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A REVIEW OF PETROLEUM EXPLORATION AND PROSPECTS IN THE CARNARVON BASIN

by

C.S. Robertson, D.K. Cronk, K.L. Lockwood
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SUMMARY

Petroleum exploration carried out in the Carnarvon Basin up to the end of 1975 has been reviewed to provide a current assessment of knowledge of the basin and to determine the need for future exploration.

The Carnarvon Basin extends along the central western margin of the Australian craton for approximately 1000 km. It consists of a number of sub-basins which differ considerably from one another and it contains Silurian to Recent sediments with a probably maximum total thickness of more than 12 000 m. Its development was greatly influenced by the breakup of Gondwanaland in the Mesozoic Era.

The northern, offshore parts of the basin have been extensively explored for petroleum and some of the most promising gas discoveries in Australia have been made in that area, in addition to some modest oil finds. There are good prospects of further petroleum discoveries on the continental shelf in the northern and central parts of the basin. Geophysical results suggest that similar geological conditions exist in the neighbouring deep-water areas such as the Exmouth Plateau, which therefore offer good prospects for the future. The prospectivity of the southern portion of the basin seems relatively poor, but some areas have been so little explored and are so poorly known that further exploration is warranted.

1. INTRODUCTION

This report is a summary of petroleum exploration and prospects in the Carnarvon Basin, an epicontinental sedimentary sequence extending along the central Western Australian coastal region and consisting of sediments ranging from Silurian to Recent. The northern and southern extremities of the basin coincide approximately with latitudes 19°S and 28°S. The eastern basin boundary is formed by sedimentary onlap onto the Precambrian shield and the western boundary is arbitrarily defined as the continental shelf edge.

The summary is based on published and non-confidential unpublished information available up to the end of 1975. Much of the unpublished information is derived from the final reports on petroleum exploration company operations subsidised by the Australian Government under the Petroleum Search Subsidy Act 1959-73. Under the terms of that Act the final reports on individual geophysical or drilling operations are available to the public. Basin data from operations in some areas relinquished by exploration companies have been released to the public by the Department of Mines of Western Australia.

2. GEOLOGY

2.1 Extent of Carnarvon Basin

The term 'Carnarvon Basin' has been used in the literature to refer to various Phanerozoic sediments draping the northwestern periphery of the Western Australian Shield and presumably occupying an elongate crustal depression or 'basin'. The word 'basin', which generally implies a structural unit, is rather inappropriate when applied to the sediments in the region currently under review. In this review the traditional term 'Carnarvon Basin' is retained for convenience, but the Carnarvon Basin is defined as a sedimentary sequence, without structural connotations. The sediments range from Silurian to Recent and are believed to have a maximum thickness of up to 12 000 m. Pre-Permian sediments are known only from the southern part of the region.

The basin is limited on the eastern side by Precambrian outcrops of the Pilbara and Gascoyne Blocks. On the western side sediments generally extend beyond the edge of the continental shelf, but the sediments in deep water beyond the 200 m bathymetric contour are largely beyond the scope of this review. As sedimentary sequences similar to those of the Carnarvon Basin, particularly the Mesozoic and Cainozoic parts, extend around the periphery of the Australian continent well beyond the Carnarvon Basin region, definition of the limits of the Carnarvon Basin in the axial direction is somewhat arbitrary. The boundaries are here taken to be the North Turtle Arch in the north and the Precambrian Northampton Block and adjoining ridges in the south (Fig. 1). The basin covers an area of about 300 000 km^2, of which about two-thirds is beneath the sea.

2.2 Exploration history

The earliest known geological investigations carried out in the basin were by F.T. Gregory in 1861. The Geological Survey of Western Australia (GSWA) surveyed the northern Carnarvon Basin between 1900 and 1920, and Maitland (1898, 1907), Woolnough (1928), Talbot (1929), Feldtman (1930), and Forman (1937) worked with the Survey in the southern part of the basin. In 1925 Clapp made the first attempt at assessing the basin's petroleum possibilities. Geologists of Oil Search Limited conducted a comprehensive survey in the basin; Dee & Rudd (1932) made a private investigation of part of the Byro Sub-basin for that company. Condit (1935) presented the earliest published report, indicating the possibility of a thick Permo-Carboniferous marine section in the basin. Raggatt in 1937 defined a major part of the Permian stratigraphy and noted the presence of Cretaceous and Eocene rocks but failed to recognise any Carboniferous or Devonian sediments. These were later recognised by Teichert (1949) who reported the discovery of Devonian and Carboniferous sediments, based on palaeontological evidence, in the Minilya district. Together, Clarke & Teichert (1948) investigated the Cretaceous rocks in the area along the lower reaches of the Murchison River. Since 1948 the Bureau of Mineral Resources (BMR) has conducted extensive field mapping in the Southern Carnarvon Basin and a partial list of its publications includes Condon (1954, 1955, 1956, 1962, 1965, 1967, 1968) Condon et al. (1956), Konecki, Dickins & Quinlan (1958), and Perry & Dickins (1960). In 1968 Marathon Petroleum Australia Ltd conducted a reconnaissance surface geological survey primarily to investigate the Lower Palaeozoic stratigraphy in the basin. West Australian Petroleum Pty Ltd (WAPET) has carried out geological investigations in the basin since 1954 and Burmah Oil Company of Australia (BOCAL) since 1964, and as a result of these companies' widespread drilling programs a large amount of subsurface stratigraphic information has become available. A comprehensive summary of previous work carried out in the Carnarvon basin is given by Condon (1965, pp. 7-10).

Nearly the entire onshore area of the basin has been mapped geologically at a scale of 1:500 000 (two maps) during a large-scale mapping project carried out by BMR between 1948 and 1956. A major part of the onshore area has been mapped at a scale of 1:250 000 by GSWA and BMR, and eight first-edition maps with explanatory notes (not including those for the Winning Pool Sheet area) have been published. Memoir 2 of GSWA, 'The Geology of Western Australia', has a useful chapter on the Carnarvon Basin.

The Carnarvon Basin has received a lot of attention in oil exploration in recent years and up to the end of 1975 a total of 212 petroleum exploration wells, plus 5 BMR stratigraphic wells, had been drilled. Most of the drilling has been concentrated in the onshore Cape Range area (Exmouth Sub-basin), on Barrow Island, and in the Dampier Sub-basin. Few wells have been drilled in the southern onshore part of the basin, where prospectivity is considered to be low. The oil companies WAPET and BOCAL presently hold petroleum exploration title areas for much of the basin. Well completion and geophysical survey reports on many petroleum exploration company operations are available on open file at BMR under the terms of the Petroleum Search Subsidy Act 1959-73 (PSSA). Copies of final reports on subsidised operations can be bought from the Australian Government Publishing Service and some private copying firms. Basic data from these operations, such as seismic record sections, cannot be copied but can be viewed at BMR in Canberra. The Western Australian Mines Department has released to the public exploration information from some areas relinquished by exploration companies.

Plate 1 shows simplified geology of the Carnarvon Basin and the location of petroleum exploration wells and BMR stratigraphic holes. The drilling operations carried out by private oil companies (with the exclusion of development wells) and BMR are listed in Appendix 1. The bibliography offers a selection of the more important references and is not intended to be comprehensive. A bibliography of the Carnarvon Basin containing all known available information current to 31-12-69 has been produced by Ozimic (1970),

2.3 Basin subdivision

A regional structural subdivision of the Carnarvon Basin region is illustrated in Figure 1 (mainly after interpretations by WAPET and BOCAL). Onshore, and particularly in the south, the Carnarvon Basin consists largely of a number of meridionally-trending Palaeozoic structural sub-basins. The most extensive of these is the Gascoyne Sub-basin occupying a large coastal area extending both onshore and offshore and centred around Shark Bay. The Gascoyne Sub-basin is bounded on the east by a north-south line of basement ridges extending from the Northampton Block (a Precambrian inlier separating the Carnarvon and Perth Basins) in the south at least as far north as Exmouth Gulf. On the eastern side of this line of ridges there is a zone of down-to-the-east normal faults (displacement is reversed in the Cretaceous sequence) known as the Wandagee-Yandi-Kennedy Fault System.

In the narrow region between the Wandagee-Yandi-Kennedy Fault System and the outcropping Precambrian rocks of the Gascoyne Block to the east lie, from north to south, the Ashburton, Merlinleigh, Byro, and Coolcalalaya Sub-basins. These are a series of narrow asymmetrical troughs, elongated north-south, containing mainly Permian sediments. With the exception of the Coolcalalaya Sub-basin, these sub-basins are bounded to the east where the sediments onlap Precambrian rocks. In the south the Coolcalalaya Sub-basin abuts the craton along the major Darling Fault System.

West of the offshore portion of the Gascoyne Sub-basin sediments extend into deep water on the Carnarvon Terrace (Fig. 1) and in the Houtman Sub-basin, which lies on the continental slope southwest of Shark Bay. These deep-water areas are currently the subject of a separate study within BMR. For further information the reader is referred to Symonds & Cameron (1977).

The Ashburton and Merlinleigh Sub-basins (Condon, 1954a) contain about 5000 m of Palaeozoic (Silurian to Permian) and ?Lower Mesozoic sediments overlain by a veneer of Cretaceous and younger rocks. They are separated by a cross-basin feature (the Marilla High) which shows evidence of growth during Early Palaeozoic time (Thomas & Smith, 1974). In GSWA Memoir No. 2, no distinction is made between these two sub-basins and the whole area is referred to as the Merlinleigh Sub-basin. The Geological Survey recognises the Bidgemia Sub-basin (Condon, 1954a) as a narrow feature paralleling the

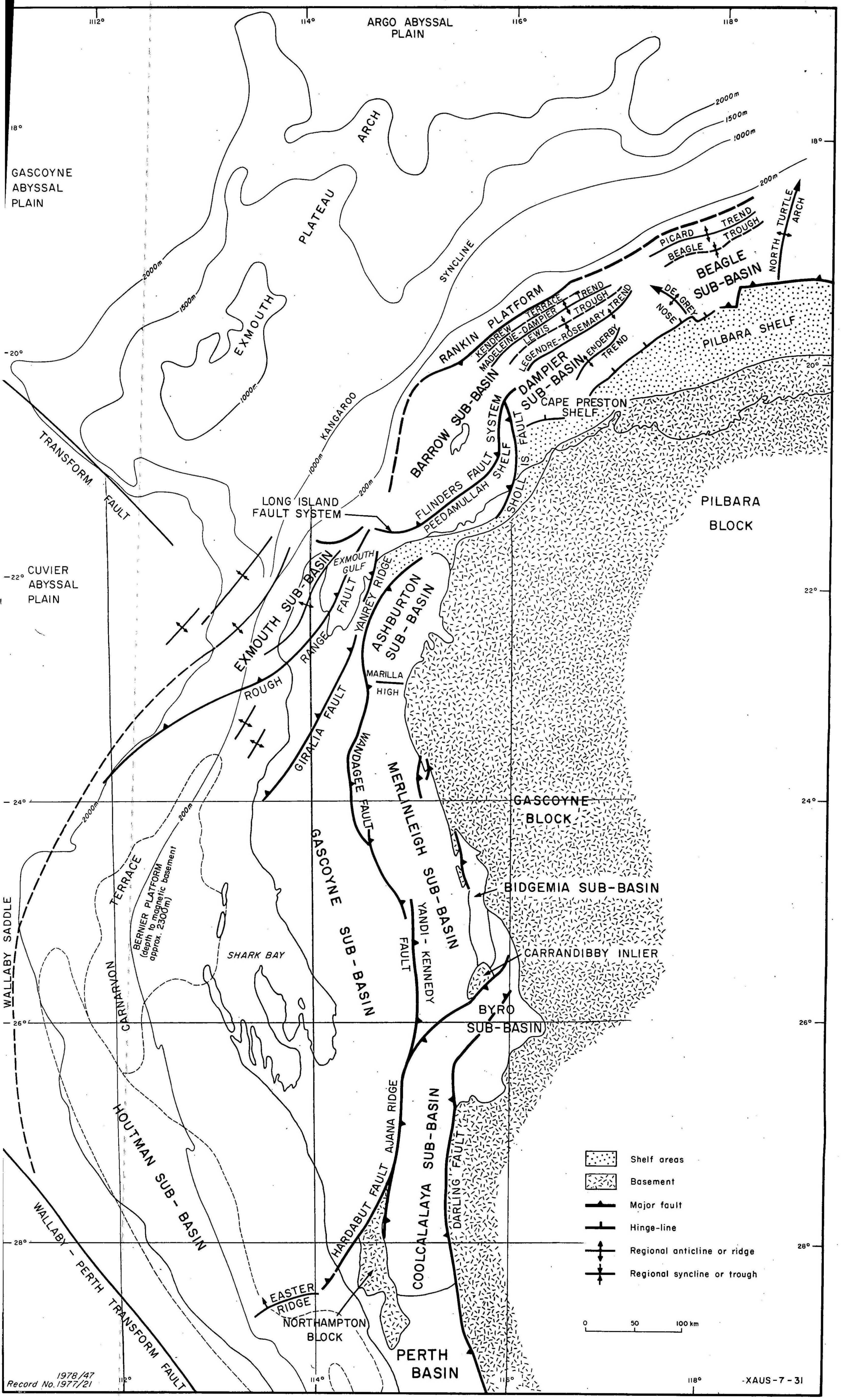


FIG. 1 STRUCTURAL SUBDIVISIONS CARNARVON BASIN

southeastern margin of the Merlinleigh Sub-basin, being restricted on either side by basement ridges and containing about 900 m of Devonian to Permian sediments.

A small Precambrian block, the Carrandibby Inlier, divides the Merlinleigh Sub-basin from the shallower Byro and Coolcalalaya Sub-basins (Condon, 1954) to the south. There has been some disagreement on whether the Coolcalalaya and Byro Sub-basins should be regarded as part of the Perth or the Carnarvon Basin. Reconnaissance gravity surveys carried out in the area suggest that the Coolcalalaya Sub-basin is structurally continuous with the Perth Basin (Fraser, 1973), which it resembles in form more than it does sub-units of the Carnarvon Basin (Konecki, 1958). The Byro Sub-basin contains up to 1500 m of Permian sediments which are faulted against the Carrandibby Inlier to the north. To the east the Sub-basin is bordered by the Precambrian Shield and to the southwest it adjoins the Coolcalalaya Sub-basin. Available stratigraphic evidence suggests there are no stratigraphic grounds for separating the Byro and Coolcalalaya Sub-basins, although separation on structural grounds has been suggested by Konecki et al. (1958) and Condon (1968). It is evident that the definition of a boundary between the eastern sub-basins of the Carnarvon Basin and the Perth Basin must be rather arbitrary. In this review we follow GSWA (1975) in regarding the Coolcalalaya Sub-basin as part of the Perth Basin and the Byro Sub-basin as part of the Carnarvon Basin.

The Gascoyne Sub-basin (Condon, 1954a) contains generally northward-dipping Palaeozoic sediments of Silurian age in the south overlain by a veneer of Cretaceous and younger sediments. At the Early Cretaceous unconformity, subcropping rocks become younger towards the north, ranging from Silurian to Late Triassic (Thomas & Smith, 1974). As already indicated, the Gascoyne Sub-basin lies to the west of an extensive basement ridge and fault system. The sediments of the sub-basin have been uplifted some 2500 to 3000 m relative to the Permian troughs to the east, along the Wandagee-Yandi-Kennedy Fault System. The Gascoyne Sub-basin is bounded on the north and northwest by the Long Island and Rough Range Faults (Fig. 1).

The southern extent of the onshore part of the sub-basin is limited by the Northampton Block. Offshore, the results of a reconnaissance aeromagnetic survey conducted by BMR (Spence, 1962) near the Abrolhos Islands suggest the presence of an offshore basement ridge which trends in a northwesterly direction from the Northampton Block. The Geelvink Channel seismic and magnetic survey, carried out in the area by BP Petroleum Development Australia, confirmed the existence of a basement ridge in the area and further defined the position of what is described as a basement 'hinge-line' which may involve normal faulting. Gun Island No. 1 well (BP Petroleum Development Australia, 1969) was drilled in the Abrolhos Islands south of the basement ridge. The nature of the succession penetrated established the vigorous development of the Perth Basin south of the ridge in the Jurassic and Triassic. Since the Triassic, sedimentation has been continuous across this ridge, but the ridge nevertheless serves as a convenient boundary between the offshore Carnarvon and Perth Basins.

In the offshore part of the Gascoyne Sub-basin, west of the town of Carnarvon, areomagnetic data, supported by results of the Geelvink Channel seismic and magnetic survey, indicate the presence of an area of relatively shallow basement referred to as the Bernier Platform (Fig. 1). This basement 'platform' has a general north-south trend, but there are indications of an east-northeast-trending spur off the main platform, which possibly continues onshore (Geary, 1970).

In the northern half of the Gascoyne Sub-basin there has been extensive block faulting with a dominant north-south trend during post-Triassic, pre-Aptian time. The overall synclinal form of the sub-basin has been modified in the central area by horsts and grabens and destroyed in the north, particularly under the Exmouth Gulf, by east-dipping blocks separated by down-to-the-west normal faults. Along some of the major faults minor reverse movements of 50-300 m, which occurred during the Late Tertiary, have produced asymmetrical anticlines in the overlying Tertiary and Cretaceous sediments.

To the north of the Gascoyne Sub-basin are the Exmouth, Barrow, and Dampier structural Sub-basins which appear to have formed a continuous depositional trough during the Jurassic, following block-faulting of the region in Early Jurassic times. The faulting occurred in a dominantly tensional regime at the time of a postulated collapse of the western side of the Carnarvon Basin (Veevers, 1971) and may be related to the northward pull-apart associated with the break up of Gondwanaland (See Chapter 4).

The Exmouth Sub-basin is the most southerly of these three sub-basins and forms an elongate Mesozoic trough containing some 5000-7000 m of mainly Jurassic, marine and fluviatile sediments. It is bounded to the south-east by the Rough Range Fault, a normal fault with a down-to-the-basin throw of up to 3000 m in the pre-Cretaceous, and plunges northeast into the Barrow Sub-basin, the southern limit of which is arbitrarily defined as the southern edge of the Neocomian Barrow Group. The position of the western boundary of the Exmouth Sub-basin is not accurately known but is for convenience taken as the edge of the Continental Shelf.

The Barrow and Dampier Sub-basins (Mollan et al., 1969) lie entirely offshore from the Pilbara Block and form a northeast-trending elongated trough dominated by Mesozoic downwarps. The sub-basins are bounded to the east by the down-to-the-west Enderby, Flinders, and Long Island Fault System, separating them from the Peedamulla, Cape Preston, and Pilbara Shelves. They are flanked to the west by the Rankin Platform and its southern extension, a high regional trend comprising block-faulted Triassic and Early Jurassic sediments unconformably overlain by a sequence (over 3000 m thick in the West Tryal area) of Cretaceous, Tertiary, and Quaternary sediments. In the Mesozoic downwarps, the sedimentary sequence is at least 5000 m thick and consists of Middle Jurassic to Early Cretaceous marine, deltaic, and fluvial sediments. Recent seismic data have indicated sedimentary sections of over 15 000 m in some areas of the Barrow Sub-basin with the possibility of a thick Palaeozoic sequence at depth. Complexly faulted Permian, Triassic, and Early Jurassic sediments are considered to underlie the downwarps but to date have only been penetrated on the high eastern and western flanks of the trough.

Despite some differences in structural style there appears to be no tectonic or depositional break between the Barrow and Dampier Sub-basins, with the Dampier Sub-basin being continuous with, and forming the north-east extension of, the Barrow Sub-basin (Kaye et al., 1972).

The Dampier Sub-basin covers an area of about 52 000 km^2. It is limited to the north by a faulted south-trending basement extension, the De Grey Nose; to the southeast the Pilbara Shelf, an area of thin sedimentary cover, forms a hinge feature separating the deep basin centre from the Pilbara Block (Fig. 1). The Rankin Platform flanks the western side of the sub-basin and is one of the four main positive trends differentiated in this area, the other three being, from west to east, the Madeleine-Dampier Trend, the Legendre-Rosemary Trend, and the Enderby Trend. The main sediment source for the sub-basin is the Pilbara Block. A northwesterly source of clastic material is believed to have existed at least in the Lower Mesozoic and possibly through to the Upper Cretaceous (Kaye et al., 1972). A wedge of basinward-thickening Tertiary sediments onlaps the entire Mesozoic substructure.

The Beagle Sub-basin lies to the northeast of the Dampier Sub-basin and is partly separated from it by the De Grey Nose. It is bounded to the north by an outer platform area considered to be similar to the Rankin Platform and to the south by the Pilbara Shelf, and is restricted in the northeast by the block-faulted, south-trending Turtle Arch (BOCAL, 1974). Other features within the sub-basin include the Beagle Trough and the Picard Trend. The Beagle Trough is a major Mesozoic depositional downwarp which appears to form the northeastern extension of the Lewis Trough of the Dampier Sub-basin. Immediately north of the trough is a series of structurally positive features referred to as the Picard Trend, on which the first exploratory well in the sub-basin, Picard No. 1, was drilled.

The Exmouth Plateau (Fig. 1) lies adjacent to the continental shelf to the northwest of the Exmouth, Barrow, and Dampier Sub-basins. As defined by Willcox & Exon (1976), the plateau is restricted by the 200 and 2000 m bathymetric contours and is limited to the northeast by a subsea canyon (Swan Canyon) debouching northward at around 117°30'E. The physiography of the plateau is described by Falvey & Veevers (1974).

The regional geology of the area has been interpreted from 12 000 km of gravity, magnetic, and reflection seismic data from the BMR Continental Margin Survey; from 6000 km of reflection seismic profiles recorded by Esso Australia, Australian Gulf Oil, and Shell Development (Australia); and from ties with exploration wells in the Carnarvon and Canning Basins. The Exmouth Plateau trends in a predominantly northeasterly direction and is characterised by gentle warping and extensive normal faulting of pre-Cretaceous sediments. A major arch (Exmouth Plateau Arch) and syncline (Kangaroo Syncline) on the plateau lie parallel to the Rankin Platform at distances of about 200 km and 80 km to the northwest of it respectively. For an interpretation of existing information on the Exmouth Plateau the reader is referred to Willcox & Exon (1976).

2.4 Structure

The structure of the southern part of the Carnarvon Basin has been described in detail by Condon (1968). This part of the basin is subdivided into a number of minor sub-basins (Condon, 1965) separated by ridges of Precambrian basement which mostly appear to have been structural 'highs' for most of time since the basin's inception. During the Palaeozoic and the greater part of the Triassic, an age when tectonically stable conditions generally prevailed, the sub-basins sagged as sediments were laid down and the original structural relief of these ridges increased. The most prominent ridge is the Wandagee Ridge, a south-trending feature which is located west of the Wandagee Fault and which forms the boundary between the Merlinleigh and Gascoyne Sub-Basins.

In the Late Triassic-Early Jurassic, extensive block-faulting occurred throughout the Carnarvon Basin region. It is thought to have developed in a taphrogenic regime linked with continental rifting, a phase marking the beginning of a process which led finally to the rupture of this part of the Gondwanaland continental block (Veevers, 1971) - see Chapter 4. Block-faulting developed around the continental margin, trending from almost north in the southern sub-basins to north-northeast in the Exmouth and Barrow Sub-basins, and to northeast in the Dampier and Beagle Sub-Basins. Most of the faults are normal with blocks downthrown towards the west. Most faults were active during the Jurassic but movement along some continued into the Late Cretaceous. Evidence in support of pre-Neocomian fault movement is found along the Flinders and Enderby Fault zones and along the Rankin Trend where thick Jurassic sections have been intersected in the downthrown blocks but are generally absent on the upthrown blocks. In the Enderby Fault zone, syndepositional faulting about the horsts has induced supratenuous folds in adjacent Jurassic and Cretaceous sediments (WAPET, 1973).

The normal down-to-the-west Enderby and Flinders Fault zones separate the shelf area from the western basinal area referred to as the Dampier Sub-basin (to the north) and the Barrow Sub-basin (to the south). The faulted shelf area borders the present-day coastline and comprises Precambrian to Early Triassic rocks unconformably overlain by a thin cover of

Cretaceous and Tertiary sediments. The shelf area is divided from north to south into the Pilbara Shelf, the Cape Preston Shelf, and the Peedamulla Shelf, which resemble fault-segmented, en echelon repetitions of the Gascoyne Platform farther to the south.

As indicated previously, the Barrow and Dampier Sub-basins contain a great thickness of Jurassic and Cretaceous sediments. In the centre of the basin, the thickness has been estimated at up to 6000 m from seismic and gravity data. Madeleine No. 1 well, drilled on the structurally positive Madeleine-Dampier Trend in the Dampier Sub-basin, intersected over 1800 m of Neocomian and Jurassic sediments before reaching total depth in the Middle Jurassic.

The Dampier Sub-Basin is restricted to the north by a south-trending basement ridge, the De Grey Nose. The northwestern margins of the Barrow and Dampier Sub-basins are marked by upfaulted horst blocks which coincide with positive gravity anomalies. In BOCAL'S area to the north, the Rankin Platform comprises a pre-Cretaceous (Triassic/Jurassic) horst block complexly segmented into a series of en echelon blocks draped by Cretaceous and thick Tertiary sediments. Farther to the south and offset to the north-west from the Rankin Platform the northwestern margin of the Barrow Sub-basin is marked by a central graben bounded by horsts on either side. This northeast horst trend has been indicated by seismic and gravity data to extend as far south as the Exmouth area and the term 'Yardie-North Rankin Trend' is used to describe the overall feature.

On the seaward side of the trend, in the area of the Dampier Sub-basin, a previously unmapped Cretaceous trough was located by the Montebello-Turtle Marine Seismic Survey (BMR File no. 72/509) conducted by BOCAL in 1972.

The Mesozoic structure in the Dampier Sub-Basin is characterised by a relatively complex system of fault blocks which probably gave rise to palaeotopography of fault scarps and basins during the Jurassic. Most of the blocks in the sub-basin would have been covered by the latest Jurassic. Exceptions were the Rankin Platform blocks, the highest of which remained emergent until the Aptian. Conditions were favourable for the formation of drape closures in the overlying Late Jurassic and Cretaceous sediments in association with the fault blocks. Shoreward from the Rankin Platform several major structural features, trending roughly northeast, have been recognised in the Dampier Sub-basin by BOCAL and these converge in a northerly direction towards the De Grey Nose. From northwest to southeast they are:

The Kendrew Terrace: a poorly defined sedimentary downwarp which narrows towards the De Grey Nose and is probably Late Jurassic to Cretaceous.

The Madeleine-Dampier Trend: an anticlinal feature in Jurassic and Early Cretaceous sediments which is possibly due to drape over pre-Jurassic fault blocks.

The Lewis Trough: a relatively narrow, deep, structurally uncomplicated depression with a thick Jurassic and Cretaceous section ranging to over 3000 m thick in the axial zone.

The Legendre-Rosemary Trend: a complex elongate horst-like structure related to two independent fault zones initiated in the Jurassic, the first being down-thrown to the southeast and the second to the northwest.

The Enderby Fault Zone: a fault complex with associated horsts, grabens, and half-grabens. Syndepositional movements along the faults are characteristic of this zone which was originally considered as part of the Pilbara Shelf but is now included in the Dampier Sub-basin (Powell, 1973).

These trends do not appear to extend south into the Barrow Sub-basin, but seismic data there are generally poor below the base Muderong reflector (Early Cretaceous). A major flexure on the base Muderong, which is thought to be related to deep-seated horst blocks, passes through Barrow Island but appears to die out northward before reaching the Dampier Sub-basin (WAPET, 1972).

After the initiation of the main positive trends in the basin, probably in the Early Jurassic, uplift in the early Middle Jurassic resulted in some minor erosion along the basin edges and on the De Grey Nose. During the Late Jurassic and Neocomian, uplift and erosion occurred over most of the southern Carnarvon Basin with sedimentation apparently continuous throughout the Neocomian only to the north and possibly to the west of Barrow Island. Uplift caused rejuvenation along some south-trending faults which fragmented the earlier horst blocks. Because there have been several erosional periods in the Late Jurassic - Early Cretaceous, preservation of lithology and stratigraphy across faults is variable.

In the northwestern part of the Carnarvon Basin there is widespread evidence for the existence of a mild tectonic phase during the Tertiary.

A series of broad north-northeast-trending anticlinal folds developed in Tertiary and Cretaceous rocks in the Gascoyne, Exmouth, and Barrow Sub-basins and were probably folded in the late Miocene (Playford & Johnstone, 1959). The Cape Range Anticline on North West Cape, formed in Miocene limestones, is the largest of these structures, being 100 km long with a structural relief of 450 m. The Rough Range Anticline runs parallel to the Cape Range Anticline to the southeast of the latter and is 70 km long with a structural relief of 90 m. The Giralia Anticline south of Exmouth Gulf is another large structure with a length of 130 km and a structural relief of 210 m. There is evidence that this structure was initiated in the Cretaceous. Smaller structures belonging to this series include the Marrilla, Warroora, Chargoo, Gerardi, Chirrita, Minilya, Grierson, Boolan, Yanki Tank, and Cape Cuvier Anticlines. The Barrow Island Anticline shows evidence of growth in the Early Cretaceous where the structure appears to be a broad north-plunging nose fault-bounded to the west, south, and east (WAPET, 1973). However, the anticlinal structure which developed at the base of the Miocene Trealla Limestone and which has at least 25 m vertical closure and 10 000 hectares of areal closure provides evidence that significant arching also occurred in the Tertiary.

The Rough Range and Giralia Anticlines are associated with high-angle reverse faults on their eastern flanks where movement appears to have been localised by older, normal faults. At Rough Range the normal fault was last active in the Late Jurassic or Early Cretaceous. Rough Range South No. 5 well intersected an interval along the reverse fault in which 126 m of Early Cretaceous sediment was repeated. Further evidence of reversal of movement along old normal faults is found along the Wandagee Fault which has a normal down-to-the-east throw of 2500-3000 m in pre-Cretaceous sediments and a reverse throw of up to 200 m in Cretaceous sediments at different points along its length. The reverse movement along this fault dies out in the incompetent shales of the Early Cretaceous Winning Group and has surface expression in broad asymmetrical anticlines in Late Cretaceous and Tertiary rocks. There is some controversy as to whether these features are a result of a postmiddle Miocene compressional phase or whether equilibrium adjustment (rebound) or inverted basin movement may be responsible. In the Barrow and Dampier Sub-basins and their adjacent borderland blocks there is no evidence of any compressional features, at least in the Mesozoic and Tertiary, and structural forces operating in these areas appear to have been entirely tensional.

