight epeirogenic uplift, whereupon the whole area became one of subaerial erosion and remained so for the next 50 million years until the great Eocene transgression began. Seismic surveys have revealed a mosaic of fault-blocks in the offshore area, and also several anticlinal features which, in the area of the Mallabie Depression at least, appear to have a preferred NW-SE orientation.

<u>Eucla Basin</u> The Eucla Basin sediments are virtually flat-lying, with an almost imperceptible regional dip to the south (Pl. 10). They rest with erosional unconformity on Cretaceous and older rocks. There are disconformities between several units of the basin sequence. These disconformities were caused by regional uplifts during the Oligocene and again during the Early Miocene. Lowry (1970) shows the base of the Tertiary as being at about 150 m above M.S.L. in the north, about 230 m below M.S.L. near the present day coast, and about 600 m below M.S.L. near the southern limits of the basin.

A few straight fault scarps have been detected trending north-south for several kilometres, the faults involved having throws of up to 60 m. Lowry (1970) mentions that in some areas the Eucla Basin limestones are well-jointed, the joints being 100 to 1500 m apart. Firman (1974) described "structural lineaments" of mega size revealed by a study of ERTS mosaics. The lineaments have preferred orientations NW and NE and are assumed to be mostly faults and joints related to structures in the basement.

4.2 Stratigraphy

Detailed stratigraphic sections are given in Appendix 3, the disposition of beds is indicated in Plate 10, and their areal extent given in Plate 1.

Basement The rocks of the crystalline basement consist of granites, gneisses, schists, and granulites.

In the review area there are several occurrences of pre-Mesozoic rocks that have been ascribed to the Officer Basin, which is also here considered to be an element of the basement:

1. Ilma Beds These are described by Lowry (1970) as consisting of medium-grained sandy oolite, occurring as an inlier near the northern limits of the Eucla Basin. The Ilma Beds are several hundreds of metres thick and have probably been both faulted and folded. The surrounding rocks are basin-margin beds of the Eucla Basin, the Colville Sandstone (App. 3). There is some slight fossil evidence that the Ilma Beds may be of Adelaidean age.
2. Assumed Officer Basin strata in petroleum wells Between the Gawler and Musgrave Blocks the Officer Basin sequence includes strata from Adelaidean to Devonian age, belonging in many cases at least, to shelf carbonate and clastic facies.

The three Hughes wells on the Nullarbor Plain near the South Australian -Western Australian border (Pl. 1, App. 3) penetrated about 45 m (average) of dolomite overlying about 140 m of redbeds. Denman No. 1, to the east of these, penetrated over 300 m of pre-Permian redbeds including over 100 m of dolomite. Cook No. 1, north of the Head of Bight, terminated in a carbonate sequence more than 100 m thick. These occurrences of carbonates and redbeds invite correlation with the Cambrian formations of the Stansbury Basin of Yorke Peninsula.

Mallabie No. 1 well at the Head of Bight (Pl. 1) penetrated several hundred metres of redbeds with basalt, but without dolomites (App. 3).

The basalts have been subjected to burial metamorphism, and resemble the Roopena Volcanics of northern Eyre Peninsula more than any others. The Roopena, Woollana, and Nacoona Volcanics, all occurring on the northern Eyre Peninsula, are placed, on stratigraphic and radiometric data, in the Willouran (i.e. the oldest) series of the Adelaidean System. This would suggest that the sediments are to be compared with the River Wakefield Group or the Burra Group of the Adelaide 'Geosyncline'.

<u>Permian</u> Permian sediments are widespread in central Australia, although they have only scanty outcrops. The earliest Permian unit is everywhere taken to be of glacial or periglacial origin, and is of Sakmarian (or even Late Carboniferous) age.

In the northern part of the Eucla Basin area the Wilkinson Range Beds cover thousands of square kilometres and consist commonly of coarse tillites, possibly ice-rafted. They are overlain in part by Colville Sandstone of the Eucla Basin and Quaternary deposits. They are thought to overlie Officer Basin beds. The thickness of the Wilkinson Range Beds is unknown but it may not be more than a maximum of 30 or 40 m, and is generally far less.

In the Denman Basin, Permian sediments have been recognised in Yangoonabie bore (Nullarbor No. 8) (Harris and Ludbrook, 1966), Mallabie No. 1 and Apollo No. 1, and farther north, Ludbrook (1966) has ascribed a Permian age to sediments intersected below the Cretaceous sequence in Hughes Nos. 1-3, and Denman No. 1.

The Mulgathing Trough (Nelson, 1976), north of Ceduna (Pl. 7) is 30 to 40 km long and about 7 km wide. It is set in granitic basement and is filled with up to 500 m of blackish mudstone and shale and basal sandstone of Early Permian age. There is no indication of marine influence, and the coarse clastics could be glacigenic. The Permian beds are overlain by fine-grained Tertiary silts, sands and clays, which could be Pidinga Formation equivalents.

Steep gravity gradients and seismic reflections suggest that the southern margin of this trough is fault-controlled.

<u>Cretaceous</u> Cretaceous rocks have been met with in most wells in the Eucla Basin area (Fig. 3, Pl. 8). Two formations are recognised, a lower formation consisting of coarse sandstone or basal conglomerate, named the Loongana Sandstone, and an upper formation named the Madura Formation, consisting of

interbedded siltstones, sandstones, and mudstones. The Loongana Sandstone is of Neocomian-Aptian age, and the Madura Formation is of Aptian-early Senonian age. The environment of deposition was shallow marine, in contrast to the fluviatile environment prevailing at the same time in the northern marginal part of the Great Australian Bight Basin. This together with the nature of the marine fossils has led to the postulate that the Madura Formation and the Loongana Sandstone were laid down in an arm of the sea that connected northeastwards with the 'Eromanga sea'. Most of Australia was submerged at this time, and the region probably resembled, cartographically if not climatically, the Arctic Islands region of present-day Canada.

Tertiary The following stratigraphic information is derived from Lowry (1970) and Playford and others (1975a). Depositional history is illustrated in Plate 8. For some 30 million years after the withdrawal of the 'Eromanga Sea' in the Middle Cretaceous, the region was probably exposed to subaerial erosion, while the fragmentation of Australia-Antarctica proceeded to the south. In the Middle Eocene the great Tertiary flooding of southern Australia began, and in the Eucla Basin area this transgression was represented by the various basal formations of the Eucla Basin. These formations, which are doubtless facies variants of the one phase, are composed of the shoreline sands of the Hampton Sandstone (chiefly in Western Australia), and the lignites, carbonaceous clays and silts of the Pidinga Formation in South Australia. The Pidinga Formation is indeed only one example of a quite common Eocene situation in the South Australian region, others being the Wanilla Formation on Eyre Peninsula, the North Maslin Sands and the Clinton Coal Measures in the St Vincent Basin, and the Eocene Beds in the Pirie-Torrens Basin. The Pidinga Formation is of Middle Eocene age and although it is dominantly terrestrial its upper horizons record the beginning of the great Eocene marine transgression.

The next phase of sedimentation was the deposition of the thickest formation in the Eucla Basin, the Wilson Bluff Limestone and its variant the Toolinna Limestone (Pl. 10). The Wilson Bluff Limestone 'consists mainly of white, chalky, bryozoan calcarenite, with horizons of chert nodules, and also includes a unit of soft, glauconitic marl near the base of the formation in the Madura area (Playford & others, 1975a). The maximum thickness of about 300 m is reached in Eyre No. 1 well, and the formation is widely distributed in the basin. The upper part of the Wilson Bluff Limestone grades laterally into the Toolinna Limestone in the western and southwestern parts of the basin. This limestone is a 'medium to very coarse-grained, well-sorted, current-bedded, bryozoan calcarenite' (Playford & others, 1975a) which grades by facies change into the basin-margin Pallinup Siltstone of the Bremer Basin in the west.

The 12 million years of the Oligocene epoch was largely a time of non-deposition if not of actual erosion in the Eucla Basin.

In the Late Oligocene or Early Miocene the Abrakurrie Limestone was laid down disconformably on the Eocene limestones (Pl. 10). Lowry describes it as 'a yellowish, medium to very coarse-grained, well-sorted bryozoan calcarenite, which is commonly current-bedded'. The greatest known thickness is 91 m near Madura, and it is largely restricted to Western Australia south of the railway.

In the Middle Miocene the Nullarbor Limestone/Colville Sandstone Formations were laid down disconformably on the older limestones, the former as a carbonate-shelf deposit, the latter as a basin-margin accumulation. The limestone is widespread on the Nullarbor Plain, and is 'a hard, poorly sorted calcarenite composed mainly of entire or fragmented foraminifera and calcareous algae'. The maximum known thickness is 31 m. The base of the formation in the Madura area consists of 'nodules of coralline algae up to 5 cm in diameter, set in a matrix of foraminiferal calcarenite', and has been designated the Mullamullang Limestone Member. Its maximum thickness is about 18 m. The Colville Sandstone (which contains subordinate claystone, limestone, and conglomerate) is 'known only from the northern margin of the basin, where it rests disconformably on the Permian Paterson Formation or unconformably on Proterozoic rocks'. The greatest known thickness is 23 m. However, the marginal facies of the Nullarbor Limestone in South Australia is known to resemble Colville Sandstone in composition. The Plumridge Beds in the far northwestern corner of the basin are considered by Lowry to be 'at least partly equivalent to the Colville Sandstone'. They consist of claystone, siltstone, and sandstone with some conglomeratic intercalations, and are thought to be up to 100 m thick.

Quaternary calcareous soils and sand dunes form a thin mantle over much of the Eucla Basin, and a thin shelly limestone (the Roe Calcarenite) around Eucla was deposited during one of the Pleistocene interglacial periods when the sea-level stood about 30 m higher than today.

The Tertiary beds of the Eucla Basin are sometimes referred to as the Eucla Group, despite the large time-break between the Abrakurrie and Wilson Bluff Limestones.

4.3 Geophysics

(a) Magnetic surveys

The locations of magnetic surveys in the area under review are shown in Plate 2. Geophysical survey names, operators, contractors, amount of coverage and other data are given in Appendix 2. Estimated depths to magnetic basement are given in Plate 3.

The eastern portion of the Eucla Basin has been surveyed magnetically in some detail. The only magnetic work in the western part of the area consisted of a series of regional aeromagnetic traverses conducted by BMR in 1954.

Onshore surveys An aeromagnetic survey by BMR in 1954 was a broad reconnaissance survey comprising six flights ranging from Kalgoorlie to Oodnadatta and from the Northern Territory border to the South Australian coastline.Although the work was not sufficiently detailed to be very precise, a general outline of sediment thickness in the Eucla Basin was provided. Greatest sedimentary thicknesses were estimated to be present in the extreme north and extreme south of the central onshore portion of the Eucla Basin.

The northeastern Eucla Basin area was covered by the Eastern Officer Basin aeromagnetic survey conducted for Exoil in 1964. Groups of three traverses 2 km apart spaced at 15 km intervals were flown at 0.7 km above sea level along north-south lines. Basement depth estimates ranged from sea level west of Coober Pedy to 2.5 km near the Western Australian border in the north of the basin.

The eastern portion of the Eucla Basin was covered by BMR surveys in 1970 and 1972. Magnetometer recordings were taken at about 150 metres above ground level. Traverses oriented east-west were separated by approximately 1.5 km and tied by north-south lines approximately 20 km apart.

Onshore in the eastern part of the Eucla Basin interpreted depths to magnetic basement (Pl. 3) generally increase to the northwest from zero to a maximum of about 3000 m. This evidently results from an increase in thickness to the northwest of non-magnetic rocks below the thin Eucla Basin sequence, which could be either Officer Basin sediments or non-magnetic basement rocks. The discrepancy between aeromagnetic contours and Lowry's (1970) Precambrian basement contours northwest of Eucla suggests the latter.

Offshore surveys The offshore eastern part of the Eucla Basin, Spencer Gulf and part of the Great Australian Bight Basin were covered by an aeromagnetic survey in 1966 for Outback Oil and Shell Development. Lines were flown at an altitude of 450 m in an approximately north-south orientation at a spacing of 13 km. One persistent magnetic horizon was interpreted as representing basement, and a few intra-sedimentary magnetic anomalies were also indicated. Basement depth estimates in the Head of Bight region agreed well with the computed depths to a seismic high-velocity layer (5900 m/s) indicated by a South Australian Mines Department refraction seismic survey carried out onshore in the area in 1964. Basement apparently shallows from 2.0 km near the Head of Bight to 500 m at about 60 km offshore, and thickens again on the continental slope (Pl. 3). Over much of the offshore Eucla Basin magnetic basement seems to be no more than 500 m below sea level.

The offshore Eucla Basin was covered by profiles of the BMR Continental Margin survey (Pl. 2). Basement depth contours derived from marine magnetic work are not available.

(b) Gravity Surveys

The earliest known gravity work in the review area was a BMR survey, consisting of a regional gravity traverse across the Eucla Basin in 1954-55 (Gunson & Van der Linden, 1956). The earliest gravity survey offshore in the Eucla Basin was made by Atlantic Oceanographic Laboratories, on a cruise of the oceanographic vessel ESSA R.V. Oceanographer (Conolly et al., 1970).

Onshore surveys A helicopter gravity survey was carried out for Outback Oil near the Head of Bight in 1965 using an approximate 4.8 km grid. Gravity readings have been taken on some seismic surveys in the Eucla Basin area. These are indicated in the list of seismic surveys in Appendix 2. The most important onshore gravity surveys in the Eucla Basin were helicopter surveys by BMR carried out as part of the regional gravity coverage of Australia.

Gravity coverage of the eastern part of the Eucla Basin was achieved by a BMR survey in 1970. This reconnaissance helicopter gravity survey in South Australia (Pettifer & Fraser, 1974) consisted of about 7800 stations on a 7 km grid. Regional Bouguer anomaly patterns, which are shown in Plate 4, were interpreted as resulting from changes in basement topography and particularly to intra-basement density contrasts. Interpreters of BMR gravity surveys have divided the region into a number of gravity provinces (Pl. 4) which may have regional significance. In the Eucla Basin area there are several gravity anomalies or provinces of interest.

The Denman Gravity Low coincides approximately with the Mallabie Depression which seismic work has indicated to be an area of deeper basement (Pls. 4 and 6). As previously indicated, this basement depression contains an infra-basin of Palaeozoic sediments beneath a Tertiary cover. To the east of this feature, the north- and northeast-trending D'Entrecasteaux Regional Gravity Ridge extends over the western part of the Gawler Block and overlaps onto the Eucla Basin in an area where sediment cover is thin. To the west of the Denman Gravity Low is a positive gravity anomaly which probably results from a topographic rise in basement. About 100 km north of this is the northwest-trending Hughes Gravity Trough, originally defined by Outback Oil (1965). This feature coincides with a known trough of possibly Upper Palaeozoic sediments. Depth to magnetic basement in this area is calculated to be 2500 m (Waller et al., 1972).

A helicopter gravity survey was conducted by BMR over the Western Australian part of the Eucla Basin during 1971-72 (Fraser, 1973a). The survey consisted of 8300 stations approximately on an 11 km grid. On the basis of the results Fraser divided the Eucla Basin part of the survey area into two gravity provinces, the Eyre Regional Gravity Complex on the western side of the Eucla Basin (Pl. 4), with no obvious directional trend, and the Wanna Regional Gravity Depression trending north across the central part of the Eucla Basin. The Fraser Regional Gravity Ridge marks the approximate western limits of the Eucla Basin onshore.

The Eyre Regional Gravity Complex was interpreted by Fraser as a possibly Archaean shield block with the positive Bouguer anomalies relating to areas of dense, probably metamorphosed basement. Most of the basement is covered by thin Tertiary and Cretaceous sediment cover. The Wanna Regional Gravity Depression is continuous to the north with the Officer Regional Gravity Depression (Pettifer and Fraser, 1974). The low gravity readings can only be attributed to low-density basement, since borehole data indicates a thin sediment cover.

<u>Offshore surveys</u> The offshore part of the Eucla Basin was surveyed by gravity meter during the BMR Continental Margin Survey in 1972. Willcox (1978) has given an interpretation of the survey results. The gravity anomaly pattern over the offshore part of the basin (Pl. 4) is similar to that onshore.

It largely consists of the offshore extensions of the Eyre Regional Gravity Complex, the Hughes Regional Gravity Shelf and the D'Entrecasteaux Regional Gravity Ridge.

Because of the relatively thin sediment cover over most of the Eucla Basin area the regional gravity picture on the whole bears little relation to sediment thickness or sedimentary basin structures. Rather, it reflects the composition and perhaps structure within the underlying basement rocks.

(c) Seismic surveys

The area has been only sparsely investigated by the seismic method. Onshore, only two small seismic surveys have been done. Offshore some thousands of kilometres of seismic traverses have been surveyed, but line spacing is generally large and few areas have been mapped in any detail.

Onshore surveys In 1964 the South Australian Department of Mines carried out a refraction seismic survey along the coast between 130 and 131 degrees longitude and extending 90 km inland. Objectives were to determine the general shape of the basin and to test the applicability of the seismic method there. Fair quality seismic refraction results were obtained despite large energy losses due to the cavernous nature of the near-surface rocks. A high-speed refractor (6000 m/s) which was mapped was found to correlate with granite basement in two water bores. Shallower refractors recorded were not identified. The results indicated the presence of a northwest-trending basement depression (Mallabie Depression) west of the Head of Bight with a maximum depth to top of basement of 2000 m, at 131 degrees longitude near the coast.

The only exploration company seismic survey conducted onshore in the Eucla Basin was the Scorpion Bight gravity and seismic refraction survey done for Coastal Petroleum in 1973. A total of 18 km of seismic traverse was shot using explosive energy sources, close to the coast near 127 degrees longitude. Objectives were to test for the onshore continuation of a sedimentary trough revealed by offshore seismic surveys. Results indicated a basement depression 19 km wide at the coast, trending northeast and diminishing in width further onshore. Sediment thicknesses in excess of 2 km were estimated to be present (Pl. 6).

<u>Offshore surveys</u> During 1967 Tenneco Australia conducted two marine seismic surveys, designated the Offshore Eucla Basin R1 and R2 surveys, which totalled 2062 km of traverse in South Australian and Western Australian waters (Pl. 5). This reflection seismic work involved 3-fold and 6-fold CDP coverage obtained using an explosive energy source. Seismic data varied from poor to good. Two main reflections were recorded. The deeper one, representing an horizon at an average depth of about 1000 m, was considered to represent basement. The shallower reflection, believed by Tenneco to be associated with a Cretaceous sandstone, was also mapped. Both of the reflecting horizons were relatively flat-lying and generally devoid of significant structures. However, seismic work indicated the existence of two approximately north-trending basement troughs, one near the Head of Bight (Mallabie Depression), the other on the western side of the Bight offshore from the town of Eyre (Pl. 6). Sediment thicknesses of up to 2200 m were indicated within these troughs.

During 1970 and 1971, a group of companies, including Genoa Oil and Hartogen Explorations, conducted the Twilight Cove and the Offshore Eyre seismic surveys, over the offshore region south of the town of Eyre to investigate the more westerly basement trough mentioned above. A total of 1696 km of 24- and 12-fold CDP reflection coverage was shot using airgun energy sources. Record quality was generally good. Three seismic horizons were mapped. The deepest of these was regarded as basement, while the other two were postulated by the operating company to represent a Permian unconformity and an horizon within the Lower Cretaceous. There is an absence of structure in the sediments, which exhibit a maximum thickness of 2200 m where basement channels have been infilled.

The basement trough near the Head of Bight was explored by Outback Oil during 1972 in their Denman Basin seismic survey. This survey employed an airgun energy source and 24-fold CDP coverage. Record quality ranged from poor to good. An unidentified shallower reflecting horizon and a deeper reflecting horizon tentatively identified by the interpreters (Long and associates) as ?Mesozoic, were mapped. The offshore part of the Denman Basin (Mallabie Depression), represented by the seismic trough investigated, appears to be controlled by two northeast-trending faults offshore. The trough is roughly 100 km wide and at least 200 km long (Pl. 6).

Sediment thickness was generally indicated to be about 1 km, but scattered reflections suggest a thicker sedimentary section in some places. A local north-trending anticlinal fold with numerous faults and crenulations was evident in the ?Mesozoic horizon towards the centre of the depression. Along this anticlinal fold, which involved a local sediment thickening suggesting sand build-ups or reefs, subsidiary anticlines may provide hydrocarbon traps.

The BMR Continental Margin survey in 1972 traversed the offshore part of the Eucla Basin (Willcox, 1978). For seismic profiling this survey employed a 120 kJ sparker energy source and both single-channel and six-channel seismic cables. Single-channel monitor seismic sections were made from the seismic system as the data were collected. These have been used for most of the interpretation done to date. The shooting configuration will permit 6-fold CDP stacking of the data recorded on magnetic tape at a later date if required. The Shell Deepwater Scientific survey conducted in 1972-73 covered only a portion of the western part of the offshore Eucla Basin. Airgun seismic energy sources were used in conjunction with 24-fold CDP coverage. These two regional seismic surveys (Pl. 5A) added little to the general picture of the offshore part of the basin which had emerged from earlier petroleum company surveys.

4.4 Petroleum

Source, reservoir and cap rocks   The Eucla Basin area is singularly lacking in significant source rocks of any appreciable thickness or extent. There are potential reservoir rocks. Sandstones, and to some extent limestones, with sufficient porosities and permeabilities are to be found in all the main basin sequences of the area. Cap rocks are generally lacking, but the Cretaceous Madura Formation, which includes clay and silt units, could provide adequate seals for petroleum.

Traps   There are few significant potential structural traps in the Eucla Basin area, but stratigraphic traps may occur in the Mallabie and Madura Depressions as a result of facies changes, and the up-valley migration of hydrocarbons.

Prospectivity   A factor which militates strongly against the occurrence of significant petroleum reserves in the area is the general lack of thick sedimentary sequences now and in the past, so that even if adequate organic carbon material had been present in the sediments originally, the depth of burial would have been inadequate for the maturation of petroleum.

Overall, the petroleum prospects of the area are low. The situations in various individual basins are considered in more detail below.

Officer Basin and Arckaringa Basin Some of the sediments intersected in the deeper wells in the Eucla Basin area (e.g. Mallabie No. 1) can be considered part of the Officer Basin or the Arckaringa Basin. Such sediments probably occur in outliers or sub-basin lobes of the Officer and Arckaringa Basins proper, and sediment thicknesses may be much less than they are in the areas of outcrop towards the basin depocentres. Little is known about the occurrence and petroleum prospects of Officer and Arckaringa Basin sediments beneath the Eucla Basin, but at present their prospects seem slight. Analysis of a Permian sandstone from Mallabie No. 1 indicated a porosity of 18%, but a permeability of less than 0.1 millidarcy.

Denman Basin The small thickness of sediment in this basin ensures that the basin sequence can have significance only insofar as it can act as a seal to underlying reservoirs, or provide reservoirs for migrating allogenic hydrocarbons. A few porous sands are known to occur.

'Wylie Lobe' of the Eromanga Basin This Early Cretaceous infra-basin contains shallow marine, marine swamp and transgressive marine sediments with very considerable extent in the Eucla Basin area. However, the thickest Cretaceous sequences which are in the Madura and Mallabie Depressions are only of the order of 300 to 400 m. There are no known lutitic rocks with significant carbon content in the area of interest either in the Eromanga Basin sediments or in those below them. The basal Loongana Sandstone is probably the most porous and permeable unit in the Eucla Basin area, and the Madura Formation includes sandstones with porosities of 35 to 40 percent and permeabilities of 1600 to 3500 millidarcies. Mudstones which could be effective cap rocks are known. For example in Mallabie No. 1 well there is a 60 m thick stratum of soft, sticky mudstone.

The Cretaceous rocks are thought to have buried a landscape possessing some physiographic relief, but practically no significant structures are known. It is evident that dips have always been slight, originally towards a basin depocentre and later to the south. In the southern part of the area the reversal of regional dip since deposition of the sediments may have allowed any hydrocarbons generated to escape from potential stratigraphic traps.

<u>Eucla Basin</u> Although the likelihood of Eucla Basin sediments providing adequate source material for hydrocarbon accumulation is slight, the Pidinga Formation, with its lignites and carbonaceous clays, offers some small potential. The Hampton Sandstone, Colville Sandstone and localised parts of the Wilson Bluff Limestone and the Nullarbor Limestone are sufficiently porous and permeable to act as reservoir beds.

However, the petroleum potential of the basin is seriously downgraded by the lack of adequate sediment thickness, inadequate depth of burial, paucity of suitable cap rocks and lack of structures which might provide traps. Furthermore, the coarser clastic rocks mentioned above as potential reservoirs are aquifers of the Eucla Artesian Basin and the Madura Formation lutites are aquicludes. Water is also obtained from the several limestone formations. Thus any minor hydrocarbon accumulations which may have tended to form in the past would in all probability have been water flushed. The petroleum potential of the Eucla Basin is therefore regarded as negligible.

5. GREAT AUSTRALIAN BIGHT BASIN

5.1 Tectonic history and structure

Plate 9 illustrates currently-held ideas regarding the formation of the Great Australian Bight Basin as a part of the Great Australian Bight region (Ch. 2). The dominant structural trends are roughly parallel to the present day coastline (Pl. 7), but there are local trends at right-angles which are thought to be due to rejuvenation of old basement trends. Slump and synsedimentary fault-patterns are frequent (Boeuf & Doust, 1975). The last major dislocations took place before the end of the Eocene.

Boeuf and Doust (1975), using results from Shell's 1972-73 Deepwater Scientific seismic survey integrated with other available seismic work, subdivided the continental margin of southern Australia into five structural zones. Four of these zones extend into the Great Australian Bight Basin, and from the shelf break seawards they can be recognised as follows:

(1) <u>A zone of landward-tilted basement blocks</u> This zone generally underlies the shelf and marginal terraces of the Great Australian Bight. It has been recognised in the Great Australian Bight Basin by Willcox (1978) to underlie the eastern Eyre Terrace, not apparently extending beyond 129°E except in some areas along the northern margins of the basin. An area of shallow igneous

basement has been interpreted by Willcox (op. cit.) to be present near the neck between the Eyre and Ceduna Terraces at 128°30'E (Pl. 6).