The Cretaceous and Tertiary sequences at various localities throughout the basin are locally effected by minor faulting and rejuvenation of older fault systems.

2.5 Stratigraphy and basin development

A generalised stratigraphic table of the Carnarvon Basin is presented in Table 1. Stratigraphic tables for individual wells in various parts of the basin are presented in Appendix 3, and well correlation charts across the main sub-basins are shown in Plates 7 to 11. The plates were prepared by A. Mond of BMR in 1975 for the ESCAP Stratigraphic Atlas, and are based on company interpretations.

The present stratigraphic subdivision of the Carnarvon Basin has evolved since the turn of the century and many of the Palaeozoic, Cretaceous, and Tertiary units, which were first recognised in the southern part of the basin but which have since been identified in the northern and offshore parts of the basin, are described in detail by Condon (1954, 1965, 1967, and 1968).

A number of published papers deal with the stratigraphy of particular areas. The Jurassic and Neocomian units of the Exmouth Sub-basin are described by McWhae and others (1958). Parry (1967) and Crank (1973) discuss the geology of Barrow Island. The following publications by BOCAL personnel cover the Dampier Sub-basin and Rankin Platform; Kaye et al. (1972), Martison et al. (1972), Powell (1973), and Dewhurst (1973). A recent account of the stratigraphy of the Northwest Shelf is given by Powell (1976).

A comprehensive and detailed description of the stratigraphy of the whole of the Carnarvon Basin is given by GSWA (1975). Thomas & Smith (1974) have also described the stratigraphy and development of the basin. Their description has provided the basis for the following summary.

Silurian

Silurian sediments subcrop extensively in the Gascoyne Sub-basin and probably extend as far north as the Exmouth Gulf area. The Early Silurian (and possibly Ordovician) Tumblagooda Sandstone (Clarke & Teichert, 1948) is a thick sequence of fluviatile redbed sediments deposited under continental to estuarine conditions. Up to 1200 m of continuous exposure of this formation crops out in river valleys on either side of the Northampton Block, in the Gascoyne and Coolcalalaya Sub-basins.

TABLE 1

GENERALISED STRATIGRAPHY OF THE CARNARVON BASIN

(after Thomas & Smith, 1974)

	AGE	UNIT		DEPOSITIONAL ENVIRONMENT	
TERTIARY	Pliocene	Unnamed unit		Marine	
	Miocene	Pilgramunna Formation Trealla Limestone Cape Range Group			
	Eocene	Giralia Calcarenite			
	Paleocene	Cardabia Group			
CRETACEOUS	Late	Miria Marl Toolonga Calcilutite			
		Gearle Siltstone Windalia Radiolarite Muderong Shale Birdrong Sandstone			
	Early	Barrow Formation or Wogatti Sandstone		Deltaic to Fluvial	
JURASSIC	Late	Learmonth Fm. or Legendre Fm.	Dupuy Member	Marginal to Nonmarine	Marine to Deltaic
	Mid		Dingo Claystone		
	Early				

TABLE 1 (Continued)

	AGE	UNIT	DEPOSITIONAL ENVIRONMENT
TRIASSIC	Late Mid Early	Mungaroo Formation Locker Shale	Fluvial to marginal Marine
			Marine to Marginal Marine
PERMIAN	Artinskian Tatarian	Kennedy Group Byro Group Wooramel Group	Marine and Marginal Marine
		Callytharra Formation	Marine
	Sakmarian	Lyons Group	Glacials Marine to Lacustrine
CARBONIFER-OUS		Harris Sandstone Yindagindy Formation Williambury Formation	Continental "Deltaic" To Marine
		Moogooree Limestone	Marine
DEVONIAN		Willaraddie Formation	Near Shore Marine
		Munabia Sandstone Gneudna Formation	Shelf to Basinal
		Nannyarra G'wacke	Continental
SILURIAN		Dirk Hartog Formation	Shelf
		Tumblagooda Sandstone	Continental
PRECAMBRIAN			

The type section extends for some 70 km along the Murchison River Gorge from near Hardabut Pool to Second Gully Point. In the Coolcalalaya Sub-basin the unit has an estimated maximum thickness of up to 2100 m. It has been penetrated in the wells Kalbarri No. 1, Tamala No. 1, Marilla No. 1, Wandagee No. 1, Quail No. 1, Dirk Hartog 17B, Yaringa No. 1, and in a number of water-bores near Carnarvon township. The formation comprises a sequence of coarse, red, cross-bedded sandstone with associated lenticles of fine silty sandstone considered to have been deposited in the downthrown area, following the relative uplift of the Precambrian hinterland along the Darling Fault. The upthrown Precambrian rocks provided a prolific source of sand during the Silurian, and with continued sedimentation and subsidence of basinal areas, activity along the Darling Fault continued.

Planation of the eastern landmass gradually exhausted the terrigenous supply of material and in the later part of the Silurian relatively quiescent shallow marine and tidal flat conditions prevailed. The sequence deposited during this time consists of a redbed succession of chocolate mudstone, purple dolomite, limestone, anhydrite, and thin salt beds and is called the Dirk Hartog Formation (McWhae et al., 1958 p. 31). It does not crop out but has been intersected in a number of wells in the Gascoyne Sub-basin. The type section for this formation is between 665 m and 1404 m in Dirk Hartog 17B well.

Late Devonian-Early Carboniferous

No sediments were deposited in the Early Devonian but following this a series of well-bedded, uniform, shallow marine shelf sediments were deposited over a wide area of the basin. The sequence largely comprises interbedded limestone (possibly associated with reef complexes) and shallow marine sandstone with some localised development of thick deltaic sandstone and boulder conglomerate along the eastern basin margin. In the Merlinleigh Sub-basin an outcropping sequence, 2200 m thick, of poorly-sorted, shallow marine, terrigenous clastics and shelf carbonates onlaps the Precambrian basement.

The Devonian units from the base upwards are as follows: the Nannyarra Greywacke (Condon, 1954a: type section at southern end of Gneudna paddock on Williambury station, 23°58'S, 115°13'E) a continental conglomeratic deposit; the Gneudna Formation (named Teichert, 1949, defined Condon, 1954a, p. 13, revised Condon 1965: type section same as before) of richly fossiliferous calcarenite, limestone, and sandstone; the Munabia Sandstone (Teichert, 1949, amended Condon 1954a: type section in Gneudna paddock on Williambury station), a mainly clean 'sparkling' quartz sandstone, often cross-bedded; the Willaraddie Formation (Condon, 1954: type section 2.8 km northwest of Gneudna Well), of poorly sorted conglomeritic sandstone and siltstone.

In the Early Carboniferous succession the basal unit, the Moogooree Limestone (Teichert 1949, Condon 1954a: type section 4 km northwest of Gneudna Well), consists of interbedded calcarenite and calcilutite. The overlying interbedded poorly sorted sandstone and cross-bedded torrential conglomerate of the Williambury Formation ('Williambury Sandstone' of Teichert, 1949, amended Condon, 1954a: type section in Gneudna paddock, 4 km southeast of Williambury homestead) are in turn overlain by the Yindagindy Formation ('Yindagindi Limestone' of Teichert, 1950, amended Condon 1954a: type section 4 km west of Williambury homestead). This uppermost Carboniferous unit dominantly comprises thin beds of sandstone with minor layers of fossiliferous, oolitic calcilutite.

Sediments in this time sequence have been recognised in wells drilled as far north as Rough Range (Gascoyne Sub-basin) and the Robe River area (Peedamullah Shelf).

Permian

Towards the end of the Carboniferous, the eastern basin margin was uplifted and this provided a new source of material for the area. Glaciers formed in the eastern highlands and during the Early Permian deposited the Lyons Group 'tillites' into the marine trough of the Carnarvon Basin. The Lyons Group ('Lyons Conglomerate' of Maitland 1912; amended Teichert, 1950) is the basal Permian (Sakmarian) unit which unconformably overlies the Lower Carboniferous rocks where present. It comprises marine siltstone and lithic sandstone, containing a number of boulder beds (tillites) which are believed to have originated as a result of ice rafting in the uplifted Pilbara Block. Over 2300 m of this unit was penetrated in the Remarkable Hill No. 1 well and the outcrop thickness of the sequence is over 1500 m. The type section of the Lyons Group is along the north side of the Wyndham River (Condon, 1967).

The Carnarvon Basin had regained tectonic stability by the Artinskian, during which time a widespread sequence of largely black shale and fine sandstone was deposited in the basin, which was possibly silled at the time.

The Sakmarian-Artinskian Callytharra Formation ('Callytharra Limestone' of Condit, 1935, amended Condon, 1954a: type section 1 km west of Callytharra Spring) overlies the Lyons Group and comprises a fossiliferous siltstone and shale unit with minor beds of limestone. Disconformably overlying this formation is the Artinskian Wooramel Group ('Wooramel Sandstone' by Condit, 1935; amended by McWhae et al., 1958 and Konecki et al., 1958), a sequence consisting of mainly quartz sandstone and greywacke with minor siltstone and shale.

The type locality for the Wooramel Group is in the Byro Sub-basin from Gap Pool to One Gum Creek junction on the Wooramel River. This unit is succeeded by the siltstone, black fossiliferous shale, and fine sandstone of the Byro Group ('Byro Limestone Group' of Dee & Rudd, 1932, 'Byro Formation' of Condit, 1935, redefined Condon, 1954a). A 1250 m thick complete sequence of this unit was penetrated in Kennedy Range No. 1 well. The uppermost Permian Kennedy Group ('Kennedy Sandstone' of Condit, 1935; 'Kennedy Stage' of Raggatt, 1936; amended Condon, 1954a), a marine sandstone unit, represents the closing regressive stages of Permian sedimentation in the southern part of the basin, before a long period of non-deposition. In the northern Carnarvon Basin sedimentation continued from the Late Permian into the Early Triassic without any major tectonic break. No formal names have been given to these sequences.

Permian sediments only outcrop along the eastern edge of the Merlinleigh Sub-basin, with the thickest surface sections being in the Kennedy Range area and measuring in excess of 4000 m. The strata, from well control, are known to underlie a large area of the northern Gascoyne Sub-basin and have been penetrated on the Peedamullah Shelf. They are probably present at considerable depth in the Exmouth, Barrow, and Dampier Sub-basins.

Triassic

The Triassic sequence is a regressive sequence which has only been preserved in the northern part of the basin, in the Exmouth, Barrow, and Dampier Sub-basins, and on the bordering Peedamullah Shelf and Rankin Platform. Scattered outcrops of Triassic sediments occur in the southern Gascoyne Sub-basin adjacent to the Hardabut Fault but these are correlated with the Kockatea Shale and Wittecarra Sandstone of the Perth Basin.

In the north two formations, the Locker Shale and the overlying Mungaroo Formation, are distinguished. The Early Triassic Locker Shale is a widespread unit which overlies the Kennedy Group with probable disconformity. It is a fine-grained marine unit which passes upwards and regresses into the Middle Triassic sandy deltaic to fluvial sediments of the Mungaroo Formation. The wells Onslow No. 1 and Long Island No. 1 are the type wells for the Locker Shale and Mungaroo Formation respectively.

In the Onslow-Long Island area the Mungaroo Formation ('Mungaroo Beds' of Parry, in WAPET, 1967; amended GSWA, 1975) consist of interbeds of fine to coarse-grained, clean sandstone alternating with red to brown clay stone and rare coal. However, the likely equivalents penetrated in the North Tryal Rocks/North Rankin Trend area are fluviodeltaic claystone and thick porous sands which are generally coarser and contain higher percentages of porous sand.

A near-shore marine influence is evident in the Late Triassic sections penetrated by Enderby No. 1 and De Grey No. 1.

The age range of the Mungaroo Beds is from Middle to Late Triassic on the Peedamullah Shelf, but on the Rankin Platform and in the Exmouth Sub-basin it extends into the Early Jurassic without evidence of any major break in deposition or change in lithology. No complete Triassic sections have been intersected in the basin to date.

Jurassic

The regressive conditions of Late Triassic sedimentation continued into the Early Jurassic except in the inner parts of the Dampier and Beagle Sub-basins where there is evidence of an unconformity between the Carnian and the Toarcian (Powell, 1976). Faulting probably began around the end of the Early Jurassic and led to the formation of the Exmouth-Barrow-Dampier trough, flanked by structurally high remnants of the older basin (Peedamullah, Cape Preston, and Pilbara Shelves, Gascoyne Sub-basin, and Rankin Platform). The horst blocks initiated during this period contain the hydrocarbon accumulations of the Rankin Platform.

During the Middle to Late Jurassic, subsidence and rapid sedimentation continued in the basin with up to 5000 m of marine sediments (Dingo

Claystone and equivalents) being deposited in some of the deepest areas. Along the shallower eastern margins where paralic conditions predominated, the sandy equivalents of the Learmonth (approximately 1600 m thick in Sandy Point No. 1) and Legendre Formations were deposited.

The Dingo Claystone (McWhae et al., 1958) was first described in the Cape Range area and the type section, consisting of 3494 m of massive marine claystone with minor interbeds of dolomite, limestone, and silty sandstone, was intersected in Cape Range No. 2 well between 1130 m and 4624 m (T.D.). The probable equivalent formation intersected in Barrow Deep No. 1 contains significant sandstone intervals.

The Dupuy Member of the Dingo Claystone was deposited in the north-eastern area of the Barrow Sub-basin during the Tithonian. It is considered to have been deposited in a near-shore marine environment and consists of very fine to fine-grained, variably argillaceous sandstone, interbedded with dark grey and brownish grey shale (type section in Barrow No. 25 well).

The Learmonth Formation (McWhae et al., 1958) is the lateral equivalent of the Dingo Claystone along the southern and eastern margins of the Exmouth Sub-basin. The transition between these two formations is rapid and this can probably be attributed to relative fault-block movement in association with basin subsidence during their time of deposition. The formation was deposited under paralic conditions and mainly comprises kaolinitic sandstone and siltstone with interbedded coal. The type section is in Rough Range No. 1 well between 1216 m and 1890 m.

In the northeastern Dampier Sub-basin for much of the Middle and Upper Jurassic fluvial and deltaic sedimentation, with brief marine incursions, prevailed, resulting in the deposition of the Legendre Formation of Kaye et al. (1972).

There appears to have been no Jurassic sedimentation on the Peedamullah and Cape Preston Shelves, but in the Barrow and Exmouth Sub-basins the total thickness of the sequence has been estimated at over 7000 m. Deposition in the Middle to Late Jurassic period was probably continuous in the deeper parts of the basin but a period of faulting and erosion (Powell, 1973) has been recognised in the Dampier and the southern Barrow Sub-basins. During the same period the southern Carnarvon Palaeozoic Sub-basins were subjected to uplift, extensive block-faulting, and deep erosion.

Early Cretaceous (Neocomian)

The cycle of deltaic and fluvial sedimentation, which began in the Jurassic (represented by the Dupuy Member) continued into the Neocomian in the Barrow and Dampier Sub-basins where it reached maximum development in the Barrow Formation ('Barrow Group' of BOCAL, 1968; amended GSWA, 1975). As a result, more than 1400 m of coarse clastic sediments accumulated in the Barrow Sub-basin. The Barrow Formation is a sequence (first intersected in Barrow No. 1, type section between 909 m and 2181 m) consisting mainly of medium to coarse-grained and commonly conglomeritic sandstone with thin interbeds of shale and claystone. These interbeds are indicative of the occasional brief marine incursions in what is considered to be a broadly deltaic sequence which generally becomes progressively less marine upwards in the section. The uppermost sediments in the Barrow Formation are probably entirely fluvial.

The thickest known section (1240 m) of Barrow Formation was penetrated at Pasco Island. Oil sands occur within the Barrow Formation in the Barrow Sub-basin at Pasco and Barrow Islands and have also been penetrated by Legendre No. 1 well in the Dampier Sub-basin but are non-commercial.

The Barrow Formation is restricted to the Barrow and Dampier Sub-basins. It is absent on the marginal shelf areas of these sub-basins and is represented by time-equivalent marine shale on the Rankin Platform. In the Exmouth Sub-basin where Neocomian sedimentation was not extensive, the Wogatti Sandstone (McWhae et al., 1958) is the time-equivalent of the Barrow Formation. This unit has a maximum thickness of 107 m and consists of coarse-grained, argillaceous, continental sandstone occurring in a belt along the downthrown side of the Rough Range Fault. The type section is in Rough Range No. 1 well between 1109 m and 1216 m.

During the late Neocomian there was considerable uplift and erosion involving the truncation of the Palaeozoic Sub-basins to the south of the Long Island Fault.

Early-Late Cretaceous (Aptian-Cenomanian)

A period of marine transgression associated with continental breakup commenced in the northern part of the basin (Beagle and Dampier Sub-basins) in the Neocomian but did not reach the Barrow Sub-basin or farther south until the early Aptian (as represented by the unconformity in Table 1). The transgression covered most of the Carnarvon Basin with a relatively uniform veneer of mainly argillaceous sediments, referred to as the Winning Group ('Winning Series' of Raggatt, 1936; Fairbridge, 1953; and Johnstone et al., 1958). These sediments transgressed the previously emergent Peedamullah and Cape Preston Shelves and provided a cap seal for the faulted Late Triassic-Early Jurassic reservoir rocks of the Rankin Platform, and also covered most of the southern Palaeozoic sub-basins.

The Winning Group is thickest (1500 m) to the northwest of Barrow Island but varies to less than 100 m in the southern part of the basin. The basal unit in the group, the Birdrong Sandstone ('Birdrong Formation' of Condon, 1954a; amended GSWA, 1975), comprises weakly lithified quartz sandstone, commonly glauconitic, with lesser amounts of interbedded siltstone and quartz greywacke. This unit has an average thickness of 15-30 m and its type section is located 1 km west of Birdrong Spring in the Kennedy Range. The overlying Muderong Shale (Condon, 1954a) was deposited to the end of the Aptian under more established marine conditions. This unit consists of shale, claystone, and siltstone and contains an upper member, the Windalia Sand, which represents the last major influx of sand into the basin during the Cretaceous. This member is the main producing horizon in the Barrow Island Field and comprises a very fine to fine-grained shaly glauconitic sandstone with a high porosity and low permeability. The type section for the Muderong Shale is 2.1 km west-southwest of the Muderong Bore on Middalya station ($24^{o}08'03''S$, $114^{o}45'49''E$). The Windalia Radiolarite (Condon, 1954a; Condon et al., 1956) rests conformably on the Muderong Shale and consists of a sequence of highly siliceous, organic sediments of mainly radiolarian tests. The type locality is at Windalia Hill near the Lyndon River. This unit is indicative of a period of high organic activity in the basin. The Gearle Siltstone (Condon, 1954a; Condon et al., 1956) is a thick marine sequence of siltstone and claystone (in part bentonitic) and is the youngest formation of the Winning Group.

Late Cretaceous (Senonian-Maestrichtian)

Tectonically stable conditions continued throughout this period, marked by a decline in the supply of terrigenous material and the establishment of shelf carbonate sedimentation. Owing to the almost complete peneplanation of the eastern source area, sediments deposited after the Gearle Siltstone are almost entirely carbonates. The Toolonga Calcilutite unit ('Toolonga Chalk' of Clarke & Teichert, 1948; amended Johnstone et al., 1958) unconformably overlies the Gearle Siltstone and comprises an argillaceous calcilutite which grades into siltstone and is characterised by fragments of *Inoceramus* (a large pelecypod). The type section for this unit is in the Toolonga Hills, 3 km north of Yalthoo Well on Murchison House station. On the Rankin Platform a marl or shaly calcilutite, the Miria Marl (Condon, 1954a; Condon et al., 1956) overlies this unit and in part is probably its lateral equivalent. It has a type section 1.2 km thick located on Toothawarra Creek on Cardabia station.

Tertiary

A regional unconformity separates the Late Cretaceous from the Palaeocene. Thomas & Smith (1974) envisage three main episodes of Tertiary sedimentation in the Carnarvon Basin, each being bounded by major disconformities. These episodes are represented by the Palaeocene-Early Eocene Cardabia Group ('Cardabia Series' of Raggatt, 1936; amended Condon, 1954a; Condon et al., 1956; Condon, 1968), the Eocene Giralia Calcarenite ('Giralian Stage' of Singleton, 1941; amended Condon et al., 1956) and its equivalents, and post-Eocene sediments including the Cape Range Group (Condon et al., 1953; amended Condon, 1968), the Trealla Limestone (Condon et al., 1953) and the Pilgramunna Formation (Condon et al., 1955).

Most Tertiary sediments are carbonates. Marine Tertiary sediments crop out in the northern part of the basin from Barrow Island to just north of Carnarvon township and also in a small area to the east of Hamelin Pool. The estimated total thickness of Tertiary sediments in the basin is about 700 m. For a more detailed account of the Tertiary stratigraphy see GSWA (1975, pp. 299-303), Quilty (1974, pp. 309-12) and Condon (1968).

Quaternary

The Quaternary deposits in the basin cover quite a large surface area but are usually thin, not often exceeding 30 m. The total maximum thickness of these sediments is estimated at about 300 m. They have not been studied in detail except in the Shark Bay area where research has been conducted by the University of Western Australia since 1965 (Logan, Davies, Read, & Cebulski, 1970).

Laterite deposits are widespread in the Carnarvon basin and are described in detail by Condon (1954a).

The Exmouth Sandstone (Craig, 1950; Condon, 1954a) unconformably overlies the Trealla Limestone or the Pilgramunna Formation. It consists of reddish quartz sandstone, partly calcareous, and has a type section 12 m thick on Cape Range at 22°21'00"S, 114°00'00"E. This unit is now taken to include the 'Vlaming Sandstone' of Condon et al., 1955; Condon, 1968). The Exmouth Sandstone is a shoreline deposit with marine affinities and although its age is uncertain it is generally regarded as Pleistocene.

The Joolabroo Conglomerate (Teichert, in Condon, 1954a) is a conglomerate, pebbly sand, and sandy clay unit in the Minilya River Valley. The type section is 8 km west-northwest of the Wandagee Station homestead at 23°44'30"S, 114°28'30"E.

Other Quaternary units recognised in the basin include the Coastal Limestone, commonly developed in coastal areas of the basin, and the Tamala Eolianite, its equivalent in the Shark Bay area; the Bundera Calcarenite and Mowbowra Conglomerate of the Exmouth Gulf area; the Walatharra Formation of Giralia Range; and the Nadarra Formation of the area between the Williambury and Coordewandy stations. Recent deposits are described by Condon (1954a).

Since the Late Cretaceous, the accumulation of up to 3000 m of carbonate sediments along the shelf edge has brought about the northwesterly tilt of the entire northern region of the Carnarvon Basin.

3. GEOPHYSICS

The geophysical exploration of the onshore Carnarvon Basin was begun by BMR with gravity surveys in 1950 and a seismic survey in 1951. BMR carried out a variety of geophysical surveys throughout the 1950s. WAPET employed the first contract seismic crew in Australia in the Carnarvon Basin in 1952. This crew worked during most of 1952 and 1953 on various surface structures in the northern part of the Carnarvon Basin (including Rough Range) and in the Kimberleys farther north. From that time onwards much of the geophysical exploration onshore in the Carnarvon Basin has been done for WAPET. The results of WAPET's surveys in the 1950s, before the introduction of PSSA, are generally not available.

Apart from a few submarine gravity observations by Venig Meinesg (1941) in the 1930s, WAPET initiated offshore geophysical exploration of the basin in 1961 with a marine seismic survey in the waters around North West Cape. Its first seismic survey on Barrow Island was done in 1963. BOCAL commenced marine geophysical operations in 1964. Since that time WAPET and BOCAL have been responsible for most of the numerous offshore surveys in the Barrow and Dampier Sub-basins respectively; a lesser amount of exploration has been done for other companies in the southern Carnarvon Basin.

3.1 Magnetic Surveys

Plates 3A, 3B show the extent of magnetic surveys, both airborne and shipborne, in the Carnarvon Basin.

Airborne geophysical surveys covering the entire onshore part of the Carnarvon Basin were conducted by BMR during the years 1956 (Parkinson, 1957), 1957 (Forsyth, 1960), 1959 and 1961 (Spence, 1961 and 1962). Magnetic and radiometric measurements were made. Observations extended eastward across the margins of the shield-type rocks of the Gascoyne and Yilgarn Blocks. Contoured maps of total magnetic intensity have been published by BMR at a scale of 1:250 000.

No comprehensive interpretation of the data has been published but unpublished work by J. Quilty (personal communication, 1975) of BMR gives estimates of basement depth over much of the onshore basin, and has been used as the basis of Plate 4.

Airborne surveys were flown over offshore areas in 1965 for Tasman Oil Pty Ltd and in 1967 and 1969 for WAPET. Magnetometer recordings were made on a number of marine geophysical surveys which are listed in Appendix 2. The ships' tracks for these surveys are shown in Plates 3A & 3B. For most of the marine magnetometer surveys, magnetic intensity data are available only in the form of profiles, often displayed as an interpretative aid on seismic record cross-sections.

Magnetic intensity contour maps are available for the aeromagnetic surveys, but datum differences between surveys mitigate against the preparation of an integrated magnetic intensity map covering the whole of the basin.

Results The onshore Carnarvon Basin magnetic coverage is of high quality, being derived from a single data acquisition technique at constant altitude with firm control over diurnal variations. The offshore regional results are very fragmentary and in general of lower reliability. Conflicting interpretations exist and these will not prove simple to resolve. Complications arise from the existence of two or more magnetic horizons.

Whitworth (1969) has divided the Northwest Shelf into geophysical provinces on the basis of magnetic, gravity, and seismic data. His province VIII, a magnetically featureless gravity 'high', corresponds to the Rankin structural trend (Fig. 1), while the adjacent province IX, corresponding to the Barrow and Dampier Sub-basins, contains recognisable magnetic features and is a region of low gravity. Several interpretations are possible, in the absence of deep crustal refraction data, and they include:

1. A basement having no magnetic expression in either province (the anomalies being generated within the sedimentary section);

2. A basement having magnetic character spatially varying between the two provinces, giving rise to magnetic anomalies in the low-gravity province and none in the high-gravity province, but shallowing from one to the other;

3. A very deep crustal source for the gravity anomaly (see gravity section);

Magnetic features in Whitworth's province XIII, the offshore extension of the Pilbara Block, tend to correlate with gravity 'highs'. The magnetic amplitudes and wavelengths are consistent with a shallow magnetic basement.

About 15-20 km west of North West Cape, a large-amplitude north-south-oriented dipole pattern has been mapped by the BMR Continental Margin survey. It was also recognised from data near the boundaries of three air-borne surveys. This magnetic feature is probably associated with the continuous belt of strongly positive gravity anomalies following the continental margin northwards from North West Cape. The magnetic and gravity anomalies possibly originate from a deep-seated horst block on basement associated with rifting at the continental margin. Magnetic basement is indicated to lie at depths in excess of 9 km in this area, although the base of prospective sediments is likely to be considerably shallower than this.

Other magnetic features of large extent outlined by the BMR Continental Margin survey include:

1. A region of low intensity northwest of Bernier Island (Pl. 3B) which may be continuous with an aeromagnetic 'low' near the north end of Shark Bay;

2. A long-wavelength magnetic 'high', possibly associated with the Bernier Platform (section 2.3 of this review and Geary, 1970), which was indicated by the results of the West Carnarvon aeromagnetic survey.

3. A magnetic 'high' 35 km northwest of Geraldton, perhaps the same anomaly previously interpreted from the Bernier seismic and magnetic survey as arising from a basement ridge near the Easter Islands which forms the northern edge of the Abrolhos Sub-basin.

A great many anomalies of the Bernier marine magnetic survey are believed to be caused by the presence of shallow magnetic material in the depth range 200-1000 m, and have been interpreted by the operating company as arising from igneous dykes and flows of a similar age. This interpretation was supported to some extent by seismic results, as there was some correlation between seismic and magnetic anomalies, and it was confirmed by the drilling of Edel No. 1 well.

Plate 4 shows interpreted depths to magnetic basement. Of the magnetic surveys for which basement depth estimates were available, not all were suitable for inclusion in Plate 4. Some were excluded for reasons of poor reliability or redundancy, e.g., the Bernier marine seismic and magnetic survey for Ocean Ventures Pty Ltd was excluded because it was in an area covered by the more extensive West Carnarvon aeromagnetic survey for Tasman

Oil Pty Ltd and because anomalies from the former survey were thought to arise from a magnetic horizon located above basement. Reliable depth estimates require well-defined anomalies, and this condition was not always met, especially for surveys narrowly confined in a single direction where the anomalies were large. Nonetheless, most of the broad features of Plate 4 are considered reliable, having been confirmed and supported by seismic and gravity data, and found to be consistent with regional geology.

In the northern onshore region of the Carnarvon Basin, magnetic results indicate a prominent north-south basement ridge (the Yanrey Ridge, Fig. 1) extending from near the northeast corner of Exmouth Gulf, near latitude 22°S, continuously to 24°S and with interuptions to 25°S. Less than 1500 m of sediment cover on basement was indicated east of this ridge near 22°30'S, but increasing thicknesses were interpreted both to the north (the Onslow Embayment) and to the south (the Merlinleigh Sub-basin). Basement depths in excess of 4500 m were interpreted for the coastal area extending as far south as Lake McLeod, except for an anomalous local basement 'high' in the south-central area of North West Cape.

In the southern Carnarvon Basin, the aeromagnetic surveys showed the presence of shallow basement in Hamelin Pool east of Faure Island (Plate 4), and thicker section along the coast from Dirk Hartog Island southwards to 27°30'S. In this area, results indicate a rise in basement toward the Hardabut Fault, which forms the western boundary of the exposed shield rocks of the Northampton Block (Fig. 1). West of Bernier Island, a region of shallow basement separating two basins to the north and south was inferred. Sediment cover seems to be particularly thin near the shelf edge between 24°30'S and 25°S where basement depths of less than 750 m have been interpreted. In the vicinity of Dirk Hartog Island acceptance of onshore and offshore magnetic basement depth indications implies unusually steep easterly basement dip or faulting, but this apparent dip must be regarded as of uncertain reliability, because of the lack of overlap of onshore and offshore magnetic surveys in the area.

3.2 Gravity Surveys

Gravity measurements in the Carnarvon Basin began with the establishment by BMR of pendulum stations at major towns in 1950 (Dooley et al., 1961), in support of reconnaissance and detailed gravity surveys in 1950 and

1951 (Thyer, 1951a, 1951b). In 1953 a detailed gravity survey was done over the Rough Range structure (Dooley & Everingham, 1956) in support of unpublished seismic work by WAPET. The same year reconnaissance gravity coverage was extended by BMR to the southern Carnarvon Basin (Chamberlain et al., 1954), and a regional traverse was run between Onslow and Derby (Dooley, 1963). This work established the main regional features of the Bouguer gravity field.

The essential onshore gravity features shown in Plates 2A & 2B are little different from those established in the 1950s. Gravity maps of the Carnarvon Basin by BMR are available at scales of 1:2.5 million and 1:250 000. A reduced version of the latter at 1:500 000 is also available. Maps based on all data currently available have been produced at scales of 1:1 million and 1:5 million (Anfillof et al., 1976). Plates 2A and 2B are preliminary versions and are subject to minor changes.

WAPET undertook gravity surveys for a variety of exploration purposes in the area during the period 1955-1965, but these results are not generally available.

The Murchison-Gascoyne helicopter gravity survey was undertaken in 1970 for Barewa Oil & Mining NL between the Murchison and Gascoyne Rivers. The use of helicopters avoided the common restriction (on ground surveys) of being confined to established tracks, fence lines, etc., but economics limited the survey to 950 stations on a 6.5 km grid. The survey objective, which was to test for the presence of a postulated graben, was achieved with a negative result. However the existence of areas of thicker section, especially the Gascoyne Depression within the Gascoyne Sub-Basin, was indicated.

Over virtually the same area in 1971-1972, Oceania Petroleum Pty Ltd conducted the Murchison-Gascoyne D-1 gravity survey as a ground operation. Results of this detailed operation (6500 stations at 0.8 km intervals on traverses approx. 12 km apart) confirmed the presence of, and refined the definition of, previously mapped gravity features.

Two other large-scale reconnaissance helicopter gravity surveys, conducted by BMR during the period 1960-1969, resulted in complete coverage of the onshore Carnarvon Basin at a station spacing of 11 km or less. The results of these surveys have been briefly discussed by Fraser (1974a, 1974b) who has termed the study region the Gascoyne Regional Gravity Complex, and a further publication has been issued (Fraser et al., 1975).

Available offshore gravity results are derived partly from the BMR Continental Margin surveys of 1970-1973, and partly from the geophysical survey of the northwest continental shelf by BMR in 1968 (Whitworth, 1969), and are presented in Plates 2A and 2B as free-air anomalies.

Results The onshore regional Bouguer anomalies of the Carnarvon Basin (Plates 2A and 2B) are dominated in the south by a northeast-trending gravity ridge extending along the southeast boundary of the basin from the Northampton Block to the Carrandibby Inlier. Another positive trend branches off this northeast ridge to the northwest from near 115°E, and extends north to the coast near 22°S. Over much of its length this north-trending gravity feature is known as the Wandagee gravity ridge. The Y-shaped ridge pattern thus separates three regions of low gravity. To the east of the 'Y' is an area of negative gravity anomalies which is the gravity expression of the Coolcalalaya and Byro Sub-basins. The intense northern gravity 'low' correlates with the thick sediments of the Merlinleigh Sub-basin, while the gravity 'low' to the west is related to the presence of sediments in the Gascoyne Sub-basin.

The north coastal area from North West Cape to the east of Onslow exhibits a large regional gravity 'high' which has three distinct components. These are:

1. The strongly positive gravity anomaly over the Cape itself. This lies at the intersection of two major tectonic trends, the southwest extension of the Rankin Trend and the southwest boundary of the Exmouth Plateau. The gravity anomaly may be related to either trend, although the negative effect of deep water on the free-air anomalies of Plate 2A makes the latter connection less obvious. When expressed as Bouguer anomalies, however, the offshore results southwest of the Exmouth Plateau suggest that a positive belt, possibly associated with a transform fault (Willcox & Exon, 1976), is intimately linked to the Cape 'high', indicating that crustal thinning is a likely cause. The amplitude and wavelength of the

anomaly support the hypothesis of a deep crustal source. Some deep refraction probes are needed to help in the interpretation of this poorly understood feature.

2. The northern extension of the Wandagee gravity ridge, coinciding with shallow basement on the Yanrey Ridge.
3. The broad anomaly over the Peedamullah Shelf, a region of shallow basement.

Farther to the north, well-defined gravity 'lows' correspond to the Barrow and Dampier Sub-basins, and these are bounded to the north by a large elongate positive anomaly which lies about 130 km offshore. It trends north-east subparallel to the coast and coincides with the structurally high Rankin Trend. The depth of the source of the gravity anomaly over this economically important structural trend is unknown. It is suggested that computer modelling of the gravity field in this area could produce useful information on the anomaly source, and its depth.

A large elongate north-south free-air anomaly, extending between latitudes 24°S and 26°S, and reaching maxima of 30 mGal, exists near the shelf edge in the central Gascoyne basin. This gravity anomaly is evidently related to the Bernier Platform, an area of shallow basement inferred from magnetic data. Shallow basement may extend over a much larger area than previously thought. Gravity data suggest that shallow basement extends onto the continental slope west of Dirk Hartog Island.

For a discussion of gravity and other geophysical results over the Exmouth Plateau, the reader is referred to Willcox & Exon (1976).

3.3 Seismic Surveys

Plates 5A & 5B illustrate the distribution of known seismic lines in the Carnarvon Basin at the time of writing. The numbers indicate the approximate locations of individual seismic surveys. Appendix 2 provides a key to the numbers, giving survey names, operators, dates, and other information on the surveys.

Onshore seismic The earliest seismic surveys in the Carnarvon basin were by BMR in 1951 (Chamberlain et al., 1954) when it carried out investigations of the Giralia Anticline south of Exmouth Gulf. In 1955 a small seismic survey was conducted by BMR in the Wandagee area. This was followed by several surveys by WAPET during the period 1952-1961, for which results are unavailable.

In the early 1960s WAPET's onshore seismic effort in the Carnarvon Basin was largely concentrated on and near North West Cape, and involved the investigation of structures having surface expression. The seismic reflection technique using explosives as energy source produced only limited results, so that the refraction technique was used to a significant extent and there was early experimentation with an alternative energy source, viz. the vibroseis system. Early exploration by WAPET included surveys near Lake McLeod and on the Wandagee Ridge. During the early 1960s BMR was active in the central and southern Carnarvon Basin, with three reflection seismic surveys and some refraction shooting.

From the mid-1960s onward, seismic activity was spread throughout the basin. Techniques continued to be influenced by the difficulty of achieving reliable reflection results. Source, geophone, and spread multiplicity were increased and the weight drop method was introduced. Surveys were conducted near Onslow, on the North West Cape, and in the Merlinleigh Sub-basin by WAPET.

Continental Oil Company of Australia Limited did two surveys east of Shark Bay. Marathon Petroleum Australia Limited conducted by far the largest seismic survey of the onshore Carnarvon Basin in 1967. This was the Mia Mia seismic survey, which used the weight drop method and extended over 2400 km of traverse.

No further seismic operations for which results are available under the Petroleum Search Subsidy Act 1959-1973 were undertaken until 1972-73 when small-scale detailed surveys were undertaken by WAPET on Barrow Island and North West Cape, and by Oceania Petroleum Pty Limited south of Hamelin Pool.

<u>Offshore seismic</u> The earliest offshore seismic work was undertaken in 1961 for WAPET in Exmouth Gulf and along a narrow near-shore strip between North West Cape and Carnarvon, primarily to test for possible offshore extensions of structures previously explored by land surveys. Rather than discuss the offshore surveys in chronological order, it will be more convenient to consider various areas separately, beginning with the northern Carnarvon Basin and then moving southwards.

In 1964 BOCAL carried out its first marine seismic survey on the Northwest Shelf, which was a regional reconnaissance survey covering parts of the Dampier Sub-basin and Rankin Platform, and extending to the northeast beyond the boundaries of the Carnarvon Basin. This marked the beginning of a long series of offshore surveys by the same operator in this area, a characteristic feature of which was the steady introduction of new technology in all phases of the seismic technique; detectors, energy source, recording instruments, position control, and processing. By 1966, 3-fold multiple coverage and digital processing were being used in an effort to overcome severe problems with multiple reflections.

Extension of BOCAL's seismic reconnaissance grid, and detailing of previously indicated structures continued year by year on the Northwest Shelf, but the northern Carnarvon Basin received no further attention until 1969. The Aquapulse energy source was then introduced, together with high source and detector multiplicity which allowed both vertical and horizontal stacking. These powerful exploration techniques were successively applied to the North Turtle and Legendre areas (1969), and to the Dampier Sub-basin, Rankin Bank, and Pilbara Block margin areas (1970).

In 1971, BOCAL applied the Maxipulse energy source to the detailing of the prospective Rankin Platform and further defined potential structures in the Beagle Sub-basin. An improvement in data quality compared with previous results was obtained. Exploration effort was also directed at the seaward flanks of the outer Beagle Sub-basin. Sonabuoy refraction profiles were recorded.

The success of the Maxipulse system ensured its further use in 1972 by BOCAL on the Montebello-Turtle, Malus-Hedland, and Steamboat Spit surveys. The first of these was aimed at detailing existing prospects and/or exploring for new leads on the Rankin, Madeleine-Dampier, and Legendre Trends and at investigating the possible northeasterly extensions into the Beagle Sub-basin of the two first-mentioned trends, and their relations to the North Turtle Arch. The North Turtle Arch is now accepted as the northern boundary of the Carnarvon Basin. The Malus-Hedland seismic survey investigated stratigraphic trap potential along the Dampier Sub-basin/Pilbara Shelf margin, and detailed structures on the Rankin Trend and in the Dampier and Beagle Sub-basins. The Steamboat Spit seismic survey provided a clearer picture of the complexly faulted Angel Field in the Dampier Sub-basin and investigated other areas outside the Carnarvon Basin.

An airgun energy source was used on the De Grey Nose seismic survey by BOCAL in 1973 to obtain high-resolution shallow data inshore from the Beagle and Dampier Sub-basins to determine the stratigraphic trap potential of the area.

South of the Dampier Sub-basin intensive offshore seismic exploration began in 1965 in widely separated areas. Surveys by WAPET were concentrated on prospects around North West Cape and Barrow Island, and major portions of these surveys fell within the PSSA excluding circles around Rough Range No. 1 well (48 km radius) and Barrow Island oil field (80 km radius). Consequently only limited portions of the results, which were obtained outside those areas, are available. The work consisted of the Barrow, Long Island, Muiron, Helby, Table, Jurabi, Fraser, and Barrow Waters surveys, in which airguns, dynamite, and Aquapulse energy sources were used, to fulfill objectives ranging from reconnaissance surveying to confirmation of closure over individual structures. Some lines were in inshore shallow water areas, and were programmed to supplement results of land surveys. A considerable number of structural leads, some of which coincided with small islands, were indicated by those surveys. During the period 1968-1975 a number of small surveys were done in the area for WAPET under the Petroleum (Submerged Lands) Act 1967-1974 (P(SL)A). Following its usual practice for areas relinquished by petroleum exploration companies, the Western Australian Department of Mines has released some of the basic data for these surveys, but interpretative results are not available to the public.

Continental Oil undertook seismic reconnaissance in Shark Bay in 1965, and successfully linked onshore seismic data with stratigraphy intersected in Dirk Hartog No. 1 well. In the Abrolhos area in the same year BP Petroleum Development Australia Pty Ltd tested 6-fold multiple coverage seismic on a limited scale with encouraging results during an otherwise single coverage survey which produced generally poor-quality data.

The first of two surveys by Canadian Superior in the tenement which they held between 23°S and 27°30'S was the West Carnarvon reconnaissance seismic survey of 1966. Although digital techniques were applied to the 3-fold data, reverberations generated at or near the sea floor were of a strength sufficient to make the results almost unusable. Multiplicity was increased in the succeeding survey of 1967 to 6-fold and fair-quality data down to one second of record time were recorded.

Marine seismic activity in the southernmost Carnarvon Basin consisted of BP Petroleum's Geelvink Channel (1970), Endeavour Oil's Ronsard (1971), and Ocean Ventures' Bernier (1971) surveys. The Geelvink Channel and Bernier surveys included magnetometer surveys as well as seismic. Those lines of the Geelvink Channel survey which fell within the Carnarvon Basin largely served reconnaissance objectives. An airgun energy source provided reasonable energy return, but continuity of reflection character was poor. The Bernier Survey consisted of two widely separated detailed projects, near the Pendock ID No. 1 and Edel No. 1 wells, with reconnaissance lines linking the two areas. The Maxipulse energy source provided significant improvement in data quality over previous work. One conclusion from the results of the survey was that Pendock ID No. 1 had not been drilled on the crest of the Pendock structure.

The Ronsard survey, west of Lake McLeod, had as its principal objective the definition of Palaeozoic structures, which had been shown by the Pendock well to be prospective, but the poor quality of the seismic results obtained using an airgun energy source, and the lack of supporting magnetometer data, made it impossible to distinguish from the results between the presence of intrusive sills, salt flows, or limestone reefs.

The BMR Northwest Shelf geophysical survey in 1968 and the BMR Continental Margin survey in 1970-73 included reconnaissance traverses over the offshore portions of the Carnarvon Basin using a sparker energy source and relatively inexpensive seismic recording equipment. The quality of seismic results from these surveys is generally poorer than those obtained on petroleum company surveys since 1968.

In 1971 Shell Development (Australia) carried out a regional marine geophysical survey mainly on the continental slope of Western Australia from near Timor in the north to the vicinity of Perth in the south. The survey included seismic, gravity, and magnetic recording. A number of traverses were surveyed on the western margin of the Carnarvon Basin and in particular on the Exmouth Plateau. In late 1971 to early 1972 Esso Australia also surveyed several seismic lines on the Exmouth Plateau. In 1972 Australian Gulf Oil carried out a reconnaissance seismic, gravity, and magnetic survey over the Northwest Shelf which included regional traverses on Exmouth Plateau and in the Dampier and Beagle Sub-basins.

Results The results of some major seismic surveys in the Carnarvon Basin have been generalised for presentation at a scale of 1:1 000 000 in Plates 6A & 6B. The plates do not include the results of seismic surveys on the Exmouth Plateau, which have been reported on by Hogan & Jacobsen (1975), and Willcox & Exon (1976).

In drawing the seismic contours, reflection time to depth conversion has generally been made on a gross scale, neglecting local velocity variations.

The quality of seismic results varies widely throughout the basin. The most intense application of modern techniques has been in the northern sub-basins, where several reflections have been reliably mapped. These have been identified stratigraphically from numerous wells in the area, and include include a near-base Tertiary, a Late Cretaceous (Toolonga Calcilutite), and Early Cretaceous-Late Jurassic horizons. The pre-Late Jurassic reflectors are absent from the Rankin Trend, and below the depth of penetration of modern seismic techniques in the Dampier & Beagle Sub-basins. Where sediments thin towards the Pilbara block margin, Triassic and Permian horizons have been mapped.

However, the seismic reflection most widely recognised and most reliably mapped in the northern part of the basin is that originating at an unconformity near the base of the Cretaceous section. This horizon is illustrated in Plate 6B and the northern part of Plate 6A. In some areas it reflects economically significant structures in underlying Mesozoic rocks, especially along the Rankin Platform. Plate 6B includes the names given to a number of structures by petroleum exploration companies.

Division of the Dampier and Beagle Sub-basins into various tectonic elements is well illustrated by the seismic contour map. Complex block faulting along the Rankin Trend is evident. Faulting is thus an important factor in the formation of structural traps for petroleum in this area. However, correlation of seismic horizons between individual fault blocks is often difficult, so that alternative interpretations are possible. Over the northern half of the Carnarvon Basin the seismic data also show the existence of large fault systems forming the south-eastern boundaries of the Exmouth and Barrow sub-basins.

Over most of the onshore southern Carnarvon Basin the post-Palaeozoic section is thin or absent and so older horizons have been presented on the seismic map. Onshore and in Shark Bay the contours shown indicate the approximate form of the Silurian Tumblagooda Sandstone in some areas, and of an unidentified Early Palaeozoic horizon elsewhere. Because they are derived from poorer-quality land and marine seismic results than contours on the base of Cretaceous horizon in the north, these contours are of lesser reliability and there is also some doubt about their identification.

Contours are not shown for the offshore area between 24°S and 25°S. As previously discussed this is an area of shallow basement (the Bernier Platform). Seismic coverage over this feature is of low density, largely because the sedimentary section is thin and has been considered non-prospective. Data are of poor quality. However, one fault-controlled anticline (the Ronsard structure), which trends parallel to the coast about 25 km offshore, has been mapped from shallow seismic data near latitude 24°S.

Offshore and to the south of Dirk Hartog Island, an intra-Mesozoic horizon, a pre-Mesozoic unconformity, and possibly an Early Jurassic horizon have been indicated.

4. PETROLEUM PROSPECTS

4.1 Discoveries of petroleum

Together with the Gippsland, Cooper, Perth, and Surat Basins the Carnarvon Basin is one of the few sedimentary basins in Australia where there has been any marked success in the discovery of hydrocarbons. Thomas & Smith (1974) provide a summary of the history of hydrocarbon discoveries in the basin and further details of BOCAL discoveries are given in Powell (1973) and Martinson et al. (1973). Table 2 provides data on hydrocarbon discoveries, including reservoir formations, whether oil, gas, or condensate, and test figures where available.

WAPET's exploration of the Carnarvon Basin had an encouraging start with the drilling of its first well, Rough Range No. 1, in 1953 on the Rough Range Anticline near Exmouth Gulf. A successful drill stem test of the

TABLE 2

CARNARVON BASIN HYDROCARBON DISCOVERIES

Field or well	Reservoir	Depth (m)	Hydrocarbons	Test figures
Barrow Island Field (see table 9)				NB. DST - Drill stem test FIT - Formation interval test bbl - barrels
Flag No. 1	Barrow Fm.	1278.6-1292	gas	1.1x10^6ft^3/d, ¼" choke
Pasco Island Field:	Barrow Fm.	5700' Sand (1738.5)	oil and gas 10.3m oil pay; 10.0 m	1973 testing: 175 bbl/d and 1550x10^3ft^3/d
Pasco No. 1			gas pay in 3 sands	
Pasco No. 2			dry	
Pasco No. 3			1 m oil pay; 7 m gas pay	
Legendre No. 1	Barrow Fm.	1894.4-1899.2		DST: 822-1014 bbl/d, 44.7 API, 3/8-3/4" choke gas: oil=1.06x10^3ft^3: bbl
Angel No. 1	Barrow Fm.	2735.9-2738.9	gas, condensate	DST No.1: gas 12.85 x 10^6ft^3/d condensate 720 bbl/d 5/8" choke
		2686.1-2690.1		No.2: gas 13.20 x 10^6ft^3/d condensate 685 bbl/d 5/8" choke
Rough Range No. 1	Birdrong Sst.	1098-1109	oil	550 bbl/d
Cape Range No. 2	Birdrong Sst.	2984.1-3080.5	gas	DST: 1193 x 10^3ft^3/d on 1/8" choke
Flinders Shoal No. 1	?	791.6-799.2	gas and oil	2.3 x 10^6ft^3/d' ½ bbl/d, 23^{o} API
Angel No. 2	Barrow Fm.	2699.3-2706.9	gas and condensate	DST:- 12.1x10^6ft^3/d; 52 bbl/10^6ft^3 5/8" choke
		2719.7-2718.5	gas and condensate	DST:- 7.4x10^6ft^3/d;50 bbl/10^6ft^3 5/8" choke

TABLE 2 (Continued)

Field or well	Reservoir	Depth (m)	Hydrocarbons	Test figures
Angel No. 2 (contd)	Barrow Fm.	2744.1-2753.2	gas and condensate	DST:- $11.2 \times 10^6 ft^3/d$; 58.6 bbl/$10^6 ft^3$ 5/8" choke
Angel No. 3	Barrow Fm.	2741.3-2749.9	gas and condensate	DST:- $14.22 \times 10^6 ft^3/d$; 46.4 bbl/$10^6 ft^3$ 3/4" choke
North Rankin No. 1	Toolonga Calcilutite	2574.2-2584.9	gas	DST:- $5.75 \times 10^3 ft^3/d$ + oil
	Mungaroo Beds	2838-2842.6	gas and condensate	DST:- $7.02 \times 10^6 ft^3/d$; 95.5 bbl/d
		3011.9-3016.5	gas and condensate	DST:- $9.93 \times 10^6 ft^3/d$; 370 bbl/d
		3104.9-3111	gas and condensate	DST:- $9.97 \times 10^6 ft^3/d$; 269 bbl/d
		3208.6-3211.7	gas and condensate	DST:- $9.79 \times 10^6 ft^3/d$; 298 bbl/d
		3252.8-3255.9	gas and condensate	DST:- $11.42 \times 10^6 ft^3/d$; 317 bbl/d
North Rankin No. 2	Mungaroo Beds	2721.2-2737.7	gas and condensate	DST:- $18.7 \times 10^6 ft^3/d$; 23.8 bbl/$10^6 ft^3$, 7/8" -h3/4" choke
		2760.2-2746.5	gas and condensate	DST:- $10.9 \times 10^6 ft^3/d$; 25.5 bbl/$10^6 ft^3$, 5/8" - 3/4" choke
		2844.1-1870.1	gas and condensate	DST:- $20.4 \times 10^6 ft^3/d$; 25.1 bbl/$10^6 ft^3$, 7/8" - 3/4" choke
		3169.9-3198.8	gas and condensate	DST:- $18.3 \times 10^6 ft^3/d$; 27 bbl/$10^6 ft^3$, 5/8" - 3/4" choke
North Rankin No. 3	Mungaroo Beds	3094.2-3140.2	gas and condensate	DST:- $28.2 \times 10^6 ft^3/d$; 28.1 bbl/$10^6 ft^3$, 3/4" choke
North Rankin No. 4	Mungaroo Beds	2978.6-2999.9	gas and condensate	DST:- $7.2 \times 10^6 ft^3/d$; 28 bbl/$10^6 ft^3$, 3/4" choke
Dockrell No. 1	Mungaroo Beds	2987-2995	gas and condensate	DST:- $13 \times 10^6 ft^3/d$; 4329 ft^3/d (condensate), 19.05 mm choke
		3004-3008.5	gas and oil	DST:- $2 \times 10^6 ft^3/d$; 10687 ft^3/d (oil) 9.525-19.95 mm choke

TABLE 2 (Continued)

Field or well	Reservoir	Depth (m)	Hydrocarbons	Test figures
Egret No. 1	Mungaroo Beds	3121.3-3130.5	gas and oil	DST:- $2.87x10^6ft^3/d$; 2729 bbl/d, API, 39^o 3/4" choke
Eaglehawk No. 1	Mungaroo Beds	2779.1-2789.8	oil	DST:- 233 bbl/d, API 30, 5/8" - 3/4" choke
		2752-2767.8		DST:- $0.4x10^6ft^3/d$, 1645 bbl/d, API 29.3, 5/8" - 3/4" choke
Lambert No. 1		3101-3106	gas, condensate and oil	DST:- $2580.83x10^6ft^3$; $59.55x10^6$ bbl/d, API 51^o, 2" - 3/4" choke
Goodwyn No. 1	Mungaroo Beds	2843.5-2848.7	gas and condensate	DST:- $11.4x10^6ft^3/d$; 490 bbl/d, API 57^o, 5/8" - 3/8" choke
		3148.5-3153.7	gas and condensate	DST:- $7.6x10^6ft^3/d$; 45 bbl/10^6ft^3, ½" - 3/8" choke
Goodwyn No. 2	Mungaroo Beds	2842.9-2909.7		? ; 70-90 bbl/10^6ft^3
Goodwyn No. 3	Mungaroo Beds	2881-2893	gas and condensate	DST:- $17.3x10^6ft^3/d$; 68 bbl/10^6ft^3, API 47.7^o; ½ - 3/4" choke
		2987.8-2995.7	condensate	DST:- 2478 bbl/d, 3/4" choke
		3017.1-3028	condensate	DST:- 2730 bbl/d 47.7^o API, ½" - 3/4" choke
Goodwyn No. 4	Mungaroo Beds	2900-2901	gas and condensate	DST:- $10.85x10^6ft^3/d$; 50.6 bbl/10^6ft^3 5/8 - 3/4" choke
		2858-2905	gas and condensate	DST:- ?, 485 bbl/10^6ft^3, 3/4 choke
West Tryal Rocks No. 2	Mungaroo Beds	3435-3450	gas and condensate	DST:- $10x10^6ft^3/d$; 104 bbl/d, ½" choke
		3295-3305	gas and condensate	DST:- $14x10^6ft^3/d$; 220 bbl/d, ½" choke
Hilda No. 1	Muderong Shale	2669.5	gas and oil	FIT 21 ft^3/d; 8000 cc

Birdrong Formation flowed 550 bbl/d of oil. This was Australia's first discovery of oil that flowed to the surface. However stepout drilling proved that the oil accumulation at Rough Range was very small and non-commercial.

WAPET discovered oil in Barrow No. 1 well on Barrow Island in 1964. This well flowed 985 bbl/d of oil from the Late Jurassic '6700 ft Sand' and hydrocarbons were also indicated in other formations. Stepout drilling confirmed a commercial oil accumulation in the shallow Aptian Windalia Sand Member. The Barrow Island oil field was declared commercial in 1966 and the only commercial production to date in the basin has been from this field. Mapping on the main producing horizon of the field shows the structure to be a broad north-plunging anticlinal nose truncated to the south by the complex down-to-the-south Barrow Fault (Crank, 1973). During 1972 and 1973 a deep test well (Barrow Deep No. 1) was drilled on Barrow Island to a total depth of 4650 m, where it was within Dingo Claystone of Middle Jurassic age. Between 3242 m and 3500 m thin porous and permeable Middle Jurassic sandstones were penetrated. Subsequent tests revealed high-pressure gas and gas condensate. However, supernormal hole pressures below 2652 m present problems in the further evaluation of the deeper horizons below Barrow Island. Non-commercial indications of hydrocarbons have been obtained in wells drilled on Pasco Island, about 7 km south of Barrow Island, and other small islands in the vicinity.

BOCAL's first well in the Dampier Sub-basin, Legendre No. 1 drilled in 1969, established the presence of 600 m net of potential Jurassic-Early Cretaceous reservoir sandstone. A maximum flow of 1014 bbl/d of 44.7^{o} API gravity oil from 6.7 m of Early Cretaceous sandstone below 1893 m was obtained on testing. Legendre No. 2 proved disappointing and the Legendre oil accumulation was considered non-commercial.

Since 1971 a number of structures have been drilled by BOCAL on the Rankin Platform. Most of these have provided indications of hydrocarbons. The three initial structures tested (North Rankin, Rankin, and Goodwyn) have gas and condensate accumulations of considerable magnitude in Late Triassic reservoirs. In addition, oil is present in the Late Triassic at Rankin No. 1, in the Toolonga Calcilutite at North Rankin No. 1, and probably in the basal Tertiary at North Rankin No. 1 (Martison et al., 1973). Near the northern end of the Rankin Platform oil was discovered in Eaglehawk No. 1 and Egret No. 1; southwest of Rankin No. 1, Dockerell No. 1 encountered gas, condensate, and oil.

Still farther to the southwest, in WAPET's area, West Tryal Rocks Nos. 1 and 2 were drilled to test the southwest extension of the Rankin Platform. These wells encountered significant quantities of gas in Late Triassic and Early Jurassic sands of the Mungaroo Beds.

Off the Rankin Platform the only hydrocarbon field of possible commercial significance discovered to date is the Angel gas/condensate field, located near the northwestern end of the Madeleine-Dampier Trend. Here the hydrocarbons were located in Late Jurassic (Late Tithonian) sandstones which are probably equivalent to the lower part of the Barrow Group (Thomas & Smith, 1974).

4.2 Petrolum accumulation in relation to basin and continental margin development

Falvey (1974) has proposed a generalised model for the formation of Atlantic-type continental margins by rifting and subsequent breakup of continents by sea-floor spreading. He recognises three main stages, giving rise to three different litho-tectonic elements, namely: pre-rift, rift valley, and post-breakup, which are in general separated by two angular unconformities. It is believed that this model can be applied to the development of the Carnarvon Basin since the Late Palaeozoic, and that it has a bearing on the generation and entrapment of hydrocarbons within the basin.

In the later Palaeozoic, Gondwanaland fronted the Tethys Sea to the north and within the continent in the vicinity of the present Carnarvon Basin a 'pre-rift intracratonic basin' developed, within which Permian and Triassic fluvio-deltaic and shallow-marine sediments accumulated on a Precambrian and Early to Middle Palaeozoic basement. These sediments constitute important source and reservoir rocks of the Carnarvon Basin, the hydrocarbons having been developed, in all likelihood, from the largely land-plant-derived organic content of the sediments.

The rift valley stage in the breakup of the former continent reached its climax in the Middle Jurassic (Callovian) with the appearance of new seafloor between the separating continental blocks, and resulted in a complex development of horsts and grabens peripheral to the separating blocks. Because the movement of the adjacent block 'India' relative to Australia was to the northwest, the main trend of faulting and of the horst and graben structures produced was northeasterly, as exhibited by the structural trends in the Dampier Sub-basin and the Kangaroo Syncline farther to seaward. The throws of some of the major faults bounding the horsts and grabens exceeded 2000 m. Extensive cross-faulting also developed. The rifting stage of continental breakup gave rise to topographically high areas close to grabens in which coastal and shallow marine sedimentation took place as the result of erosion during the Jurassic. The resulting sediments contributed reservoir and perhaps source rocks to the Carnarvon Basin.

A 'final uplift pulse associated with pre-breakup upwelling in the mantle' (Falvey, 1974) caused erratically distributed unconformities in the Late Jurassic and Early Cretaceous and the consequent deposition of shallow-water clastics which include some of the most important reservoir rocks of the basin, e.g. the Dupuy Member of the Dingo Formation, and the Barrow Formation.

Cooling of the lithosphere after the beginning of seafloor spreading between the separating continents produced subsidence and a rapid marine transgression, in accordance with Falvey's model. The onlapping sands deposited at this time are exemplified by sands at and near the base of the Upper Cretaceous Winning Group, which are important reservoir rocks in the basin. The subsequent holomarine deposits of the sedimentary wedge deposited on the new continental shelf include some of the more important cap rocks of the basin.