Basement blocks are linear and are separated by normal faults with a southwards throw of up to 7 km. Generally, throws get progressively smaller in the younger sediments, most faults ending in the Upper Cretaceous and only a few extending into the Tertiary. However, in cases where there has been considerable fault displacement at both basement and Lower Cretaceous levels, faulting appears to have been synsedimentary. The latter style of faulting has brought about substantial thickening of sediments in the downthrown blocks and the development of associated rollover anticlines.

Although most of the anticlinal features in this zone are related to block faulting some may have formed under compressional stresses resulting from transcurrent fault movements e.g. west of Kangaroo Island (Boeuf and Doust, 1975).

(2) A zone of thick sedimentation characterised by synsedimentary rotational faults This zone corresponds to the upper part of the continental slope and the outer part of the Ceduna Terrace. The faults only affect areas where the sedimentary section is thick and are absent in areas of shallow basement. Generally the fault planes are steeply inclined near the surface and probably become more horizontal with depth in the ?Lower Cretaceous. They hade seawards and strike parallel with the continental margin. Some extend from the Cretaceous into the Tertiary sequence and in the area of the Ceduna Terrace they form a belt of linear, convex-shoreward faults that follow the continental margin for several hundred kilometres. Anticlinal structures are common in the downthrown blocks and growth of these structures (thinning of sediments over the crests) is often observed.

(3) A zone of low-angle thrust faults This zone is generally present along the base of the continental slope. At the seaward limit of the Ceduna Terrace it is marked by an irregular ridge of acoustic basement that has no magnetic or gravity expression. The faults in this zone have been interpreted as possible gravity or toe-thrusts and some can be directly related to, and are thought to be connected with, the synsedimentary faults of the upper slope. From seismic sections the faults are seen to affect the Lower Cretaceous, Upper Cretaceous and Lower Tertiary units. The Upper Tertiary unit, however, is undisturbed and truncates the thrust zone. At the lower edge of the slope the basement shallows seawards and is still considered to be continental in character.

(4) A zone characterised by relatively undisturbed Cretaceous and Tertiary sediments This zone corresponds to the continental rise proper. In the Great Australian Bight, Boeuf and Doust (1975) interpret the continental rise as an area of seaward shallowing continental basement ending at the abyssal plain, where oceanic basement is overlain by flat-lying Tertiary sediments. According to Willcox (1978) the continental rise is structurally complex and apparently comprises a sedimentary section approximately 2 to 3 km thick overlying extensively block faulted continental basement. Some of the Tertiary sediments on the rise have probably been transported from the continental slope and terraces by slumping and turbidity currents.

Magnetic anomaly ridges and troughs have been interpreted by Willcox (op. cit.) on the continental rise. Except along the northern edge of the rise, these anomalies are of relatively low amplitude and are considered to be part of a 'magnetic quiet zone' (Weissel, 1972) reflecting the deep-seated underlying continental crust. A well defined anomaly ridge occurs along the northern edge of the magnetic quiet zone near Eyre Terrace, about 30-40 km south of the lower continental slope. The ridge becomes diffuse east of Eyre Terrace and cannot be followed, but westwards it extends for at least 1000 km. A closely associated magnetic anomaly trough extends across the Ceduna Terrace along latitude 134°30'S and then forms a broad arc along the shelf edge.

In the western part of the Bight the anomalies seem to coincide with a broad band of faults to the south of the lower continental slope and, in the Great Australian Bight Basin, with a band of diapirs or possible igneous intrusions. The nature and the 2000 km extent of these features suggest they are related to continental margin development (Willcox, 1978).

Duntroon Embayment

The Duntroon Embayment is the strongly fault-controlled eastern part of the Great Australian Bight Basin lying west of Kangaroo Island and south of Eyre Peninsula (Fig. 1, Pl. 7). The pattern of faulting in the Mesozoic taphrogen was the result of the complex interaction of ancient faults in the Australian-Antarctic craton, with the stresses brought into play by the forces disrupting the continent. The location of Anomaly 22 (Pl. 7) suggests that the Duntroon Embayment was close to a triple-point junction. The major rift valley wherein separation was finally to become effective, lay along Anomaly 22. Stretching southeastwards towards the Otway Basin was a leaky transform fault, the trend of which may have been dictated by pre-existing zones of weakness. The postulated 'failed arm' of the triple junction possibly developed along the pre-existing, strongly developed structural grain of the Adelaide Fold Belt to produce the South Australian Rift Valley (Pl. 7); the Snelling-Cygnet Fault displays Early Palaeozoic downthrow to the southeast, and Mesozoic/Tertiary downthrow to the northwest.

The sediments in the Duntroon Embayment overlie the basement with angular unconformity and consist of two sequences: a thick strongly folded Cretaceous sequence characterised by medium seismic velocities, and a thinner weakly deformed Tertiary sequence characterised by low to medium seismic velocities. On the basis of structural style apparent in the Cretaceous section the Duntroon Embayment has been divided into three main structural provinces. (Pattinson and others, 1976; Whyte, 1978).

(1) Inner basin This province lies in the northern part of the Embayment between the northern boundary faults of the Duntroon Embayment and the central 'high'. It is essentially a graben or half graben for its entire length with the Mesozoic sediments cut by many down-to-the-basin normal faults. Along the axis of the sub-basin a number of faulted anticlines have developed in response to basement faulting.

(2) Central 'high' The central 'high' is an area of uplifted basement in the centre of the Embayment. It is characterised by upthrown and downthrown basement blocks giving rise to three distinct anticlinal structures, and associated synclines. In all three anticlinal structures, one of which was tested by Echidna No. 1 well, the Upper Cretaceous section has probably been partly or completely eroded. The anticlines are bounded on the southern side, and probably also on the northern side, by faults that are considered to be an extension of the major fault zone bordering the Great Australian Bight Basin to the north. The main arching of the mid-basin 'high' is thought to have occurred in Late Cretaceous to Early Tertiary times.

(3) Outer growth fault belt This province lies to the south of the central 'high' and is separated from it by one or more basement faults. It has a structural style similar to that of the Great Australian Bight Basin proper and comprises a narrow zone of faults blocks bordered by two sets of faults, one trending northwest-southeast and the other trending east-west. There is little evidence for synsedimentary faulting, and the faults are considered to be the result of deep-seated basement movement.

Since the Early Tertiary there has been little structural deformation of the Duntroon Embayment sediments. The uppermost mappable seismic horizon dips gently to the southwest (drops 1.5 km over 32 km) and in places overlies the Cretaceous with clear angular unconformity. The horizon is more nearly horizontal in a northwest-trending zone where reverse dips result from either drape over pre-existing structures or movement correlatable to Miocene-Pliocene movement evident onshore (Smith and Kamerling, 1969).

5.2 Stratigraphy

Stratigraphic control in the Great Australian Bight Basin is dependent on three wells: Potoroo No. 1 drilled on the northern margin; Echidna No. 1 located in the Duntroon Embayment on the central 'high', and Platypus No. 1 in the outer growth fault belt of the Embayment (Pl. 1). The sections penetrated by the three wells are given in Whyte (1978). Plate 8 depicts the depositional history in the areas penetrated by Platypus No. 1, Echidna No. 1 and Potoroo No. 1.

The most recent detailed interpretation of the stratigraphy is contained in two unpublished confidential reports by Shell geologists. New stratigraphic names introduced in these reports have been reserved with the Australian Stratigraphic Index. The following account of the stratigraphy is largely based on these and other reports by Shell geologists. The stratigraphy of the basin is also discussed in three earlier publications by Shell geologists: Smith & Kamerling (1969); Boeuf and Doust (1975); and Pattinson and others (1976). The contribution of these authors is acknowledged, and the authors are grateful to Shell for permission to use information from unpublished company reports in this Record.

Willcox (1974) has interpreted the stratigraphy in an unpublished BMR geophysical report, and (1978) in a published report.

The sedimentary sequence contains two main subdivisions; an Early Cretaceous to Early Tertiary sequence of continental to shallow-water restricted marine clastic sediments, and a Tertiary sequence of holomarine carbonates. A regional unconformity within the upper part of the clastic sequence is interpreted as the late Paleocene 'break-up' unconformity (Ch. 2). Formal nomenclature has not yet been applied to stratigraphic units recognised in the 'pre-break-up' sequence. In Plate 8 tentative correlations with named Tertiary units in the Eucla Basin are indicated. Structural cross-sections and a schematic stratigraphic chart are given in Figures 2 and 3.

The sediments in the Great Australian Bight Basin reach a maximum thickness in the order of 6 500 to 10 000 m. The oldest dated sediments are of Neocomian age, but the presence of Jurassic sediments in the Polda Basin (Harris & Foster, 1974) suggests that sedimentation began in the Jurassic, and sediments of this age are inferred to occur at the base of the Mesozoic sequence at least in some areas. Permian sediments are also inferred to be locally preserved.

Basement rocks Basement is assumed to consist of metamorphic and igneous rocks of the Precambrian Gawler Block or in part of the lower Palaeozoic sediments of the Adelaide Fold Belt.

Early Cretaceous The Early Cretaceous sequence consists of shales and siltstones deposited in fluviatile-lacustrine environments with the likelihood of some shallow restricted-marine deposition in the west. In the Duntroon Embayment, this sequence is at least 2 500 m thick.

The Early Cretaceous section is in faulted contact with, or wedges out over, shallow basement on the Great Australian Bight Ridge (Pl. 7). It extends seawards through the shelf and slope to the continental rise, where it overlies seawards-shallowing continental crust and wedges out against the Outer Continental Margin Ridge.

The sediments, and the underlying basement, are extensively block-faulted, by normal faults trending parallel to the continental margin. Downthrow is generally seawards, and the blocks are tilted landwards.

Late Cretaceous to Early Tertiary Deposition of continental clastics appears to have been continuous from Early to Late Cretaceous, except in some areas along the northern margin and in the Duntroon Embayment where an unconformity is related to uplift and erosion at the end of the Early Cretaceous.

Sediments in the lower part of the section are coarser than in the Lower Cretaceous sequence, comprising fine to medium-grained sandstones with interbedded carbonaceous shales and coals which reach a thickness of about 1000 m in the Duntroon Embayment. The overlying units in the Embayment comprise about 1000 m of silty shale deposited in a restricted-marine environment during the late Cenomanian to Middle Campanian, overlain by a sandier sequence which extends into the Early Tertiary and appears to have been deposited in a continental environment, or under restricted marine, perhaps lagoonal, conditions.

In the western part of the basin, foreset beds seen on seismic sections may be paralic or entirely marine sequences.

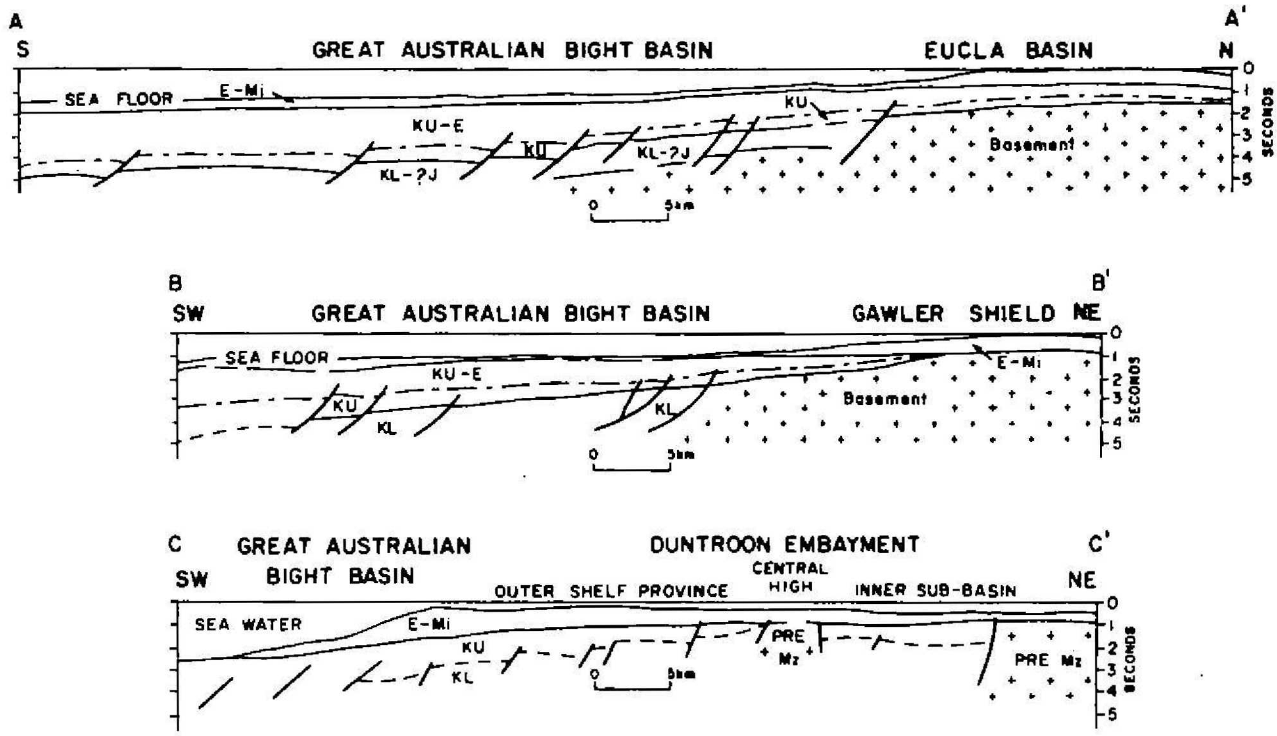


Fig.2 Structural sections across the Great Australia Bight Basin (sections located on Plate 7)

(after Pattinson and others, 1976)

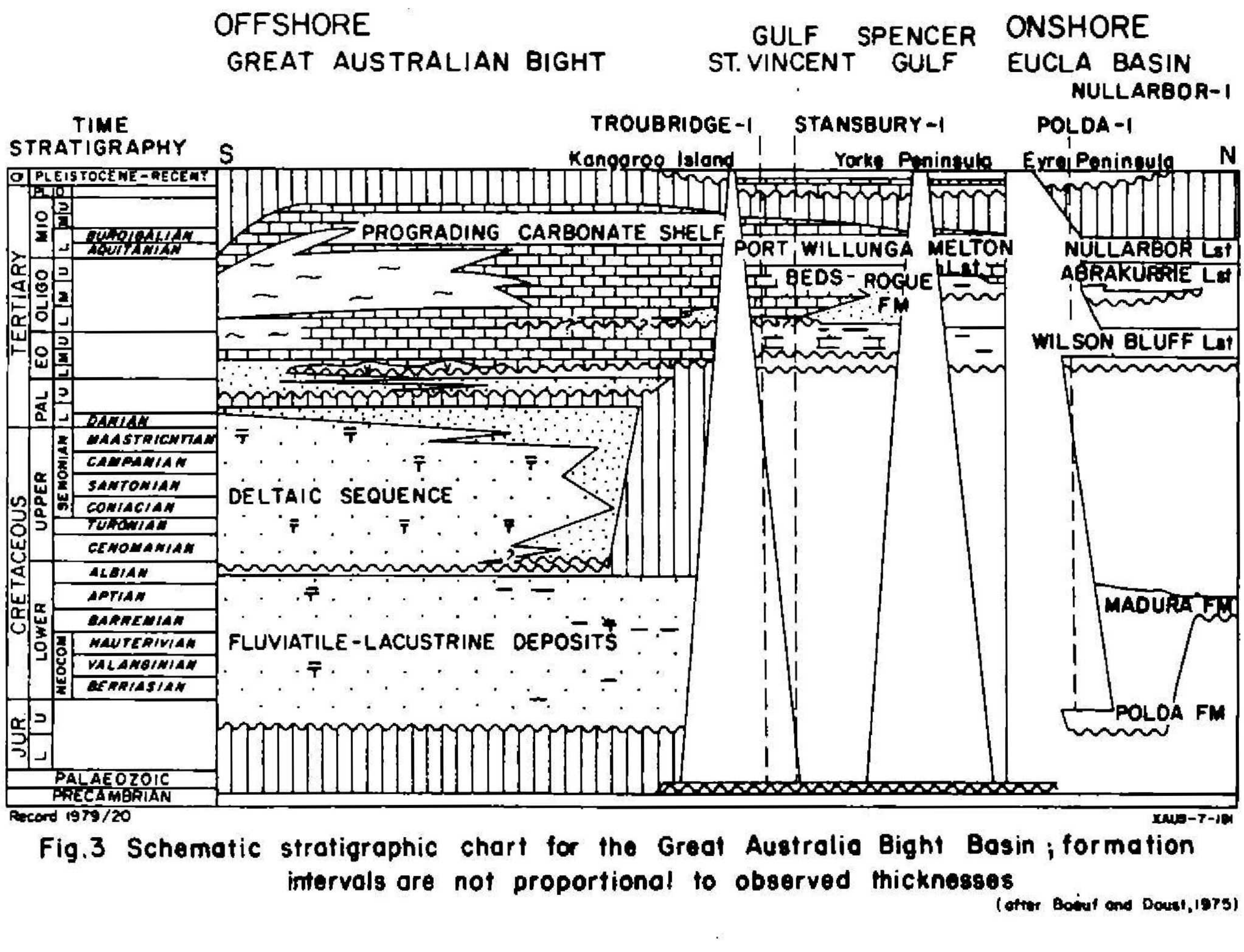


Fig.3 Schematic stratigraphic chart for the Great Australia Bight Basin; formation intervals are not proportional to observed thicknesses

(after Boeuf and Doust, 1975)

The Late Cretaceous to Early Tertiary sequence wedges out against the Great Australian Bight Ridge. It reaches its greatest thickness of about 3000 m under the Ceduna Plateau, and appears to thin rapidly seawards and to be absent from large parts of the slope and upper continental rise. Willcox (1978) considers it to be present in the western part of the Bight, south of the Eyre Terrace.

The following stratigraphic units have been recognised in the Early Cretaceous to Early Tertiary sequence.

(i) <u>Loongana Sandstone equivalent</u>

Age	:	Neocomian to early Aptian
Lithology	:	Conglomerate, sandstone and carbonaceous siltstone
Occurrence	:	Potoroo No. 1. May be present below depth reached by the Platypus and Echidna wells
Thickness	:	80 m in Potoroo No. 1
Environment	:	Non-marine. Basal conglomerate marks onset of sedimentation in the basin. Sequence reflects fluctuations in rate of basin subsidence. Correlated with shallow marine Loongana Sandstone in the Eucla Basin.

(ii) <u>'Echidna Beds' (new name)</u>

Age	:	Time correlative of the Loongana Sandstone in Potoroo No. 1
Lithology	:	Predominantly dark shale and mudstone
Occurrence	:	Echidna No. 1
Thickness	:	Echidna No. 1 was terminated after penetrating the 'Echidna Beds' for 160 m
Environment	:	Non-marine. Probably deposited in shallow lakes close to sediment source of low relief. Resembles carbonaceous siltstone units in the Loongana Sandstone.

(iii) <u>Madura Formation equivalent</u>

Age	:	Aptian-Albian in Potoroo No. 1 and Platypus No. 1, Aptian in Echidna No. 1
Lithology	:	Calcareous and glauconitic shales, mudstones, siltstones and sandstones in Potoroo No. 1. Calcareous and carbonaceous sandstones, siltstones and mudstones in Platypus No. 1 and Echidna No. 1.
Occurrence	:	Potoroo No. 1, Platypus No. 1, Echidna No. 1

Thickness : 314 m in Potoroo No. 1
515 m in Platypus No. 1
2370 m in Echidna No. 1

Environment : Restricted marine in the west, paralic in the east. Interpretation based on the presence of abundant microplankton in Potoroo No. 1, together with glauconite and microforaminifera. Microplankton present but less abundantly in Platypus No. 1, and not recognised in the Echidna well.

The microplankton peaks closely follow those recorded in the Toolebuc Limestone of the Eromanga and Carpentaria Basins, and the unit is similar in the western part of the basin to the Madura Formation in the onshore Eucla Basin (Mallabie No. 1 well).

(iv) 'Platypus Formation' (new name)

Age : Albian-Cenomanian

Lithology : Calcareous sandstone, siltstone, carbonaceous mudstone and coal (Platypus No. 1). Similar sequence but with interbedded dolomite and only minor sandstone in Potoroo No. 1.

Occurrence : Platypus No. 1, Potoroo No. 1

Thickness : 500 m in Platypus No. 1
640 m in Potoroo No. 1

Environment : Paralic in the west, continental in the east. Uplift and active erosion of the central 'high' of the Duntroon Embayment took place at this time and accounts for the increased sandstone content in the eastern part of the Basin. In the west, uplift of the Great Australian Bight Ridge created a barrier between the Great Australian Bight and Eucla Basins. However, intermittent marine incursions across the barrier are indicated by interbedded dolomite containing brachiopods in Potoroo No. 1.

(v) 'Wigunda Formation' (new name)

Age : Turonian-Campanian (Platypus No. 1)
Cenomanian (Potoroo No. 1)

Lithology : Carbonaceous and glauconitic mudstone (Platypus No. 1).
Mudstone with interbedded dolomite (Potoroo No. 1)

Occurrence : Potoroo No. 1, Platypus No. 1

Thickness : 840 m in Platypus No. 1
195 m in Potoroo No. 1

Environment : Paralic in the west, continental in the east. Lithology indicates a tectonically more stable period.

(vi) 'Potoroo Formation' (new name)

Age : Turonian-Early Paleocene (Potoroo No. 1)
Maastrichtian-Early Paleocene (Platypus No. 1)

Lithology : Sandstone, sandy siltstone, rare carbonaceous mudstone. Also glauconitic sands and coal bands in Potoroo No. 1.

Occurrence : Potoroo No. 1, Platypus No. 1

Thickness : 600 m in Potoroo No. 1
330 m in Platypus No. 1

Environment : Paralic in the west (suggested by the presence of glauconite), and continental in the east. Incoming of coarser clastics is attributed to renewed uplift along the basin margins.

Tertiary The post-break-up Tertiary sequence reflects widespread marine inundation of the basin in the mid-Eocene. After a minor regression in the Oligocene, the transgression reached a maximum during the Miocene. Coarse glauconitic sands form the base of the sequence, and these are succeeded by a thick wedge of open-marine shelf carbonates. Up to 1000 m of bryozal limestone was deposited in the Duntroon Embayment during the Miocene. There is evidence in Platypus No. 1 of slumping of shallow-water carbonates during Oligocene to early Miocene times.

5.3 Geophysics

Except for the Duntroon Embayment, the Great Australian Bight Basin largely lies in water deeper than 200 m, and for this reason there have been few detailed surveys by petroleum exploration companies, particularly in the western part of the basin. However, the basin has been traversed by some oceanographic and regional type surveys including the BMR Continental Margin geophysical survey and the Shell Deepwater Scientific survey (Pl. 2 & 5a). Shell Development has conducted a number of semi-detailed surveys over the Ceduna Terrace. In the Duntroon Embayment, where water depths are shallower, Shell has done a considerable amount of semi-detailed and detailed seismic mapping.

(a) Magnetic surveys The 1966 aeromagnetic survey conducted by Outback Oil and Shell Development (Australia) over the offshore eastern part of the Eucla Basin also covered the northern and eastern part of the Ceduna Terrace and all of the Duntroon Embayment (Pl. 2). Interpreted magnetic basement depth contours over the surveyed part of the Ceduna Terrace (Pl. 3) showed a general deepening of basement to the southwest from less than 500 m near Eyre Peninsula and Kangaroo Island to about 6000 m on the continental slope. Some local positive features on magnetic basement, which might have structural significance, were also indicated.

There is no aeromagnetic coverage over the western part of the basin. However the BMR Continental Margin survey in 1972 and the Shell Deepwater Scientific survey in 1972-73 included magnetometer recordings. Willcox (1978) includes a magnetic anomaly map of the Great Australian Bight, and he discusses magnetic anomalies in the region in conjunction with gravity anomalies. Some oceanographic cruises, such as the Lamont Geological Observatory's Vema cruise in 1962 have also recorded magnetic profiles across the basin.

Some of the semi-detailed and detailed geophysical surveying by Shell Development in the central part of the Ceduna Terrace and the Duntroon Embayment between 1969 and 1972 (see Appendix 2) included magnetic recordings.

Interpreted magnetic basement depth contours for the Great Australian Bight Basin (Pl. 3) indicated the existence of a fairly steep basement slope more or less parallel to the edge of the continental shelf and deepening to the southwest. This slope is particularly uniform in the Duntroon Embayment. Here and on the Ceduna Terrace magnetic basement is indicated at a depth of at least 5000 m near the 2000 m isobath.

(b) Gravity surveys Between 1962 and 1969, three oceanographic cruises, which included gravity measurements on a few sparse traverses, crossed parts of the Great Australian Bight Basin (Riesz & Moss, 1971). In 1972-73 Shell's Deepwater Scientific survey recorded gravity data in conjunction with seismic and magnetic surveys. Only gravity profiles are available from this survey.

The BMR Continental Margin survey in 1972 recorded gravity over the Great Australian Bight. The relevant portion of the Bouguer anomaly map on Plate 4 is based on data from that survey (Willcox, 1978).

Willcox divided the Great Australian Bight into Bouguer anomaly provinces in the manner described by Darby and Vale (1969) and followed onshore by Fraser (1973) and Pettifer and Fraser (1974). As indicated previously, in some cases it was possible to extend provinces defined onshore onto the continental shelf. Four main gravity provinces are recognised in the Great Australian Bight Basin: The Eyre Terrace Regional Gravity Gradient, the Ceduna Terrace Regional Gravity Shelf, the Warramboo Regional Gravity Complex and the Duntroon Bank Regional Gravity Gradient (Pl. 4).

The Eyre Terrace Regional Gravity Gradient corresponds with the continental slope, the Eyre Terrace (bathymetric), and the continental rise south of Eyre. The Ceduna Terrace Regional Gravity Shelf corresponds quite closely with the Ceduna Terrace, while the Warramboo Regional Gravity Complex and the Duntroon Bank Regional Gravity Gradient lie east of and south of the Ceduna Terrace Regional Gravity Shelf respectively. Gravity anomalies over the Eyre Terrace are considerably higher than those over the Ceduna Terrace. Magnetic anomalies are of greater amplitude and shorter wavelength. Willcox (1978) points out that these differences are apparently due to differences in depth to basement beneath the terraces - up to 8 km beneath the Ceduna Terrace (Boeuf and Doust, 1975) but only about 0.5 m to 1.5 km beneath the Eyre Terrace.