Progradation caused the outbuilding of the shelf and upper slope in the Tertiary and the sedimentary wedge tilted seawards, possibly because of cooling and contraction of the old lithosphere near the new continental margin as the mid-ocean ridge accreted itself farther from the margin, and possibly because of the weight of accumulating sediments. The rapid burial of the older sediments by a thick Cretaceous-Tertiary sedimentary wedge in the offshore part of the basin probably contributed to the generation of hydrocarbons, and seaward tilting may have played a significant part in the migration of petroleum.

4.3 Petroleum prospects, area by area

The Carnarvon Basin is a large basin with many disparate parts which differ widely in prospectivity for petroleum. It is thus convenient to consider the various elements of the basin separately.

Pilbara Shelf The Pilbara Shelf is a wide zone of thin sediments covering the seaward extension of the Precambrian Pilbara Block and extending north-east from the Dampier Archipelago. Only one well has been drilled on it. Hauy No. 1 well was drilled to 825 m to test a postulated pinch-out of Triassic sands. However, it encountered a sequence of predominantly lutitic Triassic beds beneath a mainly sandy Cretaceous sequence derived from the Pilbara Block, which was 100% water-saturated. The Pilbara Shelf is regarded as having virtually no hydrocarbon potential.

Cape Preston Shelf The Cape Preston Shelf is a southwesterly extension of the Pilbara Shelf between the Dampier Archipelago and the Sholl Island Fault. Hematite Petroleum drilled two shallow wells, Coonga No. 1 and Mardie West No. 1, to depths of less than 176 m. No information is available concerning these wells, but it seems reasonable to assume that they encountered very shallow basement.

Peedamullah Shelf The Peedamullah Shelf lies between the downthrown-to-the-northwest Sholl and Flinders Faults north of Onslow. It is partly onshore and partly offshore and, being downfaulted, it has a thicker sedimentary section than the shelf areas to the northeast. This section consists of northwest-dipping Palaeozoic to Triassic beds with a Cretaceous-Tertiary onlap.

The area lies updip from the petroliferous Dampier Sub-basin and numerous small gas shows have been reported from shallow wells. It may be expected that any reservoir beds, if present, would be the equivalents of those in the Barrow Island field, that is, the Windalia Sand Member of the Munderong Shale and the Birdrong Sandstone/Yarraloola Conglomerate/Wogatti Sandstone, but these might well prove to be freshwater-saturated near the basin margin. Petroleum prospects of the shelf are regarded as fairly poor.

The following petroleum wells have been drilled:

TABLE 3

PETROLEUM WELLS ON PEEDAMULLAH SHELF

Well name	Operator	Total depth (m)	Bottom formation age
On offshore islands			
Sholl No. 1	WAPET	1271.6	Early Permian
Fortescue No. 1	WAPET	609.6	Permian
North Sandy No. 1	WAPET	609.6	Mid-Early Triassic
Mangrove Island No. 1	WAPET	285.9	Early Permian
Beagle No. 1	WAPET	559.3	Permian
Mary Anne No. 1	WAPET	533.4	Mid-Early Jurassic
Direction Island No. 1	WAPET	627.7	Early Permian
Onshore			
Surprise No. 1	Hematite	216.4	-
Mulyery No. 1	WAPET	139.6	Late Jurassic
Windoo No. 1	Hematite	217.9	-
Mardie No. 1	WAPET	221.9	Palaeozoic
Mardie No. 2	WAPET	164.9	Early Cretaceous
Woorawa No. 1	Hematite	202.4	-
Peedamullah No. 1	WAPET	328.3	Devonian
Yarraloola No. 1	WAPET	271.9	Carboniferous
Cane River No. 1	Hematite	694	Early Carboniferous
Cane River No. 2	Hematite	413	-
Cane River No. 3	Hematite	254.8	-
Cane River No. 4	Hematite	172.8	-
Cane River No. 5	Hematite	200.9	-
Minderoo No. 1	WAPET	609.6	Late Carboniferous

Ashburton and Merlinleigh Sub-basins As already indicated, these sub-basins between the Wandagee Fault and the Pilbara Block (Fig. 1) contain large thicknesses of mainly Palaeozoic and Early Mesozoic sediments. They contain some good source rocks and the Ashburton Sub-basin in particular contains some sandstones with good porosities and permeabilities. Wells have encountered some small gas shows, but most potential reservoir rocks encountered to date have either been tight or water-flushed. Petroleum potential of the sub-basins is regarded as low.

The following petroleum wells have been drilled:

TABLE 4

PETROLEUM WELLS IN ASHBURTON AND MERLINLEIGH SUB-BASINS

Well name	Operator	Total depth (m)	Bottom formation age
Cunaloo No. 1	WAPET	797.9	Late Permian
Wandagee No. 2	WAPET	308.8	Early Permian
Quail No. 1	WAPET	3580.8	Silurian
Kennedy Range No. 1	WAPET	2226.6	Early Permian
East Marrilla No. 1	WAPET	638.3	Early Carboniferous (Permian absent)
Moorgoree No. 1	Hartogen	128.3	No information
Moorgoree No. 2	Hartogen	189.0	No information
Bidgemia No. 1	Hartogen	184.4	No information
Merlinleigh Nos 1-5	WAPET	135.5 to 305.7	No information

Gascoyne Sub-basin The sediments of the Gascoyne Sub-basin are similar to those in the Ashburton and Merlinleigh Sub-basins to the northeast. Silurian to Permian sediments up to 5000 m thick are overlain by Cretaceous to Recent carbonates 0 to 1000 m in thickness. Good source and seal rocks appear to be lacking in the sub-basin and possible sandstone reservoirs penetrated have either lacked suitable porosity and permeability or have been water-saturated. This applies particularly to the Tumblagooda Sandstone and also to the transgressive Birdrong Sandstone at the base of the Cretaceous. Wells have encountered only insignificant traces of hydrocarbons.

Edel No. 1 well, drilled offshore in the southern part of the sub-basin, provided evidence of considerable volcanic activity. This, together with the flat-lying disposition of the Palaeozoic and Mesozoic strata, which would have militated against hydrocarbon migration, and the prevalence of unconformities within the Palaeozoic section, must be considered as downgrading factors for the hydrocarbon potential of the Gascoyne Sub-basin.

However, Pendock ID No. 1 well, drilled offshore in the northern part of the sub-basin, encountered a Devonian reef at 1289 m (Appendix 3). The possibility of reef plays on the shelf areas of the sub-basin should not therefore be overlooked.

The following petroleum wells have been drilled:

TABLE 5

PETROLEUM WELLS IN GASCOYNE SUB-BASIN

Well name	Operator	Total depth (m)	Bottom formation age
Onshore			
Warroora No. 1	WAPET	1826.4	Permian
Chargoo No. 1	WAPET	427.9	Early Permian
Gnaraloo No. 1	WAPET	501.7	Carboniferous
Wandagee No. 1	WAPET	1073.2	Silurian
Wandagee No. 3	WAPET	222.5	pre-Cretaceous
Cape Cuvier No. 1	WAPET	457.2	Devonian
Grierson Nos 1, 2, 3	WAPET	457.2	-
Dirk Hartog Nos 1-17	WAPET	max. 1523.4	Silurian
Hamelin Pool No. 1	Magellan Petroleum	1595.3	No information
Hamelin Pool No. 2	Central Pacific Minerals	?	No information
Yaringa No. 1	Continental Oil	2288.4	No information
Tamala No. 1	Oceania Petroleum	?	No information
Kalbarri No. 1	Oceania Petroleum	?	No information
Onshore (northeast extension of sub-basin shelf)			
Lockyer No. 1	WAPET	765.7	Late Triassic
Onslow No. 1	WAPET	2997.7	Early Permian
Glenroy No. 1	WAPET	648.3	-
Urala No. 1	WAPET	762	Upper Triassic
Wonangarra No. 1	WAPET	575.5	-
Yanrey No. 1	WAPET	430.7	Precambrian
Offshore			
Pendock ID No. 1	Genoa Oil	2500.9	Silurian
Edel No. 1	Ocean Ventures	2748.7	? Silurian
Dirk Hartog No. 3	WAPET	272.8	-
Dirk Hartog No. 13	WAPET	297.2	-

<u>Beagle Sub-basin</u> It has already been indicated that the Beagle Sub-basin shows a similarity in tectonic style to that of the Dampier Sub-basin which it adjoins. However, it appears that in the Beagle Sub-basin the Middle Jurassic 'breakup unconformity' sandstones are largely missing or are replaced by claystones. Picard No. 1 well alone has a basal Neocomian sandstone, but this and all other hitherto tested potential reservoir sands in the sub-basin are 100% water-saturated. Moderately good source rocks exist in the Jurassic and hydrocarbon traces in wells become more pronounced from the Tertiary to the Jurassic.

Exploration to date in the Beagle Sub-basin has been disappointing and petroleum prospects must be rated much poorer than in the Dampier Sub-basin. However, relatively few wells have been drilled and the area cannot yet be dismissed as unprospective.

The following petroleum wells have been drilled:

TABLE 6

PETROLEUM WELLS IN BEAGLE SUB-BASIN

Well name	Operator	Total depth (m)	Bottom formation age
On the Picard Trend			
Sable No. 1	BOCAL	3971.5	Late Triassic
Ronsard No. 1	BOCAL	2848	Early Jurassic
Picard No. 1	BOCAL	4216	Early Jurassic
(Hydrocarbon traces in Early Jurassic)			
Depuch No. 1	BOCAL	4003	Early Cretaceous
Northeast flank of De Grey Nose			
Cossigny No. 1	BOCAL	3203.4	Middle Triassic
West flank of North Turtle Arch			
Poissonier No. 1	BOCAL	1962	-

Dampier Sub-basin Some details of hydrocarbon discoveries in the Dampier Sub-basin have already been given. This sub-basin is clearly the most prospective part of the Carnarvon Basin and the prospectivity of the outer portions of the sub-basin must be considered high by any standards.

Occurrence of hydrocarbons in the sub-basin are mainly associated with two major unconformities. They occur immediately below the mid-Jurassic 'rift onset' unconformity in Late Triassic to mid-Jurassic rocks of deltaic origin (Rankin Platform) and above the Late Jurassic 'break up' unconformity, in Late Jurassic and Early Cretaceous transgressive marine sands (Egret, Angel, Legendre). The unconformities provided suitable porous reservoir sandstones both in the weathered zones below the unconformities and in the overlying sediments.

In the Lewis Trough the Jurassic rocks are thought to be up to 3000 m thick, but they are much thinner and draped over Triassic horst blocks on the prospective Rankin Platform and Madeleine-Dampier Trend. The Cretaceous rocks of the 'post-breakup' stage are from about 100 m to 1500 m thick in the troughs and from about 800 m to 1200 m over the two positive trends. The Tertiary sequence thickens from about 500 m near the Pilbara Shelf to almost 3000 m over the Kendrew Terrace.

The source of the hydrocarbons now within the Late Triassic-Early Jurassic sandstones has generally been considered to be the thick Jurassic shales of the Barrow and Dampier Sub-basins. However, some wells on the Rankin Platform have provided data to suggest that the Cretaceous shales are also a source of oil and that the Triassic shales may, under favourable conditions, generate gas (Thomas & Smith, 1974). It is probable that almost all of the Mesozoic shaly section is a potentially good to excellent source.

Most of the hydrocarbon discoveries have been on the Rankin Platform, where typically the hydrocarbon traps consist of complexly faulted horst blocks of Triassic deltaic sediments overdraped by Cretaceous marine beds. The Triassic Mungaroo Beds constitute the reservoir rocks, the source rocks are thought to be mainly the thick Jurassic Dingo Claystone of the adjacent troughs, while caprock seals are provided by Cretaceous lutites.

The Rankin Platform consists of a series of horsts trending northeasterly from the Barrow Sub-basin in the south to the Beagle Sub-basin in the north. Extensive cross-faulting adds greatly to the complexity of the horst structures. The Rankin Platform (or Rankin Trend) is basically similar to the other positive trends in the Dampier Sub-basin, but it differs from them in that its horsts are more elevated and are covered by either a minimal thickness of Jurassic sediments or no Jurassic at all.

BOCAL drilled 15 wells on the Rankin Platform up to the end of 1975 and all have encountered hydrocarbons except Malus No. 1 and Lowendal No. 1. Details of the wells in the Dampier Sub-basin which encountered hydrocarbons are included in Table 2, while the unsuccessful wells are listed below.

While most of the more attractive targets in the Dampier Sub-basin have already been drilled, many targets remain and further discoveries can be expected.

TABLE 7

PETROLEUM WELLS IN THE DAMPIER SUB-BASIN WITHOUT HYDROCARBONS

Well name	Operator	Total depth (m)	Bottom formation age
Enderby No. 1	BOCAL	2151.0	? Permian
Hampton No. 1	BOCAL	2584	?
De Grey No. 1	BOCAL	2087.9	Jurassic
Rosemary No. 1	BOCAL	3909.1	Early Jurassic
Legendre No. 2	BOCAL	3618.3	Early Jurassic
Nelson Rocks No. 1	BOCAL	2190	?
Dampier No. 1	BOCAL	4141.6	Late Jurassic
Madeleine No. 1	BOCAL	4427.5	Jurassic
Lowendal No.1	BOCAL	3642	?
Malus No. 1	BOCAL	3657	Late Triassic

Barrow Sub-basin The Barrow Sub-basin, on trend with the Dampier Sub-basin to the northeast and only partly separated from it by the Rankin-Preston Arch, shows some similarities with the more northerly sub-basin. The major trends of the Dampier Sub-basin are not readily apparent in the Barrow Sub-basin, but a northeast structural grain is evident. The Barrow Sub-basin has the form of a broad syncline or half-graben, but well and seismic data suggest that most of the elevated structures in the central and western parts of the sub-basin have cores of block-faulted older rocks, similar to the draped horsts of the Dampier Sub-basin. West Tryal Rocks No. 1, like the Rankin Platform wells, encountered hydrocarbons in Late Triassic and Early Jurassic sands of the Mungaroo Beds.

As far as source rocks are concerned, the Dingo Claystone is remarkably thick in the Barrow Sub-basin and no well has hitherto passed through it. This Jurassic marine phase merged into the Neocomian deltaic Barrow Formation in which the initial discovery of hydrocarbons in the Barrow Island field was made. As indicated previously, commercial oil production on Barrow Island was from the Aptian Windalia Sand Member.

Although the success ratio for wells in the Barrow Sub-basin has not been as high as in the Dampier Sub-basin, there has been enough encouragement from exploration to date for the central and northwesterly parts of the sub-basin to be rated fairly prospective. Results of wells on the southeastern margin of the sub-basin have so far been disappointing.

The following petroleum wells have been drilled:

TABLE 8

PETROLEUM WELLS IN THE BARROW SUB-BASIN

Well name	Operator	Total depth (m)	Bottom formation age
Near southeastern margin			
*Flinders Shoal No. 1	WAPET	3616.1	Permian
Ripple No. 1	WAPET	2278.7	?
Airlie No. 1	WAPET	2218.6	Late Jurassic
Thevenard No. 1	WAPET	2075.7	Late Jurassic
Tortoise No. 1	WAPET	2133.6	Jurassic
Anchor No. 1	WAPET	3048.6	Early Jurassic
Long Island No. 1	WAPET	2158.3	Middle Triassic
Peak Island No. 1	WAPET	2141.5	Late Jurassic
Muiron No. 1	WAPET	1785.2	Jurassic
West Muiron No. 1	WAPET	780.9	No information
West Muiron No. 1A	WAPET	345.3	No information
West Muiron No. 2	WAPET	3320	No information

*These wells encountered hydrocarbons. See Table 2.

TABLE 8 (Continued)

Well name	Operator	Total depth (m)	Bottom formation age
Median belt			
Trimouille No. 1	WAPET	2435.4	Lower Cretaceous
*Flag No. 1	WAPET	3802.4	Jurassic
Pepper No. 1	WAPET	2743.2	Lower Cretaceous
*Pasco No. 1	WAPET	1900.2	Upper Jurassic
Pasco No. 2	WAPET	2442.7	Upper Jurassic
Pasco No. 3	WAPET	2452.5	Upper Jurassic
Northwestern area			
Tryal Rocks No. 1	WAPET	3697.5	Middle Jurassic
North Tryal Rocks No. 1	WAPET	3657.6	Triassic
West Tryal Rocks No. 1	WAPET	3866	Triassic
West Tryal Rocks No. 2	WAPET	3825	Triassic

*These wells encountered hydrocarbons. See Table 2.

Barrow Island wells

Over 500 wells penetrated to Windalia Sand Member level, about 50 wells penetrated the top of the Barrow Formation, but only 18 wells penetrated the Late Jurassic. It is possible that Late Triassic/Early Jurassic sands exist at Barrow Island, but evidence from Barrow Deep No. 1 (T.D. 5085 m) suggests that, if present, they are too deep to be commercially exploitable. Table 9 gives details of Barrow Island field production in 1974 and also cumulative totals (W.A. Mines Department, 1974).

Exmouth Sub-basin The Exmouth Sub-basin can be regarded as a southern extension of the Barrow Sub-basin, the division between the two sub-basins being arbitrarily chosen as the southern limit of the Neocomian Barrow Group. Deposition during and before the Jurassic was probably continuous between the two sub-basins.

TABLE 9

BARROW ISLAND FIELD PRODUCTION*

Reservoir		1974 Oil in m^3 and (bbls)	1974 Liquid Petroleum gas in m^3 and (bbls)	1974 Natural gasolene in m^3 and (bbls)	1974 Gas $10^3 m^3$	CUMULATIVE Oil in m^3 and (bbls)	CUMULATIVE Liquid petroleum gas in m^3 and (bbls)	CUMULATIVE Natural gasolene in m^3 and(bbls)	CUMULATIVE Gas $10^3 m^3$
Windalia Sand		2 140 642 (13 464 213)	5 101 (32 084)	5 748 (36 155)	133 452	16 361 302 (102 909 320)	9 897 (62 253)	10 832 (68 133)	1 632 512
Muderong Greensand		19 932 (125 371)	0	0	2 904	174 605 (1 098 233)	0	0	26 375
Barrow Formation	5 500' Sand	0	0	0	0	2 477 (15 580)	0	0	14 626
	6 200' Sand	0	0	0	0	9 140 (57 489)	0	0	80 926
	6 600' Sand	11 844 (74 498)	0	0	1 760	59 390 (373 551)	0	0	22 435
	6 700' Sand	8 089 (50 882)	0	0	8 879	185 859 (1 169 010)	0	0	103 835
Dingo Claystone	10 600'Sand	212 (1 334)	0	0	1 805	212 (1 334)	0	0	1 805
	10 900' Sand	180 (1 131)	0	0	1 085	180 (1 131)	0	0	1 085
	11 250' Sand	219 (1 379)	0	0	10 260	219 (1 379)	0	0	10 260
TOTAL FIELD		2 181 120 (13 718 808)	5 101 (32 084)	5 748 (36 155)	160 145	16 793 384 (105 627 027)	9 897 (26 253)	10 832 ((68 133)	1 893 859

*W.A. Mines Department, Annual Report 1974.

The onshore portion of the sub-basin is dominated structurally by the large Cape Range anticline, the smaller Rough Range Anticline, and the parallel Patterson and Rough Range Faults, all of which trend north-northeasterly. The area has been well tested by drilling, with no commercial success despite the oil flow from the Early Cretaceous Birdrong Sandstone in Rough Range No. 1. The anticlines differ from other hydrocarbon-bearing structures in the Carnarvon Basin in that they resulted from Late Tertiary tectonism, although Thomas & Smith (1974) reported that the surface anticline of Barrow Island also has some element of Tertiary growth. In some parts of the Exmouth Sub-basin post-Jurassic erosion has removed the Jurassic altogether, so that Cretaceous sediments rest on the Triassic.

The offshore part of the Exmouth Sub-basin has not been tested by drilling, except for the recently drilled West Muiron structure, which may be partly within the sub-basin. Seismic surveys indicate a thick sedimentary section offshore, deepening to the northwest, and a number of anticlinal structures have been indicated. The occurrence of oil in Rough Range No. 1 suggests that the offshore part of the sub-basin may have some hydrocarbon potential, but the continental shelf in this region is only about 30 km wide, and much of the sub-basin is in water more than 200 m deep.

The following petroleum wells have been drilled onshore:

TABLE 10

PETROLEUM WELLS IN THE EXMOUTH SUB-BASIN

Well Name	Operator	Total depth (m)	Bottom formation age
Cape Range No. 1	WAPET	2444.2	Middle Jurassic
*Cape Range No. 2	WAPET	4623.8	Jurassic
Cape Range No. 3	WAPET	1139	Late Jurassic
Cape Range No. 4	WAPET	1175.9	Late Jurassic
Sandy Point No. 1	WAPET	3045.6	Early Jurassic
Sandy Point No. 2	WAPET	1676.4	?
Wingaloo No. 1	WAPET	1228.3	?
Learmonth No. 1	WAPET	2327.5	Early Permian
Learmonth No. 1	WAPET	1870.6	Triassic (Jurassic absent)

*These wells encountered hydrocarbons. See Table 2.

TABLE 10 (Continued)

Well Name	Operator	Total depth (m)	Bottom formation age
Paterson No. 1	WAPET	2286	Late Jurassic
Exmouth No. 1	WAPET	536.1	Late Cretaceous
Exmouth No. 2	WAPET	618.4	Late Cretaceous
*Rough Range No. 1	WAPET	4452	Devonian
Rough Range No. 1A	WAPET	1114.7	Late Jurassic - Early Cretaceous
Rough Range Nos. 2-10	WAPET	1126.8 to 1243.3	Stepout wells to Birdrong Sandstone
Rough Range South 1, 3, 4.	WAPET	873.6; 579.1; 697.7	Cretaceous
Rough Range South No. 5	WAPET	1450.8	Permian
Rough Range South No. 6	WAPET	485.9	Cretaceous
Whaleback No. 1	WAPET	1528	Early Permian (Middle and Early Jurassic and Triassic absent)

*these wells encountered hydrocarbons. See Table 2.

Exmouth Plateau The Exmouth Plateau seems on geophysical evidence to be geologically fairly similar to the northern Carnarvon Basin. By analogy there could exist in the area suitable petroleum source rocks (especially Triassic and Neocomian sandstones). The depth of burial may have been adequate for petroleum generation in the source rocks in the pre-Cretaceous sequence.

Many large fault blocks analogous to those of the Rankin Platform appear to exist on the Plateau and if so they are likely to contain Triassic sands cap-sealed by Jurassic and Cretaceous shales. These structures are likely petroleum targets. Other possible targets are stratigraphic traps in a deltaic Jurassic-Neocomian sequence.

Exploration and development in such an area as this, where water depths exceed 800 m and primary targets are more than 200 km from shore, will be costly and difficult, perhaps limiting commercial interest to major hydrocarbon fields and to oil fields rather than gas/condensate fields.

5. FUTURE EXPLORATION REQUIRED

5.1 Geophysical

Aeromagnetic coverage of the Carnarvon Basin is complete except for the Dampier and Beagle Sub-basins and deep-water areas such as the Exmouth Plateau. There is a moderately good regional coverage of marine magnetic traverses in the two northerly sub-basins and, because of the advanced state of seismic exploration in those areas, extension of aeromagnetic coverage over the Dampier and Beagle Sub-basins would seem to rate low priority now.

However, aeromagnetic coverage of the deeper-water parts of the basin, which have been only sparsely covered by seismic lines, could be a useful prelude to systematic, more detailed seismic exploration of those areas. This is particularly so in the southern portion of the basin where Edel No. 1 well has indicated the presence of volcanics readily detectable by magnetometer within the sedimentary section. Unfortunately, aeromagnetic surveying of the Exmouth Plateau could involve difficult navigational problems because of the great distances from land.

The magnetic coverage of the Carnarvon Basin is made up of a large number of separate surveys recorded at different magnetic epochs, with different magnetometer altitudes and other parameters. It would be useful to reprocess existing magnetic data on a common basis to produce a single magnetic intensity map of the basin. Such a map could be expected to show regional trends better than existing data and it would also be useful in resolving conflicts in interpretation between adjacent surveys.

Regional gravity coverage is complete over the onshore part of the Carnarvon Basin and there are considerable areas with semi-detailed cover. Further semi-detailed or detailed gravity work could be useful onshore in helping to solve specific exploration problems, particularly where the quality of seismic data is poorest.

Although Plates 2A and 2B show gravity contours over the offshore areas, offshore data is mostly very sparse. It is to be hoped and expected that gravity recordings made in conjunction with future seismic traverses will provide the necessary fill-in data to upgrade the reliability of offshore gravity contours. Systematic marine gravity surveys, per se, do not appear to be warranted at this stage of exploration of the Carnarvon Basin.

On the other hand further interpretational studies on existing gravity data are warranted. As a first step the available rock density data in the basin could be assembled and collated. Gravity features such as the large positive anomalies near North West Cape and the Rankin Trend should be analysed to determine their depths of origin and hence possible modes of origin.

The degree of seismic coverage within the basin is very variable, ranging from very dense in parts of the Dampier Sub-basin to very sparse or non-existent onshore in areas such as the Gascoyne Sub-basin. There is a need for more seismic work in most areas of the basin, although the seismic objectives will vary from providing more detailed mapping of complexly faulted and folded structures with good hydrocarbon potential on the Rankin and Madeleine-Dampier Trends to providing basic reconnaissance information on some onshore areas. Onshore, the difficulties of obtaining useful data require the application of the most modern seismic techniques with maximum effort.

Considering likely prospectivities in various parts of the basin, the priority for further seismic work would seem to be for a semi-detailed grid of traverses on the Exmouth Plateau and the deep-water margins of the Dampier, Barrow, and Beagle Sub-basins in order to locate possible drilling targets. Any structural leads indicated will of course require further detailing before drilling.

5.2 Drilling

There is much scope for further drilling in the Carnarvon Basin, but as prospectivity and intensity of past exploration vary greatly from area to area it is difficult to generalise about future drilling requirements. Decisions to drill future wells will naturally depend on seismic and other evaluation of geological situations and assessment of the economics of exploring in various environments.

Onshore the prospectivities of the various sub-basins are fairly low, but the cost of drilling is low compared with offshore areas and, apart from the North West Cape area, wells are very sparse. There is considerable need for further drilling in the southern, onshore portion of the basin to improve stratigraphic knowledge, particularly where the quality of seismic results is very poor.

Although most of the more obviously attractive structures offshore in water depths of less than 200 m have already been drilled, numerous moderately attractive drilling prospects remain on the continental shelf in the Beagle, Dampier, Barrow, and Exmouth Sub-basins, although many of these require better seismic definition. As seismic coverage is extended over the deeper-water areas and, as deep-water drilling technology and economics improve, drillable prospects in those areas will undoubtedly emerge.

6. CONCLUSIONS

The Carnarvon Basin is a large, disparate Basin which has been explored almost continuously for petroleum since about 1950. Despite WAPET's early apparent success in Rough Range No. 1 well in 1953, exploration onshore has been disappointing and most of the onshore part of the basin must be regarded as having fairly low prospectivity. However, much of the southern Carnarvon Basin onshore is lacking both seismic coverage and drilled holes and it cannot therefore be said to have been adequately explored.

Since the 1960s, exploration of the northern, offshore portion of the basin has proceeded steadily, making this one of the most intensely prospected areas in Australia. Significant discoveries have been made at Barrow Island, on the Rankin Platform, and elsewhere in the Barrow and Dampier Sub-basins and further discoveries, possibly related to existing finds, may be expected. By contrast, the southern offshore portion of the basin on the continental shelf seems to be less favourable geologically for petroleum accumulation and has been less intensively explored. But as large areas with appreciable sediment thicknesses are devoid of a single well they can scarcely be dismissed as unprospective at this stage.

Reconnaissance geophysical surveys have indicated that deep-water areas on the outer margin of the continental shelf and on the Exmouth Plateau hold considerable promise of petroleum prospects for the future.

7. SELECTIVE BIBLIOGRAPHY

ANFILLOFF, W., BARLOW, B.C., MURRAY, A., DENHAM, D., & SANDFORD, R., 1976 - Compilation and production of the 1976 1:5 000 000 gravity map of Australia. BMR Journal of Australian Geology and Geophysics, 1, 261-271.

BEICIP and ROBERTSON RESEARCH INTERNATIONAL LTD, 1973-75 - Northwest continental shelf of Australia, regional geological synthesis and follow-up studies.

BOCAL (BURMAH OIL COMPANY OF AUSTRALIA LTD), 1972 - MonteBello - Turtle marine seismic survey, final report. Bureau of Mineral Resources, Australia, File 72/509.

BOCAL, 1974 - Ronsard No. 1 well completion report. Bureau of Mineral Resources, Australia, File 72/3330 (unpublished).

BOW, G.W.G., & TURPIE, A., 1964 - Southern Carnarvon Basin seismic survey, Western Australia, 1963 (Traverse A, Tamala-Narryer Area). Bureau of Mineral Resources, Australia, Geophysical Progress Report 1964/16 (unpublished).

BP (BP PETROLEUM DEVELOPMENT AUSTRALIA PTY LTD), 1969 - Gun Island No. 1 well completion report. Bureau of Mineral Resources, Australia, File 68/2015 (unpublished).

BP, 1971 - Geelvink Channel marine seismic survey, final report. Bureau of Mineral Resources, Australia, File 70/241 (unpublished).

CHAMBERLAIN, N.G., DOOLEY, J.C., & VALE, K.R., 1954 - Geophysical exploration in the Carnarvon (N.W.) Basin, Western Australia. Bureau of Mineral Resources, Australia, Record 1954/44 (unpublished).

CLAPP, F.G., 1925 - Geology and geography of the North West and Desert Basin of Western Australia. Proceedings of the Linnaean Society of New South Wales, 50(2), 47-66.

CLARKE, E. deC., & TEICHERT, C., 1948 - Cretaceous stratigraphy of the lower Murchison River area. Journal of the Royal Society of Western Australia, 32, 19-47.

CONDIT, D.D., 1935 - Oil possibilities in the North West district, Western Australia. Economic Geology, 30(8), 860-78.

CONDON, M.A., JOHNSTONE, D., & PERRY, W.J., 1953 - Stratigraphy and structure. In The Cape Range Structure, Western Australia. Bureau of Mineral Resources, Australia, Bulletin 21 (edition I), (1), 7-42.

CONDON, M.A., JOHNSTONE, D., & PERRY, W.J., 1955 - Stratigraphy and structure. In The Cape Range Structure, Western Australia. Bureau of Mineral Resources, Australia, Bulletin 21 (edition II), (1), 7-48.