In the southern part of the Warramboo Regional Gravity Complex there are two negative Bouguer anomalies northwest of the western extremity of Kangaroo Island, which probably reflect an increase in thickness of sediments south of the Cygnet-Snelling Fault (Pl. 4). The steep regional gradient observed in the area of the Duntroon Bank Regional Gravity Gradient tends to obscure the gravity effect of near-surface geology.

For more detailed discussion of gravity and magnetic anomalies in the Great Australian Bight the reader is referred to Willcox (1978).

(c) Seismic surveys It is convenient to consider seismic surveys in the Great Australian Bight Basin in three separate areas: the Eyre Terrace in the west and the Ceduna Terrace and Duntroon Embayment in the east. Seismic results are summarised on Plate 6, which shows regional seismic depth contours and sediment thickness.

The earliest seismic profiles across the Eyre Terrace were surveyed during the 1967 *Oceanographer* cruise using an airgun energy source. Reflection quality over the Terrace, where water depths range from about 200 m to 2000 m, was good. About 1000 m of sediments overlying a strong reflector, possibly representing crystalline basement, were indicated (Connolly et al, 1970).

The BMR Continental Margin survey conducted in 1972 has since delineated the Eyre Terrace more fully. Fair quality reflections were obtained from single-fold profiles using the sparker energy source. Sediment thicknesses were indicated to range from about 200 m to 2000 m, with the maximum section occurring on the far eastern flank of the Terrace. The northern and southern margins of the Eyre Terrace are marked by block faulted structures downthrown to the north and south respectively. Along the southern margin, basement is close to the ocean floor and forms a small ridge with about 100 m elevation.

Shell Development explored part of the Eyre Terrace during 1972-73 in their Deepwater Scientific survey, using airgun energy sources and 24-fold CDP coverage. Results over the Eyre Terrace indicate that basement dips landward and is divided into blocks by normal faulting. Sediments were deposited over this foundation along a linear trend and become shallower seawards towards the small basement ridge previously mentioned.

The Shell Deepwater Scientific survey and the BMR Continental Margin survey explored seismically both the Ceduna Terrace and the Duntroon Embayment, but Shell Development have examined these two areas in much finer detail with a number of detailed and semi-detailed seismic surveys.

The <u>Ceduna Terrace</u> was explored between 1966 and 1976 by Shell Development with eleven reconnaissance and semi-detailed seismic surveys, commonly using airgun energy sources and more rarely 'Aquapulse' or explosive energy sources. CDP coverage increased from 3-fold to 48-fold over this period. Data obtained prior to 1969 was relatively poor, but data quality in more recent years has mainly been fairly good. It has been adequate to allow mapping of structure at several levels in the Cretaceous to Tertiary section, which is complicated by numerous faults. The structure of the Great Australian Bight Basin, described elsewhere in this chapter, is predominantly based on the seismic data. The seismic results over the Ceduna Terrace indicated the presence of between 4 km and 8 km of sediments overlying a somewhat irregular basement.

The <u>Duntroon Embayment</u> has been mapped seismically in much greater detail than any other area in the Great Australian Bight Region (Pl. 5). Shell Development has carried out a number of seismic surveys in the area between 1966 and 1973. Techniques used were similar to those used on the Ceduna Terrace, and data quality, at least from the more recent surveys, was mainly good. In the Platypus-Echidna area south of Eyre Peninsula and west of Kangaroo Island Shell has established a dense grid of seismic lines averaging about 2 x 2 km. It is possible to map seismically several of the horizons in the Cretaceous to Tertiary sediments. A number of structures have been delineated, two of which have been tested by drilling.

5.4 Petroleum

Exploration Permits for Petroleum (EPP) SA-5, SA-6, and SA-7 were granted to Shell Development (Australia) Pty Ltd at the end of 1968 under the terms of the Petroleum (Submerged Lands) Act, 1967 (Fig. 4). The permits formed part of the original Offshore Exploration Licence (O.E.L.) 38 which had been held by Shell since the beginning of 1966. The deep water permits SA-10 and SA-11 were also acquired by the Company at the end of 1968.

Petroleum exploration activity carried out by Shell in the Great Australian Bight Basin since the beginning of 1966 is reviewed in Whyte (1978). It involved the recording of 24 546 km of seismic data and the drilling of one well in each of the three permits, SA-5, SA-6, and SA-7. No wells were drilled in the deep water permits.

The Company relinquished SA-5, SA-6, and SA-7 in 1975, and the deep water permits SA-10 and SA-11 in 1977.

The sections following are in part based on interpretative data contained in Shell confidential reports, permission for the use of which is gratefully acknowledged.

Drilling results Platypus No. 1 and Echidna No. 1 were drilled in the Duntroon Embayment to test structural closures in the outer growth fault belt, and the central 'high' respectively.

Echidna No. 1 was located in approximately 150 m of water on an anticline with minor crestal faulting. The form and extent of the drilled structure were not well defined seismically. The well penetrated about 2450 m of Lower Cretaceous claystone and siltstone (Madura Formation equivalent and 'Echidna Beds') underlying the regional Tertiary unconformity (Pl. 8). No reservoir sands were encountered below the seismic horizon on which the structure was mapped. The well was plugged and abandoned in the 'Echidna Beds' at 3832 m (below rotary table).

Platypus No. 1 was drilled in 149 m of water on a structure interpreted as a possible growth fault anticline. Although the well penetrated a Cretaceous sequence of Maastrichtian to Aptian age in which the 'Platypus Formation' (Pl. 8) contained sandstones with good reservoir characteristics, no hydrocarbons were encountered. Later reprocessing of the geophysical data indicated that structural closure was absent on the Platypus prospect. The well was plugged and abandoned at 3893 m (b.r.t.).

Potoroo No. 1 was drilled on the northern margin of the basin in SA-5. It was located in 252 m of water on a fault-controlled structure. The main objective was an Upper Cretaceous sequence tentatively correlated with the 'Platypus Formation' intersected by Platypus No. 1. However in Potoroo No. 1 this sequence proved to contain only minor sandstone. Sands with good porosity at the base of the Cretaceous sequence were water bearing. The well was plugged and abandoned in Precambrian basement at 2924 m (b.r.t.).

<u>Source, reservoir and cap rocks</u> Cretaceous sediments with hydrocarbon source potential, which would also be effective cap rocks, were present in all three wells drilled in the basin.

During the drilling of the Cretaceous sequence in Potoroo No. 1 numerous indications of methane were recorded. Peaks of up to 6000 ppm were common, and were associated with coal in the upper part of the 'Platypus Formation'. One peak of 18 000 ppm was recorded from a 4 m thick seam. Source rock studies on samples from the Cretaceous sequence showed that the source rocks contained organic matter of humic and mainly-humic types. At the well location it was estimated that the depth at which the level of organic maturation necessary for hydrocarbon generation is reached lies just above or within the basement, i.e. between 2800 and 2900 m, so that the source rocks in Potoroo No. 1 are probably immature.

In Platypus No. 1, coal and soft dark carbonaceous clay occur throughout the Aptian to Turonian section between about 2440 and 3900 m. The coal has a cumulative thickness of 24 m in the 'Platypus Formation', and generally occurs interbedded with clay in units 3 to 9 m thick. In Echidna No. 1 a 27 m thick section of dark grey shale grading in part to lignite was intersected at about 1443 m in the upper part of the Aptian section. The shale is very rich in organic matter of mainly-humic type. As in Potoroo No. 1 the source rocks in the Echidna and Platypus wells appear to have a greater potential for gas rather than oil generation. The basal shale section in Echidna No. 1 (816 m thick) seems to be post-mature for petroleum generation.

Potential reservoir sands occur at three stratigraphic levels in the Duntroon Embayment. The Early Eocene section contains unconsolidated transgressive sands with porosities of up to 33 percent, the Paleocene to Maastrichtian sequence, channel and shoreline sands with thicknesses of up to 23 m and

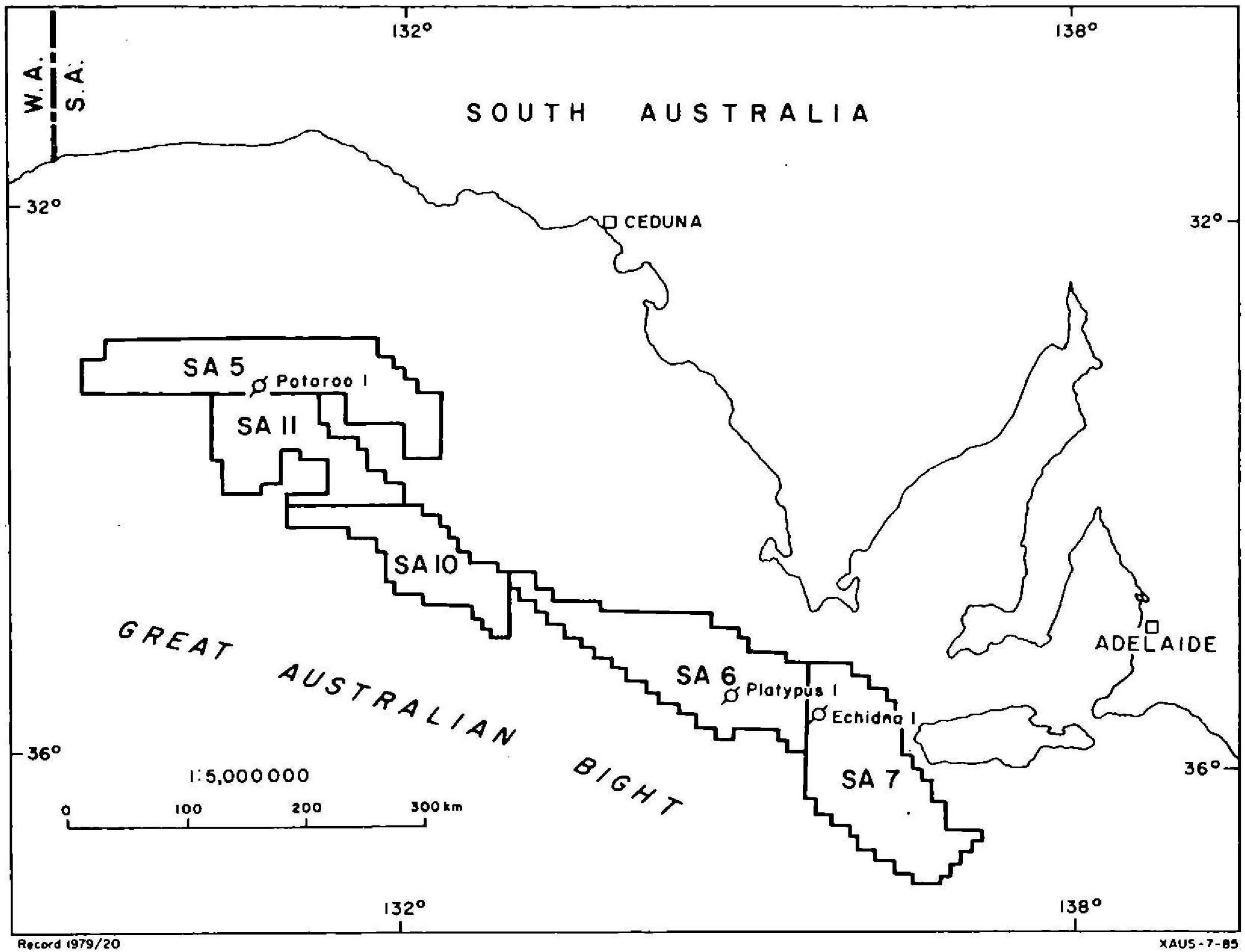


Fig. 4 Petroleum exploration permit areas in the Great Australian Bight Basin (as at July 1975)

porosities from 20 to 30 percent, and the Cenomanian to Albian 'Platypus Formation', channel sands with thicknesses of up to 30 m and porosities of from 15 to 24 percent. In structural traps dependent on fault closure, the relatively high percentage of sand (up to 58%) in the Cretaceous sequence reduces the chance of sealing across the faults by interbedded shales.

In the main basin area Potoroo No. 1 intersected good potential reservoir sands in the Middle Eocene to Late Paleocene, the Early Paleocene to Cenomanian, and the Neocomian sections. At the upper two levels the sands were mainly unconsolidated, with porosities of up to 35 percent. The Neocomian sands were poorly sorted and clean in the top 30 m of the sequence and well sorted, pyritic and micaceous in the bottom 50 m. Porosities ranged from 9 to 25 percent.

Prospectivity Further exploration will be necessary before the prospectivity of the Great Australian Bight Basin can be adequately assessed. The three wells drilled have provided broad stratigraphic control and identification of mapped seismic horizons. They have also demonstrated the presence of suitable source, reservoir and cap rocks. However, post-drilling analysis indicates that they were not optimally sited for hydrocarbon entrapment. The geophysical work carried out in the basin has provided broad regional, and locally detailed, structural control.

Existing data indicate few, if any, well-defined prospects in the shallower water areas.

The 'central high' in the Duntroon Embayment appears to have poor petroleum prospects because of the partial or complete erosion of the Upper Cretaceous section containing the prospective Platypus Formation. The results of Echidna No. 1 downgraded the prospectivity of two other anticlinal closures mapped in the Lower Cretaceous strata.

The petroleum potential of the main basin area is still virtually untested since the only well drilled intersected potential reservoir sands at various levels but appears to have been drilled on a structure without seal on the bounding fault. Since the source rocks intersected in the Potoroo well should be mature for hydrocarbon generation at deeper levels within the basin there is a chance that up-dip entrapment could have occurred at other locations on the northern margin.

At this stage of exploration the prospectivity of the deep water permits, considered purely in terms of the existence of hydrocarbons, must be rated as fair to good. However the high cost of drilling in water depths of over 1000 m, and more than 200 km from shore, is a discouraging factor, particularly as the source rocks in the area appear likely to be gas prone. Only large structures can be considered as possible drilling targets in the deep water areas. One such prospect has been indicated by seismic surveys in SA-10.

6. BREMER BASIN

6.1 Tectonic history and structure

The basal sediments of the onshore part of the Bremer Basin are in strong unconformity with the Archaeozoic crystalline rocks of the Yilgarn Block. The beds are everywhere flat-lying and there are no unconformities within the sedimentary sequence. No faulting has been observed. There has been no sedimentation onshore since the Late Eocene. As a result of epeirogenic movements from Oligocene times to the present, marine Eocene rocks occur at elevations of up to 300 m above sea level, as for example at Ravensthorpe, some 50 km inland from Bremer Bay (Cope, 1975).

Offshore there are no wells and the tectonic history must be inferred from largely uncontrolled geophysics. Seismic data suggest that Tertiary sediments directly overlie Precambrian basement on the continental shelf. On the continental slope seismic profiles presented by Cooney, Evans and Eyles (1974) indicate a thicker section. Those authors interpret a thick lower Cretaceous unit which is block-faulted, overlain by Upper Cretaceous, lower Tertiary and upper Tertiary sediments, each has been structured by lateral movements, then deeply eroded prior to rapid 'pull-apart' movements associated with the separation of Australia and Antarctica.

6.2 Stratigraphy

The onshore sediments in the coastal region of the Bremer Basin comprise the Plantagenet Group. Further inland, sediments occurring at isolated locations are known as the Eudynie Group. All the formations of both groups are related to the Eocene transgression that followed on the beginning of seafloor spreading to the south. Since Eundynie Group outliers are found as far north as Norseman it is reasonable to assume that the Eocene transgression spread over the southeast corner of the Yilgarn Block from the present limits of the Eucla Basin to Albany, or at least extended inland along broad shallow river valleys.

The stratigraphy of the Plantagenet and Eundynie Groups is given in Table 1.

Pending the drilling of one or more wells the details of stratigraphy offshore must remain unknown.

6.3 Geophysics

Because of the discouraging nature of sedimentary outcrops onshore in the Bremer Basin there have been no onshore geophysical surveys for petroleum except for a regional gravity survey. Offshore, a number of oceanographic cruises have crossed the region and the basin has been investigated by the BMR Continental Margin survey and the Shell Deepwater Scientific survey. One petroleum exploration company has carried out reconnaissance aeromagnetic and seismic surveys over the offshore basin and two other companies have also done seismic surveys.

(a) Magnetic surveys

Plate 2 shows the position of aeromagnetic flight lines and marine magnetic traverses. Aeromagnetic basement depth contours are shown in Plate 3.

Between 1960 and 1967 five oceanographic cruises, which included magnetic measurements, were made over the Bremer Basin region (Riesz and Moss, 1971). Not all the results of these cruises are readily available. The data produced are largely superseded by later surveys.

The magnetometer profiles produced on the BMR Continental Margin survey in 1972, the Shell Deepwater Scientific survey in 1973 and a seismic survey by Esso Australia in 1974 are useful for correlation with seismic sections made concurrently on those surveys, but interpretation of the magnetic profiles is not generally available.

The most important magnetic survey in the basin was the Bremer Basin aeromagnetic survey done for Esso Australia in 1972 (Esso, 1973). This survey extended from Point D'Entrecasteaux in the west to Esperance in the east and from the coastline to about 50 km offshore. Flight lines were in pairs 6 km apart, roughly perpendicular to the coast with approximately 18 km between pairs.

Aeromagnetic interpretation indicated generally shallow magnetic basement on the continental shelf, particularly on the eastern portion (Pl. 3). Somewhat thicker sediments were indicated in basement depressions in the central and western portions of the shelf.

On the western part of the shelf results indicated an east-trending trough with a maximum sediment thickness of about 2 km. Water depths over this trough vary from 0.2 to 2 km. In the central portion of the survey area, a long narrow northeast-trending trough with approximately 1.6 km of probable sediments is indicated to lie close to the continental slope, beneath water depths of between 0.2 to 0.5 km. On the eastern flank of the survey area probable sediment thickness is indicated by the aeromagnetic survey to be less than 0.6 km. However, within an infilled graben on the edge of the continental shelf, sediments may attain a thickness of about 4 km. This is in an area where Teledyne detected several submarine canyons during a sparker seismic survey in 1970. Water depths range from 1 km to 4 km over this interpreted graben. Over the whole of the Bremer Basin magnetic basement appears to be close to the sea floor near the continental rise.

(b) Gravity surveys

Onshore, the only extensive gravity survey of the Bremer Basin region was a BMR reconnaissance helicopter gravity survey of the southwest of Western Australia carried out by BMR in 1969 as part of the regional gravity coverage of Australia (Fraser, 1974). Many thousands of gravity stations were read on an approximately 11 km grid.

Gravity readings were made offshore from Albany on a number of regional oceanographic cruises between 1960 and 1963 (Riesz and Moss, 1971), but only the data from the Argo 2 cruise for the Scripps Institute of Oceanography are available within BMR. The Shell Deepwater Scientific survey in 1973 included gravity readings over the outer part of the basin. The gravity anomalies depicted offshore in Plate 4 are based on data from the BMR Continental Margin survey. These are preliminary values and are subject to some error because of uncertainty in positioning.

The outstanding gravity feature onshore is the 'Porongorup Regional Gravity Low' extending east-west for about 200 km north of Albany (Fraser, 1974) and covering most of the onshore portion of the Bremer Basin. This negative Bouguer anomaly coincides approximately with a large outcrop of Proterozoic granite and it can therefore be attributed to the low-density granite rather than to the presence of a significant thickness of sediments. Similarly, the negative Bouguer anomalies observed north of Bremer Bay are considered by Fraser to be caused mainly by the low-density granites of the Yilgarn Block.

Offshore the Bouguer anomaly pattern is dominated by a steep gravity gradient trending approximately parallel to the coast and located some 50 to 100 km from the shore. Bouguer values become more positive seawards. This gravity gradient, in the vicinity of the continental slope, is evidently associated with the thinning of continental crust across the continental margin. There is some evidence of local negative anomalies superimposed on the regional gradient, for example in the area south of Albany and south and east of Bremer Bay, which may indicate the presence of thicker than usual accumulations of sediments.

(c) Seismic surveys

Apart from oceanographic surveys mentioned previously, the first offshore reconnaissance seismic survey in the Bremer Basin was conducted by Teledyne in 1970. The Teledyne reconnaissance survey used a sparker energy source with 12-fold CDP coverage. Data quality was generally fair. Exploration was restricted to the deepwater areas parallel to the edge of the shelf where a number of seafloor ravines and block faulted structures were discovered.

The offshore part of the Bremer Basin was traversed seismically by the BMR Continental Margin survey in 1972. The resolution of the BMR sparker lines in this area was generally poor and it was difficult to recognise basement. With the exception of the eastern portion of the basin, BMR work in the Bremer Basin has not been reported on at the time of writing.

The nearshore eastern flank of the Bremer Basin was explored by Continental Oil in 1972 with their Offshore Esperance seismic survey. Recordings were made with an airgun energy source and 24-fold CDP coverage. A shallow high speed refractor was detected over all of the survey area on the continental shelf at depths of between 100 and 600 m. Since islands in the area are largely composed of Archaean rock, it is reasonable to assume that the high-speed refractor is Precambrian basement. The near-horizontal sediments form a thin wedge ranging from zero thickness near the shoreline to 1000 m at the edge of the continental shelf.

Several lines of the Shell Deepwater Scientific survey of 1973 provided additional reconnaissance seismic cover over the Bremer Basin from the continental shelf seawards for about 300 km from the coast (Pl. 5B). The use of airgun energy sources and 24-fold CDP recording gave poor to fair quality seismic data.

The seismic results indicated that tectonic trends offshore follow the east-west trend of the coastline. The continental slope is steep and characterised by deep erosion channels and slumps. Measured seismic velocities of 5.6 km/s suggest that Precambrian metamorphics underlie the shelf over much of the Bremer Basin area. At the seaward ends of the Shell traverses magnetic and seismic data suggest that basement is of volcanic character and there is magnetic evidence that volcanics may occur higher up the continental slope and on the shelf.

Sedimentary cover on the shelf was indicated to be thin and tectonically undisturbed. Some thousands of metres of sediments were indicated on parts of the continental shelf and rise. On the slope the thickness of sediments was very variable and faults and unconformities were evident. The Shell survey was insufficiently detailed to indicate whether prospective structures were present.

In 1974 Esso Australia carried out the Offshore Bremer (R74A) marine seismic survey, consisting of 2224 km of seismic lines on the continental shelf and slope between latitudes 116° and 122°E (Pl. 5B). Airgun energy sources were used in conjunction with mainly 24-fold CDP coverage. 247 km of 48-fold coverage were recorded. Seismic data quality was generally poor to fair. Poor results may have been partly due to strong reflection of energy from a hard water bottom. Magnetic profiles are shown on the seismic sections.

The results of this survey confirmed that sediment cover on the continental shelf is relatively thin and tectonically undisturbed. The continental slope is very steep in some places, but in others it is interrupted by terracing. Whereas sediment thickness was generally indicated by the seismic results to be less than 1000 m on the shelf, more significant accumulations of sediments were indicated on parts of the slope. In the area southeast of Bremer Bay more than 6000 m of sediments were indicated in an areally small depression with an arm extending southwestwards along the edge of the continental shelf. A number of faulted anticlines were indicated by the seismic data.

6.4 Petroleum prospects

The petroleum prospects of the onshore part of the Bremer Basin are virtually nil, as the region is devoid of structure and lacks adequate source and cap rocks. Nevertheless, three very shallow petroleum exploration wells have been drilled, without success (App. 1).

The offshore part is known only from geophysical surveys and inference. The shelf area can be considered unprospective, since the situation appears similar to that onshore. Geophysical results in the continental slope area indicate isolated pockets of thicker sediments (6000 m or more). On the western Bremer Basin continental slope, seismic results disclosed two major eroded anticlines which exhibit apparent closure. Water depths over these structures are in excess of 700 m. On the eastern slope, no potential structural or stratigraphic hydrocarbon traps are known.

Overall, the prospectivity of the Bremer Basin is low. Some prospects exist on the continental slope, but because of the depth of water and the remoteness of the region these prospects do not currently appear economically attractive as drilling targets.

7. POLDA BASIN

7.1 Tectonic history and structure

Although the Polda Basin is located near the southern margin of the Australian continent, its origin is not as clearly related to the major tectonic events accompanying the separation of Australia from Antarctica as is the case, for example, with the Great Australian Bight and Bremer Basins. The main part of the basin, the Elliston Graben, is bounded by major faults oriented east-west rather than parallel to the edge of the continental shelf in the vicinity. Two wells drilled in the Polda Basin (see Section 7.2) indicated that Tertiary and Late Jurassic sediments overlie basement and that Cretaceous sediments are absent, at least in the eastern portion of the basin.

Griffiths (1971a) suggested that the Elliston Graben was an incipient major rift or 'splay' which developed at a bend in the main rift valley preceding separation of Australia and Antarctica. However it appears that the axis of the main rift valley was considerably to the south of the Elliston Graben, and this seems to preclude any simple relationship between the graben and continental break-up.

Both aeromagnetic and gravity surveys over the Elliston Graben suggest that the boundary faults of the graben have throws greater than the 860 m depth of the base of Late Jurassic sediments, and it is possible that faulting in the Elliston Graben in the Jurassic represented a rejuvenation of much older faults. Moreover, a number of grabens of similar size containing sediments older than Jurassic are known within the Gawler and Musgrave Blocks (Pl. 7). The

Moorilyanna Graben, 700 km to the north, is one of the more distant of these, but it has almost the same dimensions and strike as the Elliston Graben. It was formed during a strong tectonic event in the Mid-Adelaidean (Upper Proterozoic) and was rapidly filled with an ?Adelaidean clastic sequence locally up to 6000 m thick (Thompson, 1970). The only well in the offshore portion of the Elliston Graben encountered 'granitic' material below Jurassic sediments, but it is possible that elsewhere in the graben basement consists of Proterozoic sediments, particularly as seismic events which could represent layered sediments have been recorded from greater depths than the base of the Jurassic sediments in some areas, whilst presumed Proterozoic clastics are found onshore.

It is worth noting that the fault bounding the Great Australian Bight Ridge (Pl. 7) appears as a possible extension of the southern marginal fault of the Elliston Graben. If these faults are in fact related, then they constitute a very large-scale east-west fault lineament.

7.2 Stratigraphy

(i) Polda hydrologic basin. The hydrologic basin is bounded on the west by conglomerates and sandstones resting on granites. These sediments are commonly assumed to be of Precambrian age. The sediments of the hydrologic basin itself, as revealed in Polda Stratigraphic Hole No. 1 (Pl. 1), were described by Harris and Foster (1974) and this description is summarised in Appendix 3. It is thought that the sequence is not much thicker than the depth of the well (172 m), and that the Jurassic Polda Formation overlies 200 m or more of ?Precambrian coarse clastics.

The only well drilled offshore, and the only well in the basin to reach a considerable depth, is Gemini No. 1. This was drilled for Outback Oil in the eastern part of the Elliston Graben about 50 km offshore in 1975. The sediments from the seafloor to a depth of 285 m were not sampled, so neither the nature of the sediments nor their age is known with certainty. However there was some evidence that Tertiary limestones were present. The South Australian Department of Mines identified all sidewall cores from 294 m to the base of the sedimentary section at 856 m as Late Jurassic in age and non-marine in origin. Below 856 m the drilling rate decreased, the cuttings had 'granitic characteristics' and the logs indicated practically zero porosity in the interval from 856 m to the bottom of the hole at 884 m. The stratigraphy of Gemini No. 1 is shown in Appendix 3.

7.3 Geophysics

The offshore part of the Polda Basin (Elliston Graben) has been geophysically surveyed in considerable detail by an aeromagnetic survey and two petroleum exploration company seismic surveys (Pls. 2 and 5B). Apart from some gravity readings there has been no geophysical work in the small part of the basin located onshore.

(a) Magnetic surveys. The Elliston graben was covered by the Shell Development portion of the 1966 aeromagnetic survey of the eastern part of the Great Australian Bight (done for Outback Oil and Shell Development). Flight lines were oriented northeast-southwest and spaced about 13 km apart.

The aeromagnetic results delineated the graben particularly well. It was interpreted as a long, narrow, east-trending depression in magnetic basement about 180 km long, 20 to 30 km wide and generally 1500 m deep. Magnetic basement was deeper in several local depressions within the graben, the maximum interpreted depth being about 2500 m. By contrast, magnetic basement north and south of the graben was indicated to lie at only about 300 m.

(b) Gravity surveys. The offshore part of the Polda Basin has been sparsely covered by several gravity profiles surveyed as part of the BMR Continental Margin survey. Onshore there is regional gravity coverage.

Despite the rather sparse gravity information available in the area, the Elliston Graben is clearly evident on the Bouguer anomaly map (Pl. 4) as an east-trending negative anomaly of several tens of milligals extending west from the coast at latitude approximately 33°30'E. The extent and orientation of the graben as indicated by gravity are similar to those indicated by the aeromagnetic data.

(c) Seismic surveys. The two main seismic surveys which have been done in the Elliston Graben were carried out by the contractor Teledyne Exploration in 1970 and 1971 for Bridge Oil and Target Exploration respectively. These surveys involved more than 1000 km of 24-fold CDP reflection coverage using airgun energy sources, a number of refraction profiles and some single-fold reconnaissance reflection profiling outside the graben using a sparker energy source. The quality of the multi-fold shooting was mostly fair, while the sparker sections were adequate to demonstrate the presence of shallow basement.

The seismic results confirmed the existence of the Elliston graben as outlined by the aeromagnetic survey. It is a fault-bounded east-west depression filled with sediments exhibiting complex structures, surrounded by a shelf area with flat-lying sediments overlying shallow basement. The width of the graben is indicated by seismic data to be about 20 km.

Reflections from immediately below the sea bed are strong, near-horizontal and undisturbed. These evidently represent Tertiary shelf deposits. At about 0.6 to 1.0 seconds reflection time (500 to 1200 m depth) there is a strong band of reflections representing a very uneven, probably erosional surface. In some areas there are strong events beneath the erosional surface which, before the drilling of Gemini No. 1 on a seismic structure in the eastern part of the Elliston Graben, were interpreted as relatively flat lying sediments of Proterozoic or early Palaeozoic age. This interpretation was consistent with indications from the aeromagnetic data and with evidence from refraction profiles or low to medium velocity rocks extending to depths in excess of 1500 m. However, the occurrence of 'granitic' or volcanic material at about 860 m in Gemini No. 1 well has cast doubt on this interpretation and raised the possibility that the uneven erosional surface evident on the seismic sections at this depth is in fact economic basement. However, if the igneous material encountered at the bottom of Gemini No. 1 represents a volcanic flow or a sill then it could be underlain by a deeper sedimentary sequence.

Assuming that the irregular surface probably does represent economic basement, the seismic sections indicate that 'basement' is overlain by gently to moderately dipping sediments, some of which reflect 'basement' relief to some extent. Faulting is evident, but this is generally poorly defined within the graben. The results of Gemini No. 1 indicate that these sediments between the flat-lying Tertiary sediments and the irregular 'basement' are Late Jurassic in age. There is unfortunately no evidence from the seismic data that 'basement' is significantly deeper elsewhere in the Elliston Graben than it is at Gemini No. 1.

7.4 Petroleum prospects

Gemini No. 1 was drilled on a seismically delineated prospect where the seismic sections suggested the presence of at least 2000 m of sediments, most of which the Company hoped would be a thick marine Lower Cretaceous section overlying lacustrine and fluviatile Jurassic sediments. There was no evidence from the samples that the Cretaceous was present at all, and the well was abandoned in igneous rocks at depth of 894 m. This result has seriously downgraded the prospectivity of the Polda Basin, but some doubt remains as to whether the igneous material encountered represents solid basement or whether it may be underlain by prospective sediments. A second offshore well will eventually be required in order to resolve this question. At present the prospectivity of the Polda Basin is regarded as low but not completely hopeless.

8. EYRE-ENCOUNTER BAY SHELF

8.1 Tectonic history and structure

As the Shelf is submerged (except for several scattered Tertiary hydrologic basins) little is known of its structure. Gravity and magnetic surveys having indicated a shallow basement, the area has been eschewed by oil companies.

The only faults of any consequence hitherto detected are in the Gawler Block - the boundary faults of the Elliston Graben on the western side, and the Spencer Gulf faults, mostly onshore. Miles (1952) showed that Plio-Pleistocene faulting on Eyre Peninsula resulted in the foundering of the Spencer Gulf sunkland.

It is probable that most if not all the shelf area was submerged in the Eocene transgression, as marine Eocene beds have been found in the Talia Lobe of the Polda Basin, in the Uley-Cummins-Wanilla Basin (a shallow, elongate, Tertiary, hydrologic basin on the southern part of Eyre Peninsula) in the St Vincent Basin, and in the Encounter Bay area near the mouth of the Murray. Other evidences of marine transgressions in the Shelf region are:

(i) possible Miocene sediments in the Robinson Basin (another Tertiary hydrologic basin, on the western side of Eyre Peninsula);

(ii) the occurrence of the Quaternary Bridgewater Formation in coastal cliffs and islands, as for example Wedge Island at the entrance to Spencer Gulf, where the Bridgewater Formation forms cliffs 200 m high;

(iii) the drowning of the Encounter Bay area by a sub-Recent (Flandrian) transgression, such that the old Murray course can be traced from its present mouth, across the seafloor, to its pre-Flandrian mouth south of Kangaroo Island.

Some geophysical data have been interpreted as showing that the onshore Padthaway Ridge (the northwest-trending, largely buried Early Palaeozoic connection between the Fleurieu Peninsula and the Western Highlands of Victoria) really extends offshore as a "Padthaway Platform" in which a deep valley (possibly modified by glacial action) filled with Permian sediments extends in a northwest direction roughly along the line of the Coorong Towards the Permian sediments on the Fleurieu Peninsula.

It is not impossible that some igneous rocks may exist in that part of the Shelf between Kangaroo Island and the Otway Basin. The volcanic activity of the Mt Gambier region took place along northwest-trending faults and joints, and the prolongation of this volcanic belt would traverse the area in question. On Kangaroo Island both Middle Jurassic and Recent basalts have been found.

8.2 Stratigraphy

The only stratigraphic information available about the Eyre-Encounter Bay Shelf concerns its landward fringe, but is is reasonable to assume that the thin shallow offshore sedimentary cover resembles sediments known onshore.

On Eyre Peninsula the Wanilla Formation (Harris, 1966) has been intersected in many shallow water bores in the Uley-Cummins-Wanilla Basin. It consists of micaceous and carbonaceous quartz sands with interbedded brown lignites, and its greatest known thickness is about 85 m. It contains a rather stunted marine microfauna of Middle to Late Eocene age (Lindsay, 1974). Sandy limestones thought to be of Miocene age have been found in water-wells in the Robinson Basin on the peninsula.

In the Encounter Bay region, onshore wells indicate that Kanmantoo metasediments with intrusive Delamerian granites form the basement of the area. Permian sediments are also known. The Donna No. 1 well onshore north of Encounter Bay (Pl. 1) drilled more than 450 m of Permian and 150 m of Cainozoic sediments.

8.3 Geophysics

Because of early aeromagnetic indications of thin sedimentary section there has been no intensive geophysical exploration of the Eyre-Encounter Bay Shelf northwest of Kangaroo Island. The BMR Continental Margin survey provided sparse, regional geophysical coverage of much of the area (Pl. 5B).

(a) Magnetic surveys In 1966 Aero Service Limited carried out a large regional aeromagnetic survey for Shell Development and Outback Oil which covered most of the Eyre-Encounter Bay Shelf. This survey involved more than 16 000 km of traverses with a line spacing of about 11 km covering the whole of the South Australian continental shelf northwest of Kangaroo Island (Pl. 2). The results indicated that most of the shelf was underlain by shallow magnetic basement. Over large areas magnetic basement was indicated at depths of only about 300 m. The magnetic results clearly outlined the Polda Basin as a narrow east-trending region of deeper magnetic basement cutting across the shelf, and also indicated small depressions in magnetic basement immediately offshore near the Head of Bight and within portion of Spencer Gulf. The only other areas of relatively deep basement were along the edge of the shelf and on the continental slope.

The portion of the Eyre-Encounter Bay Shelf east of Kangaroo Island was covered by the Bass Strait-Encounter Bay aeromagnetic survey flown by Aero Service Limited for Haematite Explorations in 1961. Line spacing was mostly about 5 km. As on the remainder of the Shelf, magnetic results indicated shallow magnetic basement, ranging from about 300 to 1000 m below M.S.L., in the region between Kangaroo Island, Encounter Bay and Cape Jaffa.

(b) Gravity surveys The regional gravity contours shown in Plate 4 for the Eyre-Encounter Bay Shelf region are largely derived from data recorded on the widely spaced traverses of the BMR Continental Margin geophysical survey. The regional gravity contours mainly reflect intrabasement composition and structure and are of little or no significance in petroleum exploration.

(c) Seismic surveys Since 1966 numerous seismic surveys have covered parts of the Eyre-Encounter Bay Shelf (Pl. 5B). The seismic surveys have tended to confirm aeromagnetic indications of widespread shallow basement. Basement in the region was generally seismically mapped at depths of less than 1000 m, although thicker sedimentary sequences were indicated in the Polda Basin, Duntroon Embayment and Gulf St Vincent. The thin sedimentary sequence overlying basement of the Eyre-Encounter Bay Shelf is horizontal or only gently dipping and is structurally undisturbed.

8.4 Petroleum prospects

Because the sedimentary sequence overlying economic basement on the Shelf is very thin, near-horizontal and lacking in structure, its petroleum prospects are considered negligible.

9. GULF ST VINCENT AREA

9.1 Tectonic history and structure

(i) Stansbury Basin The Stansbury Basin sediments were laid down during the last depositional phase of the development of the Adelaide Fold Belt. Deposition had gone on in this belt since the early Adelaidean (Proterozoic), with interludes of tectonism of greater or lesser intensity. Adelaidean times concluded with the Duttonian Tectonism, but the Cambrian did not usher in any great change in the depositional pattern. The shelf sediments deposited on the southeastern part of the Gawler Block are those which today constitute the Stansbury Basin. Table 2 summarises the stratigraphy and the tectonic history of the basin.

Towards the end of the Early Cambrian the Kangarooian Movements resulted in uplift (Cassinian Uplift) and erosion of the Lower Cambrian sediments in part of the present Stansbury Basin area. The eroded sediments were deposited in the Stansbury Basin, and in the subsiding Kanmantoo Trough to the south (Waitpingian Subsidence) where they were subsequently metamorphosed and intruded by granite during the Delamerian Orogeny. Consequently Middle Cambrian sediments in the Stansbury Basin are equivalent to metasediments of the Kanmantoo Group on Kangaroo Island and Fleurieu Peninsula, while similar Lower Cambrian sediments occur in both areas (Table 2, & Figs. 42 and 43 in Parkin, 1969).

The Delamerian Orogeny was the climactic event in the development of the Adelaide Fold Belt, and no sedimentation occurred there for another 200 million years, and indeed there has been very little even to this present time.

Latter-day faulting in the Cainozoic, associated with the formation of the St Vincent-Pirie-Torrens Basin, has affected the Stansbury Basin.

(ii) Troubridge Basin The Permian Troubridge Basin sediments rest with angular unconformity on Cambrian and older rocks, the actual surface of unconformity being in places a glaciated pavement, whilst in others glaciated valleys have been excavated in the older rocks and have been filled in with Permian glacigene debris. Still other areas seem to have been below the sea and to have received an enveloping rain of till components from melting glaciers.

There seem to be no significant structures in the Permian apart from the faults belonging to the Cainozoic tectonism.

(iii) St Vincent Basin The Cainozoic St Vincent Basin was extensively influenced by faulting associated with the Cretaceous tectonism preceding the separation of Australia from Antarctica. Roughly parallel north-south step-faults formed on Yorke Peninsula, while to the east northwardly divergent faults appear to have followed the Delamerian structural grain on Fleurieu Peninsula. An aggregate of fault blocks extending from Gulf St Vincent northwards through Lake Torrens, evidently following the ancient tectonic trend lines of the Adelaide Fold Belt, is known as the South Australian Rift Valley. This is the most tectonically active part of Australia at the present day (Pls. 1 & 7).

The sea gained access to the rapidly subsiding southern end of the growing rift-valley system in the early Eocene and advanced as far north as a cross-block called the Nantawarra Ridge, a little to the north of the present-day head of Gulf St Vincent. The Gulf has thus been in existence from the Eocene to the present, its extent being at times greater and at other times lesser than it is now. The St Vincent Basin consists of the sediments laid down in that part of the rift-valley south of the Nantawarra Ridge, and its small sub-basins are those extensions of sedimentation in areas controlled by the divergent faults on the Fleurieu Peninsula.

Unconformities within the St Vincent Basin sequence are shown in Figure 5 and Plate 8, from which it may be seen that sedimentation was much more sporadic in the northern end of the Basin than in the southern. It is thought probable that in the central parts of the southern end of the Basin sedimentation was continuous from the Eocene to the present; the sediments are known to be more than 300 m thick west of Adelaide.

North of Gulf St Vincent the rift valley narrows across the 'thigh' of Yorke Peninsula and continues so through Port Augusta to the southern end of Lake Torrens, whence it becomes broader again (Pls. 1 & 7). The Pirie-Torrens Basin occupies this northern section of the rift valley, which in the Lake Torrens depression itself has subsided some 500 m between the Torrens Fault on the west and a series of splinter faults on the Flinders Ranges side. This northern basin has been the site of fluvio-lacustrine deposition to varying degrees since the Eocene, the only exception being a small marine transgression of Quaternary age in the Port Augusta region when the waters of the Late Tertiary Spencer Gulf broke into the older rift valley system.

The Mount Lofty Ranges, which form the east ramparts of the rift valley in the Adelaide region, are reckoned to have been uplifted some 200 m in Late Pliocene times.

9.2 Stratigraphy

i) Stansbury Basin   The stratigraphy of the Stansbury Basin is shown in Table 2. The basin can be regarded as belonging to the Cambrian phase of the development of the Adelaide Fold Belt for which the type area is in the Flinders Ranges. Sedimentation began in the early Adelaidean, and continued for the following 900 million years, until it was terminated by the Delamerian Orogeny. A widespread Proterozoic depositional unit extends through the Adelaide region into northern Australia, and has equivalents in Antarctica.

Cambrian sedimentation was preceded by a regressive period at the end of Adelaidean time, during which the eastern margin of the Gawler Block was exposed. A stable shelf, called the Stuart Shelf, extended from Kangaroo Island to the area west of Lake Torrens. In the early Cambrian the sea again transgressed across the Stuart Shelf, where shelf-carbonates were deposited, interfingering with shales in the deeper offshore areas. There was a regression of the sea towards the end of Early Cambrian times, and in the south the Kangarooian Movements were sufficient to allow exposure and erosion of Lower Cambrian sediments. The Middle Cambrian was characterised by the deposition of redbed clastics and shelf carbonates on what was left of the southern part of the Stuart Shelf, whilst to the east thereof the Kanmantoo Trough developed.

The Lower Cambrian strata in the Stansbury Basin correlate with the Hawker Group, and the Middle Cambrian with the Lake Frome Group of the type localities in the Flinders Ranges.

ii) Troubridge Basin   The type section for the Troubridge Basin is seen in the Cape Jervis Beds of the southern end of the Fleurieu Peninsula. These consist of about 30 m of clay shale, sandstone and till (Ludbrook, 1967) overlying the Cambrian Kanmantoo Group.

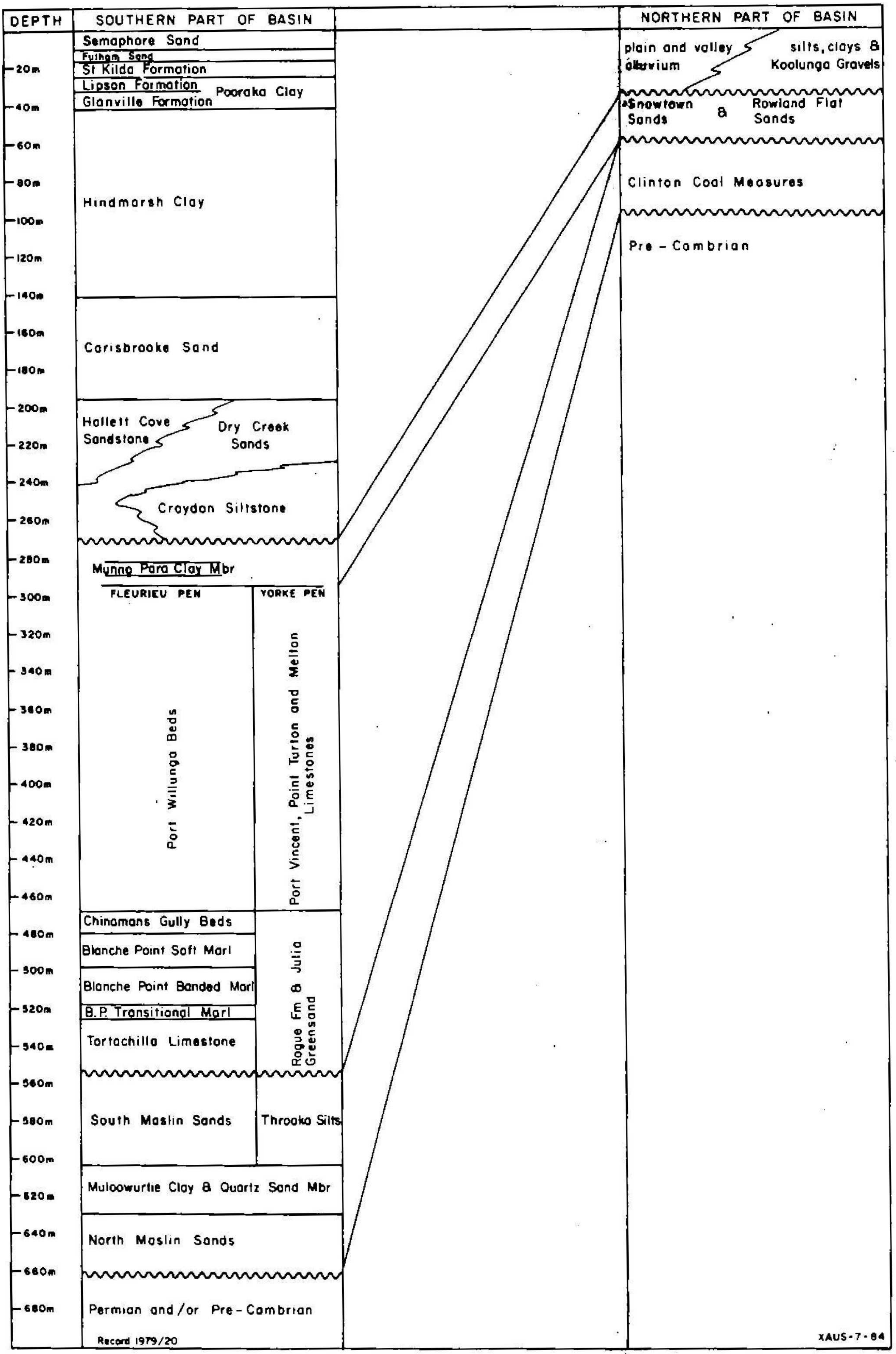


Fig. 5 Generalised stratigraphy of St Vincent Basin

In the Encounter Bay area the Permian, as intersected by W.G. Goyder's Donna No. 1 well (Pl. 1), consists of over 450 m of sands with shale interbeds.

iii) St Vincent Basin The generalised stratigraphy in the northern and southern parts of the basin is shown in Table 3 and Figure 5 against time and depth scales respectively. The stratigraphic sequence resembles that of the Torquay Basin more than it does the stratigraphy of the north-western areas of the Otway Basin, even though these are much nearer to Gulf St Vincent (Pl. 8).

The oldest beds (corresponding to the Eastern View Coal Measures) are of Middle to Late Eocene age and include the Clinton Coal Measures and the terrestrial North Maslin Sands. The beginning of the Tertiary marine transgression is recorded in sands of the Muloowurtie Clay on Yorke Peninsula even though conditions remained non-marine with clay deposition on Fleurieu Peninsula. Full marine conditions obtained with the laying down of the South Maslin Sands on Fleurieu Peninsula and the Throoka Sands on Yorke Peninsula.

Following a brief regression, the Tortachilla bryozoal limestone was laid down on Fleurieu Peninsula and the Rogue Formation (sandstones, sandy limestones, and clays) with the Port Julia Greensand Member, was laid down on Yorke Peninsula. There was no deposition in the northern part of the basin in Late Eocene and Oligocene times.

The Tortachilla Limestone was followed by a variety of marls (the Blanche Point Marls) and locally by variegated sands and clays (Chinamans Gully Beds) and then throughout the Oligocene and half the Miocene by the Port Willunga Beds. These consist of at least four limestone units plus the Munno Para Clay Member. On Yorke Peninsula the Port Vincent Limestone, of very variable thickness, is the part-equivalent of the Port Willunga Beds, and is in part gradational with the Rogue Formation. The Melton Limestone occurs at the northern end of Gulf St Vincent and the Point Turton Limestone on the 'instep' of the Peninsula. At least three marine ingressions have been postulated to account for variations in these mid-Cainozoic limestones.

The Late Miocene is characterised throughout southern Australia by a marine regression. The Pliocene transgression is recorded in the St Vincent Basin in the Croydon Siltstone, the Dry Creek Sands/Hallett Cove Sandstone, and the Carisbrooke Sand. A Pleistocene ingression is recorded in the Hindmarsh Clay and Glanville Formation.

At Port Augusta, equivalents of the Clinton Coal Measures, the Snowtown Sands, and Rowland Flat Sands are overlain by equivalents of the Hindmarsh Clay/ Glanville Formations with Anadara. The total thickness is about 150 m. The Anadara-bearing bed represents the only known marine incursion into the tip of the Spencer Gulf region.

In the Lake Torrens area, too, early Tertiary lignitic clays and sands exist.

9.3 Geophysics

The St Vincent Gulf area has been fairly well explored geophysically, mainly by Beach Petroleum, which held exploration licences over the Gulf and Investigator Strait for a number of years. The surveys, carried out principally between 1960 and 1972, included ground and airborne magnetic surveys, gravity surveys, and both land and marine seismic surveys. The BMR Continental Margin survey included a few regional lines through Investigator Strait to Gulf St Vincent, but the results of these lines are overshadowed by the more detailed information available from the Beach Petroleum surveys.

(a) Magnetic surveys

In 1955 the South Australian Department of Mines did the Southern Yorke Peninsula aeromagnetic survey. The Lake Fowler seismic, magnetic and gravity survey by Beach Petroleum on the southern portion of Yorke Peninsula in 1969-70 involved ground magnetic and gravity readings on seismic lines. The magnetic and gravity readings indicated two possible basement 'highs'.

The most significant magnetic survey over the Gulf proper was the St Vincent Gulf aeromagnetic survey flown for Beach Petroleum in 1964. The whole of the Gulf and Investigator Strait was surveyed by radiating flight lines approximately normal to the eastern and southern coasts of Yorke Peninsula. Flight lines were generally in pairs, about 2 km apart, while the spacing between pairs varied considerably, from about 2 km to 15 km.

The survey indicated a zone of high-amplitude magnetic anomalies on the western side of the Gulf and northern part of Investigator Strait, extending 20-30 km offshore from Yorke Peninsula. This zone of anomalies is interpreted as representing a considerably faulted region with magnetic basement at relatively shallow depths, less than 1500 m. In the Gulf this magnetically disturbed zone is bounded on the east, near the centre of the Gulf, by a north-trending magnetic gradient which has been interpreted as a major fault or hinge line.

To the east of this north-trending gradient magnetic anomalies are much broader and less intense. A depression in magnetic basement occupying the eastern half of Gulf St Vincent and extending southwards to Investigator Strait north of Kangaroo Island is indicated. The maximum depths of magnetic basement in this depression are interpreted to exceed 3000 m. However, some of the non-magnetic rocks overlying magnetic basement in this area could be Proterozoic sediments such as are known to occur onshore to the east.

(b) Gravity surveys

Gravity surveys were carried out onshore around Gulf St Vincent in the 1950s by the South Australian Department of Mines (Kerr-Grant, 1951, 1952; Seedsman, 1957) and Beach Petroleum did a number of gravity surveys on Yorke Peninsula between 1966 and 1969. Gravity readings were also taken on some seismic surveys by Beach Petroleum (App. 2). However, the principal gravity survey in the Gulf itself was a rather unusual underwater gravity survey done in 1964 for Beach Petroleum. 342 gravity stations at about 3 km intervals on east-west traverses about 8 km apart were read on the sea floor with the aid of a diving bell or with an encapsulated gravity meter and scuba equipment. The underwater gravity coverage was extended, with about 60 stations in Investigator Strait, in 1970-71.