CONDON, M.A., 1954a - Progress report on the stratigraphy and structure of the Carnarvon Basin, Western Australia. Bureau of Mineral Resources, Australia, Report 15.

CONDON, M.A., 1954b - Manilya - 4 mile Geological Series. Bureau of Mineral Resources, Australia, Explanatory Notes SF/49-16.

CONDON, M.A., 1955 - Petroleum geology of Western Australia. Bureau of Mineral Resources, Australia, Record 1955/55, (unpublished).

CONDON, M.A., 1958 - Depositional structures in the Carnarvon Basin, Western Australia. International geological Congress 20th Session, Mexico, 2, 174-88.

CONDON, M.A., 1962a - Kennedy Range, Western Australia - 1:250 000 Geological Series. Bureau of Mineral Resources, Australian, Explanatory Notes SG/50-1.

CONDON, M.A., 1962b - Glenburgh, Western Australia - 1:250 000 Geological Series. Bureau of Mineral Resources, Australia, Explanatory Notes SG/50-6.

CONDON, M.A., 1965a - Wooramel, Western Australia - 1:250 000 Geological Series. Bureau of Mineral Resources, Australia, Explanatory Notes SG/50-5.

CONDON, M.A., 1965b - The geology of the Carnarvon Basin, Western Australia. Part I: Pre-Permian stratigraphy. Bureau of Mineral Resources, Australia, Bulletin 77.

CONDON, M.A., 1967 - The geology of the Carnarvon Basin, Western Australia, Part II: Permian stratigraphy. Bureau of Mineral Resources, Australia, Bulletin 77.

CONDON, M.A., 1968 - The geology of the Carnarvon Basin, Western Australia. Part III: Post-Permian stratigraphy, structure, economic geology. Bureau of Mineral Resources, Australia, Bulletin 77.

CONDON, M.A., JOHNSTONE, D., PRICHARD, C.E., & JOHNSTONE, M.H., 1956 - The Giralia and Marilla anticlines, North-West Division, Western Australia. Bureau of Mineral Resources, Australia, Bulletin 25.

CRAIG, E., 1950 - Structures of the North-West Basin in Western Australia. World Oil, 130(4), 210-4.

CRANK, K., 1973 - Geology of Barrow Island oil field. The APEA Journal, 13(1), 49-57.

DEE, T.W.H., & RUDD, E.A., 1932 - Report of investigations, geological survey, Wooramel River area, Western Australia. Private report to Oil Search Ltd (unpublished).

DEPARTMENT OF MINES, WESTERN AUSTRALIA, 1974 - Table: Barrow Island field production. Annual report of Department of Mines, Western Australia for the year 1974, 22.

DEWHURST, J.D., 1973 - Exploration on the continental shelf of north-west Australia. Petroleum Review, 27(313), 14-22.

DOOLEY, J.C., 1963 - Onslow/Derby regional gravity traverse, Western Australia, Bureau of Mineral Resources, Australia, Record 1963/13 (unpublished).

DOOLEY, J.C., & EVERINGHAM, I.B., 1956 - Detailed gravity survey of Rough Range anticline, near Learmonth, Western Australia, Bureau of Mineral Resources, Australia, Record 1956/14B (unpublished).

DOOLEY, J.C., McCARTHY, E., KEATING, W.D., WILLIAMS, L.W., & MADDERN, C.A., 1961 - Pendulum measurements of gravity in Australia, 1950-51. Bureau of Mineral Resources, Australia, Bulletin 46.

EXON, N.F., & WILCOX, J.B., 1976 - Mesozoic outcrops on the lower continental slope off Exmouth, Western Australia. BMR Journal of Australian Geology and Geophysics, 1, 205-209.

EXON, N.F., & WILLCOX, J.B., - The regional geology of the Exmouth Plateau and adjacent areas. Bureau of Mineral Resources, Australia, Bulletin (in preparation).

EXON, N.F., WILLCOX, J.B., & PETKOVIC, P., 1975 - A preliminary report on the regional geology of the Exmouth Plateau. Bureau of Mineral Resources, Australia, Record 1975/158 (unpublished).

FAIRBRIDGE, R.W., 1953 - Australian stratigraphy. University of Western Australia Text Books Board 516.

FALVEY, D.A., 1974 - Continental margin development and plate tectonic theory. The APEA Journal, 14(1), 95-106.

FALVEY, D.A., & VEEVERS, J.J., 1974 - Physiography of the Exmouth and Scott Plateaus, Western Australia and adjacent northeast Wharton Basin. Marine Geology, 17, 21-59.

FELDTMAN, F.R., 1930 - Report on the reputed discovery of a structure suitable for boring in search of oil, Byro Plains (south of Wooramel River). Geological Survey of Western Australia Annual Report 1929, 19-20.

FORMAN, F.G., 1937 - Artesian and sub-artesian water possibilities, Woodleigh Station, Murchison District. Geological Survey of Western Australia Annual Report 1936, 9-11.

FORSYTH, W.A.L., 1960 - Carnarvon Basin airborne magnetic and radiometric survey, W.A., 1959 - Bureau of Mineral Resources, Australia, Record 1960/132 (unpublished).

FRASER, A.R., 1973 - Reconnaissance helicopter gravity survey, Western Australia, 1971-72. Bureau of Mineral Resources, Australia, Record 1973/130 (unpublished).

FRASER, A.R., 1974a - Reconnaissance helicopter gravity survey of the south-west of Western Australia, 1969. Bureau of Mineral Resources, Australia, Record 1969/99 (unpublished).

FRASER, A.R., 1974b - Reconnaissance helicopter gravity survey of the north-west of Western Australia, 1969. Bureau of Mineral Resources, Australia, Record 1974/27 (unpublished).

FRASER, A.R., MOSS, F.J., & TURPIE, A., 1975 - Reconnaissance gravity survey of Australia. Geophysics, 41, 1337-45.

GEARY, J.K., 1970 - Offshore exploration of the southern Carnarvon Basin. The APEA Journal, 10(2), 9-15.

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA, 1975 - Geology of Western Australia. Geological Survey of Western Australia Memoir 2.

GREGORY, F.T., 1861 - On the geology of part of Western Australia. Quarterly Journal of the Geological Society of London, 17.

HOGAN, A.P., & JACOBSON, E.P., 1975 - Geophysical results from the northwest margin. Bureau of Mineral Resources, Australia, Record 1975/101 (unpublished).

JOHNSTONE, D., CONDON, M.A., & PLAYFORD, P.E., 1958 - The stratigraphy of the lower Murchison River area and Yaringa North Station, Western Australia. Journal of the Royal Society of Western Australia, 41, 13-16.

KAYE, P., EDMOND, G.M., & CHALLINOR, A., 1972 - The Rankin Trend, northwest shelf, Western Australia. The APEA Journal, 12(1), 3-8.

KONECKI, M.C., DICKINS, J.M., & QUINLAN, T., 1958 - The geology of the coastal area between the Lower Gascoyne and Murchison rivers, Western Australia. Bureau of Mineral Resources, Australia, Report 37.

KRIEWALDT, M., 1964 - Dampier and Barrow Island, Western Australia - 1:250 000 Geological Series. Geological Survey of Western Australia, SF/50-1, 2.

LOGAN, B.W., DAVIES, G.R., READ, J.F., & CEBULSKI, D.E., 1970 - Carbonate sedimentation and environments, Shark Bay, Western Australia. American Association of Petroleum Geologists, Memoir 13.

McWHAE, J.R.H., PLAYFORD, P.E., GLENISTER, B.F., & BALME, B.E., 1958 - The stratigraphy of Western Australia. Journal of the Geological Society of Australia, 4(2).

MAITLAND, A.G., 1898 - The country between Northampton and Peak Hill. Geological Survey of Western Australia, Annual Report for 1897, 14-19.

MAITLAND, A.G., 1907 - Possibility of the occurrence of artesian water in the Northampton and Geraldton districts. Geological Survey of Western Australia, Bulletin 26, 7-9.

MARATHON PETROLEUM AUSTRALIA LTD, 1969 - Remarkable Hill No. 1, well completion report. Bureau of Mineral Resources, Australia, File 68/2050 (unpublished).

MARTINSON, N.W., McDONALD, D.R., & KAYE, P., 1972 - Exploration on the continental shelf off northwest Australia. Australian Oil and Gas Review, 19(3), 8-18.

MOLLAN, R.G., CRAIG, R.W., & LOFTING, M.J.W., 1969 - Geological framework of the continental shelf off northwest Australia. The APEA Journal 9(2), 49-59.

OZIMIC, S., 1970 - Bibliography of the Carnarvon Basin, Western Australia (to 31-12-69). Bureau of Mineral Resources, Australia, Record 1970/71 (unpublished).

PARKINSON, W.D., 1957 - Preliminary report on airborne surveys (scintillometer and magnetometer) of Geraldton - Onslow region, Western Australia, 1956. Bureau of Mineral Resources, Australia, Record 1957/9 (unpublished).

PARRY, J.C., 1967 - The Barrow Island oil field. The APEA Journal 7(2), 130-3.

PERRY, W.J., & DICKINS, J.M., 1960 - The geology of the Badgeradda area, Western Australia. Bureau of Mineral Resources, Australia, Report 46.

PLAYFORD, P.E., HORWITZ, R.C., PEERS, R., & BAXTER, J.L., 1970 - Geraldton, Western Australia - 1:250 000 Geological Series. Geological Survey of Western Australia Explanatory Notes SH/50-1.

PLAYFORD, P.E., & JOHNSTONE, M.H., 1959 - Oil exploration in Australia. Bulletin of the American Association of Petroleum Geologists, 43(2), 397-433; 43(10) 2497-2499.

POWELL, D.E., 1973 - Hydrocarbon occurrences offshore from the Pilbara Block. Australasian Institute of Mining and Metallurgy: Papers presented at the Western Australia Conference, 1973, 193-203.

POWELL, D.E., 1976 - The geological evolution and hydrocarbon potential of the continental margin off northwest Australia. The APEA Journal 16(1), 13-23.

POWELL, T.G., & McKIRDY, D.M., 1973 - Crude oil correlations in the Perth and Carnarvon Basins. Bureau of Mineral Resources, Australia, Record 1972/142 (unpublished).

QUILTY, P.G., 1974 - Tertiary stratigraphy of Western Australia. Journal of the Geological Society of Australia, 21(3), 301-18.

RAGGATT, H.G., 1936 - The geology of the North West Basin, Western Australia. Journal of the Royal Society of New South Wales, 70(1), 100-174.

RAITT, J.S., & TURPIE, A., 1965 - Southern Carnarvon Basin seismic survey (Traverse D, Pelican Hill Core), Western Australia, 1964. Bureau of Mineral Resources, Australia, Record 1965/40 (unpublished).

SINGLETON, F.A., 1941 - The Tertiary geology of Australia. Proceedings of the Royal Society of Victoria, 53, 1-125.

SPENCE, A.G., 1961 - Carnarvon Basin airborne magnetic and radiometric survey, Western Australia, 1959. Bureau of Mineral Resources, Australia, Record 1961/56 (unpublished)

SPENCE, A.G., 1962 - Carnarvon Basin airborne magnetic and radiometric survey, Western Australia, 1961. Bureau of Mineral Resources, Australia, Record 1962/191 (unpublished).

SYMONDS, P.A., & CAMERON, P.J., 1977 - The structure and stratigraphy of the Carnarvon Terrace and Wallaby Plateau. The APEA Journal, 17(1).

TALBOT, H.W.B., 1929 - Reports to Wooramel Oil Syndicate. Geological Survey of Western Australia File 63/28 (unpublished).

TEICHERT, C., 1949 - Discovery of Devonian and Carboniferous rocks in the North West Basin, Western Australia. Australian Journal of Science, 12(2).

THOMAS, B.M., & SMITH, D.N., 1974 - A summary of the petroleum geology of the Carnarvon Basin. The APEA Journal, 14(1), 66-76.

THYER, R.F., 1951a - Detailed gravity traverse, northern end Giralia structure, North West Basin, Western Australia. Bureau of Mineral Resources, Australia, Record 1951/68 (unpublished).

THYER, R.F., 1951b - Gravity reconnaissance (1950), North West Basin, Western Australia. Bureau of Mineral Resources, Australia, Record 1951/69 (unpublished).

VALENTINE, R.J.H., & TURPIE, A., 1967 - Southern Carnarvon Basin seismic survey, Western Australia, 1964 (Traverse C, Gascoyne Junction). Bureau of Mineral Resources, Australia, Record 1967/10 (unpublished).

VEEVERS, J.J., 1971 - Phanerozoic history of Western Australia related to continental drift. Journal of the Geological Society of Australia, 18(2), 87-96.

VEEVERS, J.J., FALVEY, D.A., HAWKINS, L.V., & LUDWIG, W.J., 1974 - Seismic reflection measurements of northwest Australian margin and adjacent deeps. Bulletin of the American Association of Petroleum Geologists, 58(9), 1731-50.

VEEVERS, J.J., & JOHNSTONE, M.H., 1974 - Comparative stratigraphy and structure of the Western Australian margin and the adjacent deep ocean floor, in VEEVERS, J.J., et al. - Initial Reports Deep Sea Drilling Projects 27, 571-85.

VENING MEINESZ, F.A., 1941 - Gravity expeditions at sea 1934-1939, Volume III, The expeditions, the computations, and the results. Publication of the Netherlands Geodetic Commission, Waltman, Delft.

WAPET (WEST AUSTRALIAN PETROLEUM PTY LTD), 1967 - Onslow No. 1, well completion report. Bureau of Mineral Resources, Australia, File 66/4218 (unpublished).

WAPET, 1972 - North Tryal Rocks No. 1, well completion report. Bureau of Mineral Resources, Australia, File 72/2069 (unpublished).

WAPET, 1973 - Barrow Deep No. 1, well completion report. Bureau of Mineral Resources, Australia, File 72/2862 (unpublished).

WHITWORTH, R., 1969 - Marine geophysical survey of the Northwest Continental Shelf, 1968. Bureau of Mineral Resources, Australia, Record 1969/99 (unpublished).

WILLCOX, J.B., & EXON, N.E., 1976 - The regional geology of the Exmouth Plateau. The APEA Journal, 16(1), 1-11.

WILLCOX, J.B., & EXON, N.E., 1978 - The geology and petroleum potential of the Exmouth Plateau of Western Australia. American Association of Petroleum Geologists.

WILLIAMS, I.R., 1968 - Yarraloola, Western Australia - 1:250 000 Geological Series. Geological Survey of Western Australia, Explanatory Notes SF/50-6.

WOOLNOUGH, W.G., 1928 - Petroleum prospects of an area on the Wooramel River. Geological Survey of Western Australia, File 63/28 (unpublished).

APPENDIX 1(a)

PETROLEUM EXPLORATION WELLS, CARNARVON BASIN

COMPANY Well Name BMR File no. if subsidised	Latitude South Longitude East o	 '	 "	1:250 000 Sheet area	Elevation (m) GL/WD KB/RT	Date spudded TD reached	TD (m)	Status at 31.12 of year drilled
B.O.C. OF AUSTRALIA LTD (BOCAL)								
Angel No. 1 BMR file 71/617	19 116	30 35	20 48	E50/14	WD 79.8 RT 9.5	12.10.71 12. 1.72	3410.7	Abandoned gas-condensate well
Angel No. 2 BMR file 72/857	19 116	27 39	57 25	E50/14	WD 86.6 RT 9.5	7. 3.72 21. 5.72	4396.7	Abandoned gas-condensate well
Angel No. 3	19 116	32 37	30 43	E50/14	WD 67.1 RT 9.5	27. 4.73 21. 6.73	3779.8	Abandoned gas-condensate well
Cossigny No. 1 BMR file 72/3063	19 117	19 17	53 26	E50/15	WD 112.8 RT 12.5	15.10.72 5.11.72	3203.5	PA (dry hole)
Dampier No. 1 BMR file 68/2052	19 116	52 00	21 49	E50/14	WD 76.2 RT 9.1	22.11.68 9. 4.69	4141.6	Abandoned well with show of oil and gas
De Grey No. 1 BMR file 71/616	19 117	29 05	20 08	E50/15	WD 94.5 RT 29.0	10. 9.71 16.10.71	2087.9	PA (dry hole)
Depuch No. 1 BMR file 73/283	18 117	50 55	07 19	E50/11	WD 134.0 KB 10.0	4. 2.74 30. 3.74	4300.0	PA (dry hole)
Dockrell No. 1	19 115	47 46	17 47	E50/14	WD 110.0 RT 29.9	30. 6.73 17. 8.73	3895.0	Abandoned gas-condensate and oil well
Eaglehawk No. 1 BMR file 73/3177	19 116	30 16	30 37	E50/14	WD 120.4 RT 12.5	10.11.72 14.12.72	3505.2	Abandoned oil well

APPENDIX 1(a) (Continued)

COMPANY Well Name BMR File no. if subsidised	Latitude South Longitude East o	'	"	1:250 000 Sheet area	Elevation (m) GL/WD KB/RT	Date spudded TD reached	TD (m)	Status at 31.12 of year drilled
Egret No. 1 BMR file 72/3357	19 116	30 20	23 50	E50/14	WD 118.9 RT 12.5	24.12.72 16. 5.73	3657.6	Abandoned oil well
Enderby No. 1 BMR file 70/737	20 116	09 24	25 24	F50/2	WD 53.9	10. 9.70 10.10.70	2149.1	PA (dry hole)
Goodwyn No. 1 BMR file 71/732	19 115	41 53	37 44	E50/14	WD 125.6 RT 29.0	22.10.71 25.11.71	3535.7	Abandoned gas-condensate well
Goodwyn No. 2	19 115	39 51	53 53	E50/14	WD 133.5 KB 9.5	27. 3.72 28. 5.72	3750.0	Abandoned gas-condensate well
Goodwyn No. 3	19 115	44 52	09 40	E50/14	WD 118.9 RT 30.2	16.12.72 8. 2.73	3657.6	Abandoned oil and gas well
Goodwyn No. 4	19 115	41 50	38 54	E50/14	WD 129.8 RT 30.2	24. 2.73 7. 6.73	3632.3	Abandoned gas-condensate well
Hampton No. 1	20 116	07 32	05 47	F50/2	WD 50.0 RT 30.0	22. 3.74 23. 4.74	2584.0	Abandoned well with show of gas
Hauy No. 1 BMR file 72/3186	19 117	47 15	39 15	E50/15	WD 65.5 RT 30.2	25.11.72 8.12.72	825.4	PA (dry hole)
Lambert No. 1	19 116	27 29	23 23	E50/14	WD 125.0 KB 10.0	13.11.73 30. 1.74	3700.0	Abandoned oil well
Legendre No. 1 BMR file 68/2016	19 116	40 43	16 57	E50/14	WD 51.8 RT 9.1	7. 6.68 17.11.68	3472.6	Abandoned well with show of oil

APPENDIX 1 (a) (Continued)

COMPANY Well Name BMR File no. if subsidised	Latitude South Longitude East o	 '	 "	1:250 000 Sheet area	Elevation (m) GL/WD KB/RT	Date spudded TD reached	TD (m)	Status at 31.12 of year drilled
Legendre No. 2	19	37	27	E50/14	WD 57.9	16.10.70	3618.3	PA (dry hole)
BMR file 70/769	116	46	49			16.12.70		
Lowendal No. 1	19	52	49	E50/14	WD 83.0	31. 1.74	3642.0	PA (dry hole)
	115	38	03		RT 30.0	16. 3.74		
Madeleine No. 1	19	38	59	E50/14	WD 68.9	15. 5.69	4427.5	Abandoned well with show of
BMR file 69/2006	116	21	31		RT 9.1	10.11.69		oil and gas
Malus No. 1	19	45	16	E50/14	WD 85.4	7.10.72	3657.6	PA (dry hole)
BMR file 72/3058	115	32	02		RT 9.8	5.11.72		
Nelson Rocks No. 1	19	33	37	E50/14	WD 74.9	30. 6.73	2189.9	PA (dry hole)
	116	51	19	RT 10.1	RT 10.1	30. 7.73		
North Rankin No. 1	19	35	55	E50/14	WD 122.2	3. 5.71	3533.5	Abandoned gas-condensate well
BMR file 71/254	116	07	30		RT 30.2	25. 6.71		
North Rankin No. 2	19	33	54	E50/14	WD 126.5	9. 6.72	3749.9	Abandoned gas-condensate well
	116	08	46		RT 12.5	1. 8.72		
North Rankin No. 3	19	31	41	E50/14	WD 127.1	4. 8.72	4062.5	Abandoned gas-condensate well
	116	10	14		RT 29.3	14. 9.72		
North Rankin No. 4	19	35	07	E50/14	WD 127.1	30. 9.72	4026.4	Abandoned gas-condensate well
	116	06	42		RT 30.2	11.11.72		
Picard No. 1	18	59	00	E50/11	WD 140.8	28. 7.72	4216.0	PA (dry hole)
BMR file 72/2710	117	37	20		RT 9.5	23. 9.72		

APPENDIX 1 (a) (Continued)

COMPANY Well Name BMR File no. if subsidised	Latitude South Longitude East o	 '	 "	1:250 000 Sheet area	Elevation (m) GL/WD KB/RT	Date spudded TD reached	TD (m)	Status at 31.12 of year drilled
Poissonnier No. 1	19	18	31	E50/15	WD 83.0	20.12.73	1962.0	PA (dry hole)
	118	09	20		RT 29.0	22. 1.74		
Rankin No. 1	19	47	56	E50/14	WD 93.0	31. 7.71	4110.5	Abandoned oil and gas-conden-
BMR file 71/495	115	44	31		RT 9.5	23. 9.71		sate well
Ronsard No. 1	19	08	31	E50/15	WD 160.0	12.10.73	2848.1	PA (dry hole)
BMR file 72/3330	117	09	39		KB 10.1	11.11.73		
Rosemary No. 1	19	57	16	E50/14	WD 65.4	13.11.72	3909.1	PA (dry hole)
BMR file 72/3127	116	20	41		RT 9.5	26. 3.73		
Sable No. 1	19	14	04	E50/14	WD 150.9	21. 8.72	3971.5	PA (dry hole)
BMR file 72/2770	116	54	59		RT 12.5	12.10.72		
Tidepole No. 1	19	46	07	E50/14	WD 110.0	18.10.75	3491.0	Abandoned Oil and gas well
	115	53	06		KB 30.5	26.11.75		
CONTINENTAL OIL COMPANY OF AUSTRALIA LTD								
Yaringa No. 1	26	03	58	G50/9	GL 21.3	2. 7.66	2290.9	PA (dry hole)
BMR file 66/4215	114	21	35		KB 26.8	14. 8.66		
GENOA OIL N.L.								
Pendock ID No. 1	23	17	02	F49/16	WD 131.1	18. 7.69	242.6	PA (dry hole)
BMR file 69/2020	113	20	10		KB 10.4	30. 7.69		
Pendock ID No. 1A	23	17	02	F49/16	WD 131.1	29. 7.69	2500.9	PA (dry hole)
BMR file 69/2020	113	20	10		KB 10.4	13.11.69		

APPENDIX 1 (a) (Continued)

COMPANY Well Name BMR File no. if subsidised	Latitude South Longitude East o	 '	 "	1:250 000 Sheet area	Elevation (m) GL/WD KB/RT	Date spudded TD reached	TD (m)	Status at 31.12 of year drilled
HARTOGEN EXPLORATION PTY LTD								
Bidgemia No. 1	25	16	00	G50/5	GL 201.8	6.11.72	227.7	PA (dry hole)
	115	20	20		RT 203.3	23.11.72		
Moogooree No. 1	24	15	20	G50/1	GL 271.9	8.10.72	137.8	PA (dry hole)
	115	15	30		RT 272.4	15.10.72		
Moogooree No. 2	24	16	50	G50/1	GL 276.5	18.10.72	205.7	PA (dry hole)
	115	12	40		RT 277.1	27.10.72		
Coonga No. 1	21	03	08	F50/6	GL 5.8	14.12.72	176.5	PA (dry hole)
	116	01	48		RT 7.9	19.12.72		
HEMATITE PETROLEUM PTY LTD								
Cane River No. 1	21	40	51	F50/5	GL 7.7	29.11.71	694.0	PA (dry hole)
BMR file 71/751	115	05	54		RT 10.3	9.12.71		
Cane River No. 2	21	38	13	F50/5	GL 4.5	17.12.71	413.0	PA (dry hole)
	115	15	51		RT 7.3	23.12.71		
Cane River No. 3	21	42	28	F50/5	GL 14.9	29.12.71	185.6	PA (dry hole)
	115	19	29		RT 17.7	2. 1.72		
Cane River No. 4	21	35	54	F50/6	GL 13.1	16. 1.72	172.8	PA (dry hole)
	115	33	45		RT 15.9	21. 1.72		
Cane River No. 5	21	47	22	F50/5	GL 34.1	8. 1.72	200.9	PA (dry hole)
	115	28	48		RT 36.9	10. 1.72		

APPENDIX 1 (a) (Continued)

COMPANY Well Name BMR File no. if subsidised	Latitude South Longitude East o	'	"	1:250 000 Sheet area	Elevation (m) GL/WD KB/RT	Date spudded TD reached	TD (m)	Status at 31.12 of year drilled
Mardie West No. 1	21	11	56	F50/6	GL 6.4	5.12.72	135.3	PA (dry hole)
	115	55	24		RT 8.5	8.12.72		
Surprise No. 1	21	17	58	F50/6	GL 9.8	14.11.72	216.4	Abandoned well with show of gas
	115	49	27		RT 12.8	28.11.72		
Windoo No. 1	21	21	18	F50/6	GL 2.1	17.10.72	218.9	Abandoned well with show of gas
	115	46	55		RT 4.3	22.11.72		
Woorawa No. 1	21	21	55	F50/6	GL 13.4	14. 9.72	202.4	Abandoned well with show of gas
	115	47	33		RT 15.9	27. 9.72		
MARATHON PETROLEUM AUSTRALIA LTD								
Remarkable Hill No. 1	22	57	20	F50/9	GL 106.7	15.10.68	3206.5	PA (dry hole)
BMR file 68/2050	114	09	20		KB 110.9	2. 2.69		
OCEAN VENTURES PTY LTD								
Edel No. 1	27	06	48	G49/16	WD 92.9	23. 5.72	2749.6	PA (dry hole)
BMR file 72/2074	113	23	23		KB 29.6	21. 7.72		
OCEANIA PETROLEUM PTY LTD								
Kalbarri No. 1	27	16	01	G50/13	GL 129.2	11. 9.73	1539.5	PA (dry hole)
BMR file 72/3358	114	06	27		KB 133.2	2.10.73		
Tamala No. 1	26	38	48	G49/12	GL 2.7	4. 4.73	1225.3	PA (dry hole)
BMR file 72/3358	113	38	4		KB 7.0	6. 5.73		
OIL SEARCH LTD								
Byro Deep Bore	26	04	38	G50/10	GL 268.2	1934?	676.0	PA (dry hole)
	115	32	22		KB -			

APPENDIX 1 (a) (Continued)

COMPANY Well Name BMR File no. if subsidised	Latitude South Longitude East o ' "	1:250 000 Sheet area	Elevation (m) GL/WD KB/RT	Date spudded TD reached	TD (m)	Status at 31.12 of year drilled
WEST AUSTRALIAN PETROLEUM PTY LTD (WAPET)						
Airlie No. 1	21 19 30 115 09 55	F50/5	GL 4.9 KB 9.1	11. 9.67 5.10.67	2218.6	PA (dry hole)
Anchor No. 1 BMR file 69/2019	21 32 51 114 42 37	F50/5	WD 18.0 RT 24.4	12. 7.69 28. 8.69	3048.6	PA (dry hole)
Barrow No. 1 BMR file 64/4030	20 48 58 115 22 58	F50/1	GL 51.8 KB 55.2	7. 5.64 4. 8.64	2982.5	Abandoned oil well
Barrow No. 2	20 49 24 115 22 26	F50/1	GL 46.9 KB 50.3	30. 8.64 20.10.64	2328.7	Abandoned oil well
Barrow No. 3	20 49 24 115 22 57	F50/1	GL 45.7 KB 49.1	4.11.64 29.11.64	2209.8	Abandoned oil well
Barrow No. 4	20 50 16 115 23 25	F50/1	GL 30.8 KB 34.1	15.12.64 20. 1.65	2382.3	Abandoned oil well
Barrow No. 5	20 48 05 115 23 26	F50/1	GL 65.8 KB 69.2	12. 2.65 16. 3.65	2252.5	Abandoned oil well
Barrow No. 6	20 48 58 115 23 24	F50/1	GL 61.6 KB 64.9	1. 4.65 12. 5.65	2354.9	Abandoned oil well
Barrow No. 7	20 43 57 115 25 16	F50/1	GL 45.7 KB 49.1	18. 5.65 16. 6.65	2439.0	Abandoned oil well
Barrow No. 8	20 48 58 115 23 50	F50/1	GL 63.7 KB 67.1	8. 7.65 4. 8.65	2255.8	Abandoned oil well

APPENDIX 1 (a) (Continued)

COMPANY Well Name BMR File no. if subsidised	Latitude South Longitude East o	'	"	1:250 000 Sheet area	Elevation (m) GL/WD KB/RT		Date spudded TD reached	TD (m)	Status at 31.12 of year drilled
Barrow No. 9	20	51	38	F50/1	GL	14.0	18. 8.65	2432.6	Abandoned oil well
	115	24	53		KB	17.4	23. 9.65		
Barrow No. 10	20	49	54	F50/1	GL	36.0	25. 9.65	749.8	Abandoned oil well
	115	24	52		KB	39.3	8.10.65		
Barrow No. 11	20	50	42	F50/1	GL	34.4	10.10.65	695.2	Abandoned oil well
	115	22	29		KB	37.8	19.10.65		
Barrow No. 12	20	49	00	F50/1	GL	50.0	22.10.65	781.5	Abandoned oil well
	115	24	49		KB	53.3	31.10.65		
Barrow No. 13	20	49	47	F50/1	GL	38.7	2.11.65	718.1	Abandoned oil well
	115	21	32		KB	42.1	8.11.65		
Barrow No. 14	20	48	58	F50/1	GL	51.2	10.11.65	723.6	Abandoned oil well
	115	22	26		KB	54.6	17.11.65		
Barrow No. 15	20	51	10	F50/1	GL	26.5	18.11.65	686.1	Abandoned oil well
	115	21	34		KB	29.9	22.11.65		
Barrow No. 16	20	51	31	F50/1	GL	20.1	28.11.65	731.2	Abandoned oil well
	115	20	39		KB	23.5	3.12.65		
Barrow No. 17	20	49	00	F50/1	GL	28.7	5.12.65	948.2	Abandoned oil well
	115	20	39		KB	32.0	11.12.65		
Barrow No. 18	20	48	57	F50/1	GL	18.6	13.12.65	799.5	Abandoned dry observation well
	115	26	12		KB	21.9	22.12.65		