The surveys showed that a marked gravity gradient crosses the Gulf, with gravity contours trending north to northeast. The most positive Bouguer anomalies occur near the west coast and anomalies become more negative to the southeast. A gravity depression with steep southeastern flank trends northeast through Adelaide (not evident on the regional gravity map in Plate 4). A pronounced east-west gravity gradient in the centre of the Gulf coincides approximately with the major fault or hinge-line suggested by the aeromagnetic results. The magnetic and gravity data therefore agree in indicating that dense, metamorphic or igneous basement lies much deeper in the eastern part of the than in the west.

(c) Seismic surveys

Onshore surveys The first seismic surveys in the St Vincent Gulf area were done onshore in several places around the Gulf by the South Australian Mines Department in the 1950s. The Adelaide Plains seismic survey by Geosurveys of Australia in 1960 used a simple, single-fold reflection technique and included some refraction work. The results were interpreted as indicating a sedimentary section of some 2000 m near the Adelaide beaches.

The southeast part of Yorke Peninsula was explored seismically by Beach Petroleum in 1965-66 with their Stansbury and Yorketown-Port Vincent seismic surveys. These surveys used single-fold coverage with explosives as energy source. The quality of results was generally poor, especially near the coast. The surveys demonstrated a general increase in thickness of Palaeozoic sediments to the southeast, towards the Gulf, and several anticlines were investigated.

The Lake Fowler seismic, magnetic and gravity survey was done by Beach Petroleum in the same area in 1969-70. The seismic work, using explosives, was mainly single-fold reflection shooting, with 3-fold coverage in selected areas. A number of refraction probes were shot in one direction only. The quality of reflection results was poor to fair. Reflections were recorded to a maximum of about 0.8 second (approximately 1500 m) in the southeastern corner of Yorke Peninsula. Three seismic horizons were mapped. These were identified by ties to Edithburgh No. 1 and Stansbury West No. 1 wells as a near-basement reflection, a reflection from the Cambrian Parara-Kulpara Limestone and a reflection from the Middle Cambrian Ramsay Limestone. Of these, only the second horizon can be regarded as being reliably mapped. Several small anticlines were indicated, perhaps the most notable one being a few miles southwest of Edithburgh (Sultana Point structure).

Between 1955 and 1966 a number of small magnetic, gravity and seismic surveys were done for the Department of Mines of South Australia, Santos Ltd and Geosurveys of Australia onshore in the Pirie-Torrens Basin north of Spencer Gulf (Kendall, 1966). These surveys, and a number of bores drilled, showed that a thin sequence (up to about 400 m) of Cainozoic sediments rests on Cambrian or Precambrian basement in the area.

<u>Offshore surveys</u> Between 1967 and 1972 Beach Petroleum carried out two marine seismic surveys in the Gulf and one small survey in a limited area of Investigator Strait. These surveys were all recorded with analogue magnetic tape equipment and coverage ranged from single-fold to 6-fold. The quality of results was generally poor, particularly on the first survey.

This survey, in 1967, was a reconnaissance survey over most of the Gulf. Despite poor results from mostly single-fold data, the survey broadly confirmed structural trends indicated by aeromagnetic and gravity surveys and suggested the presence of several anticlines, including one near Troubridge Island in the southwest of the Gulf. The Troubridge Island area seismic survey in 1969 employed the 'Aquaseis' (explosive cable) energy source and 6-fold coverage. It helped to define the Sultana Point structure in the vicinity of Edithburgh and another structure in the centre of the Gulf, although neither of these structures can be regarded as well-defined by seismic surveys. A refraction probe shot near Troubridge Island showed that about 1675 m of sediments probably overlie high-velocity Lower Cambrian limestones in the area. This was in general agreement with the reflection results.

The small Marsden seismic survey in Investigator Strait in 1972 provided evidence of a structural 'nose' northeast of Kangaroo Island, where some 2000 m of sediments probably overlie Proterozoic basement.

9.4 Petroleum Prospects

(i) Stansbury Basin This Cambrian Basin is underlain by Proterozoic Adelaidean sediments, which are about 600 m thick on Yorke Peninsula and up to 10 000 m thick in the Mt Lofty Ranges area. Some of these Adelaidean sediments contain organic matter, but their porosity is virtually nil. It is unlikely that they contribute to the petroleum potential of the overlying sediments.

The Cambrian rocks are adequately thick for oil or gas accumulation, with thick potential source beds and competent cap rocks. Some of the limestones have secondary porosities even though the sandstones appear to be tight and impermeable.

There are over 760 m of Lower Cambrian shales and limestones in the Sellick Hill section south of Adelaide. Dark colour, fine grain, and fetid small on breaking suggest oil-source potential throughout the section. On Yorke Peninsula some of the Lower Cambrian limestones are lighter in colour, there is more contained benthos, and there are associated redbeds, all of which imply a lower source potential. The limestones have a known maximum aggregate thickness of about 640 m.

The Lower Cambrian Kulpara Limestone in Yorke Peninsula has 'restricted good porosity and permeability. Vugular porosity dominates, but pinpoint, intercrystalline, solution and fracture porosity are also represented' (Beach Petroleum, 1967b). On Fleurieu Peninsula porosity and permeability are poorer due to the nearness of the region to the strongly metamorphosed Kanmantoo Fold Belt.

The Cambrian strata were folded in the Delamerian Orogeny, but few closed structures have hitherto been identified. The Cambrian sediments are now preserved in broad fault-controlled synclines, and are unconformably overlain by flat-lying Lower Permian glacigene-marine sandy and pebbly clays. Some anticlinal features associated with drag along faults (thrusts) are believed to exist.

The intra-Cambrian unconformity resulting from the Kangarooian Movements could have allowed hydrocarbons to escape into the atmosphere or, alternatively, could have provided reservoirs with good porosity. Whether its overall effect was deleterious or advantageous for hydrocarbon accumulation is not known.

Beach Petroleum drilled five wildcat wells (three of them subsidised under PSSA) and one shallow stratigraphic bore on Yorke Peninsula in the period 1963 to 1967.

Stansbury West No. 1 well (Pl. 1) was drilled on the southern end of the regional and south-pitching Curramulka anticline, with closure defined on the unconformity between the top of the Cambrian redbeds and the Permian. The Archaean basement was about 830 m deeper than expected, showing that the Stansbury Basin becomes deeper towards Gulf St Vincent. No hydrocarbons were detected, but the dolomitised Cambrian beds were shown to have good reservoir characteristics, even though they and other porous beds were water-saturated.

The target beds in Edithburgh No. 1 well were the basal Permian sands and the dolomitised Parara-Kulpara carbonates, especially the Archaeocyatha Beds and the lower dolomitised Kulpara Limestone. Oil and gas shows in Cambrian sediments had been reported from shallow wells drilled in the Minlaton-Curramulka region, and from similarly dolomitised biohermal zones elsewhere e.g. the Santos Wilkatana, Delhi-Santos Gidgealpa and Exoil Ooraminna wells. No traces of hydrocarbons were found in Edithburgh No. 1. The dolomitised Cambrian section and the Permian sands were shown to have good reservoir characteristics but were salt-water bearing. The well demonstrated local facies variations from nearby wells, and Beach Petroleum concluded 'that the prospects for occurrence of commercial hydrocarbon accumulation through facies variation, or stratigraphic or structural trapping, remain high when one considers the black shale correlatives of the Yorke Peninsula carbonates which are present on Kangaroo Island'.

Stansbury Town No. 1 well was drilled on a structure thought to be a thrust-controlled anticline in the Cambrian strata (Pl. 11). Westerly thrusting along the east-hading fault was thought to have caused underdrag on the overriding block, producing an asymmetric anticline with a steep westerly limb on a gently dipping easterly limb. Such structures are common within the Proterozoic and Cambrian on Fleurieu Peninsula. At Stansbury Town, however, the fault has allowed interconnection between the Cambrian reservoirs, which are apparently water-saturated. Traces of hydrocarbon gas were detected in the basal Cambrian Transition Beds. The dolomitised Kulpara Limestone is considered to have good porosity and permeability in restricted areas, and the basal sandstone has a porosity of 11%.

The other wells drilled were Black Point No. 1a and Troubridge No. 1 and the shallow stratigraphic bore was Port Vincent No. 1 (Appendix 1).

On Kangaroo Island there are more than 6 000 m of comparatively gently folded unmetamorphosed Cambrian limestone, shales, and sandstones. The sandstones are tight, however, and there has been plenty of opportunity for any hydrocarbons generated to have been lost from the section.

(ii) Troubridge Basin The cold oceans of the Early Permian may be assumed to have been very rich in organic life, but they may have been well oxygenated if in an open environment, so abundant Permian marine life may have contributed little towards hydrocarbon accumulation in this situation.

The Permian sequence on Yorke Peninsula includes some marine lutites in which hydrocarbons could possibly have been generated given adequate depth of burial, but the relative thinness of the Permian section militates against this. Consequently, the Troubridge Basin has never been seriously considered as a good petroleum prospect per se. The best situation envisaged is that hydrocarbons might have migrated into the Troubridge beds from the underlying Stansbury Basin and might have been held in stratigraphic traps. Consequently, the wildcat wells that have been drilled in this area have usually included possible Permian sands as secondary targets. These fluvio-glacial sands are water-bearing and no significant hydrocarbons have ever been found in them, apart from some grease of unknown source in bores at Minlaton and Stansbury, and discounting some dubious accounts of gas occurrences. Nevertheless, the basal Permian in both the Minlaton and Stansbury bores is a coarse water-bearing bed which constitutes a potential hydrocarbon reservoir.

(iii) St Vincent Basin The Tertiary sequence includes carbonaceous shales and lignite or brown coal beds that could have been source rocks for hydrocarbons. These indeed probably have been the sources for such traces of hydrocarbons as have been found in St Vincent Basin sequences, for example near Lake Torrens and in Grange No. 1 well (Pl. 1). The Clinton Coal Measures are of the order of 60 m thick.

Some of the Tertiary limestones of the St Vincent Basin have, at least locally, good porosities due to solution, whilst some sandstones are not too clogged with clay and/or chalk to have significant porosities and permeabilities. In fact it is from such rocks in the Eocene, i.e. from the paludal deposits at the base of the Tertiary succession, that slight traces of hydrocarbons have been obtained.

Movements along the Cainozoic faults of the Rift Valley System are assumed to have caused some folded structures, such as the Grange Dome, and may of course have produced a variety of other fault-dependent structures.

Shales, marls, and dense limestones are available in the Tertiary sequence to act as cap rocks.

The St Vincent Basin has attracted little attention from the oil companies, although some desultory drilling was carried out in the early days of exploration by individuals and small companies, guided by a variety of determining factors including, for example, the use of the divining rod. The Adelaide Plains and nearby areas are dotted with abundant boreholes, most of them shallow, to tap underground water supplies. Marchant (1974) lists a variety of unsubsidised wells, and Beach Petroleum have drilled one well which was subsidised under PSSA.

This well, Grange No. 1, was drilled near Adelaide on an elongated dome discovered by a seismic reconnaissance survey. A vertical closure of at least 45 m was indicated on the base Tertiary, with a closed area measuring 5 km x 2 km. It was drilled in the hope that relatively unmetamorphosed marine Cambrian limestones and/or Upper Proterozoic sediments would occur beneath Tertiary and Permian sediments. Insignificant traces of gas were detected in the North Maslin Sands, below which the well encountered totally unprospective rocks of the Adelaide Fold Belt.

The thickest known Tertiary sequence in the St Vincent Basin is 683 m in the Croydon Bore, but the sequence is believed to be much thicker in the submerged part of the basin.

In the 1950s and early 1960s exploration for petroleum was carried out in the northern part of the St Vincent Basin, in the Lake Torrens area (Pirie-Torrens Basin). Santos Ltd commenced drilling operations in the Wilkatana area in 1954 and in the first percussion bore verified the existence of trace amounts of oils in early Tertiary lignite-bearing clays and sands at depths between 90 and 120 m. In 1957 Santos's Wilkatana bore No. 20 completed a pattern drilling program on a gridded area. Cambrian cherts and siliceous limestones were intersected (Kendall, 1968).

Following gravity and magnetic surveys in the Motpena area in 1956 and 1957, Santos Ltd drilled two wells 10.5 km west-southwest of Parachilna. These Motpena wells penetrated a Cambrian or Proterozoic basement at 168 m, the total well depth being about 214 m. Available data show that the steep westerly-dipping strata of the Flinders Ranges form a syncline beneath Parachilna and an anticline in the Motpena area, and are then downfaulted some 600 m to the west.

The unconformity between the Tertiary and the Cambrian at Wilkatana and Motpena suggests that any possible petroleum-bearing Cambrian beds have probably been heavily eroded and weathered with subsequent loss or even destruction of petroleum content. Petroleum prospects of the Lake Torrens area are now regarded as very poor.

Conclusions on prospectivity Any petroleum prospects in the Gulf St Vincent area seem to depend heavily on the Cambrian beds of the Stansbury Basin. These contain potential source, reservoir and cap rocks, but there is some doubt whether the sediments were subjected to adequate depths of burial to have generated hydrocarbons. Even if hydrocarbons were generated these could have escaped at the mid-Cambrian unconformity, the post-Cambrian unconformity or during a later period of erosion. Prospects of the area are regarded as poor, but there has been insufficient drilling, particularly in the submerged part of the ara, to allow a conslusion that the Gulf St Vincent area is without prospects.

10. CONCLUSIONS AND RECOMMENDATIONS

The most prospective basin for petroleum in the region reviewed is the offshore Great Australian Bight Basin, in which the Cretaceous sequence appears to meet all the criteria for hydrocarbon generation and entrapment. Lack of success in the few wells drilled is attributed to either lack of closure on the structures tested or absence of the prospective section. Until at least two more wells are drilled on well-defined closures, one in the deep-water part of the main basin area and another in the Duntroon Embayment, the hydrocarbon potential of the basin cannot be said to have been adequately tested. Decisions to drill particular structures will of course be strongly influenced by economic assessments of potential discoveries, as much of the basin lies in water deeper than 200 m and is fairly remote from large markets. While the basin may not be economically very attractive in the short term, it is considered to have considerable longer-term potential.

One or two structures indicated by seismic work on the continental slope of the Bremer Basin may also have some long-term potential.

Prospects in the Polda Basin and Gulf St Vincent area are considered poor, but further exploration is warranted to complete petroleum assessment of the areas.

The petroleum prospects of the Eucla Basin area and the Eyre-Encounter Bay Shelf, which together comprise a large proportion of the region reviewed, must be regarded as negligible.

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TABLE 1 - STRATIGRAPHY OF THE BREMER BASIN
(based on Playford and others, 1975b)

Group	Stratigraphy	Lithology	Maximum Thickness
Plantagent Group	Pallinup Siltstone Late Eocene	White, brown, red siltstone and spongolite Marine	61 m in Albany Aerodrome Bore; 47 m on Pallinup River
Plantagent Group	Nanarup Limestone Member of Werillup Formation	Brown - white friable limestone Shallow marine	4.6 m at Nanarup Quarry
Plantagent Group	Werillup Formation Late Eocene	Grey and black clay, siltstone, sandstone, lignite, carbonaceous siltstone. Paralic. N.B.:- lignites are up to 3 m thick in the Fitzgerald River area, and around Nornalup Inlet, but are not important economically	49 m in Albany Aerodrome Bore; 40 m in Werillup No. 3 Bore
CRYSTALLINE BASEMENT			

Group	Stratigraphy	Lithology	Maximum Thickness
Bundyne Group	Princess Royal Spongolite, late Eocene by analogy	Spongolite with minor clay and shale shallow marine	21 m exposed at Princess Royal
Bundyne Group	Cowan Dolomite	white dolomite	Cowan Dolomite at Lake Cowan Princess Royal and Lake Dundas where it is 12 m thick
Bundyne Group	Norseman Limestone Late Eocene	Shelly, bryozoan limestone, opaline shallow marine	9.1 m near Norseman
CRYSTALLINE BASEMENT			

TABLE 2 - STRATIGRAPHY AND TECTONICS OF THE STANSBURY BASIN

	Yorke Peninsula	Fleurieu Peninsula & Kangaroo Island
Late Cambrian Ord	DELAMERIAN OROGENY	
	open folds	intense folding, metamorphism, intrusion of granites
Mid-Cambrian	red-pink clastics) Upper 800 m) Red c. to red-grey clastics) Beds 1,800 m	Kanmantoo Group (mainly metasandstones; rapidly deposited; derived from a crystalline basement with an Adelaidean/Lower Cambrian cover; about 18,000 m thick)
	Dalrymple Limestone c. 60 m	
	grey-green clastics c. 30 m	
	Stansbury Limestone c. 60 m	
	red-green clastics c. 60 m	
	Ramsay Limestone c. 100 m	
	Lower Red Beds c. 150 m	
	Minlaton Conglomerate c. 25 m	
	KANGAROOIAN MOVEMENTS	
	<u>Cassinian Uplift</u>	<u>Waitingan Subsidence</u>
Early Cambrian	Parara Limestone c. 300 m	Heatherdale Shale
	Kulpara Limestone c. 300 m	Forktree Limestone
		Sellick Hill Limestone
	Transgressive Arkose c. 130 m	Wangkonda Limestone
		Mt Terrible Formation
Precambrian	DUTTONIAN TECTONISM	
	Adelaidean Era sequences of the Adelaide Fold Belt	

TABLE 3 - GENERALISED STRATIGRAPHY OF THE ST VINCENT BASIN

EPOCH	AGE	Southern end of Basin		Northern end of Basin
		Semaphore & Fulham Sands St Kilda Fm Lipson Fm		Fluvial Clays
PLEISTOCENE	1 m.y.	Pooraka Clay Glanville Fm Hindmarsh Clay		
	2 m.y.	wwwwwwwwwwwwwwwwwwwwwwwwwwwwwwwww		Koolunga Gravels
PLIOCENE		Carisbrooke Sand Dry Creek Sands/Hallett Cove Sst, Croydon Siltstone		
	5 m.y.	/ / / / / / / / / / / / / / / / / / non deposition / / / / / / / / / / / / / / / / / /		/ /
		wwwwwwwwwwwwwwwwwwwwwwwwwwwwwwwww		wwwwwwwwwwwwwwwwwwwwwwwww
MIOCENE		Port Willunga	Port Vincent	Rowland Flat Sands Snowtown Sands
	22 m.y.			/ / / / / / / / / / / / /
OLIGOCENE		Beds	Limestone	/ / / / / / / / / / / / / / /non deposition / / / / / / / / / / / / / / /
	38 m.y.	Chinamans Gully Beds Blanche Point Marls Tortachilla Lst	Rogue Formation, with Port Julia Greensand	/ /
		wwwwwwwwwwwwwwwwwwwwwwwwwwwwwwwww		wwwwwwwwwwwwwwwwwwwwwwwww
EOCENE		South Maslin Sands Muloowurtie Clay North Maslin Sands		Clinton Coal Measures
	50 m.y.	wwwwwwwwwwwwwwwwwwwwwwwwwwwwwwwww		wwwwwwwwwwwwwwwwwwwwwwwww

APPENDIX 1 - PETROLEUM EXPLORATION WELLS, GREAT AUSTRALIAN BIGHT REGION

BASIN or AREA, Company, Well, BMR File no. if subsidised	Latitude (S) Longitude (E)	Elevation (metres) G.L. Ground level R.T. Rotary table K.B. Kelly bushing W.D. Water depth	Date spudded; Date reached Total depth	Total depth (metres)	Status
BREMER BASIN					
Silfar Oil & Gas:					
Kendenup No. 1	34°29'36" 117°45'22"	G.L. 159	19.12.73 25.1.74	117	PA due to unsuccessful fishing
Sunday Swamp No. 1	34°45'07" 118°17'37"	G.L. 99	7.2.74 14.3.73	175	PA Thin coals between 60 and 90 m. Oil traces alleged (?from drilling mud).
Ocumup No. 1	34°32'45" 119°12'53"	G.L. 38 R.T. 40	10.6.76 29.6.76	273	PA Dry
EUCLA BASIN					
Exoil Pty Ltd:					
Eyre No. 1 62/1053	32°07' 126°58'	G.L. 14.6 R.T. 1.5	27.11.59 24.1.60	514	PA in granite beneath Cretaceous
Gambanga No. 1 62/1052	32°16' 124°50'	G.L. 119 R.T. 1.5	14.2.60 5.3.60	391	PA in granite beneath Cretaceous
Alliance Oil Dev.:					
Eucla No. 1 64/4004	31°52'15" 128°13'21"	G.L. 12	21.1.64 27.2.64	222	PA in granite beneath Cretaceous
Outback Oil:					
Cook No. 1	30°50' 130°41'	G.L. 100 R.T. 1	27.10.64 23.11.64	279	Completed as a water-bore at 274.3 m in assumed Lower Cambrian limestone
Hughes No. 1	30°42'50" 129°30'44"	G.L. 142.1	16.2.66 6.4.66	480	PA in assumed Cambrian redbeds
Hughes No. 2	30°31'42" 129°14'45"	G.L. 142.13	10.4.66 2.5.66	243	PA in assumed Cambrian dolomite
Hughes No. 3	30°29'45" 129°38'07"	?	6.5.66 4.6.66	280	PA in assumed Cambrian dolomite
Denman No. 1	30°39'20" 129°58'47"	G.L. 140 (?)	6.6.66 13.7.66	549	PA in ?Cambrian dolomite and shale
Mallabie No. 1 69/2013	31°32'14" 130°36'06"	G.L. 56.1 K.B. 59.8	21.6.69 5.8.69	1497	PA in granitic gneiss
Apollo No. 1	32°32'16" 130°51'13"	K.B. 8.54 W.D. 74.7	7.10.75 11.10.75	877	PA in granite No traces of hydrocarbons

BASIN or AREA, Company, Well, BMR File no. if subsidised	Latitude (S) Longitude (E)	Elevation (metres) G.L. Ground level R.T. Rotary table K.B. Kelly bushing W.D. Water depth	Date spudded; Date reached Total depth	Total depth (metres)	Status
POLDA BASIN Outback Oil:					
Gemini No. 1	33°28'44" 134°12'4"	K.B. 8.54 W.D. 68.32	18.10.75 27.10.75	894	PA in granite or syenite No traces of hydrocarbons
GREAT AUSTRALIAN BIGHT BASIN Shell Development (Australia) Pty Ltd:					
Potoroo No. 1	33°23'14" 130°46'07"	R.T. 261 W.D. 252	17.3.75 17.4.75	2924	PA in Neocomian sandstone No significant hydrocarbon shows
DUNTROON EMBAYMENT Shell Development (Australia) Pty Ltd:					
Echidna No. 1	35°36'15" 135°37'12"	R.T. 30 W.D. 13	16.1.72 12.3.72	3832	PA in Neocomian clay No traces of hydrocarbons
Platypus No. 1	35°25'10" 134°49'28"	R.T. 30 W.D. 158	21.3.72 27.4.72	3893	PA in Aptian sandstone No traces of hydrocarbons
GULF ST VINCENT AREA Beach Petroleum N.L.:					
Grange No. 1 62/1096	34°53'08" 138°30'05"	G.L. 6.1 R.T. 9.2	3.3.62 10.5.62	605	PA in Proterozoic shales, slates and quartzites Faint gas trace a little above basement
Port Vincent No. 1	34°47' 137°52'	1 metre above M.L.W.	29.1.63 20.2.63	46	PA in ?Oligocene brown clay Stratigraphic test
Troubridge No. 1	35°07'02" 137°49'42"	G.L. 0	17.5.63 7.6.63	488	PA Dry
Black Point No. 1A	34°37'13" 137°54'19"	G.L. 7.6	14.9.64 3.10.64	184	PA in presumed Lower Cambrian "redbeds" Stratigraphic test
Stansbury West No. 1 66/4204	34°54'02" 137°42'46"	G.L. 91.4 K.B. 98.1	12.5.66 24.6.66	1745	PA in Archaean gneiss. No traces of hydrocarbons. Permeable horizons fresh or saltwater bearing
Edithburgh No. 1 66/4225	35°06'10" 137°38'40"	G.L. 59.7 K.B. 63.4	7.9.66 25.9.66	1053	PA in Archaean gneiss No trace of hydrocarbons. Permeable horizons saltwater bearing.
Stansbury Town No. 1 67/4248	34°54'24" 137°46'46"	G.L. 32.6 K.B. 36.6	29.4.67 25.5.67	1269	PA in Archaean gneiss. Traces of gas in basal Cambrian Transition Beds.

PA - plugged and abandoned

APPENDIX 2 - GEOPHYSICAL SURVEYS, GREAT AUSTRALIAN BIGHT REGION

Magnetic surveys

Survey name	Year	Operator	Contractor	Survey altitude (m)	Traverse spacing (km)	Total traverse length (km)	Reference no.
Reconnaissance aeromagnetic survey of the Eucla Basin	1954	BMR	-	450	-	5,600	BMR Rec. 1958/87
Southern Yorke Peninsula aeromagnetic	1955	South Australian Dept of Mines	-	-	-	-	-
Ravensthorpe aeromagnetic & radiometric survey of Western Australia	1960	"	-	150	0.4	4,000	BMR Rec. 1962/2
Encounter Bay and Bass Strait aeromagnetic	1960-61	Haematite Exploration	Aero Service	609	32	1,500	PSSA 62/1710-11
Eastern Officer Basin aeromagnetic	1964	Exoil	Adastra Hunting Geophysics	700	2 & 15	23,877	PSSA 64/4608
St Vincent Gulf aeromagnetic	1964	Beach Petroleum	Aero Service	600	2.5	4,408	" 64/4609
Offshore South Australia aeromagnetic	1966	Outback Oil & Shell Development	" "	450	13	16,000	" 66/4620-21
Young Rocks aeromagnetic	1968	Hematite Petroleum	Compagnie Generale de Geophysique	457	3	2,860	" 68/3055
Eucla Basin aeromagnetic & radiometric survey, South Australia	1970	BMR	-	150	1.5	3,000	BMR 1972/60
Bremer Basin aeromagnetic	1972	Esso Australia	Geometrics International	300	24	7,025	PSLA 72/21
Magnetic & radiometric survey of the Coompana, Nullabor, Fowler, & Nuyts (onshore) 1:250 000 sheet areas, SA 1972/3	1972-73	BMR	-	150	1.5 & 3	3,200	BMR Rec. 1977/52

N.B. Seismic surveys which included magnetic readings are shown in the seismic survey listing.

APPENDIX 2 (continued)

Gravity surveys

Survey name	Year	Operator	Contractor	Traverse spacinge (km)	Station spacing (km)	No. of stations	Reference or file number
Regional gravity traverses across the Eucla Basin	1954/55	BMR	-	-	8	395	BMR Rec. 1956/145
St Vincent Gulf submarine gravity	1964	Beach Petroleum	Geosurveys of Australia	8	2	374	PSSA 63/1914
Eucla Basin gravity	1965	Outback Oil	" "	5	5	960	" 65/4819
Investigator Strait gravity*	1970	Beach Petroleum	" "	8	3	64	" 70/975
Reconnaissance helicopter gravity, Western Australia	1971-2	BMR	Wongela Geophysical	11	11	8300	BMR Rec. 1973/130
Reconnaissance helicopter gravity of the Southwest of Western Australia	1969	"	" "	11	11	3961	" 1974/26
Reconnaissance helicopter gravity of South Australia	1970	"	" "	7	7	7800	" 1974/88

N.B. Offshore and onshore seismic surveys, which included gravity readings, are shown in the seismic survey listing.
*This survey was not subsidised under P.S.S.A., although the results are available.

APPENDIX 2 (continued)

Seismic surveys

Map key number (Plate 5)	Survey name	Operator	Seismic energy source	CDP coverage (fold)	Contractor	Year	No. of km	Reference or file number
1	Adelaide Plains seismic	Geosurveys of Australia	Explosives	1	Geosurveys	1960-61	34	PSSA 62/1530
2a	Reconnaissance seismic*, Eucla Basin	S.A. Department of Mines	"	-	-	1964	254	SA Rep. 60/30
2b	Reconnaissance seismic*, Pirie-Torrens Basin	" " "	"	1	-	1965	80	SA Min. Rev. 124
3	Stansbury seismic & gravity	Beach Petroleum	"	1	Geosurveys	1965	168	PSSA 65/11020
	Yorketown-Pt Vincent seismic*	" "	"	1	"	1966	142	" 66/11101
5	South Australian Shelf R-1 seismic	Shell Development	"	3, 6	Western Geophysical	1966	720	" 66/11135
6	Offshore Eucla Basin R-1 seismic*	Tenneco	"	6	" "	1967	865	" 66/11139
7	ESSA R.V. Oceanographic cruise, seismic, gravity & magnetic	Atlantic Oceanic Laboratories	Airgun	-	-	"		Conolly et al. 1970
8	St Vincent Gulf seismic	Beach Petroleum	Explosives	3	Geosurveys	1968	660	PSSA 67/11192
9	Offshore Eucla Basin R-2 seismic	Tenneco	"	3	Western Geophysical	1967	1197	" 67/11195
10	Spencer Gulf seismic*	"	"	-	" "	1967	70	" 67/11201
11	Spencer Gulf R-2 seismic*	Delhi Petroleum	"	3	" "	1967	145	" 67/11203
12	South Australian Shelf R-2 seismic*	Shell Development	Airgun & explosives	6 & 24	Namco Geophysical	1968	740	" 67/11205
12a	Otway ER-68 seismic & magnetic	Esso Exploration	'Aquapulse'	12	Western Geophysical	1968	1786	" 68/3036
13	South Australian Shelf R-3 seismic*	Shell Development	Airgun & explosives	6 & 24	Shell BIPM	1968	1300	" 68/3048
14	Troubridge Island Area seismic	Beach Petroleum	Explosives	6	Geosurveys	1969	193	" 69/3061

APPENDIX 2 (continued)

Seismic surveys (continued)

Map key number (Plate 5)	Survey name	Operator	Seismic energy source	CDP coverage (fold)	Contractor	Year	No. of km	Reference or file number
15	Lake Fowler seismic*, magnetic & gravity	Beach Petroleum	Explosives	1 & 3	Geosurveys	1969-70	100	PSSA 69/3077
16	South Australian Shelf R-4 seismic* & magnetic	Shell Development	Airgun	24	GSI **	1969	4151	P(SL)A 69/2
17	Great Australian Bight R-5 seismic* & magnetic	" "	Airgun and 'Aquapulse'	24	GSI & Western Geophysical	1970-71	7752	" 70/1
18	Teledyne reconnaissance seismic	Teledyne Exploration	Sparker	12	-	1970	1600	" 70/19
19	Polda Basin seismic*	Bridge Oil	Airgun & Sparker	1 & 24	Teledyne Exploration	"	521	PSSA 70/163
19a	Baudin seismic & magnetic	Hematite Petroleum	'Aquapulse'	3 & 12	Western Geophysical	"	490	" 70/178
20	Offshore Twilight Cove seismic & magnetic	Hartogen Explorations***	Airgun	12	GSI	"	1640	" 70/440
21	South Australian Shelf R-6 seismic & magnetic	Shell Development	"	24	"	1971-72	1663	P(SL)A 71/2
22	Polda Basin 2 seismic	Target Exploration	Airgun & sparker	1 & 24	Teledyne Exploration	1971	1159	PSSA 71/355
23	Offshore Eyre seismic	Hartogen Explorations***	Airgun	24	GSI	"	56	P(SL)A 71/34
24	Offshore Esperance seismic	Continental Oil	"	"	"	1972	957	" 72/7
25	Denman Basin seismic	Outback Oil	"	"	"	"	1844	" 72/17
26	Shell Deepwater Scientific seismic gravity & magnetic	Shell Development	"	"	Shell BIPM	1972-73	2500	" 72/30
27	Marsden seismic	Beach Petroleum	Explosives	6	Geosurveys	1972	36	PSSA 72/2523
28	Scorpion Bight seismic* & gravity	Coastal Petroleum	"	-	"	1973	18	" 72/3276
29	Great Australian Bight R-7 seismic	Shell Development	Airgun	24	GSI	"	1895	P(SL)A 73/6

APPENDIX 2 (continued)

Seismic surveys (continued)

Map key number (Plate 5)	Survey name	Operator	Seismic energy source	CDP coverage (fold)	Contractor	Year	No. of km	Reference or file number
30	Great Australian Bight R-8 seismic & magnetic	Shell Development	Airgun	24 & 48	GSI	1974	1767	P(SL)A 74/2
31	Bremer (R74A) marine seismic	Esso	"	"	"	"	2224	" 74/3
32	BMR Continental Margin seismic, gravity & magnetic	BMR	Sparker	1	Compagnie Generale de Geophysique	1972	10,000	BMR Rec. 74/15
33	Great Australian Bight R-9 seismic	Shell Development	Airgun	24	GSI	1974	981	P(SL)A 74/21
34	Great Australian Bight R-10 seismic & magnetic	" "	Airgun	24	Prakla-Seismos	1976	833	" 76/7

* Included refraction seismic
** Geophysical Service International
*** For a consortium of 8 companies

Regional Marine Geophysical Surveys (Data not held by BMR) - from Riesz & Moss (1971)

Ship	Organisation	Type of measurement
Vema, RV(1)	Lamont Geological Observatory	magnetic
Vema, RV(2)	1962, Lamont Geological Observatory, Cruise U-18	magnetic & seismic
Vema, RV and Diamantina, HMAS	1960 " " " (Hawkins, Hennion, Nafe & Doyle, 1965)	magnetic & gravity
Zarja, SS	USSR	magnetic

APPENDIX 3 - STRATIGRAPHIC TABLES, GREAT AUSTRALIAN BIGHT REGION EUCLA BASIN AREA

AGE	UNIT	GAMBANGA NO. 1 (after Ludbrook, 1960) Depth (m)	Thickness (m)	LITHOLOGY
PLEISTOCENE		0-3.1	3.1	Pinkish silicified and recrystallized limestone and some kunkar
MIOCENE	Nullarbor Limestone	3.1-6.1	3.0	Pink buff dense recrystallised limestone
		6.1-18.3	12.2	Pink buff miliolid limestone with *Marginopora* fauna
		18.3-53.3	35.0	no recovery
EOCENE	Wilson Bluff Limestone	53.3-56.4	3.1	Core, of partly recrystallized bryozoal calcarenite, with *Maslinella* fauna, pelecypods, spicules
		56.4-116.1	59.7	Virtually no recovery; bit samples indicate soft lutitic limestone
		116.1-170.7	54.6	Partly recrystallized white chalky bryozoal calcarenite with *Maslinella* fauna
		170.7-204.2	33.5	Grey marly bryozoal limestone grading down into glauconitic marl with rich *Globoquadrina* fauna
	Hampton Sandstone	204.2-231.6	27.4	Sandstone, buff, fine to coarse grained, marly with glauconite near top. Forams
CRETACEOUS	Madura Formation	231.6-321.5	89.9	Greensand, quartz medium to coarse grained
		321.5-365.8	44.3	Sandy siltstone with abundant glauconite fish fragments, pyritized wood
		365.8-368.5	2.7	Dark carbonaceous mudstone, pyrite, coal fragments
	Loongana Sandstone	368.5-370.7	2.2	Feldspathic sandstone, highly carbonaceous, plant remains
		370.7-387.1	16.4	Carbonaceous feldspathic sandstone grading down into grey brown feldspathic sandstone with granite fragments
ARCHAEAN		389.8-390.6 (T.D.)	5.8	Granite gneiss

AGE	UNIT	GAMBANGA NO. 1 (Exoll, 1960b) Depth (m)	Thickness (m)	LITHOLOGY
RECENT		0-1.8	1.8	Soil with limestone pebbles
MIOCENE	Nullarbor Limestone	1.8-6.1	4.3	Limestone, porcellanous, creamy, pelecypods, chert
		4.3-12.2	7.9	Limestone as above but apparently interbedded with reddish-brown calcarenite. Forams
		12.2-18.3	6.1	Calcarenite as above, with abundant forams.
		18.3-33.6	15.3	No samples; caverns
EOCENE	Wilson Bluff Limestone	33.6-53.3	19.7	No samples; constant drilling rate in soft rock
		53.3-56.4	3.1	Core of limestone, chalky, white, soft bryozoa, forams, pelecypods, spicules
		56.4-116.1	59.7	Virtually no samples; bit-samples indicate soft lutitic limestone
		116.1-167.6	51.5	Limestone, fine arenite to lutite, cream, soft, low porosity. Contains glauconite, forams, bryozoa, echinoderm spines, detrital quartz.
		167.6-198.1	30.5	As above, but with clay, which increases with depth. Some detrital quartz
		198.1-205.7	7.6	Claystone calcareous - similar to above section
CRETACEOUS	Madura Formation	205.7-234.7	29.0	Sandstone, white, grey, glauconitic, pyritic, calcareous, medium to coarse grained, rounded to well rounded, moderately well sorted. Thin layers of highly glauconitic claystone
		234.7-312.4	77.7	Greensand. Quartzose, highly glauconitic, pyritic
		312.4-342.9	30.5	Greensand. Glauconitic, pyritic, carbonaceous
		342.9-384.0	41.4	Mudstone, black, quartzose, plastic, possible plant remains
	Loongana Sandstone	384.0-389.8	5.8	Arkosic sand. Possibly weathered basement
ARCHAEAN		389.8-390.6 (T.D.)	0.8 mt	Granite

AGE	UNIT	EYRE NO. 1 (after Ludbrook, 1960) Depth (m)	Thickness (m)	LITHOLOGY
PLEISTOCENE		0-15.2	15.2	Limestone, bryozoal, slightly to largely recrystallized. *Marginapora* fauna
EOCENE	Wilson Bluff Limestone	15.2-309.3 (Upper Member)	294.1	Limestone bryozoal, partially recrystallized. Forams often common, including *Maslinella* fauna
		309.3-341.4 (Lower Member)	32.1	Limestone, marly glauconitic, often with abundant forams including *Globoquadrina* fauna
	Hampton Sandstone	341.4-359.7	18.3	Sandstone, brown, medium to coarse grained. Poorly preserved marine fossils
CRETACEOUS	Madura Formation	359.7-405.4	45.7	Greensand. Quartz medium to coarse grained, some siltstone. Arenaceous forams, *Inoceramus* prisms, fish and possibly reptilian fragments
		405.4-457.2	51.8	Mudstone, grey glauconitic grading down into dark grey and siltstone. Pyritic. Arenaceous forms, radiolaria, vertebrate fragments and plant debris
		457.2-481.6	24.4	Siltstone, dark green, sandy. Arenaceous forams abundant, same as Albian of Great Artesian Basin
	Loongana Sandstone	481.6-520.6	39.0	Greensand. Fish teeth and vertebrate fragments. Quartz coarse grained, sub-rounded
ARCHAEN		520.6-524		Granite

AGE	UNIT	EYRE NO. 1 (Exoil, 1960a) Depth (m)	Thickness (m)	LITHOLOGY
PLEISTOCENE		0-1.5	1.5	Soil, pebbles of limestone, quartz, sandstone siltstone
		1.5-12.8	11.3	Calcarenite, cream, porous. Molluscs, forams, spicules
MIOCENE	Nullarbor Limestone	12.8-15.2	2.4	Calcarenite, hard, dense, pink, rare fossils
EOCENE	Wilson Bluff Limestone	15.2-167.6	152.4	Calcarenite, creamy, poorly to moderately consolidated. Bryozoa, spicules, forams. Cavernous but not porous
		167.6-239.3	71.7	Limestone, milky chalky, calcilutite and some arenaceous bands. Bryozoal
		239.3-301.8	62.5	Calcilutite as above, but with glauconite increasing with depth. Fewer fossils mostly bryozoa and forams
CRETACEOUS	Madura Formation	301.8-339.8	38.0	Siltstone, with calcite, glauconite, gypsum, carbonaceous stuff, forams, brachiopods. Porosity nil. Shallow marine
		339.9-359.7	19.9	Sandstone, quartzose with glauconite, calcareous grains, carbonaceous stuff, fossil fragments. Shallow marine
		359.7-426.7	67.0	Greensands. Highly glauconitic quartz sands, calcareous grains; carbonaceous stuff becomes abundant at base. Shallow marine
		426.7-483.1	56.4	Mudstone, dark grey, plastic carbonaceous, euxinic mud. Quartz sand increases in grain size and quantity with depth. Barred or restricted marine
	Loongana Sandstone	483.1-518.2	35.1	Sand, quartzose, clear, frosted, milky and green mineral; mudstone bands
		518.2-520.6	2.4	Sand as above, but with chalky and nacreous fossil fragments. Shallow marine to shoreline
ARCHAEAN		520.6-524 (T.D.)	4 m	Granite

AGE	UNIT	W.A. GOVT. SURVEY BORE MADURA NO. 1 (after Ludbrook, 1958) Depth (m)	Thickness (m)	LITHOLOGY
		0-2.4	2.4	Light loam
		2.4-9.1	6.7	Limestone, cream, molluscan shells
EOCENE	Wilson Bluff Limestone	9.1-154.8	145.7	Limestone, white, bryozoal
		154.8-234	79.2	Limestone, dense, chalky, chalcedonic bands
		234-275.2	41.2	Limestone, greenish white, partially recrystallized, glauconitic, bryozoal, dominant pelagic forams
	Hampton Sandstone	275.2-276	0.8	Grit, brown, calcareous
		276-282.6	6.6	Sandstone, friable, quartz coarse grained, brown limonitic, glauconitic
CRETACEOUS	Madura Formation	282.6-293.9	11.1	Sandstone, grey-green, quartz, medium to coarse grained, silty carbonaceous, highly glauconitic a few forams
		293.9-295.0	1.1	Sandstone, glauconitic, hard, fine grained
		295.0-301.7	6.1	Sandstone greenish-grey, highly carbonaceous, glauconitic, silty. Arenaceous forams
		301.1-309.8	8.7	Grit, greenish-grey, silty, glauconite arenaceous forams
		309.8-327.0	172.0	Greensand, hard, ferruginous, silty, pyritic, fish remains
		327.0-336.5	9.5	Greensand, soft, unconsolidated, silty, fish remains, no forams
		336.5-464.2	127.7	Mudstone, dark grey, soft, carbonaceous, glauconitic, pyritic, _Haplophragmoides_ fauna
		464.2-560.5	96.3	Sandstone, grey, fine grained, carbonaceous, silty, some glauconite, pyrite, no forams
		560.5-603.2	42.7	Mudstone, grey, sandy, carbonaceous, some pyrite and glauconite; radiolaria but no forams
		603.2-606.9	3.7	Sandstone and grit, dark grey-brown, carbonaceous. Abundant arenaceous forams of Great Artesian Basin type
		606.9-c.624.8	17.9	Sandstone, brown, in part fine silty in part hard, in part incoherent. Arenaceous forams
		c.624.8-640.4 (T.D.)	15.6 +	Shale, grey, fine laminated, quartz grains, coarse, angular, plant fragments.

Note:- This is the thickest recorded Cretaceous sequence in the Eucla Basin Area ca. 358 m.

AGE	UNIT	COOK NO. 1 (after Ludbrook, 1965) Depth (m)	Thickness (m)	LITHOLOGY
QUATERNARY		0-7.6	7.6	Sandy kunkar and reddish limestone. Some forams
MIOCENE	Nullarbor Limestone	7.6-53.3	45.7	Limestone, cream, crystalline. Forams include Marginopora
EOCENE	Wilson Bluff Limestone	53.3-105.5	52.2	Limestone, cream, bryozoal, Maslinella fauna. Base of formation is sandy, glauconitic, pyritic
	Pidinga Formation	105.5-143.3	37.8	Clay and quartz sand, highly carbonaceous, pyrite aggregates. Planktonic forams near the top. A brown lustrous mineral characterized the bottom 1.5 m
?CRETACEOUS or ?PERMIAN		143.3-160.0	16.7	Quartz sands, coarse grained, subangular to angular, lithic grains, abundant pyrite. No forams or carbonaceous stuff. Resemble somewhat the Permian sands of the W. margin of Great Artesian Basin
?CAMBRIAN, LOWER		160.0-278.9 (T.D.)	118.9	Limestone, hard, grey, in places carbonaceous, oolite bands. Pyrite and calcite veinlets. Some chert. Sandy interbeds, fine grained, silty, micaceous, calcareous matrix, occasional mottling

AGE	UNIT	HUGHES NO. 1 (after Ludbrook, 1966) Depth (m)	Thickness (m)	LITHOLOGY
MIOCENE	Nullarbor Limestone	0-27.4	27.4	Limestone, dense, with <u>Marginopora</u> fauna
		27.4-48.8	21.4	Limestone, glauconitic, with forams
EOCENE	Wilson Bluff Limestone	48.8-100	51.2	Limestone, white bryozoal, with chalcedony
	Hampton Sandstone	100-115.8	15.8	Quartz sand, fine to coarse grained, limonitic, part pyritic, coaly fragments, sharks tooth
CRETACEOUS	Madura Formation	115.8-173.7	57.9	Siltstone, grey, radiolaria abundant in places, richly glauconitic in places, some cone-in-cone calcite
		173.7-189	15.3	Mudstone, grey, with sandy patches; plant fragments and pyrite replacements
	Loongana Sandstone	189-249	60.0	Sandstone, gritty, feldspathic, some coaly fragments
CAMBRIAN?		249-260	11.0	Sandstone, fine grained, angular, little cement
		260-265.2	5.2	Siltstone, grey, micaceous, pyritic, some quartz sandstone, some dolomite nodules
		265.2-271.3	6.1	Dolomite, light grey, dense, pyritic, vugs
		271.3-298.7	27.4	Siltstone, red, green-grey, pyritic, calcareous, some clay laminae
		298.7-301.8	3.1	Dolomite, pyritic, calcareous, gypseous
		301.8-329.2	27.4	Siltstone and carbonates as above
		329.2-359.7	30.5	Siltstone, red, brown, chocolate, green, grey, with some gypsum; some thin sandstones
PROTEROZOIC?		359.7-371.9	12.2	Dolomite, dolomitic limestone, voltic, partly silicified, some galena
		371.9-418.2 (T.D.)	46.3	Siltstone, green and chocolate, some gypsum. Isotopic age for bottom 3 m is 930 ± 30 m.y.

AGE	UNIT	HUGHES NO. 2 (after Ludbrook, 1966) Depth (m)	Thickness (m)	LITHOLOGY
MIOCENE	Nullarbor Limestone	0-18.3	18.3	Limestone, dense, pink-cream, with Marginopora fauna
		18.3-24.4	6.1	Limestone, glauconitic, with forams
EOCENE	Wilson Bluff Limestone	24.4-63.4	39.0	Limestone, cream, recrystallized, bryozoal, glauconitic, sandy with forams
	Hampton Sandstone	63.4-73.2	9.8	Quartz sand, with ill-sorted subangular coarse grains, limonitic
		73.2-76.2	3.0	Clay, ferruginous with scattered quartz grains and pyrite
CRETACEOUS	Madura Formation	76.2-149.4	73.2	Siltstone, grey, with radiolaria, forams etc glauconite
		149.4-167.6	18.2	Mudstone, pyritic, glauconite and radiolaria above, muscovite and carbonaceous stuff below
	Loongana Sandstone	167.6-215.8	48.2	Sandstone, feldspathic, coarse grained to gritty, pyritic rare forams and ostracodes, some coal fragments
		215.8-222.5	6.7	Mudstone with carbonaceous flecks, pyritic dolomite globules
		222.5-228	5.5	Sandstone, fine grained, angular
		228-243.5 (T.D.)	15.5+	Dolomite, part oolitic, stylolitic, cherty, with solution cavities (Possibly = Kulpara Lst)

AGE	UNIT	HUGHES NO. 3 (after Ludbrook, 1966) Depth (m)	Thickness (m)	LITHOLOGY
MIOCENE	Nullarbor Limestone	0-27.4	27.4	Limestone, dense, recrystallized, with Miliolidae, ferruginized sandy band
		27.4-36.6	9.2	Limestone, glauconitic, with forams
		36.6-39.6	3.0	Limestone and green glauconitic marl
EOCENE	Wilson Bluff Limestone	39.6-54.3	14.7	Limestone, whitish, bryozoal, recalcified, forams
	Hampton Sandstone	54.3-76.5	22.2	Sand, quartz, yellow subangular and grit
CRETACEOUS	Madura Formation	76.5-100.6	24.1	Siltstone, grey, carbonaceous, with carbonized and pyritized woody material
		100.6-115.8	15.2	Siltstone, grey, carbonaceous, abundant radiolaria and glauconite
		115.8-136.6	20.8	Siltstone grey glauconitic
	Loongana Sandstone	136.6-163.1	26.5	Sandstone, grey, gritty, feldspathic
		163.1-166.7	3.6	Sandstone, yellowish, subrounded quartz grains, little cement
		166.7-176.8	10.1	Sandstone feldspathic, red brown; sandstone greenish white; chalcedony
		176.8-192.0	15.2	Siltstone, sandstone, limestone, grey and purple, pyrite
		192.0-216.4	24.4	Dolomites, grey and purple, pyrite stylolites
		216.4-219.5	3.1	Siltstone, calcareous, sandy, red-grey, dolomite grains
		219.5-222.5	3.0	Limestone, dolomitic, reddish, grey, dense
		222.5-225.6	3.1	Siltstone, dark grey calcareous
		225.6-234.7	9.1	Limestone, grey, red chert, oolites
		234.7-250	15.3	Dolomite, oolitic, vugs, pink limestone
		250-253	3.0	Sandstone greenish, fine grained
		253-271.3	18.3	Sandstone, siltstone, limestone, dolomitic
		271.3-274.3	3.0	Limestone, pink, and sandstone
		274.3-277.4	3.1	Sandstone fine grained
		? -281.3 (T.D.)	3.9+	Dolomite grey, stylolitic, chert

AGE	UNIT	DENMAN NO. 1 (after Ludbrook, 1966) Depth (m)	Thickness (m)	LITHOLOGY
MIOCENE	Nullarbor Limestone	0-25	2.5	Limestone, pink-cream, dense, crystalline, with Marginopora
EOCENE	Wilson Bluff Limestone	25-62.5	37.5	Limestone, bryozoal, recrystallized with forams
	Hampton Sandstone	62.5-67.1	4.6	Sand, brownish, subangular quartz, some limonite
CRETACEOUS	Madura Formation	67.1-70.1	3.0	Silt, sandy, ferruginized, glauconitic
		70.1-88.4	18.3	Silt, sandy, pyritic, glauconitic, rare forams, fish tooth
		88.4-97.5	9.1	Siltstone, grey, dolomitic, fine mica, glauconite, pyrite, siderite, carbonaceous stuff, forams
		97.5-103.6	6.1	Siltstone with cone-in-cone calcite
		103.6-137.2	33.6	Siltstone with abundant forams and radiolaria, and glauconite
		137.2-153.3	16.1	As above; fewer radiolaria
		153.3-179.8	26.5	Mudstone grey, some quartz grains, forams
	Loongana Sandstone	179.8-201.2	21.4	Grit, arkosic, pyrite, glauconite
		201.2-228.6	27.4	As above, with carbonized wood fragments
		228.6-239	10.4	Sandstone, grey, coarse angular quartz, feldspar, pyrite matrix, pyritized wood
		239-243.8	4.8	Sandstone, fine to medium grained interlocking, little cement
		243.8-268.2	24.4	Siltstone pale green, with dolomite light brown
		268.2-278.3	10.1	Siltstone, sandy, red and green
		278.3-291.7	13.4	Sandstone grey-white, fine to medium grained, angular to subangular

AGE	UNIT	DENMAN NO. 1 continued Depth (m)	Thickness (m)	LITHOLOGY
		291.7-301.8	10.1	Siltstone red, green-grey mottled
		301.8-310.9	9.1	Sandstone red and abundant "green mineral"
		310.9-320	9.1	Siltstone red and sandstone; micaceous
		320-323.1	3.1	Dolomite pink, sandstone and siltstone, "green mineral"
		323.1-361.4	38.3	Red siltstone, very minor sandstone
		361.4-363.6	2.2	Siltstone, red, green, grey, minor sandstone, part calcareous, some gypsum
		363.6-399.3	35.7	Sandstone, red, grading to quartz grit
		399.3-451.1	51.8	Dolomite, pink to grey, some gypsum, anhydrite, limestone, siltstone; halite moulds
		451.1-502.9	51.8	Siltstone, mottled red and green; gypsum
		502.9-545.6	42.7	Dolomite, cherty in part
		545.6-548.6	3.0	Dolomite and red and green siltstone

AGE	UNIT	NULLARBOR NO. 8 (YANGOONABIE) BORE (R.L. 76.25 m)(after Harris & Ludbrook, 1966) Depth (m)	Thickness (m)	LITHOLOGY
PLEISTOCENE		0-11.6	11.6	Clay, sandy, calcareous
MIOCENE	Nullarbor Limestone	11.6-30.5	18.9	Limestone, dense, crystalline
EOCENE	Wilson Bluff Limestone	30.5-152.5	122.0	Limestone, bryozoal, chalky, with flints
		152.5-161.0	9.5	Limestone, bryozoal, glauconitic
	Hampton Sandstone	161.0-164.1	3.1	Sand, gritty
CRETACEOUS (Aptian)	Madura Formation	164.1-207.4	43.3	Siltstone, grading to fine sandstone
		207.4-271.5	64.1	Mudstone, green grey
		271.5-279.1	7.6	Siltstone and sandstone, grey
(Neocomian)	Loongana Sandstone	279.1-339.2	60.1	Sandstone, feldspathic, cobbly, and siltstone
		339.2-345.3	6.1	Grit, pyritic
PERMIAN, Lower		345.3-423.0	77.7	Claystone, grey (no evidence of any glacial sediments); microfloral and foraminiferal fossils of Sakmarian/Artinskian age (Harris & Ludbrook, 1966)
PRECAMBRIAN		423.0-457.5 (T.D.)	34.5	"Feldspar porphyry" (a rapidly cooled volcanic rock)

AGE	UNIT	APOLLO NO. 1 (after Outback Oil, 1975a) Depth (m)	Thickness (m)	LITHOLOGY
	?			No samples taken until 364 m
EOCENE	Wilson Bluff Limestone	? -378.6		Fragments of corals, shells & sponge spicules
	Pidinga Formation	378.6-424.5	45.9	Glauconitic sand, medium to coarse grained, shaly, some lignite
CRETACEOUS	Madura Formation	424.5-546.5	122.0	Predominantly shale, grading into sandy shale with numerous thin sandstones and siltstones
	Loongana Sandstone	546.5-781.5	235.0	Predominantly sandstone fine to coarse grained, with thin beds of shale, sandy shale and siltstone. N.B. Palynology indicates chiefly Albian age
PERMIAN		781.5-862.5	81.0	Upper part consisted of shales and mudstones, soft, pink to light brown. Several sandstones in the lower part, unconsolidated, medium to coarse grained
ARCHAEAN (?)		862.5-876.3 (T.D.)		Granite or granite gneiss

Note:- Comparatively poor sample recovery from this, the only offshore well in the Eucla Basin, reduced its interest from the stratigraphic point of view.