APPENDIX 1 (a) (Continued)

COMPANY Well Name BMR File no. if subsidised	Latitude South Longitude East o	'	"	1:250 000 Sheet area	Elevation (m) GL/WD KB/RT	Date spudded TD reached	TD (m)	Status at 31.12 of year drilled
Barrow No. 19	20	47	13	F50/1	GL 42.4	2. 1.66	749.5	Abandoned oil well
	115	22	30		KB 43.0	10. 1.66		
Barrow No. 20	20	47	37	F50/1	GL 33.2	12. 1.66	751.3	Abandoned oil well
	115	24	51		KB 36.6	19. 1.66		
Barrow No. 21	20	50	19	F50/1	GL 29.0	22. 1.66	742.2	Abandoned oil well
	115	20	11		KB 32.3	27. 1.66		
Barrow No. 22	20	51	09	F50/1	GL 15.2	2. 2.66	825.7	Abandoned oil well
	115	23	27		KB 18.6	9. 2.66		
Barrow No. 23	20	45	55	F50/1	GL 57.6	15. 2.66	786.4	Abandoned oil well
	115	23	53		KB 61.0	20. 2.66		
Barrow No. 24	20	48	30	F50/1	GL 51.5	24. 2.66	2240.0	Abandoned oil well
	115	22	30		KB 54.9	25. 3.66		
Barrow No. 25	20	40	17	F50/1	GL 16.2	12. 4.66	2534.1	PA
	115	26	19		KB 19.5	17. 5.66		
Barrow No. 26	20	43	41	F50/1	GL 52.1	21. 5.66	2400.3	Abandoned gas well
	115	25	32		KB 55.8	15. 6.66		
Barrow No. 27	20	49	24	F50/1	GL 66.1	5. 7.66	2226.3	Abandoned gas well
	115	23	28		KB 69.5	22. 7.66		
Barrow No. 28	20	48	45	F50/1	GL 57.3	5. 8.66	2133.6	Abandoned oil well plugged
	115	23	12		KB 60.7	25. 8.66		back to 708.7 m

Barrow development wells are not included

APPENDIX 1 (a) (Continued)

COMPANY Well Name BMR File no. if subsidised	Latitude South Longitude East o	'	"	1:250 000 Sheet area	Elevation (m) GL/WD KB/RT	Date spudded TD reached	TD (m)	Status at 31.12 of year drilled
Barrow Deep No. 1	20	50	07	F50/1	GL 38.4	16. 9.72	4650.0	Abandoned gas well
BMR file 72/2862	115	22	58		KB 46.6	19. 6.73		
Beagle No. 1	21	11	50	F50/5	GL 4.6	31. 5.69	559.3	PA (dry hole)
(Core hole)	115	38	00		RT 6.1	16. 6.69		
Biggada No. 1	20	48	35	F50/1	GL 50	20. 6.75	3624.0	Abandoned gas well
	115	23	11		RT 58	29.11.75		
Cape Cuvier No. 1	24	13	30	G49/4	GL 71.9	16. 7.55	457.2	PA (dry hole)
	113	23	44		KB 73.2	5. 9.55		
Cape Range No. 1	22	03	57	F50/9	GL 147.2	2. 9.54	2444.2	PA (dry hole)
	114	00	32		KB 150.0	27.12.54		
Cape Range No. 2	22	05	50	F49/12	GL 281.6	20. 4.55	4629.0	PA (dry hole)
	113	59	41		KB 285.3	14. 4.56		
Cape Range No. 3A	22	08	43	F49/12	GL 266.7	14. 7.56	1139.0	PA (dry hole)
	113	59	54		KB 269.4	-. -.56		
Cape Range No. 4	22	19	26	F49/12	GL 130.8	21. 9.56	1175.9	PA (dry hole)
	113	56	09		KB 133.5	10.10.56		
Chargoo No. 1	23	35	52	F49/16	GL 26.5	14-20.10.67	427.9	*
	113	55	49		KB 27.7			
Cunaloo No. 1	22	00	48	F50/9	GL 12.2	22. 3.72	797.4	PA (dry hole)
BMR file 72/53	114	53	47		RT 15.2	31. 3.72		
Direction Island No. 1	21	32	03	F50/5	GL 4.6	26. 4.68	672.7	PA (dry hole)
(Core Hole)	115	07	42		RT 6.1	6. 5.68		

APPENDIX 1 (a) (Continued)

COMPANY Well Name BMR File no. if subsidised	Latitude South Longitude East o	'	"	1:250 000 Sheet area	Elevation (m) GL/WD KB/RT		Date spudded TD reached	TD (m)	Status at 31.12 of year drilled
Dirk Hartog No. 1	25	43	15	G49/8	GL	-	1955	338.3	*
	113	03	05		KB	3.0			
" " " 2	25	44	10	G49/8	GL	-	1955	256.0	*
	113	00	45		KB	18.0			
" " " 3	25	45	10	G49/8	GL	-	1955	272.8	*
	112	58	20		KB	27.4			
" " " 4	25	42	00	G49/8	GL	-	1955-56	457.2	*
	113	00	20		KB	37.5			
" " " 5	25	45	40	G49/8	GL	-	1956	281.6	*
	113	01	50		KB	47.2			
" " " 6	25	47	40	G49/8	GL	-	1956	304.8	*
	113	02	00		KB	37.8			
" " " 7	25	46	10	G49/8	GL	-	1956	81.7	*
	113	04	30		KB	-			
" " " 7A	25	46	40	G49/8	GL	-	1956	274.3	*
	113	04	50		KB	18.0			
" " " 8	25	48	25	G49/8	GL	-	1956	237.1	*
	112	58	50		KB	57.6			
" " " 8A	c25	48	25	G49/8	GL	-	1956	364.5	*
	112	58	50		KB	57.6			
" " " 9	25	52	25	G49/8	GL	-	1956	54.9	*
	113	06	15		KB	2.4			

APPENDIX 1 (a) (Continued)

COMPANY Well Name BMR File no. if subsidised	Latitude South Longitude East o	 '	 "	1:250 000 Sheet area	Elevation (m) GL/WD KB/RT	Date spudded TD reached	TD (m)	Status at 31.12 of year drilled
Dirk Hartog No. 9A	c25 113	52 06	25 15	G49/8	GL - KB 2.4	1956	257.6	*
" " " 10	25 113	56 09	50 20	G49/8	GL - KB 3.0	1956	267.0	*
" " " 11	25 113	57 07	20 35	G49/8	GL - KB 7.0	1956	249.0	*
" " " 12	25 113	57 06	45 05	G49/8 KB 17.1	GL -	1956	277.4	*
" " " 13	26 113	02 01	00 00	G49/8	GL - KB 2.7	1956	297.2	*
" " " 14	25 113	53 08	25 45	G49/8	GL - KB 31.4	1956	297.2	*
" " " 15	25 113	53 02	27 02	G49/8	GL - KB 34.1	1956	321.0	*
" " " 16	25 113	49 06	22 21	G49/8	GL - KB 1.2	1956	259.1	*
" " " 17	c25 113	51 04	00 00	G49/8	GL - KB 1.2	1956	259.1	*
" " " 17A	25 113	51 04	49 43	G49/8	GL - KB 89.9	1956	164.9	*
" " " 17B	25 113	51 04	58 40	G49/8	GL 87.2 KB 89.9	18. 2.57 -. -.57	1523.4	PA (dry hole)

APPENDIX 1 (a) (Continued)

COMPANY Well Name BMR File no. if subsidised	Latitude South Longitude East o ' "			1:250 000 Sheet area	Elevation (m) GL/WD KB/RT		Date spudded TD reached	TD (m)	Status at 31.12 of year drilled
East Marilla No. 1 BMR file 72/960	22 114	54 36	48 58	F50/9	GL RT	59.1 62.2	15. 4.72 25. 4.72	638.3	PA (dry hole)
Exmouth No. 1	22 114	33 06	01 38	F50/9	GL KB	- 14.6	1956	536.1	*
" " 2	22 114	21 08	25 17	F50/9	GL KB	 20.7	1956	618.4	*
Flacourt No. 1	20 115	44 22	44 40	F50/1	GL RT	50.3 53.3	8. 6.68 13. 6.68	816.9	Abandoned oil well
Flag No. 1	20 115	27 38	55 45	F50/2	WD RT	36.6 23.2	2. 9.69 30. 1.70	3802.7	Abandoned well with show of gas
Flinders Shoal No. 1	21 115	04 31	16 18	F50/6	WD RT	14.9 25.9	10. 4.69 9. 7.69	3616.1	Abandoned well with show of gas
Fortescue No. 1 (Core Hole)	21 115	01 51	05 17	F50/6	GL RT	4.6 6.1	20. 6.69 26. 6.69	609.6	PA (dry hole)
Giralia No. 1	22 114	59 14	35 20	F50/13	GL KB	109.7 112.5	3. 6.55 20. 7.55	1243.6	PA (dry hole)
Glenroy (W.A.) No. 1	21 114	49 52	05 28	F50/5	GL KB	3.0 4.6	19.10.66 28.10.66	648.3	PA (dry hole)
Gnaraloo No. 1	23 113	40 47	38 28	F49/16	GL KB	46.3 47.9	30.10.67 10.11.67	501.7	*
Grierson No. 1	24 113	12 46	00 20	G49/4	GL KB	- 11.9	1955	438.0	*

APPENDIX 1 (a) (Continued)

COMPANY Well Name BMR File no. if subsidised	Latitude South Longitude East o ' "	1:250 000 Sheet area	Elevation (m) GL/WD KB/RT	Date spudded TD reached	TD (m)	Status at 31.12 of year drilled
Grierson No. 2	24 12 00 113 47 05	G49/4	GL - KB 4.3	1955	450.5	*
Grierson No. 3	24 12 02 113 45 30	G49/4	GL - KB 1.5	1955	442.0	*
Hilda No. 1	21 12 01 114 38 02	F50/5	WD 144.0 KB 12.0	10. 3.74 28. 4.74	1546.0	PA (dry hole)
Hilda No. 1A	21 12 00 114 38 13	F50/5	WD 139.0 KB 19.0	28. 4.74 23. 9.74	3466.0	Abandoned well with show of oil and gas
Hope Island No. 1 BMR file 68/2003	22 09 34 114 28 35	F50/9	GL 4.9 RT 9.1	26. 2.68 13. 3.68	1426.5	PA (dry hole)
Kennedy Range No. 1 BMR file 66/4235	24 29 50 114 59 19	G50/1	GL 295.0 KB 298.7	1.12.66 19. 1.67	2226.6	PA (dry hole)
Learthmonth No. 1	22 10 58 114 03 31	F50/9	GL 20.1 KB 22.9	24. 9.57 6. 2.58	2327.5	PA (dry hole)
Learthmonth No. 2 BMR file 63/1327	22 17 35 114 03 48	F50/9	GL 21.9 KB 25.3	22. 1.64 29. 2.64	1870.6	PA (dry hole)
Locker No. 1 BMR file 67/4253	21 43 16 114 45 35	F50/5	GL 2.7 KB 4.3	6. 6.67 9. 7.67	765.7	*
Long Island No. 1 BMR file 66/4217	21 37 10 114 41 10	F50/5	GL 4.9 KB 9.1	21. 9.66 31.10.66	2158.3	PA (dry hole)

APPENDIX 1 (a) (Continued)

COMPANY Well Name BMR File no. if subsidised	Latitude South Longitude East o	 '	 "	1:250 000 Sheet area	Elevation (m) GL/WD KB/RT	Date spudded TD reached	TD (m)	Status at 31.12 of year drilled
Mangrove Island No. 1 (Core Hole)	21 115	14 46	22 04	F50/6	GL 4.6 RT 6.1	6. 6.68 14. 6.68	285.9	PA (dry hole)
Mardie No. 1	21 115	21 42	14 23	F50/6	GL 4.9 KB 6.4	20. 7.67 16. 8.67	221.9	*
Mardie No. 2 (Core Hole)	21 115	20 43	42 28	F50/6	GL 6.1 RT 7.9	17. 5.69 12. 5.69	164.9	PA (dry hole)
Mardie No. 1A (Core Hole)	21 115	21 42	19 30	F50/6	GL 6.7 RT 9.4	21.11.74 3.12.74	164.3	Abandoned well with show of gas
Marilla No. 1 BMR file 63/1200	22 114	55 30	45 00	F50/9	GL 47.2 KB 48.8	17. 3.63 3. 4.63	456.6	*
Mary Anne No. 1 (Core Hole)	21 115	17 30	55 04	F50/5-6	GL 4.6 RT 6.1	12. 5.68 10. 5.68	533.4	PA (dry hole)
Merlinleigh No. 1	24 114	29 59	48 15	G50/1	GL 290.2 KB 292.0	18-26. 5.66	304.8	*
Merlinleigh No. 2	24 114	28 59	45 27	G50/1	GL 292.9 KB 294.4	30. 5.66 15. 6.66	306.3	*
Merlinleigh No. 3	24 114	29 59	08 53	G50/1	GL 293.8 KB 295.4	30. 6.66 6. 7.66	166.1	*
Merlinleigh No. 4	24 114	29 58	08 57	G50/1	GL 289.6 KB 291.1	6-10. 7.66	135.6	*

APPENDIX 1 (a) (Continued)

COMPANY Well Name BMR File no. if subsidised	Latitude South Longitude East o ' "	1:250 000 Sheet area	Elevation (m) GL/WD KB/RT	Date spudded TD reached	TD (m)	Status at 31.12 of year drilled
Merlinleigh No. 5	24 28 27 114 59 07	G50/1	GL 290.2 KB 291.7	14-18. 7.66	175.3	*
Minderoo No. 1 BMR file 63/1200	21 50 40 115 04 40	F50/5	GL 10.7 KB 12.2	9-27. 4.63	609.6	*
Muiron No. 1 BMR file 67/4259	21 39 04 114 21 18	F50/5	GL 4.9 KB 9.1	1.12.67 24.12.67	1785.2	PA (dry hole)
Mulyery No. 1 (Core Hole)	21 18 26 115 47 48	F50/6	GL 4.6 RT 6.1	11. 1.68 18. 1.68	139.6	PA (dry hole)
Ningaloo No. 1	22 34 25 113 46 40	F49/12	GL 114.3 RT 107.9	18. 3.71	1228.3	PA (dry hole)
North Sandy Island No. 1 (Core Hole)	21 06 25 115 38 56	F50/6	GL 4.6 RT 6.1	24. 5.68 1. 6.68	609.6	PA (dry hole)
North Tryal Rocks No. 1 BMR file 72/2069	19 59 18 115 19 11	E50/13	WD 106.7 RT 12.1	3. 6.72 28. 7.72	365.6	Abandoned well with show of gas
Observation No. 1 BMR file 67/4275	21 44 28 114 32 12	F50/5	GL 4.9 KB 9.1	1. 1.68 12. 2.68	2289.0	PA (dry hole)
Onslow No. 1 BMR file 66/4218	21 45 56 114 52 17	F50/5	GL 0.0 KB 4.9	1. 9.66 8.11.66	2997.7	PA (dry hole)
Pasco No. 1	20 58 19 115 19 30	F50/1	GL 7.6 KB 11.9	20. 4.67 25. 5.67	1898.9	Abandoned oil well

APPENDIX 1 (a) (Continued)

COMPANY Well Name BMR File no. if subsidised	Latitude South Longitude East o	 '	 "	1:250 000 Sheet area	Elevation (m) GL/WD KB/RT	Date spudded TD reached	TD (m)	Status at 31.12 of year drilled
Pasco No. 2	20 115	57 19	41 20	F50/1	GL 3.7 KB 7.9	31. 5.67 -. 6.67	112.8	PA (dry hole)
Pasco No. 2A	20 115	57 19	51 20	F50/1	GL 3.7 KB 7.9	11. 6.67 19. 7.67	2441.1	PA (dry hole)
Pasco No. 3	20 115	58 19	05 52	F50/1	GL 10.1 KB 15.2	24. 7.67 16. 8.67	2450.9	Abandoned oil and gas well
Paterson No. 1 BMR file 63/1211	22 113	27 55	34 56	F49/12	GL 97.5 KB 100.9	8.11.63 14. 1.64	2286.0	PA (dry hole)
Peak No. 1 BMR file 67/4260	21 114	36 30	17 22	F50/5	GL 4.9 KB 9.1	17.10.67 23.11.67	2141.5	PA (dry hole)
Peedamulla No. 1 (Core Hole)	21 115	24 37	26 50	F50/6	GL 5.5 RT 7.0	24.12.67 7. 1.68	328.3	PA (dry hole)
Pepper No. 1	21 115	03 18	29 05	F50/5	WD 7.6 KB 27.4	13. 3.70 3. 5.70	2743.2	Abandoned well with show of gas
Quail No. 1 BMR file 63/1010	23 114	57 29	04 57	F50/13	GL 114.6 KB 118.3	19. 5.63 16. 1.64	3580.5	PA (dry hole)
Ripple Shoals No. 1	21 115	07 24	10 03	F50/5	WD 7.9 KB 24.1	6. 2.70 4. 3.70	2278.7	PA (dry hole)
Rough Range No. 1	22 144	25 04	07 54	F50/9	GL 56.7 KB 60.7	5. 9.53 -. -.54	4452.2	Abandoned oil well
" " 1A	22 114	25 04	06 55	F50/9	GL - KB 70.7	1954	1114.7	Abandoned oil well

APPENDIX 1 (a) (Continued)

COMPANY Well Name BMR File no. if subsidised	Latitude South Longitude East o ' "	1:250 000 Sheet area	Elevation (m) GL/WD KB/RT	Date spudded TD reached	TD (m)	Status at 31.12 of year drilled
Rough Range No. 2	22 25 50 114 04 05	F50/9	GL 94.8 KB 97.5	4. 7.54 8. 8.54	1243.3	PA (dry hole)
" " 3	22 24 40 114 05 09	F50/9	GL 61.3 KB 64.0	15. 9.54 12.10.54	1193.3	PA (dry hole)
" " 4	22 25 23 114 04 54	F50/9	GL 59.7 KB 62.5	16.10.54 3.11.54	1146.0	PA (dry hole)
" " 5	22 25 07 114 04 33	F50/9	GL 71.9 KB 74.4	10.11.54 26.11.54	1149.7	PA (dry hole)
" " 6	22 25 13 114 04 49	F50/9	GL 60.4 KB 62.8	1954 1955	1126.8	PA (dry hole)
" " 7	22 26 40 114 04 06	F50/9	GL 86.0 KB 88.4	1955	1240.5	PA (dry hole)
" " 8	22 26 46 114 03 44	F50/9	GL 102.4 KB 105.2	1955	1194.5	PA (dry hole)
" " 9	22 26 50 114 04 22	F50/9	GL 51.2 KB 53.6	1955	1171.7	PA (dry hole)
" " 10	22 25 05 114 05 02	F50/9	GL 61.0 KB 66.4	1957	1139.6	PA (dry hole)
Rough Range South No. 1	22 37 17 113 57 38	F49/12	GL 85.0 KB 87.8	1956	873.6	*
" " " 2	22 23 48 114 00 20	F50/9	GL 79.2 KB 82.0	1956	464.2	*

APPENDIX 1 (a) (Continued)

COMPANY Well Name BMR File no. if subsidised	Latitude South Longitude East o	 '	 "	1:250 000 Sheet area	Elevation (m) GL/WD KB/RT	Date spudded TD reached	TD (m)	Status at 31.12 of year drilled
Rough Range South No. 3	22	30	09	F50/9	GL 56.1	1956	579.1	*
	114	02	29		KB 58.8			
" " " 4	22	32	00	F50/9	GL 67.4	1956	697.7	*
	114	01	28		KB 70.1			
" " " 5	22	34	25	F49/12	GL 106.4	1956	1450.8	*
	113	59	16		KB 108.8			
" " " 6	22	32	22	F50/9	GL 96.6	1956	485.9	*
	114	00	42		KB 99.4			
Sandy Point No. 1	22	25	52	F49/12	GL 111.6	30.11.67	3045.2	PA (dry hole)
	113	47	47		RT 115.2	29. 1.68		
" " " 2	22	22	18	F49/12	GL 100.9	17. 4.71	1676.4	PA (dry hole)
	113	50	42		RT 104.9	6. 5.71		
Sholl Island No. 1	20	57	00	F50/2	GL 4.9	7. 1.67	1271.6	PA (dry hole)
	115	53	50		KB 9.1	31. 1.67		
Stokes Point No. 1	20	52	55	F50/1	GL 17.4	9. 5.68	2484.1	PA (dry hole)
	115	22	55		RT 21.6	15. 6.68		
Thevenard No. 1	21	27	45	F50/5	GL 4.9	28. 3.68	2075.7	PA (dry hole)
	115	01	05		RT 9.1	28. 4.68		
Tortoise No. 1	21	35	08	F50/5	GL 4.9	14.11.66	2133.6	PA (dry hole)
BMR file 66/4229	114	51	11		KB 9.1	13.12.66		
Trimouille No. 1	20	24	11	F50/2	GL 4.9	12. 2.67	2435.4	PA (dry hole)
	115	34	09		KB 9.1	15. 3.67		

APPENDIX 1 (a) (Continued)

COMPANY Well Name BMR File no. if subsidised	Latitude South Longitude East o ' "	1:250 000 Sheet area	Elevation (m) GL/WD KB/RT	Date spudded TD reached	TD (m)	Status at 31.12 of year drilled
Trimouille No. 1A	50' E of No. 1	F50/2	GL 4.9 KB 9.1	21. 3.67 3. 4.67	685.8	PA (dry hole)
Trimouille No. 1B	960'SE of No. 1	F50/2	GL 4.9 KB 9.1	20. 5.67 2. 6.67	228.6	PA (dry hole)
Tryal Rocks No. 1	20 24 42 115 09 07	F50/1	WD 152.0 KB -	17. 5.70 16. 8.70	12123	PA (dry hole)
Urala No. 1	21 49 06 114 43 22	F50/5	GL 2.1 RT 3.7	15. 9.68 7.10.68	762.0	PA (dry hole)
Wandagee No. 1 BMR file 62/1215	23 53 15 114 23 51	F50/13	GL 68.6 KB 71.3	25. 4.62 12. 6.62	1073.2	*
Wandagee Corehole No. 1	23 53 15 114 23 51	F50/13	GL 68.6 KB 71.3	6. 1.62 14. 1.62	219.8	*
Wandagee Corehole No. 2	23 53 13 114 31 38	F50/13	GL - KB 103.0	16-25. 1.62	308.8	*
" " " 3	23 49 43 114 20 03	F50/13	GL 55.8 KB -	30. 1.62 2. 2.62	222.5	*
Warroora No. 1	23 30 30 113 52 48	F49/16	GL 26.2 KB 29.0	1955	1826.4	PA (dry hole)
West Muiron No. 1 BMR file 72/2738	21 34 34 114 14 40	F50/5	WD 140.2 RT 6.1	16. 8.72 29. 9.72	780.9	PA (dry hole)
West Muiron No. 1A BMR file 72/2738	21 34 44 114 14 45	F50/5	WD 63.1 RT 12.2	5.10.72 19.10.72	345.3	PA (dry hole)

APPENDIX 1 (a) (Continued)

COMPANY Well Name BMR File no. if subsidised	Latitude South Longitude East o	 '	 "	1:250 000 Sheet area	Elevation (m) GL/WD KB/RT		Date spudded TD reached	TD (m)	Status at 31.12 of year drilled
West Muiron No. 2	21 114	35 13	39 31	F50/5	WD KB	61.6	9. 8.75 10.10.75	3320.0	PA (dry hole)
West Tryal Rocks No. 1 BMR file 72/3108	20 115	13 02	45 04	F50/1	WD RT	137.8 12.2	23.10.72 4. 3.73	3866.4	Abandoned gas-condensate well
West Tryal Rocks No. 2	20 115	12 03	55 58	F50/1	WD RT	126.0 12.0	1.10.74 25.11.74	3825.0	Abandoned gas-condensate well
Whaleback No. 1 BMR file 63/1319	22 113	43 51	35 37	F49/12	GL KB	53.9 57.0	30. 7.63 21.10.63	1528.0	PA (dry hole)
Windoo No. 1A	21 115	21 40	18 55	F50/6	GL RT	5.8 7.9	8.12.74 5.12.74	174.3	Abandoned well with show of gas
Wonangarra No. 1 (Core hole)	22 114	09 41	03 20	F50/9	GL RT	6.1 7.9	21. 4.69 2. 5.69	575.5	PA (dry hole)
Yanrey No. 1	22 114	15 34	16 57	F50/9	GL KB	13.7 16.5	1957	430.7	*
Yarraloola No. 1	21 115	23 45	07 52	F50/6	GL KB	15.2 16.8	27.11.67 19.12.67	271.9	*

APPENDIX 1(b)

BMR STRATIGRAPHIC HOLES, CARNARVON BASIN

Strat. hole name	Latitude South Longitude East o	 '	 "	1:250 000 Sheet area	Elevation (m) GL/KB	Date spudded TD reached	TD(m)	Reference
BMR No. 5 (Giralia)	22 114	39 14	25 25	F50/9	GL 74.1 KB 75.6	26. 6.58 31. 7.58	630.9	BASTIAN, L.U. & WILLMOTT, S.P., 1965 - Bur.Miner.Resour.Aust. Rep. 84, 1-17.
BMR No. 6 (Muderong)	24 114	05 46	55 30	G50/1	GL 173.7 KB 175.3	10. 8.58 19. 8.58	305.4	PERRY, W.J., 1965 - Bur. Miner. Resour. Aust. Rep. 81, 1-16
BMR No. 7 (Muderong)	24 114	05 46	55 30	G50/1	GL 173.7 KB 175.3	21. 8.58 14. 9.58	602.6	PERRY, W.J., 1965 - Bur. Miner. Resour. Aust. Rep. 81, 1-16
BMR No. 8 (Mt Madeline)	25 115	44 40	50 40	G50/6	GL 243.8 KB 245.4	25. 5.59 12. 7.59	915.6	MERCER, C.R., 1967 - Bur.Miner. Resour. Aust. Rep. 37, 114.
BMR No. 9 (Daurie Creek)	25 115	32 52	20 50	G50/6	GL 274.3 KB 275.8	16. 7.59 12. 8.59	700.7	MERCER, C.R., 1967 - Bur. Miner. Resour. Aust. Rep. 108, 1-19. (Figs. 1, 3, 4, & Plate 2).

Elevation

GL - Ground level
WD - Water depth
KB - Kelly bushing
RT - Rotary table

Status

* - Petroleum exploration wells drilled for stratigraphic purposes
PA - Plugged and abandoned
'Abandoned' includes wells that have been secured, suspended, or plugged for possible future re-entry

APPENDIX 2

GEOPHYSICAL SURVEYS

Magnetic Surveys

Survey name & type	Map key No. (Plates 3A & 3B)	Year	Operator	Contractor	Survey altitude (ft)	Traverse spacing (km)	Total traverse length (km)	Reference
Carnarvon Basin airborne surveys	1	1956	BMR	-	500	1.6		BMR Record 1957/9
	2	1957	"	-	"	"		BMR Record 1960/132
	3	1959	"	-	"	"		BMR Record 1961/56
	4	1961	"	-	"	"		BMR Record 1962/191
West Carnarvon aeromagnetic	5	1965	Tasman Oil	Adastra Hunting Geophysics	1500	1.6-10	8200	PSSA 65/4615
Offshore Onslow aeromagnetic	6	1967	WAPET	Adastra Hunting Geophysics	1000	1.6-6.5	3900	PSSA 67/4628
Offshore Bernier aeromagnetic	7	1969	WAPET	Hunting Geology and Geophysics	1000	2.4-13	4400	PSSA 69/3031
NW Continental Shelf marine geophysical	8	1968	BMR	-	"	20	25000	BMR Record 1969/99
Offshore West Beagle aeromag	9	1969	WAPET	Hunting Geology and Geophysics	?	3.2	4500	PSSA 69/3050
Geelvink Channel marine seismic and magnetic	10	1970	BP Petroleum Development Australia	Geophysical Services International (GSI)	Sea Level	6-14	1430	PSSA 70/241
Bernier Marine Seismic and magnetic	11	1971	Ocean Ventures	Western Geophysical	"	7-25	1420	PSSA 71/722

APPENDIX 2 (Continued)

Survey name & type	Map key No. (Plates 3A & 3B)	Year	Operator	Contractor	Survey altitude (ft)	Traverse spacing (km)	Total traverse length (km)	Reference
Offshore Australia marine seismic, magnetic and gravity	12	1971	Shell Development (Australia)	Seismograph Service (Marine)	"	-	8005	P(SL)A 71/19
Gulf regional geophysical reconnaissance, seismic, magnetic and gravity	13	1972	Australian Gulf Oil	Gulf Oil	Sea Level	-	5300	P(SL)A 72/9
BMR Continental Margin survey	14	1970-73	BMR Generale de	Compagnie Generale de Geophysique	"	50		BMR Record 1974/15

APPENDIX 2 Cont.