AGE	UNIT	WALLABIE NO. 1 (after Outback Oil,,1969) Depth (m)	Thickness (m)	LITHOLOGY
MIOCENE LOWER	Nullarbor Limestone	0-32.9	32.9	A thin layer of calcareous sand and clay overlying limestone, hard, dense, white to light brown, <u>Marginopora</u> fauna, pelecypods, some chert
EOCENE	Wilson Bluff Limestone	32.9-171.7	138.8	Poor samples.
	Pidinga Formation	171.7-182.2	10.5	Assumed to be present
CRETACEOUS	Madura Formation	182.2-259.3	77.1	Mudstone, grey, sticky, siltstone and sandstone; glauconitic, carbonaceous; with <u>Haplophragmoides audax</u>
		259.3-323.3	64.0	Sandstone, white, friable, medium to coarse grained, sub-angular to sub-rounded, porous
	Loongana Sandstone	323.3-341.6	18.3	Conglomerate, quartz medium to pellet size, some limestone granules
PERMIAN		341.6-363.0	21.4	Interbedded sandstone, white, friable, and siltstone, grey, soft
		363.0-390.4	27.4	Claystone, grey, sticky
		390.4-396.5	6.1	Sandstone, very fine to medium grained
		396.5-411.8	15.3	Siltstone, white to grey
		411.8-436.2	24.4	Sandstone, clear, fine to coarse grained
		436.2-463.7	27.5	Sandstone, yellow, brown, reddish, friable to hardish, angular to sub-rounded, fine to medium grained, poorly sorted; glacigenic
		463.7-541.4	77.7	Interbedded sandstone/siltstone, varicoloured
		541.4-732.0	190.6	Sandstone, orange, fine to medium grained, gypseous
		732.0-916.8	194.8	Interbedded sandstone/siltstone, orange, fine to medium grained, trace gypsum
		916.8-1211.6	294.8	"Porphyry" or altered basalt
		1211.6-1342	130.4	Sandstone, white, yellow, red, medium to coarse grained, unconsolidated, sub-angular to rounded. Red clay matrix.
ARCHAEAN		1342-1496.6	154+	granite gneiss

POLDA BASIN

AGE	UNIT	POLDA STRATIGRAPHIC HOLE (after Harris & Foster, 1974) Depth (m)	Thickness (m)	LITHOLOGY
QUATERNARY:	Bridgewater Formation	0-11.6	11.6	Limestone, buff to light brown; in part sandy (well-rounded quartz grains) or clayey. The main aquifer of the Polda Hydrologic Basin.
		11.6-16.8	5.2	Clay, orange to brown, sandy, calcareous. Aeolinitic.
EOCENE, MIDDLE:	Poolpena Formation	16.8-35.1	18.3	Sand, dark brown to black, poorly to well sorted, angular to well-rounded quartz, fine to medium grained, slightly clayey, micaceous, carbonaceous in places.
		35.1-37.5	2.4	Silt, pale to dark brown, carbonaceous to micaceous, some wood fragments. Pockets of poorly sorted quartz sand.
		37.5-48.2	10.7	Sand, brown, fine to medium grained, quartz subangular to rounded, carbonaceous.
		48.2-58.4	10.2	Lignite
		58.4-68.3	9.9	Sand, silty at top, brown to black, quartz medium to coarse grained. Paludal/fluviatile/barred basin.
JURASSIC, UPPER	Polda Formation	68.3-98.1	29.8	Sand, grey, medium-grained, subrounded, clay matrix.
		98.1-99.1	1.0	Clay, black, carbonaceous, very coarse grained quartz grains, pyritic.
		99.1-117.3	18.2	Interbedded silts and clays, some sand, grey-brown to dark brown, carbonaceous, lignitic, impure lignite 108.8 to 109.4.
		117.3-127.4	10.1	Sand grey, medium-grained, subangular, silty and clayey.
		127.4-151.2	23.8	Clay, dark grey, carbonaceous.
		151.2-162.8	11.6	Interbedded clay, silt and sand; grey, carbonaceous. Silt has gneissic fragments.
		162.8-172.2 (T.D.)	9.4	Clay, dark brown to grey green, some weathered igneous and metamorphic fragments, paludal.

ELLISTON GRABEN

AGE	UNIT	GEMINI NO. 1 Depth (m)	 Thickness (m)	LITHOLOGY
TERTIARY ?	? Wilson Bluff Limestone etc.	0-285.0	285.0	No samples.
JURASSIC, UPPER	Polda Formation	285.0-856.5	571.5	The upper limit of the Jurassic is unknown, but in the upper levels down to about 370 m hard white micritic limestone fragments, thought to belong to the Wilson Bluff Limestone, are present. Predominantly sandstone, unconsolidated, fine to very coarse grained, subangular to subrounded, poorly sorted, whitish. Thin beds of siltstone and shale, light to dark grey, soft to firm, sometimes sandy. A rather good grade of coal which could probably be classed as bituminous was found from 749.8 m to 762.0 m (12.2 m). Fossils of microflora, but no microfauna. Lacustrine and fluviatile.
ARCHAEAN? or UPPER PROTEROZOIC		856.5-893.7		Granite? or Syenite, or volcanics, and to be equated with Roopena, Woltana, and Nacoona Volcanics of northern Eyre Peninsula.

GULF ST VINCENT AREA

EDITHBURGH (after Beach Petroleum, 1967a)

AGE	UNIT	Depth (m)	Thickness (m)	LITHOLOGY
TERTIARY		0-18.3	18.3	?
		18.3-29.9	11.6	Varicolored soft limestones, in part very sandy or argillaceous
		29.9-32.9	3.0	Marl
		32.9-105.5	72.6	Sandstones, poorly consolidated with kaolin matrix
PERMIAN		105.5-117.7	12.2	Clay, grey, soft, massive
		117.7-146.4	28.7	Clay, blue-grey + a few pebbles of quartzite, igneous and metamorphic rocks
		146.4-271.5	125.1	Clay interbedded with light grey and red fine-grained sandstones, well rounded grains
		271.5-502.6	231.1	Interbedded claystones, red, pink, green, generally massive, and sandstones fine to medium grained rounded grains; minor carbonaceous siltstone; rock fragments
		502.6-520	17.4	An increase in boulder and sand content Glacigene; marine
CAMBRIAN		520-667	147.0	Sandstone, red-brown, very fine grained, hard, sub-angular/subrounded quartz; common interbeds of varicoloured mudstone; basal 18 m has interbedded green dolomitic shales; pebbles and fragments of igneous and metamorphic rocks
	Dalrymple Limestone	667-691.1	24.1	Limestone, brown, white, finely crystalline
		691.1-703.3	12.2	Red-brown sandstones, silty dolomite

AGE	UNIT	EDITHBURGH continued Depth (m)	Thickness (m)	LITHOLOGY
	Kulpara Limestone	703.3-951.0	247.7	Dolomite, grey, white, micro-fine crystalline. Vugular or intercrystal porosity in places. Minor varicoloured shales and sandstones. Glauconite.
	Transition Beds	951-976.6	25.6	Sandstone, pink, red, very fine-grained in dolomitic matrix.
		976.6-1014.7	38.1	Dolomite, grey to brown; minor light grey sandstone interbeds; some glauconite
		1014.7-1048.3	33.6	Sandstone, brown, soft and friable. Fine to medium grained, but coarse grained to gravelly in lower 6 m.
ARCHAEAN		1048.3-1053.8 (T.D.)	5.5+	Pink and red gneiss

AGE	UNIT	STANSBURY WEST NO. 1 (after Beach Petroleum, 1966) Depth (m)	Thickness (m)	LITHOLOGY
TERTIARY		9.2-18.3	9.2	White, hard, siliceous and sandy limestone
		18.3-32.0	13.7	Yellow, poorly sorted very fine to coarse-grained sandstone
PERMIAN (Lower Sakmarian)		32.0-135.7	103.7	Soft light grey and blue-grey clays with fine to very coarse-grained subrounded to round clear quartz, lithic and pebble fragments
		135.7-335.5	199.8	Claystone, chocolate brown, firm, with clastics as above grading to minor sandstone interbeds, white, soft, subangular to subrounded quartz with kaolinitic or calcareous matrix. Glacigene marine
Middle Cambrian		335.5-536.8	201.3	Uniform sandstone with minor shaley partings
		536.8-579.5	42.7	Dark grey and brown shale and silt
	Ramsay Formation Unit A	579.5-672.5	93.0	Crypto- and Microcrystalline limestones, partly dolomitic and stylolitic
	Unit B	672.5-706.1	33.6	Red to brown, hardish, very fine to fine-grained sandstone
	----	672.5-739.6	67.1	Dark grey and green-grey shales
	Unit C	739.6-782.3	42.7	Grey limestone; sponge and brachiopod fossils;
		782.3-828.1	46.8	Hard dolomite, with shale and limestone interbeds.
	Unit D	828.1-925.7	97.6	Red, purple, brown, green shales, micaceous silty, partly dolomitic. A grey limestone between 2795' and 2828'
	Parara Limestone	925.7-1288.9	363.2	Limestones, varicoloured, and minor dolomites

AGE	UNIT	STANSBURY WEST NO. 1 continued Depth (m)	Thickness (m)	LITHOLOGY
	Kulpara Dolomite	1288.9-1639.4	350.5	An upper light grey phase grading into the Parara Limestone, and a lower dark grey and brown phase. Vugular and fracture porosity.
	Transitional Beds	1639.4-1740.9	101.5	Sandstones of various colours and grain sizes, grading upwards into Kulpara Dolomite. Porosity up to 12%.
ARCHAEAN		1740.9-1745.8 (T.D.)	4.9+	Gneiss Note: No hydrocarbons at all were detected.

AGE	UNIT	STANSBURY TOWN NO. 1 (after Beach Petroleum, 1967b) Depth (m)	Thickness (m)	LITHOLOGY
		9.1-15.2	6.1	Sand, yellow to orange, very fine to fine-grained
Miocene, Port Willunga Beds		15.2-57.9	42.7	White, yellow, orange limestones with occasional fine sand and yellow clay interbeds. The calcarenite has coarse-shell fossils and some quartz. Shallow marine to strand-line
		57.9-138.7	81.8	Grey clay, soft and sticky, firming downwards
		138.7-144.8	6.1	Light grey, soft, very fine to fine-grained sand
Lower Permian		144.8-149.4	4.6	Grey clay as above
		149.4-213.4	64.0	Dark brown clay, firm, sandy in part, with scattered pebbles of igneous and metamorphic rocks.
		213.4-257	43.6	Firm blocky claystone, with a thin hardish sandstone at the base, very fine to coarse-grained with lithic pebbles. Marginal glacio-marine.
Middle Cambrian	Unit 1	257-805.6	548.6	Upper Red Beds. Sandstones range to purple and white, with quartz very fine to fine-grained minor feldspar and liths. Streaks to interbeds of shale below 1500' are brown, red, purple, green. Gypsum, worm tracks, trilobite tracks. Nearshore marine, periodically exposed to atmosphere.
	Unit 2A	805.6-818.1	12.5	Greyish oolitic limestone) burrows,) trilobites, Greenish-grey shale, calcareous) brachiopods Marine carbonate-bank
		818.1-837.3	80.2	Dolomite limestone, dytolitic. Below 2800' are interbeds of blackish shales, gypsum and sulphides.
		837.3-917.5		Restricted marine carbonate shelf.
	Unit 2B	917.5-960.0	43.5	Interbeds of orange, grey and green fine grained sandstone with minor shale. Lowlying shoreline
		960.0-975.5	15.5	Dark green grey silty shale

AGE	UNIT	STANSBURY TOWN NO. 1 continued Depth (m)	Thickness (m)	LITHOLOGY
	Ramsay Limestone Unit 2C	975.5-1016.3	40.8	Brown to white hard limestones; some shale interbeds. *Hyolithes*, *Redlichia*. Shallow marine.
		1016.3-1049.8	33.5	Dolomite, minor limestone and shale
	Missing 2D			
	Minlaton Conglomerate Unit 2E	1049.8-1076.7	26.9	Hard orange, red, brown, pinkish conglomerate with pebbles of gneiss and dolomite (Kulpara Limestone). Transgressive shoreline marine.
Lower Cambrian	Unit 3A missing			
	Unit 3B Kulpara Limestone	1076.7-1220	143.3	Dolomite, white to purple, hard, styolitic. Sandy towards base! Shallow-marine shelf.
	Unit 4 "Transitional Beds"	1220-1233.4	13.4	Sandstone, partly dolomitic, partly shaly. Orange, white, brownish, fine to coarse grained.
		1233.4-1245	11.6	Dolomite, chocolate, green, white, silty.
		1245-1253.9	8.9	Shale, dark red-brown
		1253.9-1261.2	7.3	Sandstone, orange, green, red-brown soft, fine to coarse grained, quartz and minor feldspar. Marine transgression.
ARCHAEAN		1261.2-1269.4 (T.D.)	7.2	Gneiss

Notes: There were traces of gas in the "Transition Beds".

The Kulpara Limestone had restricted good porosity and permeability, with vugular porosity predominating.

AGE	UNIT	GRANGE NO. 1 (after Beach Petroleum N.L., 1962) Depth (m)	Thickness (m)	LITHOLOGY
RECENT to PLEISTOCENE		0-97.6	97.6	Sands and clays, brown and grey; unsorted quartz grains up to pebble size. Horizons with limestone nodules common. No fossils.
PLIOCENE	Dry Creek Sands	97.6-167.8	70.2	A sequence of limestones soft, sandy, clayey, fossiliferous (forams molluscs, bryozoa). Almost a coquina in places.
MIOCENE to OLIGOCENE	Port Willunga Beds	167.8-323.3	155.5	Limestones grey, sandy and glauconitic, hard and soft, recrystallized in parts. Bryozoa and forams common. Partly sideritic and pyritic, often with abundant glauconite. Generally porous and permeable.
OLIGOCENE to UPPER EOCENE	Blanche Point Marls	323.3-512.4	189.1	Limestones and marls, with clay and shale lenses and cherts. The upper part is similar to the Port Willunga Beds, the boundary at 323.3 m being chosen by incoming of abundant spicules. At 372 m there is a gradation into glauconitic and pyritic marl with *Turritella aldingae* and common forams
MIDDLE EOCENE	North Maslin Sands	512.4-571.0	58.6	Fine sands, grey, clayey to 530 m, then fine to coarse grey, clayey sands and grits with mica and pyrite, and some carbonaceous clay lenses.
? MARINOAN		571.0-602.4	31.4	Shales, red brown.
? STURTIAN		602.4-604.8 (T.D.)	2+	Slates and quartzites

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PLATE I

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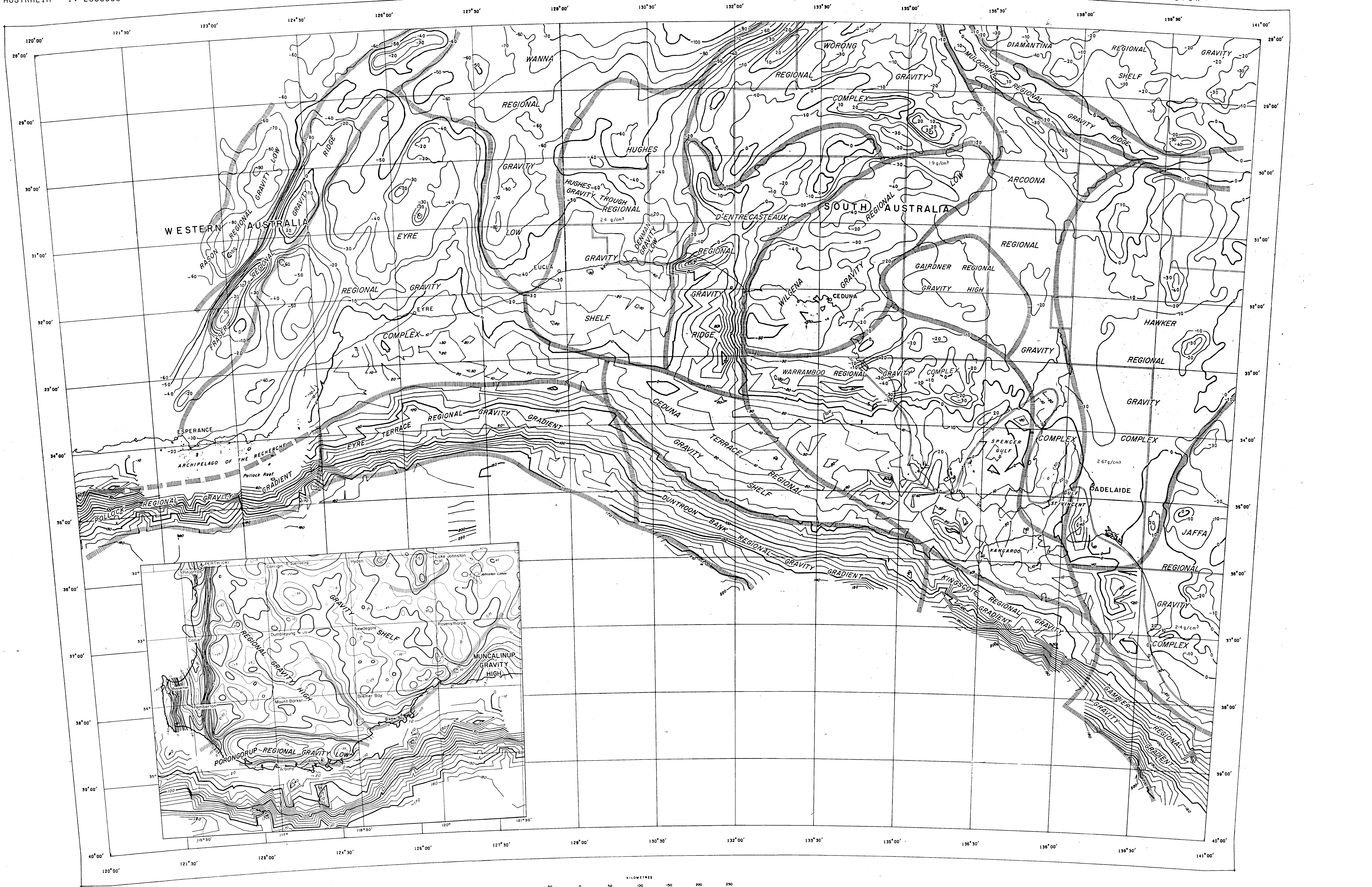
PLATE 2
GREAT VICTORIA DESERT
NULLARBOR PLAIN
W.A.
S.A.
Traverses oriented N-S at 2 km spacing in groups of three 15 km apart
Lake Gidgi
Lake Maurice
Lake Eyre North
Lake Eyre South
Lake Torrens
EXOIL 1964
BMR 1954
1954
BMR 1970
Traverses oriented E-W at 1·5 km spacing
BMR 1972
Traverses oriented E-W at 1·5 km spacing
Eucla
Head of Bight
Eyre
Norseman
Ceduna
Port Augusta
Port Pirie
Elliston
EYRE PENINSULA
SPENCER GULF
YORKE PENINSULA
ADELAIDE
GULF ST VINCENT
KANGAROO ISLAND
FLEURIEU PENINSULA
Encounter Bay
Traverses oriented normal to Yorke Peninsula coastlines at 2·5 km spacing
Beach Petroleum 1969
Beach Petroleum 1964
Outback Oil & Shell Development 1966
Shell Development 1969-72 (see plate 5)
BMR 1960
Traverses oriented E-W at 0·4 km spacing
Esperence
Archipelago of the Recherche
Bremer Bay
Albany
BMR Continental Margin 1972
Oceanographer 1967
Vema II 1962
Vema I
Vema & Diamantina 1960
Esso Aeromagnetic 1972
Shell Depeater Scientific Survey 1972-3
200m
1000m
2000m
5000m
GREAT AUSTRALIAN BIGHT REGION
AEROMAGNETIC AND MARINE MAGNETIC LINE LOCATIONS
1:2500000
0 50 100 150 200 250km
Note: Refer to Appendix 2 for further information on surveys indicated
(Based on XAUS-7-26)
Record 1979/20
XAUS-7-634
116° 118° 120° 122° 124° 126° 128° 130° 132° 134° 136° 138° 139°
28° 30° 32° 34° 36° 38°


076119
PLATE 3
GREAT VICTORIA DESERT
NULLARBOR PLAIN
W.A.
S.A.
Lake Gidgi
Lake Maurice
Lake Eyre North
Lake Eyre South
Lake Torrens
Interpreted basement faulting along approximately northeast and northwest trends
Eucla
Head of Bight
Ceduna
Eyre
Norseman
Port Augusta
Port Pirie
Elliston
EYRE PENINSULA
SPENCER GULF
YORKE PENINSULA
ADELAIDE
GULF ST VINCENT
KANGAROO ISLAND
FLEURIEU PENINSULA
Encounter Bay
Esperence
Archipelago of the Recherche
Bremer Bay
BREMER FAULT
Albany
200m
1000m
2000m
5000m
GREAT AUSTRALIAN BIGHT REGION
MAGNETIC BASEMENT DEPTH CONTOURS
1:2 500 000
50 0 50 100 150 200 km
Bathymetric contour
Generalised contour (m) on Precambrian basement, after Lowry (1970). (From drilling and seismic data)
Magnetic basement contour (km) based on company reports
Fault
Trend
Approximate boundary between surveys whose results have not been integrated
Record 1979/20
XAUS-7-534



(Based on SA/88-22-1)
After Willcox, 1976 (in press); Pettifer & Fraser, 1974; Fraser, 1973.

50 0 50 100 150 200 250
0 50 100
NAUTICAL MILES

DENSITY = 2·20 GMS/CC
EXCEPT WHERE DIFFERENT VALUE IS SHOWN

AUSTRALIAN NATIONAL SPHEROID
SIMPLE CONICAL PROJECTION
WITH TWO STANDARD PARALLELS
AT 18° 0′ AND 36° 0′ SOUTH

Record 1979/20

NOTE: *The information contained in this map has been obtained by the Department of Minerals and Energy, as part of the policy of the Australian Government, to assist in the exploration and development of mineral resources. It may not be published in any form or used in a company prospectus or statement without the permission in writing of the Director, Bureau of Mineral Resources, Geology and Geophysics.*

GREAT AUSTRALIAN BIGHT REGION

GRAVITY ANOMALIES

Contour interval 10 mGals

||||||||||||||||||||| Major gravity province boundary

All data used are preliminary

Offshore results are based on hourly values extracted on board the survey vessel. No adjustments have been applied for misties at traverse intersections.

Contour lines are drawn by computer using a triangular contouring program. A triangular plate is defined by three adjacent stations whose circumscribing circle contains no other stations. Linear interpolation is then used on the triangular plate. Should any side of an acceptable triangle exceed 40 nautical miles, that plate is not contoured. While onshore anomalies are Bouguer anomalies no correction has been made offshore for the water layer.

GREAT AUSTRALIAN BIGHT

GREAT AUSTRALIAN BIGHT REGION

SEISMIC SURVEY AND LINE LOCATIONS

1:2500000

50 0 50 100 150 200 km

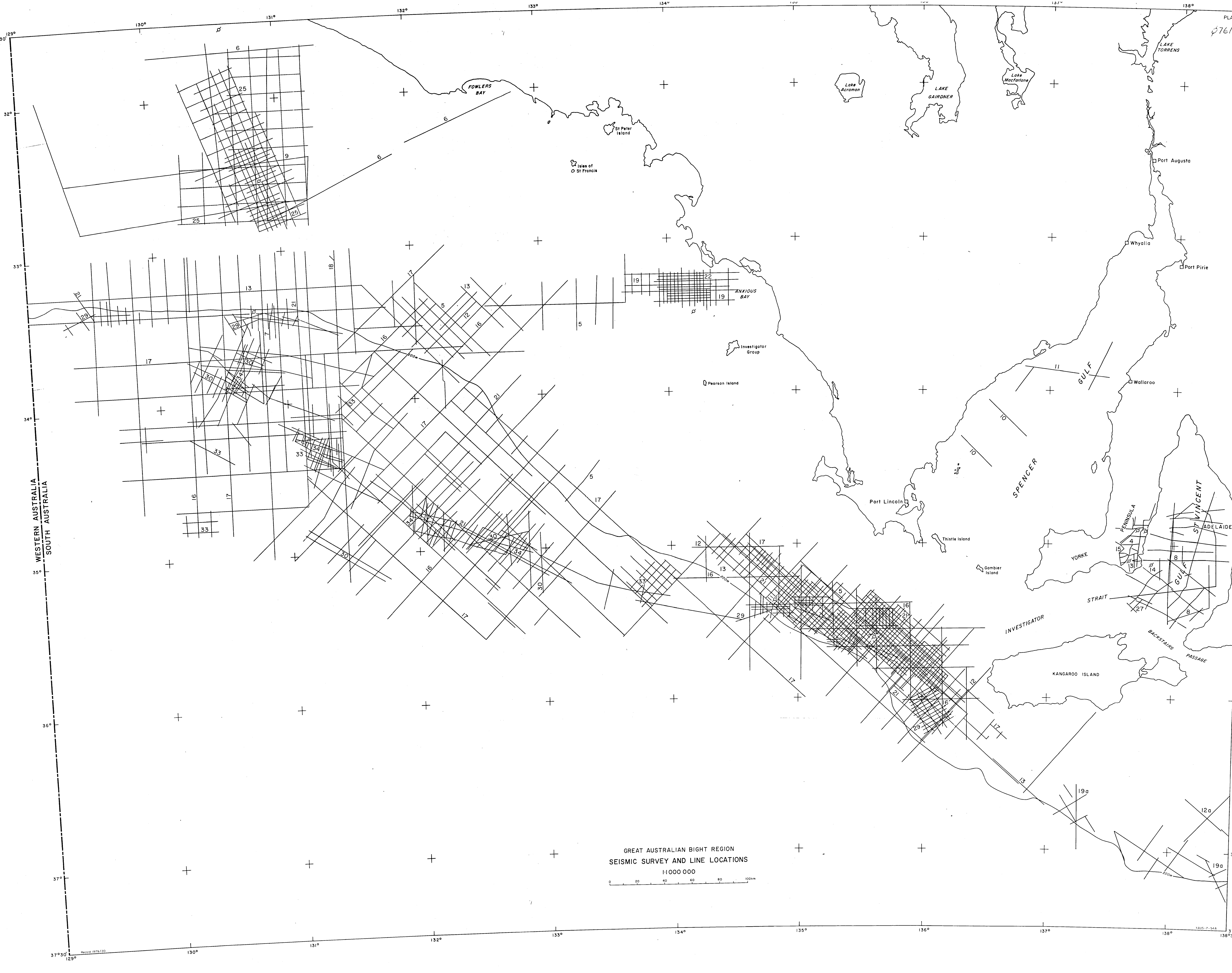
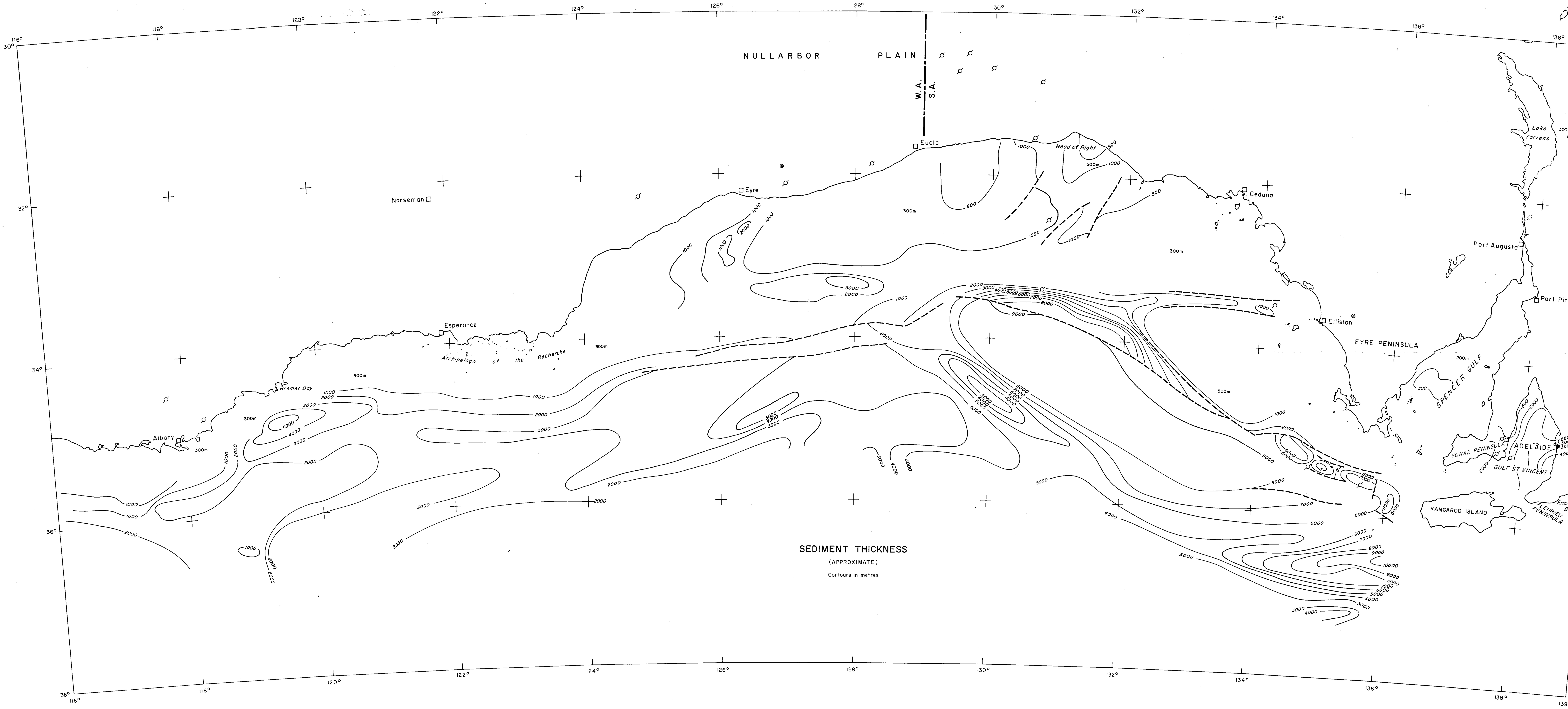
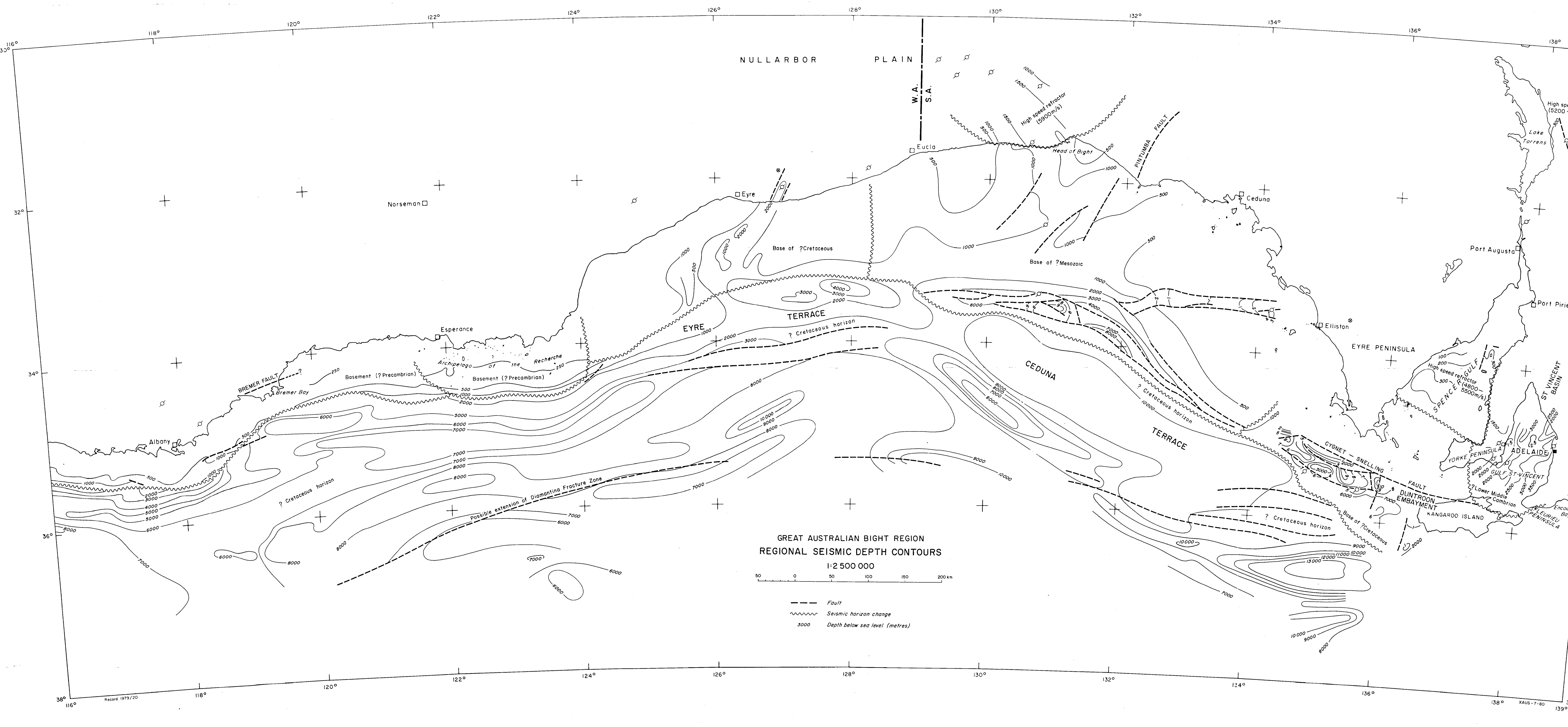


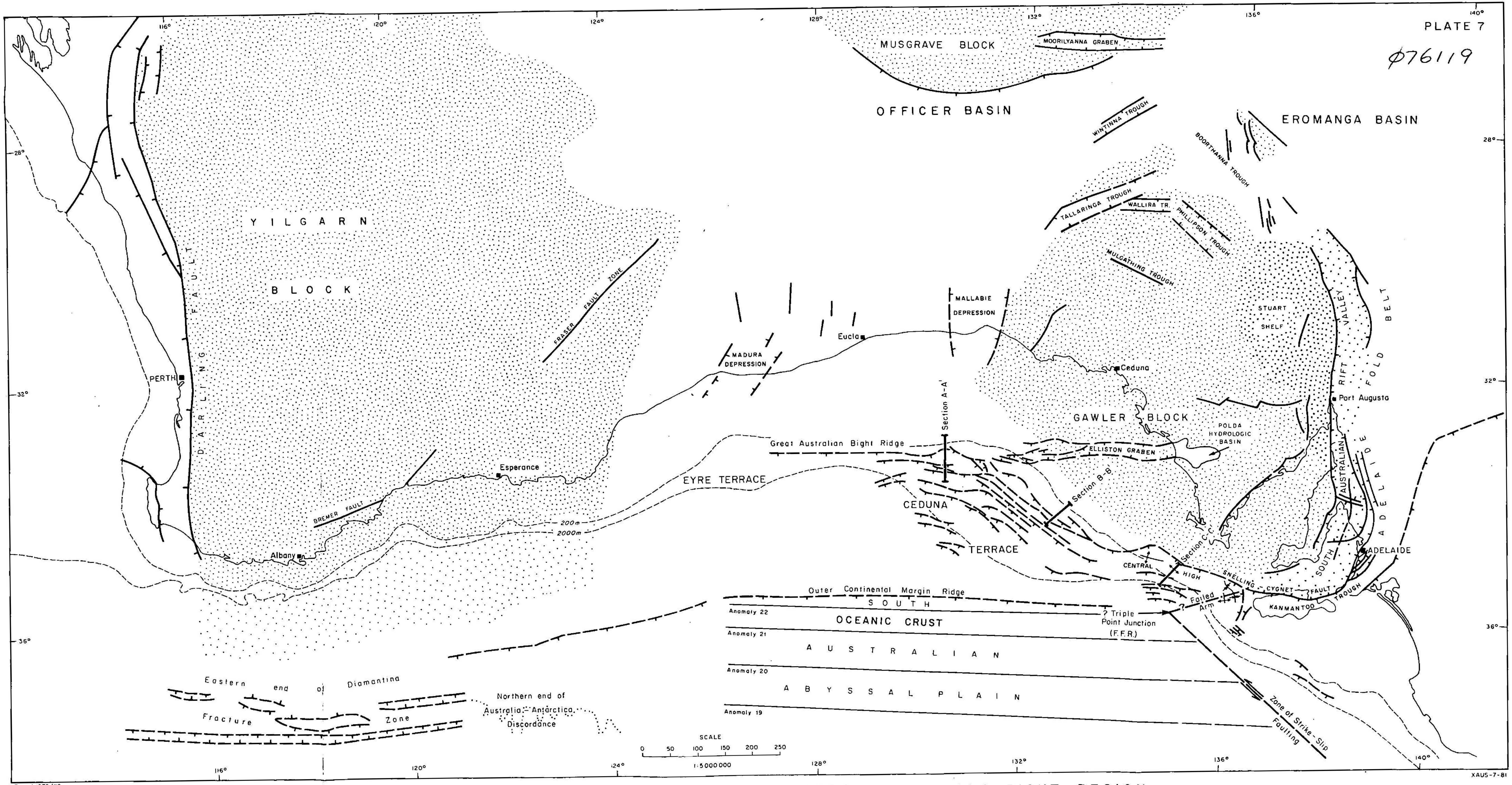
PLATE 58
GREAT AUSTRALIAN BIGHT REGION
SEISMIC SURVEY AND LINE LOCATIONS
1:1 000 000
WESTERN AUSTRALIA
SOUTH AUSTRALIA
FOWLERS BAY
St Peter Island
Isles of St Francis
ANXIOUS BAY
Investigator Group
Pearson Island
Port Lincoln
Thistle Island
Gambier Island
LAKE TORRENS
Lake Acraman
LAKE GAIRDNER
Lake Macfarlane
Port Augusta
Whyalla
Port Pirie
Wallaroo
SPENCER GULF
YORKE PENINSULA
ST VINCENT GULF
ADELAIDE
INVESTIGATOR STRAIT
BACKSTAIRS PASSAGE
KANGAROO ISLAND

076119

PLATE 6







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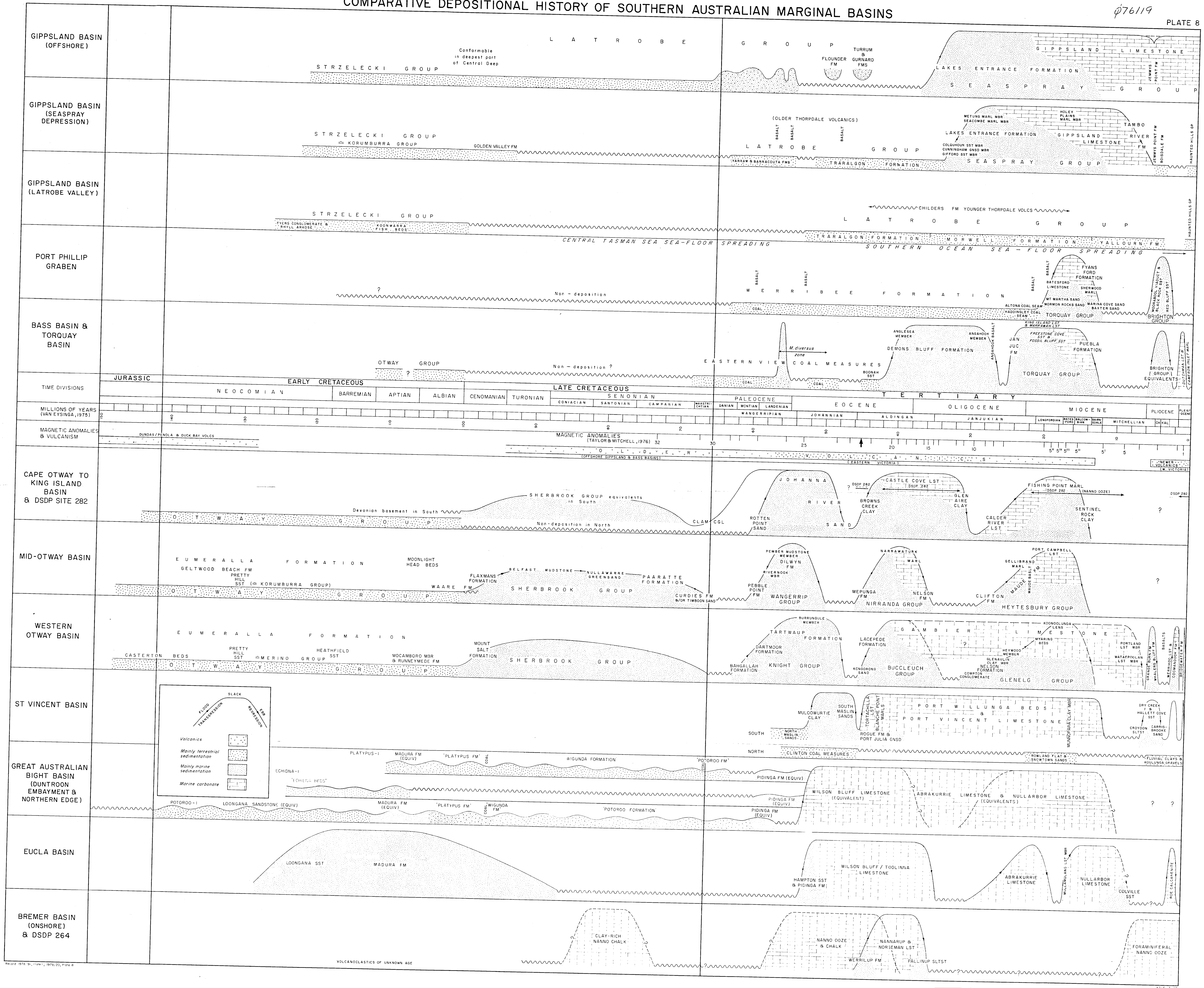
MAJOR STRUCTURAL ELEMENTS IN THE GREAT AUSTRALIAN BIGHT REGION

Ø76119

PLATE 8

COMPARATIVE DEPOSITIONAL HISTORY OF SOUTHERN AUSTRALIAN MARGINAL BASINS



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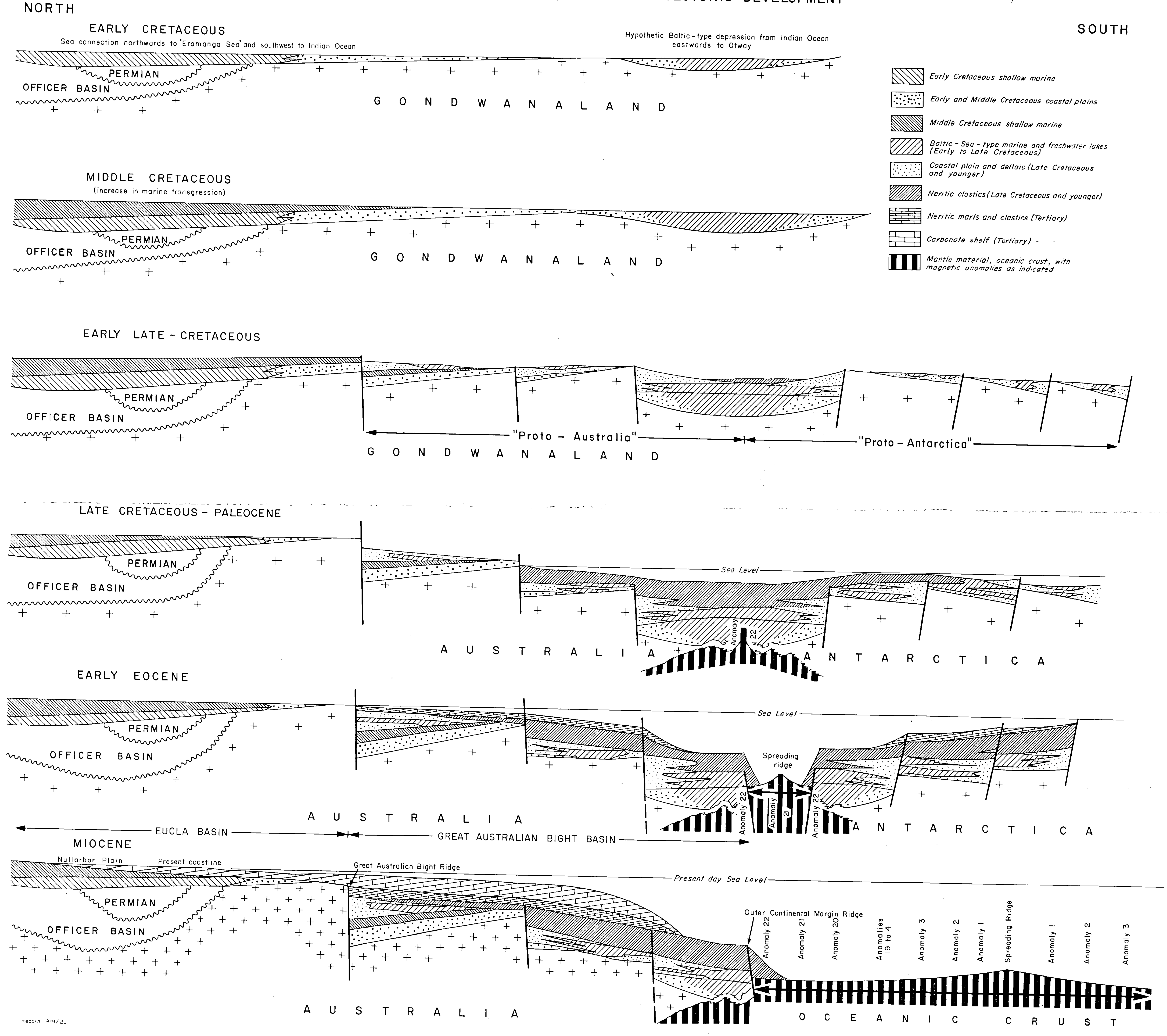
GREAT AUSTRALIAN BIGHT REGION, POSTULATED TECTONIC DEVELOPMENT

PLATE 9



CROSS-SECTION, EUCLA BASIN REGION

Scales: Vertical - 1cm = 100m
Horizontal - 1cm = 25·6 km

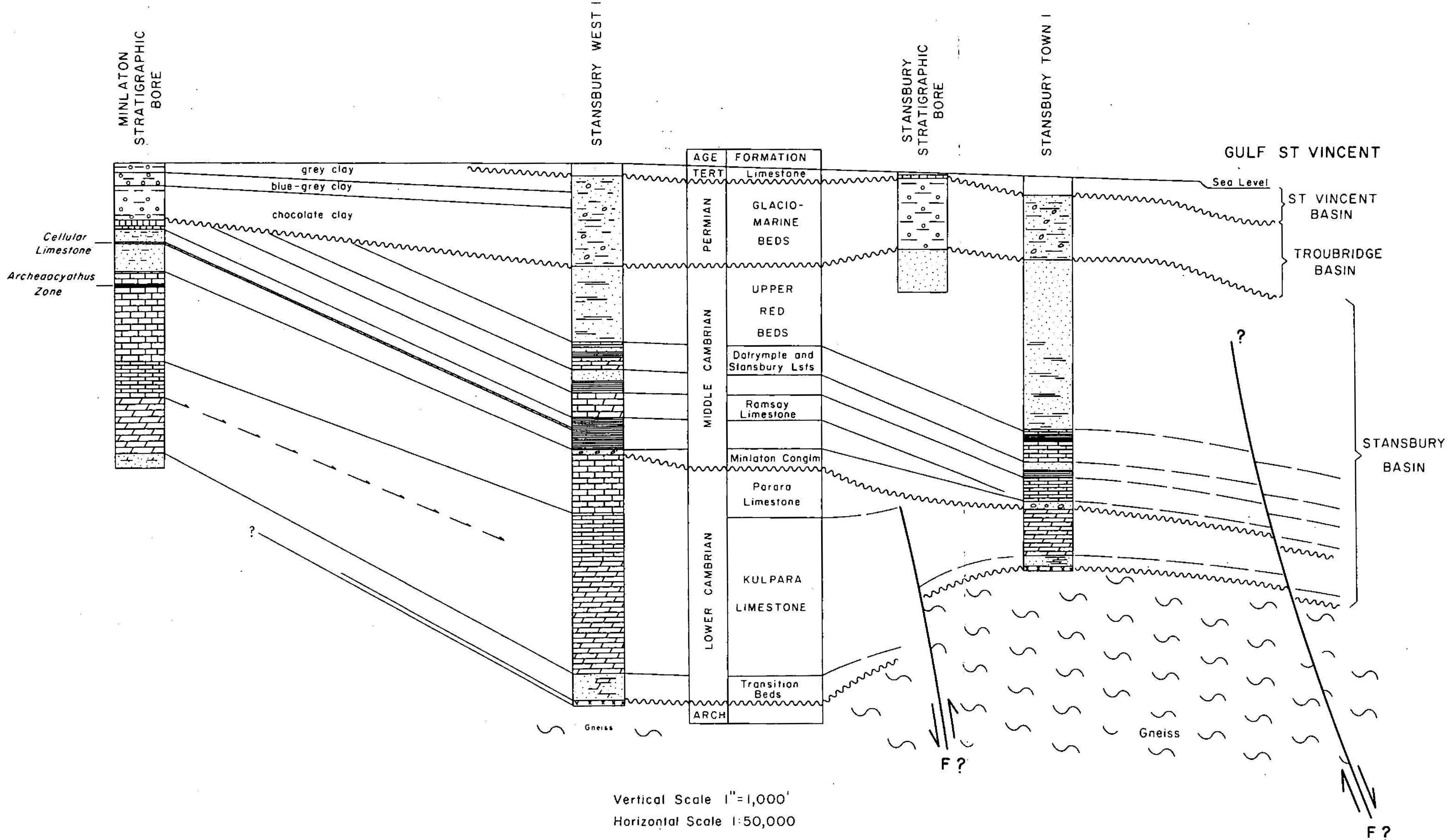
Ø76119

PLATE II

YORKE PENINSULA, ST VINCENT AREA

STRATIGRAPHIC CORRELATIONS

(after BEACH PETROLEUM N.L.)



Vertical Scale 1"=1,000'
Horizontal Scale 1:50,000

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