Land gravity surveys

Survey name and type	Year	Operator	Contractor	Traverse spacing (km)	Station spacing (km)	No. of stations	Reference
Pendulum observations	1950	BMR	-	-	-	59	BMR Bulletin 46
Reconnaissance gravity	1950	BMR	-	30-40	6.4	260	BMR Record 1951/69
Giralia detail gravity	1951	BMR	-	-	0.4	63	BMR Record 1951/68
Rough Range detail gravity	1953	BMR	-	1-3	0.4	300	BMR Record 1956/148
Onslow-Derby gravity traverse	1953	BMR	-	-	32	44	BMR Record 1963/13
Carnarvon Basin reconnaissance gravity	1953	BMR	-	10-20	5-9	-	BMR Record 1954/44
Wandagee Ridge detail gravity	1962	WAPET	-	-	0.4	375	(Confidential)
Barrow Island reconnaissance gravity	1962	WAPET	-	-	-	-	(")
Barrow Island detail gravity	1965	WAPET	-	-	-	-	(")
Reconnaissance helicopter gravity	1968	BMR	Wongela Geophysical	11	11	3961	BMR Record 1974/26
Reconnaissance helicopter gravity	1969	BMR	Wongela Geophysical	11	11	3297	BMR Record 1974/27
Murchison Gascoyne helicopter gravity	1970	Barewa Oil & Mining	Wongela Geophysical	6.5	6.5	956	PSSA 70/326
Murchison Gascoyne D1 detail gravity	1971-72	Oceania Petroleum	Austral United Geophysical	12	0.8	6576	PSSA 71/555

Marine gravity surveys

Survey name and type	Year	Operator	Contractor	Traverse spacing (km)	Km surveyed	Reference
Northwest Continental Shelf Marine gravity seismic and magnetic	1968	BMR	-	20	25000	BMR Record 1969/99
BMR Continental Margin gravity seismic magnetic	1970-73	BMR	-	50	-	BMR Record 1974/15
Offshore Australia marine seismic, magnetic and gravity	1971	Shell Development (Australia)	Seismograph Service (Marine)	-	8005	P(SL)A 71/9
Gulf regional geophysical reconnaissance seismic, magnetic and gravity	1972	Australian Gulf Oil	Gulf	-	5200	P(SL)A 72/9

Land seismic surveys

Map key No. (Plates 5A and 5B)	Survey name and type	Year	Operator	Contractor	Energy source	Km surveyed	CDP coverage (%)	Reference
1	Giralia seismic	1951	BMR	-	Explosives	-	100	BMR Record 1954/67 1951/62
2	Wandagee reconnaiss-ance seismic	1955	BMR	-	Explosives	48	100	BMR Record 1962/117
3	Wandagee Ridge seismic	1961-62	WAPET	Geophysical Services International (GSI)	Explosives	240	100	PSSA 62/1576
4	Salt Marsh seismic	1961-62	WAPET	GSI	Explosives	179	100	PSSA 62/1585
5	Quail Anticline Seismic	1962-63	WAPET	GSI	Explosives	179	100	PSSA 62/1622
6	Whaleback seismic	1962	WAPET	GSI	Explosives	113	100	PSSA 62/1635
7	Kubura-Learmonth seismic	1962	WAPET	GSI	Explosives	35	100	PSSA 62/1637
8	Ningaloo seismic	1963	WAPET	GSI Seismograph Service Ltd (SSL)	Explosives Vibroseis	122	100	PSSA 63/1504
9	Paterson Trap seismic	1963	WAPET	GSI SSL	Explosives Vibroseis	116	100	PSSA 63/1509
10	Southern Carnarvon Basin seismic Refraction Traverse A	1963	BMR	-	Explosives	-	-	Geophys. Prog. Report 1964/6

Land seismic surveys (Continued)

Map key No. (Plates 5A and 5B)	Survey name and type	Year	Operator	Contractor	Energy source	Km surveyed	CDP coverage (%)	Reference
11	Traverse C seismic	1964	BMR	-	Explosives	64	100	BMR Record 1967/10
12	Traverse D Pelican Hill Bore seismic	1964	BMR	-	Explosives	39	100	BMR Record 1965/40
13	Barrow Island Refraction seismic	1963	WAPET	GSI	Explosives	60	-	PSSA 63/1536
14	Wooramel reconnaissance seismic	1965	Continental Oil	Ray Geophysics Western Geophysical	Explosives Weight Drop	1200	1200	PSSA 64/4545
15	Yalbalgo-Yaringa seismic	1965	Continental Oil	Western Geophysical	Explosives Weight Drop		400-1200	PSSA 65/11021
16	Kennedy seismic	1965	WAPET	GSI	Explosives	29	100- 400	PSSA 65/11038
18	Merlinleigh Anticline seismic	1966	WAPET	Western Geophysical	Weight Drop	29	600	PSSA 66/11075
19	Onslow seismic	1966	WAPET	Western Geophysical	Weight Drop	170	200- 600	PSSA 66/11073
20	Cane River seismic	1967	WAPET	United Geophysical	Explosives	61	300	PSSA 67/11159
21	Locker seismic	1967	WAPET	United Geophysical	Explosives	301	300- 600	PSSA 67/11162
22	Mia-Mia seismic	1967	Marathon Petroleum	Ray Geophysics	Weight Drop	2410	100- 600	PSSA 67/11179
23	Mandu seismic	1968	WAPET	GSI	Explosives	33	600	PSSA 68/3042

Land seismic surveys (Continued)

Map key No. (Plates 5A and 5B)	Survey name and type	Year	Operator	Contractor	Energy source	Km surveyed	CDP coverage (%)	Reference
24	Lyndon-Quobba seismic	1972	WAPET	GSI Digicon	Explosives	221	600	PSSA 72/891
25	Hamelin seismic	1972	Oceania Petroleum	Austral-United Geophysical	Explosives	79	600-1200	PSSA 72/2075
26	Murat seismic	1973	WAPET	GSI	Vibroseis	42	1200	PSSA 73/231
27	Norwegian 2 seismic	1973	WAPET	GSI	Explosives	5	1200	PSSA 73/274
28	Barrow 3 seismic	1973	WAPET	GSI	Vibroseis	16	2400	PSSA 73/227

Marine seismic surveys

Map key No. (Plates 5A and 5B)	Survey name and type	Year	Operator	Contractor	Energy source	Km surveyed	CDP coverage (%)	Reference
29	Exmouth Gulf seismic	1961	WAPET	SSL	Explosives	1210	100	PSSA 62/1563
30	Northwest Shelf W.A. & N.T. seismic	1964	BOCAL	Western Geophysical	Explosives	1900	200	PSSA 64/4529
31	Abrolhos seismic	1965	BP Petroleum	Western Geophysical	Explosives	1160 64	100 600	PSSA 65/4592
32	Shark Bay seismic	1965	Continental Oil Company	Western Geophysical	Explosives	295	600	PSSA 64/4551
33	Barrow seismic	1965	WAPET	GSI	Explosives	248 628	100 300	PSSA 65/11031
34	Montebello-Mermaid Shoal seismic	1965	BOCAL	Western Geophysical	Explosives	4100 2120 116	200 300 600	PSSA 65/11015
35	West Carnarvon seismic	1966	Canadian Superior	GSI	Explosives	2220	300	PSSA 66/11089
36	Rankin-Troubadour seismic	1966	BOCAL	Western Geophysical	Explosives	2750	300	PSSA 66/11104
37	Zeewyk Channel seismic	1966	BP Petroleum	United Geophysical	Explosives	98	100	PSSA 66/11112
38	West Gnarraloo seismic	1967	Canadian Superior	GSI	Explosives	900	600	PSSA 67/11158

Marine seismic surveys (Continued)

Map key No. (Plates 5A and 5B)	Survey name and type	Year	Operator	Contractor	Energy source	Km surveyed	CDP coverage (%)	Reference
39	Long Island seismic	1967	WAPET	Western Geophysical	Explosives	314	300	PSSA 67/11153
40	Muiron seismic	1967	WAPET	GSI	Explosives	550 111	400 300	PSSA 67/11167
41	Helby seismic	1968	WAPET	Western Geophysical	Aquapulse	130	1200	PSSA 68/3045
42	Table seismic	1968	WAPET	GSI	Airguns Explosives Explosives	48 490 282	2400 400 400-600	PSSA 68/3001
43	Northwest Shelf seismic magnetic gravity	1968	BMR	CGG	Sparker Airguns	24 200	100	BMR Record 1969/99
44	Legendre-Marie seismic	1969	BOCAL	Western Geophysical	Aquapulse	7000	2400	PSSA 69/3005
45	Jurabi seismic	1969	WAPET	GSI	Explosives	14.5	600	PSSA 68/3049
46	Fraser seismic	1969	WAPET	GSI	Airguns Explosives	198 219	2400-3600 600-1200	PSSA 69/3015
47	Geelvink Channel seismic and magnetic	1970	BP Petroleum	GSI	Airguns	1440	2400	PSSA 70/241
48	Barrow Waters seismic	1970	WAPET	GSI	Airguns	214	2400	PSSA 70/127
49	Tryal-Evans seismic	1970	BOCAL	Western Geophysical	Aquapulse	7400	1200-2400	PSSA 70/245

Marine seismic surveys (Continued)

Map key No. (Plates 5A and 5B)	Survey name and type	Year	Operator	Contractor	Energy source	Km surveyed	CDP coverage (%)	Reference
50	Ronsard seismic	1971	Endeavour Oil	GSI	Airguns	338	2400	PSSA 71/79
51	Geelvink Channel D-1 seismic	1971	BP Petroleum	Western Geophysical	Aquapulse	300	2400	PSSA 71/35
52	Bernier seismic & magnetic	1971	Ocean Ventures	Western Geophysical	Maxipulse	1450	2400	PSSA 71/722
53	Trimouille-Dillon seismic	1970-1971	BOCAL	Western Geophysical	Aquapulse Maxipulse	6550	1200-2400	PSSA 70/976
54	Rankin Trend seismic	1971	BOCAL	Western Geophysical	Maxipulse	795	1200-2400	PSSA 71/538
54A	Offshore Australia marine seismic, magnetic and gravity	1971	Shell Development (Australia)	Seismograph Service (Marine)	Airguns	8005		P(SL)A 71/9
55	Montebello-Turtle seismic	1972	BOCAL	Western Geophysical	Maxipulse	2880	1200-2400	PSSA 72/509
56	Malus-Hedland seismic	1972	BOCAL	Western Geophysical	Maxipulse	570	2400	PSSA 72/2701
57	Steamboat Spit seismic	1972	BOCAL	Western Geophysical	Maxipulse	2640	2400	PSSA 72/3253
58	De Grey Nose seismic	1973	BOCAL	GSI	Airgun	630	2400	PSSA 73/213

Marine seismic surveys (Continued)

Map key No. (Plates 5A and 5B)	Survey name and type	Year	Operator	Contractor	Energy source	Km surveyed	CDP coverage (%)	Reference
59	BMR Continental Margin seismic, magnetic and gravity	1970-1973	BMR	Compagnie Generale de Geophysique	Sparker	-	100	BMR Record 1974/15
60	Exmouth Plateau seismic	1971-1972	Esso Australia	Western Geophysical	Aquapulse	1270	1200	P(SL)A 72/39
61	Gulf regional geophysical reconnaissance seismic, magnetic and gravity	1972	Australian Gulf Oil	Gulf Research and Development	Aquapulse	4670	2400	P(SL)A 72/9

APPENDIX 3

STRATIGRAPHIC TABLES, CARNARVON BASIN WELLS

MERLINLEIGH SUB-BASIN

AGE	UNIT	QUAIL NO. 1 Depth(m) D.F.	Thickness (m)	LITHOLOGY
QUATERNARY	Undifferentiated	4	5	Sand, red, fine to coarse-grained, poorly sorted, clayey; and clay, medium to light grey and yellow-red
	UNCONFORMITY			
(Artinskian)	Coyrie Fm.	9	58	Predominantly dark to medium grey siltstone pyritic with occasional brachiopod fragments, containing a few calcareous beds which grade into silty limestone
"	Billidee Fm.	67	206	Sequence of interbedded sandstone and siltstone. Sandstone is light grey, commonly silty, kaolinitic, and micaceous; siltstone is dark grey, micaceous, sandy in part, occasionally calcareous. Few thin coal seams between 168 m and 174 m
"	Moogooloo Sandstone	273	113	Sandstone, well to moderately sorted, interbedded with dark grey, carbonaceous, micaceous siltstone (decreasing in amount with depth) with traces of black, lignitic, in parts vitreous coal
PERMIAN "	Cordalia Greywacke	386	60	Sandstone, brown to grey, fine to medium-grained, fine to very fine micaceous and silty beds, pyritic, slightly calcareous; and siltstone, dark grey, micaceous, with some calcareous beds grading into limestone. Basal interval of siltstone from 405 m to 447 m

MERLINLEIGH SUB-BASIN (Continued)

AGE	UNIT	QUAIL NO. 1 Depth (m) D.F.	QUAIL NO. 1 Thickness (m)	LITHOLOGY
(Sakmarian)	Callytharra Fm.	446	146	A fairly fossiliferous (except the interval 463 m to 537 m) siltstone, containing bryozoa, brachiopods, foraminifera, and pelecypods. Siltstone is dark grey, pyritic, sandy in part, micaceous, poorly bedded and calcareous with thin beds of limestone towards base of unit
"	Lyons	592	1509	Interbedded tillite, claystone, sandstone, siltstone, shale, quartz greywacke, and minor limestone. The tillite, quartz greywacke, and some siltstone are characterised by their extremely poor sorting. In Quail No. 1 this group has been divided into seven units based on the distribution of the tillites
UPPER CARBONIFEROUS	Siltstone Unit	2101	67	Mainly siltstone, medium to dark grey, fine to medium-grained with silky lustre, grading in part to fine-grained quartz greywacke
	Sandstone Unit	2168	285	Fairly uniform sandstone with a matrix of secondary quartz and in part of dolomite and calcite; occasional thin beds of siltstone, shale, quartz greywacke, and limestone. The sandstone unit has negligible porosity throughout
		UNCONFORMITY		
LOWER CARBONIFEROUS	Carbonate Unit	2453	257	2453 m - 2582 m: predominantly calcilutite with interbedded calcarenite and minor calcareous siltstone and shale. The upper 9 m is grey, fine-grained, quartzitic sandstone 2582 m - 2710 m: predominantly dolomite with interbedded calcilutite and calcarenite
		UNCONFORMITY		

MERLINLEIGH SUB-BASIN (Continued)

AGE	UNIT	QUAIL NO. 1 Depth (m) D.F.	Thickness (m)	LITHOLOGY
UPPER DEVONIAN	Sandstone Unit	2710	31	Sandstone, white and light grey, fine-grained, well-sorted, quartzitic, pyritic, non-porous; believed to be equivalent to the Willaradie Formation and Munabia Sandstone, or may be an upper member of the Gneudna Formation
MIDDLE-UPPER DEVONIAN	Gneudna Formation	2741	341	2741 m - 2760 m: dolomite grading to calcilutite 2760 m - 3026 m: calcarenite in the upper 76 m but mainly calcilutite with interbedded shale, siltstone, dolomite, and minor sandstone 3026 m - 3082 m: interbedded sandstone with a few beds of dolomite, calcilutite, siltstone, and shale
	Silurian Unit 'A' (Nannyarra Greywacke?)	3082	124	Sandstones, generally fine-grained, moderately to poorly sorted and silty, containing a few beds of siltstone, and traces of shale and claystone
SILURIAN	Dirk Hartog Limestone	3206	343	3206 m - 3355 m: dolomite, with some oolitic beds interbedded with siltstone and minor sandstone 3355 m - 3417 m: interbedded anhydrite, light to dary grey and pink, occurring in beds and veins, dolomite, siltstone, and traces of shale 3417 m - 3549 m: interbedded dolomite, siltstone, with minor shale and claystone

UNCONFORMITY

MERLINLEIGH SUB-BASIN (Continued)

AGE	UNIT	QUAIL NO. 1 Depth(m) D.F.	Thickness (m)	LITHOLOGY
SILURIAN	Tumblagooda Sandstone	3549	31+	Sandstone, very fine-grained, well-sorted, quartzitic, clay matrix, minor amounts of disseminated graphite (?), grading to siltstone, very clayey and sandy
	TOTAL DEPTH	3580		

Notes

1) No signs of crude oil were noted in the well. Insignificant traces of methane were detected in the drilling mud from 165 m to T.D. Traces of gasoline fractions were present in mud samples in the interval 366 m - 457 m.

2) Argillaceous calcilutites and shales of the ?Lower Carboniferous Carbonate Unit and Gneudna Formation constitute the only possible source rocks penetrated in this well but retain no traces of oil and very little gas, possibly owing to deep burial and compaction

(from WAPET, 1964)

GASCOYNE SUB-BASIN (Continued)

AGE	UNIT	TAMALA NO. 1 Depth(m)K.B.	Thickness(m)	LITHOLOGY
QUARTERNARY (Pleistocene)	Coastal limestone	Surface(4)	34+	White, fine to medium-grained calcarenite with minor quartz sandstone
TERTIARY (Paleocene)	Upper Cardabia Group	38	122	White to yellow glauconitic calcarenite with abundant fossil fragments and soft calcareous glauconitic mudstone
UPPER CRETACEOUS (Campanian) (Santonian)	Toolonga Calcilutite	160	183	Fossiliferous calcarenite, calcareous glauconitic mudstone, argillaceous calcilutite
LOWER CRETACEOUS (Turonian)	Winning Group Alinga Fm	343	16	Calcareous shale, glauconitic mudstone, minor chert
(Albian)	Windalia Radiolarite	359	14	hard, siliceous slightly calcareous shale, in part very glauconitic
(Aptian)	Muderong Shale	373	5	Shale, brown to blue and hard or light grey and fissile, with trace of brown chert
(Aptian)	Birdrong Sandstone	378	20	Light, grey sandstone and coarse-grained loose quartz
UNKNOWN - DEVONIAN?	Unknown Fm.	398	27	Grey to orange to red brown sandstone with calcareous cement, thin shale beds

GASCOYNE SUB-BASIN (Continued)

AGE	UNIT	TAMALA NO. 1 Depth(m)K.B.	Thickness(m)	LITHOLOGY
SILURIAN (Llandoverian-Ludlovian)	Dirk Hartog Fm.	425	693	Dolomite and limestone with interbedded siltstone and mudstone
?	?	?	?	?
SILURO-ORDOVICIAN (Llandoverian-Ashgillian)	Tumblagooda Sandstone	1118	107+	Fine-grained, white to red-brown sandstone with thin shale beds
		T.D. 1225		

Notes

The basal Cretaceous section is similar to that in Dirk Hartog No. 17B (drilled in 1956 on Dirk Hartog Island) except for the absence of Eocene sediment, and the presence of the Turonian Alinga Formation.

(from OCEANIA PETROLEUM PTY LTD, 1973)

AGE	UNIT	WEST TRYAL ROCKS No. 1 Depth (m) RT	Thickness (m)	LITHOLOGY
TERTIARY (Recent-Upper Miocene)	Undifferentiated Carbonates	150	1163	Predominantly calcilutite, calcarenite and calcisiltite with rare interbeds of chalk; below 997 m there is a great variety of microfossils with traces of pyrite and glauconite in parts
		UNCONFORMITY		
(Middle Miocene-Oligocene)	Cape Range Group	1313	616	Mainly calcilutite, calcisiltite and marly calcilutite with minor calcarenite, chalk and marl, and rare limestone, dolomite and chert
		UNCONFORMITY		
(Upper-Middle Eocene)	Giralia Calcarenite Equivalent	1929	211	Upper unit of marl, calcisiltite, calcilutite with minor limestone; middle unit of mainly limestone; thin lower unit with chalk, calcisiltite, limestone and a thin (1.5 m) basal, tight sandstone
		UNCONFORMITY		
(Lower Eocene-Paleocene)	Cardabia Group	2140	119	Mainly dark, marly calcilutite with minor limestone, chalk, claystone and calcisiltite and a basal transgressive, very fine grained glauconitic, shallow marine sandstone
		UNCONFORMITY		
UPPER CRETACEOUS	Toolonga ? Equivalent	2259	34	A thin upper unit of sandy calcilutite grading downwards to marl and marly sand; lower unit of dark claystone with traces of silt, glauconite and pyrite grading to silty sandstone in parts with a 1.5 m basal sand
		UNCONFORMITY		
LOWER-UPPER CRETACEOUS	Gearle Siltstone Equivalent	2292	297	Mainly marly calcilutite with calcareous claystone shale and siltstone

AGE	UNIT	WEST TRYAL ROCKS No. 1 Depth (m) RT	Thickness (m)	LITHOLOGY
LOWER CRETACEOUS	Windalia Radiolarite Equivalent	2589	38	Mainly siltstone, dark grey, glauconitic, calcareous, radiolaria common, with rare interbeds of claystone and marl
LOWER CRETACEOUS	Muderong Shale	2627	606	Interbedded siltstone, clay and shale with darker colours predominating; minor marl and lignite and rare limestone
		UNCONFORMITY		
LOWER JURASSIC -LOWER TRIASSIC	Mungaroo Beds	3233*	633+	Mainly thick-bedded, coarse sandstones with interbeds of shale and light-coloured claystone with minor coal. Sandstones are typically carbonaceous. Grainsize and porosity decrease near to top of sands due to increased clay matrix, and in some cases porosity decreases in the bottom of the sands due to increased silica cement
	TOTAL DEPTH	3866*		

NOTES

1)* Depths for sidetracked hole

2) The absence of a thick upper shaly section encountered in North Tryal Rocks resulted in a significant hydrocarbon accumulation in the West Tryal Rocks Structure. Log analysis indicates the presence of 90 m of possible pay. The hydrocarbon column extends over a gross interval of 265 m with a transitional hydrocarbon-water contact from 3498-3501 m.

(from WAPET, 1973)

BARROW SUB-BASIN

AGE	UNIT	BARROW DEEP No. 1 Depth(m) K.B.	Thickness (m)	LITHOLOGY
TERTIARY (Miocene)	Trealla Limestone	8	7?	Limestone, medium to finely crystalline, richly fossiliferous grading to coquinite in parts, and sand
UNCONFORMITY				
(Eocene)	Giralia Calcarenite	15?	117?	Limestone, hard, calcarenitic in part, low porosity; sand, medium, subrounded, moderately sorted quartz; and siltstone, red-brown, low porosity, very fine micaceous, non to slightly calcareous
UNCONFORMITY				
(Paleocene-Eocene)	Cardabia Group	132?	68?	Calcilutite, with loose fossil fragments, becoming more coarse with depth, grading to calcarenite, very fine to silty, slightly fossiliferous, increasingly glauconitic with depth
UNCONFORMITY				
UPPER CRETACEOUS (Santonian-Campanian)	Toolonga Calcilutite	200	68	Chalk, slightly glauconitic, occasionally sandy, and minor beds of calcarenite grading to calcisilite with depth, and limestone in interval 200-223 m
UNCONFORMITY				
UPPER CRETACEOUS (Cenomanian-Turonian)	Upper Gearle Siltstone	268	38	Siltstone, massive, calcareous, glauconitic, grading to mudstone, with minor thin interbeds of calcarenite and calcisiltite, and traces of limestone grading to chalk
LOWER-UPPER CRETACEOUS (Albian-Cenomanian)	Lower Gearle Siltstone	307	298	Siltstone, slightly glauconitic and pyritic, with rare fossil radiolaria, and minor beds of calcarenite grading to calcisiltite in part and limestone with traces of sandstone and siderite in the lower part of the interval

BARROW SUB-BASIN (Continued)

AGE	UNIT	BARROW DEEP No. 1 Depth(m) K.B.	Thickness (m)	LITHOLOGY
LOWER CRETACEOUS (Albian-Aptian)	Windalia Radiolarite	605	12	Siltstone, glauconitic, with traces of radiolaria and fossil fragments, with minor interlaminations of sandstone, grading into siltstone, and rare brown siderite(?)
LOWER CRETACEOUS (Aptian)	Muderong Shale	617	268?	
	Top Windalia Sand Member	617	36	Sandstone, very fine to silty, moderately to poorly sorted, glauconitic, good to fair porosity, with strong petroliferous odour and traces of oil stain, occasionally grading to sandy siltstone; interbedded and interlaminated shale from 635-644 m
	Base Windalia Sand Member	653	192	Shale, slightly glauconitic, pyritic and micaceous, grading to siltstone particularly near top and bottom of the interval, with minor sandstone and traces of dolomitic limestone and calcarenite.
LOWER CRETACEOUS (Aptian-Neocomian)	Muderong Greensand Member	845	40?	Sandstone/greensand, generally fine-grained, with a silty matrix, moderately well sorted, very glauconitic, poor to fair visual porosity, and a light to moderate petroliferous odour, but no stain
	Barrow Group	885?	1100?	
	Unit A	885?	374?	Sandstone, very fine to very coarse and granular, poorly sorted, traces pyrite, feldspar and glauconite, very good visual porosity, and interbeds of siltstone, and minor coal and traces of dolomite

AGE	UNIT	BARROW DEEP No. 1 Depth (m) K.B.	Thickness (m)	LITHOLOGY
	Unit B	1259	344	Siltstone, occasionally carbonaceous, argillaceous, and sandstone, fine to very coarse, moderately to poorly sorted, with good visual porosity, and minor beds of coal, and dolomite
LOWER CRETACEOUS		1500	18	Shale, very soft, puggy, with minor siltstone, soft argillaceous
(Neocomian)		1518	85	Sandstone, and minor thin interbeds of siltstone, and claystone/shale and traces of dolomite
	Unit C "6000' Sand"	1603 1824	264 - -	Mainly sandstone with interbedded siltstone and shale and minor dolomite. The interval called the "6000' Sand" constitutes the basal sequence of unit C and trace to poor oil and gas shows were observed during penetration
	Unit D "6200' Sand"	1862 1885	123 - -	Siltstone and sandstone ("6200' Sand" - only a trace gas show recorded during penetration), with minor dolomite and claystone
	Dingo Claystone	1985	2665+	Mainly marine claystone, siltstone, and shale, with significant sand developments at late Middle to early Upper Jurassic levels
	Top Dupuy Sand Member	1985	193	Exhibited trace to poor gas shows during drilling
	"6700' Sand"?	2031	- -	Only minor indications of hydrocarbons

BARROW SUB-BASIN (Continued)

AGE	UNIT	BARROW DEEP No. 1 Depth(m) K.B.	Thickness (m)	LITHOLOGY
	Base Dupuy Sand Member	2177	- -	2177-2880 m: thick sequence of petroliferous silt-stones grading with depth to claystones and shales From 2880 m on, the section became more sandy and from about 3240 m; three major porous and permeable Middle Jurassic sandstone bodies were intersected each exhibiting fair to good shows:
MIDDLE-UPPER JURASSIC	Top 10600' Sand	3242	12	Top zone; calculated open flow potential (COFP) 0.42 MMCMD with some condensate and water; inconclusive test due to apparent severe formation damage; proven net gas pay 3 m and probable gas pay 4.3 m
	Base 10600' Sand	3254	- -	
	Top 10900' Sand	3329	34	Middle zone; COFP 0.25 MMCMD with some condensate and water, and considerable depletion; proven net gas pay 3.7 m
	Base 10900' Sand	3363	- -	
	Top 11250' Sand	3424	76	Bottom zone; COFP 5.66 MMCMD with some condensate and water, and very little, if any, depletion; proven net gas pay 9.5 m
	Base 11250' Sand	3500		
				In addition to these three main zones there are 4.3 m of possible gas pay at 3129 m - 3133 m
	TOTAL DEPTH	4650		

Notes

1) Barrow Group, and all subdivisions thereof, are WAPET informal names
2) The primary objectives - the Upper Triassic to Lower Jurassic sandstones - are probably too deep to be commercially exploitable.
3) Palaeontological data has shown that the Middle Jurassic - Upper Jurassic boundary may lie at about 3185 m, above the gas sands

(from WAPET, 1973)

AGE	UNIT	WEST TRYAL ROCKS No. 1 Depth(m) RT	Thickness (m)	LITHOLOGY
TERTIARY (Recent-Upper Miocene)	Undifferentiated Carbonates	150	1163	Predominantly calcilutite, calcarenite and calcisiltite with rare interbeds of chalk; below 997 m there is a great variety or microfossils with traces of pyrite and glauconite in parts
		UNCONFORMITY		
(Middle Miocene-Oligocene)	Cape Range Group	1313	616	Mainly calcilutite, calcisiltite and marly calcilutite with minor calcarenite, chalk and marl, and rare limestone, dolomite and chert
		UNCONFORMITY		
(Upper-Middle Eocene)	Giralia Calcarenite Equivalent	1929	211	Upper unit of marl, calcisiltite, calcilutite with minor limestone; middle unit of mainly limestone; thin lower unit with chalk, calcisiltite, limestone and a thin (1.5 m) basal, tight sandstone
		UNCONFORMITY		
(Lower Eocene-Paleocene)	Cardabia Group	2140	119	Mainly dark, marly calcilutite with minor limestone, chalk, claystone and calcisiltite and a basal transgressive, very fine grained glauconitic, shallow marine sandstone
		UNCONFORMITY		
UPPER CRETACEOUS	Toolonga ? Equivalent	2259	34	A thin upper unit of sandy calcilutite grading downwards to marl and marly sand; lower unit of dark claystone with traces of silt, glauconite and pyrite grading to silty sandstone in parts with a 1.5 m basal sand
		UNCONFORMITY		

BARROW SUB-BASIN (Continued)

AGE	UNIT	WEST TRYAL ROCKS No. 1 Depth(m) RT	Thickness (m)	LITHOLOGY
LOWER-UPPER CRETACEOUS	Gearle Siltstone Equivalent	2292	297	Mainly marly calcilutite with calcareous claystone shale and siltstone
LOWER CRETACEOUS	Windalia Radiolarite Equivalent	2589	38	Mainly siltstone, dark grey, glauconitic, calcareous, radiolaria common, with rare interbeds of claystone and marl
LOWER CRETACEOUS	Muderong Shale	2627	606	Interbedded siltstone, clay and shale with darker colours predominating; minor marl and lignite and rare limestone
UNCONFORMITY				
LOWER JURASSIC -LOWER TRIASSIC	Mungaroo Beds	3233*	633+	Mainly thick-bedded, coarse sandstones with inter-beds of shale and light-coloured claystone with Minor Coal. Sandstones are typically carbonaceous. Grainsize and porosity decrease near to top of sands due to increased clay matrix, and in some cases porosity decreases in the bottom of the sands due to increased silica cement
	TOTAL DEPTH	3866*		

NOTES

1)* Depths for sidetracked hole
2) The absence of a thick upper shaly section encountered in North Tryal Rocks resulted in a significant hydrocarbon accumulation in the West Tryal Rocks Structure. Log analysis indicates the presence of 90 m of possible pay. The hydrocarbon column extends over a gross interval of 265 m with a transitional hydrocarbon-water contact from 3498-3501 m.

(from WAPET, 1973)

GASCOYNE SUB-BASIN

AGE	UNIT	PENDOCK No. 1 Depth(m) K.B.	PENDOCK No. 1 Thickness (m)	LITHOLOGY
QUATERNARY (Pleistocene)	Exmouth Sandstone	141	67	Dolomite, coquinitic limestone, firm to hard reddish brown siliceous sandstone and minor grey-white quartzite
		UNCONFORMITY		
TERTIARY (Miocene)	Trealla Limestone?	208	110	Sequence of interbedded sandstone, light grey to white unsorted, calcareous, soft and friable with abundant bentonite and kaolinite in the matrix, glauconitic in part, poor to fair porosity, poor permeability, and dolomite, light brown to cream, fossiliferous with abundant forams and bryozoa, poor to fair vuggy porosity
		DISCONFORMITY		
	Tulki Limestone	318	50	Dolomite, light brown, very fossiliferous with scattered forams and bryozoa, having fair vuggy porosity
(Miocene)	Mandu Calcarenite	368	54	Dolomite, brown to tan, abundant forams and bryozoa, fair vuggy porosity, with traces of limestone
		DISCONFORMITY		
(Eocene)	Giralia Calcarenite	422	95	Dolomite, tan to brown, with traces of glauconite and pyrite, dense with poor porosity and permeability; and limestone with the two lithologies grading into one another

GASCOYNE SUB-BASIN (Continued)

AGE	UNIT	PENDOCK No. 1 Depth(m) K.B.	PENDOCK No. 1 Thickness (m)	LITHOLOGY
	Jubilee Calcarenite	517	55	Limestone (calcarenite), light brown to cream, abundant bryozoa and forams, slightly argillaceous and glauconitic, with poor porosity and permeability
	Cashin Calcarenite	572	23	Dolomite, orange to orange-pink, very finely crystalline and tight
(Paleocene)	Basal Cardabia Group	595	164	Limestone, grey to greenish grey, dolomitic in parts very argillaceous grading to marl, poorly fossiliferous, extremely glauconitic, with poor porosity and permeability
		DISCONFORMITY		
UPPER CRETACEOUS	Korojon Calcarenite	759	35	Limestone (calcarenite) consisting primarily of coarse fibrous Inoceramus fragments in a soft greenish-grey glauconitic calcilutite matrix, with poor to fair porosity in part and poor permeability
	Toolonga Calcilutite	794	34	Limestone (calcilutite), greenish grey, argillaceous and soft with minor traces of fibrous Inoceramus fragments throughout, poor porosity and permeability
		DISCONFORMITY		
	Gearle Siltstone	828	140	Shale or mudstone and minor siltstone, grey, calcareous and micaceous with abundant lignitic or carbonaceous material

GASCOYNE SUB-BASIN (Continued)

AGE	UNIT	PENDOCK No. 1 Depth(m) K.B.	Thickness (m)	LITHOLOGY
LOWER CRETACEOUS	Windalia Radiolarite	968	38	Siltstone and radiolarite, light to medium grey, mottled in parts with occasional white specks (bentonite?)
	Muderong Shale	1006	16	Shale grading to siltstone with abundant thin interbeds of fine grained, glauconitic sandstone
	Birdrong Fm.	1022	8	Sandstone, light grey, fine-medium grained, slightly calcareous and glauconitic with abundant intergranular pyrite. Sand is loose and friable with excellent porosity and permeability
		UNCONFORMITY		
CARBONIFEROUS	Moogooree Fm.	1030	77	Dolomite with minor thin interbeds of shale
		UNCONFORMITY		
DEVONIAN	Gneudna Fm.	1107	182	Unit 'A': limestone, very fossiliferous, argillaceous in parts and dolomitic in streaks, trace vuggy porosity, interbedded with thin shale beds
		1289	320	Unit 'B' (reefal): dolomite, dense, argillaceous in parts with traces of pyrite and black carbonaceous material, fossiliferous with fossil components typical of those which characterise the Devonian Reef Complex of Western Canada; occasional thin shaley stringers
		1609	1656	Unit 'C': limestone, argillaceous or chalky in streaks, fossiliferous, dolomitic in parts, poor porosity and permeability

GASCOYNE SUB-BASIN (Continued)

AGE	UNIT	PENDOCK No. 1 Depth(m) K.B.	Thickness (m)	LITHOLOGY
	Nannyarra Greywacke	1665	185	Sandstone, generally fine-grained, poorly sorted, glauconitic in part with traces of biotite and pyrite poor to fair porosity, poor permeability, with minor interbeds of siltstone and shale
		UNCONFORMITY		
		1850	342	Unit 'A'" dolomite and anhydrite with thin interbeds and lenses of siltstone, sandstone and shale; dolomite has poor porosity and permeability
SILURIAN	Dirk Hartog Fm.	2192	95	Unit 'B'" sandstone with traces of siltstone and shale; sandstone has poor porosity and permeability; slight trace of oil staining observed near top of unit
		2286	215+	Unit 'C': dense dolomite with minor amounts of anhydrite
	TOTAL DEPTH	2501		

Notes

1) No significant hydrocarbon shows. Interval from 1716 m to 1722 m showed light brown, live oil staining. This interval appeared to be a tight zone between two more porous, flushed sandstone units. Only other show of hydrocarbons was some faint, light brown staining in a fine to very fine-grained sandstone from 2195 m to 2201 m
2) Jurassic and/or Triassic sediments absent; it appears that thepinchout or erosional edge of these sediments occurs somewhere between Pendock No. 1 and Whaleback No. 1 wells

(from GENOA OIL N.L., 1970)

GASCOYNE SUB-BASIN

AGE	UNIT	KALBARRI NO. 1 Depth(m)K.B.	Thickness(m)	LITHOLOGY
QUARTERNARY (Pleistocene)	Coastal Limestone	Surface(4)	16+	Surface sand grading into soft sandstone with calcareous cement, numerous crynoid fragments
UPPER CRETACEOUS (Camponian) (Santonian)	Toolonga Calcilutite	20	104	Sandstone, glauconitic calcareous mudstone, soft chalky calcilutite, bryozoa fragments common
LOWER CRETACEOUS (Aptian)	Winning Group Birdrong Sandstone	124	58	Grey sandstone, interbedded siltstone, some bryozoa and shell fragments, glauconites in basal parts
SILURIAN (Ludlovian-Llandoverian)	Dirk Hartog Formation	182	90	Finely interbedded argillaceous dolomite and dolomitic shale, some sandstone beds.
SILURO-ORDOVICIAN (Llandoverian-Ashgillian)	Tumblagooda Sandstone	272	1268+	Largely pink to red-brown sandstone with thin beds of shale, siltstone, and anhydrite
		T.D. 1540		

Notes

No indications of hydrocarbons.

(from OCEANIA PETROLEUM PTY LTD, 1973)

DAMPIER SUB-BASIN (RANKIN PLATFORM)

	AGE	UNIT	Goodwyn No. 1 Depth(m)R.T.	Thickness(m)	LITHOLOGY
					No samples taken
			465		
	Pliocene to Middle Miocene	Trealla equivalent	111	1033	Dominantly calcarenite with interbedded calcirudite, sandstone, dolomite, calcisiltite and marl
			1498		
	Lower Miocene (Burdigalian)			27	Dominantly calcilutite overlain by calcarenite
			1525		
	(Aquitanian)			286	Dominantly calcisiltite with interbeds of calcilutite and marl
			1811		
TERTIARY	Oligocene			157	Dominantly calcilutite with interbeds of calcisiltite and marl
			1968		
	Eocene (Upper)	Giralia equivalent		93	Dominantly calcilutite with interbeds of calcisitite and marl
			2061		
	(Middle)			70	Dominantly marl overlain by calcilutite and calcisiltite
			2131		
	(Lower)	Cardabia Group equiv.		182	Dominantly marl with interbedded claystone
			2313		
	Paleocene			151	Dominantly calcilutite with interbedded calcisiltite overlying marl
			2464		

	AGE	UNIT	Goodwyn No. 1 Depth(m)R.T.	Thickness(m)	LITHOLOGY
	Maestrichtian to Campanian	Miria Marl equiv.		151	Dominantly marl with interbedded calcareous claystone
			2615		
	Santonian	Toolonga Calcilutite equiv.		67	Dominantly calcilutite with interbedded marl
			2682		
CRETACEOUS	Coniacian			12	Calcilutite overlying marl
			2694		
	Turonian			16	Calcarenite overlying marl
			2710		
	Cenomanian			27	Dominantly marl
			2737		
	Albian			37	Marl
			2774		
	Aptian			9	Claystone
			2783		
	Neocomian	Birdrong equiv.		14	Claystone, glauconitic at base
			2797		
	Upper			469	Dominantly claystone interbedded with sandstone
TRIASSIC	?	?	3266	?	?
	Middle(?)			270	as above
			T.D. 3536		

DAMPIER SUB-BASIN (RANKIN PLATFORM) (Continued)

Notes

1) Produceable gas and condensate occurs in the Upper Triassic sandstones between 2797 and 3175 m. Hydrocarbons were present in the Toolonga Calcilutite equivalent but the formation was too tight to warrant testing.
2) Barrow Beds are absent in this well.
3) All Jurassic sediments are absent as at Rankin No. 1 and North Rankin No. 1.

(from BOCAL, 1972)

DAMPIER SUB-BASIN (RANKIN PLATFORM)

AGE	UNIT	EAGLEHAWK NO. 1 Depth(m)R.T.	Thickness(m)	LITHOLOGY
		13		Sea level
		133		Sea bed
TERTIARY (Pliocene)				No samples
(M. Miocene)		429	1226	Sandstone, calcerenite, calcirudite, dolomite
(M. Miocene)		1359		Calcarenite, calcisiltite
			251	
(Burdigalian)				Calcilutite, marl
		1610		
(Aquitanian)			103	Calcisiltite, calcilutite, marl
(Basal Aquitanian)			85	Calcilutite
(Upper Oligocene)				
		1798		
(Oligocene)			322	Calcisiltite, marl, Claystone
		2120		
(U.&M. Eocene)	Giralia			Calcilutite, claystone, chert
		2230		
(L. Eocene)			201	Marl, claystone
	Cardarbia	2431		
				Marl, claystone
(U. Paleocene)			134	
				cal€ilutite
	Group	2565		
(Basal U. Pal)			17	Marl, claystone
(M. Paleocene)				Glauconitic sandstone
		2582		

DAMPIER SUB-BASIN (RANKIN PLATFORM) (Continued)

AGE	UNIT	EAGLEHAWK NO. 1 Depth(m)R.T.	Thickness(m)	LITHOLOGY
UPPER CRETACEOUS (U. Maestrightian)			23	Calcilutite, marl
(U. - M. Maestrichtian)	Miria	2605	15	Marl, claystone
		2620		
(L. Maest.)	Marl		59	Marl, claystone
		2679		
(U. Campanian)			22	Marl
		2701		
(L. Campanian)	Toolonga		9	Calcilutite
		2710		
(Santonian)	Calcilutite		3	Calcilutite
		2713		
(Basal Santonian)			4	Calcilutite, marl
		2717		
(Coniacian)			8	Calcilutite, marl
		2725		
(Turonian)	Winning		6	Calcilutite, marl
		2731		
(U. & M. Cenomanian)	Group		6	Calcilutite, marl
		2737		
(Basal Cenomanian) (Albian)			3	Calcilutite, marl
		2740		

AGE	UNIT	EAGLEHAWK NO. 1 Depth(m)R.T./Thickness(m)		LITHOLOGY
LOWER CRETACEOUS (Aptian) (Neocomian)	Winning Group		10	Claystone
UPPER TRIASSIC (Rhaeto-Norian)	Mungaroo Beds	2750	740	Sandstone, claystone Siltstone, coal
		T.D. 3490		

Notes

The uppermost Triassic section contained crude oil with a specific gravity between 29.3° and 30° A.P.I.. On drill-stem testing between 2750 m and 2766 m oil was produced at a rate of 1645 b.p.d. accompanied by gas at a rate of 0.141 MMCFD through 3/4 inch bottom hole and 5/8 inch surface chokes.

(from BOCAL, 1973)

DAMPIER SUB-BASIN (Rankin Platform)

	AGE	(EQUIVALENT) *UNIT	EGRET NO. 1 Depth(m)R.T.	Thickness(m)	LITHOLOGY
SEA LEVEL			13		
SEA BED			131		
	Burdigalian To Pliocene		442	1233	No samples Calcarenite, sandstone, dolomite
			1364		
	Burdigalian			190	Calcarenite, calcilutite, calcisilite
			1553		
	Aquitanian			154	Calcilutite, calcisilite
			1707		
TERTIARY	Oligocene	Cape Range Gp		358	Calcisilite, calcilutite and minor calcarenite, marl, claystone
			2065		
	Upper & Middle Eocene			71	Calcilutite with 15-40% chert
		Giralia	2136		
	Middle Eocene			9	Claystone
			2145		
	Lower Eocene			211	Marl, claystone
			2356		
	Upper Paleocene	Cardabia Group	2493	137	Marl, minor calcilutite & claystone
	Basal U. Pal. Mid-Paleocene			96	Marl, minor claystone Siltstone & glauconitic sandstone
			2589		

DAMPIER SUB-BASIN (Rankin Platform) (Continued)

	AGE	(EQUIVALENT) *UNIT	EGRET NO. 1 Depth (m) R.T.	Thickness (m)	LITHOLOGY
	Upper Maestrichtian		2616		Calcilutite, marl, claystone
	Upper - Middle Maestrichtian	Miria	2629	13	Marl, claystone
UPPER	Lower Maestrichtian	Marl	2708	79	Marl, minor claystone
CRETACEOUS	Upper Campanian		2758	50	Marl
	Lower Campanian	Toolonga Calcilutite	2771	13	Calcilutite
	Santonian		2804	33	Calcilutite
	Basal Santonian		2816	12	Calcilutite, marl
	Coniacian		2833	17	
	Turonian	Winning	2844	11	Marl
	Upper & Middle Cenomanian		2868	24	Marl

DAMPIER SUB-BASIN (Rankin Platform) (Continued)

AGE		(EQUIVALENT) *UNIT	EGRET NO. 1 Depth(m)R.T.	Thickness(m)	LITHOLOGY
	Basal Cenomanian Albian	Group		38	Calcilutite, marl
			2906		
LOWER	Aptian and Upper Neocomian			75	Claystone
			2981		
CRETACEOUS	Lower Neocomian	Legendre		114	Claystone, minor siltstone
			3095		
UPPER JURASSIC	Tithonian	Fm.		203	Sandstone claystone, minor siltstone
			3298		
UPPER TRIASSIC	Rhaeto-Norian	Mungaroo Beds	T.D.	360	Sandstone, claystone
			3658		

Notes

1) *Unit names have been interpreted from the ages and lithologies supplied by the Company.
2) Crude oil at 39° A.P.I. gravity was recovered from the top sand in the Tithonian section, the first occurrence of oil in Upper Jurassic sediment in the Dampier sub-basin. On drill-stem testing between 3119 m and 3129 m oil was produced at a rate of 2729 b.p.d. accompanied by gas at a rate at 2.37 MMCFD through a 3/4" surface hole.

(from BOCAL, 1973)

DAMPIER SUB-BASIN (Legendre-Rosemary Trend)

AGE	UNIT	ROSEMARY NO. 1 Depth(m)K.B.	Thickness(m)	LITHOLOGY
		10		Sea level
			64	
		74		Sea bed
			397	No samples recovered
		471		
CRETACEOUS (Lower Maestrichtian)	Miria		552	Sandstone & claystone with minor dolomite
		1023		
(Campanian)	Marl		75	Claystone
		1098		
(Cenomanian)	Winning Group		186	Claystone with minor coal
		1284		
(Cenomanian-Albian)			202	Claystone
		1486		
(Aptian)			342	Claystone with minor sandstone
		1828		
(Basal Aptian-Neocomian)			119	Sandstone with minor claystone
		1947		
(Upper Neocomian)			213	Claystone with minor sandstone and dolomite
		2160		
(Lower Neocomian)	Barrow Beds		47	Claystone with minor sandstone
		2207		

DAMPIER SUB-BASIN (Legendre-Rosemary Trend)

AGE	UNIT	ROSEMARY NO. 1 Depth(m)K.B./Thickness(m)	LITHOLOGY
JURASSIC (Upper Tithonian)	Barrow Beds	71	Sandstone
		2278	
(Lower Tithonian)	"Dampier"	125	Sandstone
		2403	
(Kimmeridgian)	Beds	49	Sandstone
		2452	
(Kimmeridgian -Oxfordian)		159	Claystone with minor sand- stone
		2611	
(Oxfordian)	"Legendre" Beds	87	Claystone and siltstone with minor sandstone
		2698	
(Callovian)		421	Claystone with minor silt- stone and sandstone
		3119	
(Callovian- Bathonian)	"Legendre" Beds	23	Claystone siltstone and sandstone
		3142	
(Bathonian- Bajocian)	"Enderby"	266	Sandstone, claystone and siltstone with minor coal
		3368	
(Toarcian)	Beds	541	Sandstone with interbedded claystone & siltstone with minor coal
		T.D. 3909	

DAMPIER SUB-BASIN (Legendre-Rosemary Trend)

Notes

Well-developed potential reservoirs were intersected in sandstone of Tithonian to Kimmeridgian age below a potential seal of Neocomian claystone. High gas readings were obtained during drilling but five Formation Interval Tests and electric log interpretation showed all zones to be water-bearing.

(from BOCAL, 1973)

DAMPIER SUB-BASIN (De Grey Nose)

AGE	HAUY NO. 1 Depth(m)R.T.	Thickness(m)	LITHOLOGY
	30		Sea level
	96		Sea bed
			No samples prior to running marine riser
	259		
AGE INDETERMINATE		107	Dominantly claystone with interbedded dolomite and minor sandstone overlying limestone
	366		
		126	No returns probably limestones?
?	492	?	?
UPPER CRETACEOUS (Albian)		63	Dominantly claystone and siltstone with minor sandstone
	555		
LOWER CRETACEOUS (Aptian) ?	556	?	
	592	63	
?	619	?	Dominantly sandstone with interbedded siltstone underlying greensand
(U. Neocomian)		61	
	680		
M. TRIASSIC			Dominantly claystone with minor sandstone and siltstone
	782		
?	791	?	
	793		Dominantly sandstone with minor claystone

DAMPIER SUB-BASIN (De Grey Nose)

AGE	HAUY NO. 1 Depth(m)R.T./Thickness(m)		LITHOLOGY
L. TRIASSIC	– ? 794 – – – – ? – – – – ? – – – – ? – –	11	
	805		
AGE INDETERMINATE	T.D. 825	20	Altered fine to medium-grained basic igneous rocks

Notes

1) No hydrocarbons were detected

2) In other wells drilled in the basin the contact between the Albian and the Aptian is unconformable

(from BOCAL, 1973)

BEAGLE SUB-BASIN

AGE	*UNIT	COSSIGNY NO. 1 Depth(m)R.T./Thickness(m)		LITHOLOGY
		125(sea bed)		
				No samples before running marine riser
		433		
TERTIARY (Pliocene-U. Miocene)			128	Dominantly calcisilite with calcilutite, calcarenite and minor dolomite
		561		
		625		
(U. - M. Miocene)			326	Dominantly dolomite with calcarenite, calcilutite, calcisiltite, recrystallised limestone and minor sandstone
		887		
(M. Miocene-Burdigalian)			188	
		1075		
(U. - M. Eocene)	Giralia		139	Calcisiltite and calcilutite with beds of chert
		1214		
(L. Eocene)	Cardabia		65	
		1279		
(Basal U. - M. Paleocene)	Grp		52	Marl and claystone with minor calcisiltite and calcilutite
		1331		
CRETACEOUS (L. Maestrichtian -Campanian)	Miria Marl		246	
		1577		

BEAGLE SUB-BASIN

AGE	*UNIT	COSSIGNY NO. 1 Depth(m)R.T.	Thickness(m)	LITHOLOGY
(Santonian)	Toolonga Calcilutite		69	Calcilutite
		1646		
(Basal Santonian -Turonian)	Winning Grp		151	Claystone and minor marl
		1797		
M. JURASSIC	Legendre Fm		318	Dominantly massive sandstones, dominantly fine-grained and moderately sorted, with minor claystone siltstone and coal
		2115		
L. JURASSIC (Toarcian)			179	
		2294		
EARLY U. TRIASSIC	Mungaroo Beds		446	
		2740		
		2874		
M. TRIASSIC				Dolomite and recrystallised limestone
		2940	464	Dominantly sandstone with claystone and siltstone and minor coal
		T.D. 3204		

Notes

1)* Unit names have been interpreted from the ages and lithologies supplied by the Company.
2) No significant hydrocarbons were recorded in this well and wireline logs indicate that the entire section penetrated was water-saturated.

(from BOCAL, 1972)

BEAGLE SUB-BASIN

	AGE	*UNIT	RONSARD NO. 1 Depth(m)R.T.	Thickness(m)	LITHOLOGY
	SEA BED		170		
				325	No samples before installing the marine riser
			495		
	Lower Pliocene			158	Calcilutite
			653		
	Upper Miocene to Burdigalian			696	Calcarenite, dolomite
			1349		
	Aquitanian			279	Calcarenite, calcilutite with minor clacisilite
			1628		
	Oligocene	Caperange Gp.		57	Calcarenite, calcilutite
			1685		
TERTIARY	Upper to Middle Eocene	Giralia		126	Calcilutite, calcisilite
	?	?	1811	?	?
	Lower Eocene			19	Marl, claystone
			1830		
	Upper Paleocene	Cardabia		25	Marl, claystone
			1855		
	Middle Paleocene	Group		65	Marl
			1920		

<u>BEAGLE SUB-BASIN</u>

	AGE	*UNIT	RONSARD NO. 1 Depth(m)R.T./Thickness(m)	LITHOLOGY
	Lower Paleocene		39	Marl, claystone
			1959	
	Upper Maestrichtian	Miria Marl	47	Marl, claystone
			2006	
	Lower Maestrichtian		34	Marl, claystone
			2040	
UPPER CRETACEOUS	Campanian	Toolonga Calcilutite	155	Claystone, marl, calcilutite
			2195	
	Santonian		20	Calcilutite
			2215	
	Coniacian	Winning	10	Marl
			2225	
	Albian	Group	31	Claystone, marl, calcilutite
			2256	
LOWER CRETACEOUS	Early Aptian to Late Neocomian		38	Claystone
			2294	
LOWER JURASSIC	Toarcian	Legendre	472	Sandstone, claystone
			2766	
	Pre-Toarcian	Fm.	82	Sandstone, claystone
			T.D. 2848	

BEAGLE SUB-BASIN

Notes

1) *Unit names have been interpreted from the ages and lithologies supplied by the Company.

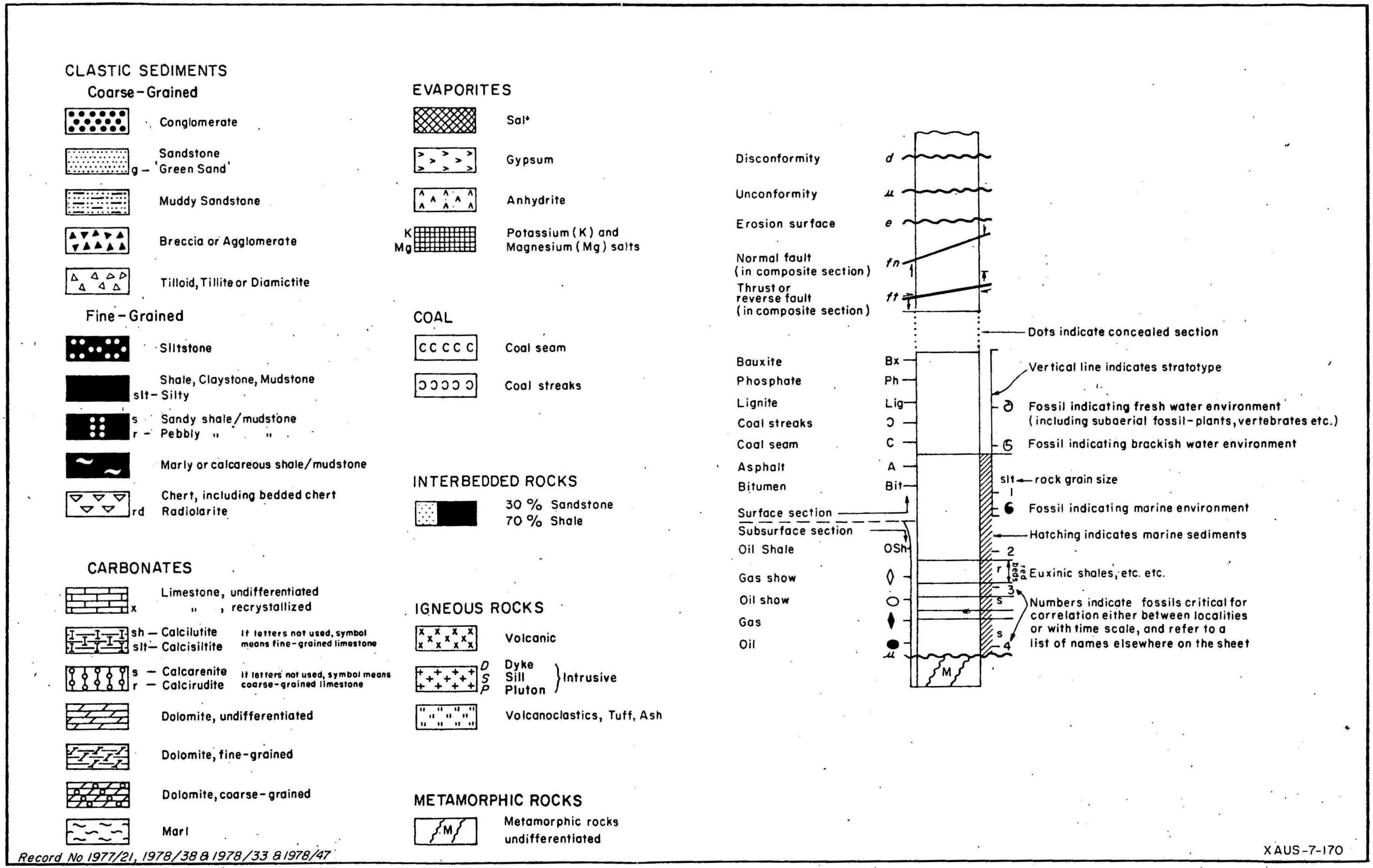
2) No significant hydrocarbon shows were recorded.

3) Thirty-eight metres of Lower Cretaceous (early Aptian-Late Neocomian) sediments were penetrated in Ronsard No. 1, indicating that inundation of the block occurred at a time earlier than at Sable No. 1 or Cossigny No. 1.

4) A regional unconformity (nominated seismic event 'F') which has only been previously recorded in the Beagle Sub-basin in Picard No. 1 separates sediments of Albian and Aptian age.

5) The intra-Upper Cretaceous unconformity has not been recorded previously in the Beagle Sub-basin.

(from BOCAL, 1973)



Standard Legend for Stratigraphic Columns.


PLATE 1A
CARNARVON BASIN NORTH
SIMPLIFIED GEOLOGY
0 20 40 60 80 100km
Quaternary
Tertiary
Precambrian
Well - dry, abandoned
Oil well
Oil well-abandoned
Well with show of oil-abandoned
Well with show of gas-abandoned
Oil and gas well-abandoned
Well with show of oil and gas-abandoned
Gas condensate well-abandoned
200m Bathymetric contour
112° 113° 114° 115° 116° 117° 118° 119°
18° 19° 20° 21°
1000m
200m
Depuch I
Picard I
Ronsard I
Sable I
Corsigny I
Poissonnier I
Egret I
Lambert I
Angel 2
Angel 1
Angel 3
De Grey I
North Rankin 3
Eaglehawk I
North Rankin 2
North Rankin 4
North Rankin I
Nelson Rocks I
Legendre 2
Legendre I
Madeleine
Goodwyn 2
Goodwyn 4
Goodwyn I
Goodwyn 3
Tidepole I
Malus
Rankin I
Dockrell I
Hauy I
Dampier I
Lowendall I
Rosemary I
North Tryal Rocks I
Hampton I
Enderby I
West Tryal Rocks 2
West Tryal Rocks I
Tryal Rocks I
Trimouille 1,1A,1B
Monte Bello Islands
Flag I
Port Hedland
pЄ
Dampier
Yule River
Turner River
Flacourt I
BARROW ISLAND
BARROW OILFIELD
Biggada I
Barrow Deep I
Stokes Point I
Pasco 1,2,2A,3
Sholl Island I
Record No. 1977/21 & 1978/47
XAUS-7-39


CARNARVON BASIN SOUTH
SIMPLIFIED GEOLOGY
0 20 40 60 80 100 km
Quaternary
Tertiary
Cretaceous
Jurassic
Permian
Carboniferous
Ordovician - Silurian
Precambrian
Well - dry, abandoned
Oil well - abandoned
Well with show of gas - abandoned
Stratigraphic hole
200m Bathymetric contour
EXMOUTH GULF
North West Cape
Onslow
Thevenard Island
Muiron Island
Long Island
Carnarvon
GASCOYNE RIVER
BERNIER ISLAND
DORRE ISLAND
SHARK BAY
DIRK HARTOG ISLAND
PERON PENINSULA
Faure Island
Kalbarri
HARDABUT FAULT
DARLING FAULT
MURCHISON RIVER
PERTH BASIN
GERALDTON
HOUTMAN ABROLHOS
Wallabi Group
Easter Group
Pelsart Group
BMR 9 (Daurie Creek)
BMR 8 (Mt Madeline)
XAUS-7-40

PLATE 2A

Record No 1977/21
1978/47

— -20 — Bouguer anomaly contour
· Gravity station
— — 200m — — Bathymetric contours

Note: The Bouguer anomaly contours shown are subject to change, particularly offshore where control is sparse. In the offshore area no correction has been made for the water layer.

CARNARVON BASIN NORTH
GRAVITY ANOMALIES
1:1 000 000

0 20 40 60 80 100 km

XAUS-7-33

PLATE 2B

Record No 1977/21 & 1978/47

—— -20 —— Bouguer anomaly contour
· Gravity station
— — 200m — — Bathymetric contour

Note: The Bouguer anomaly contours shown are subject to change, particularly offshore where control is sparse. In the offshore area no correction has been made for the water layer.

CARNARVON BASIN SOUTH
GRAVITY ANOMALIES
1:1 000 000

0 20 40 60 80 100 km

XAUS-7-34


PLATE 3A
CARNARVON BASIN NORTH
MAGNETIC TRAVERSES AND AEROMAGNETIC COVERAGE
1:1000 000
0 20 40 60 80 100 km
Survey numbers: For key to names see Appendix 2
Areas bounded by hatchuring represent aeromagnetic surveys
(aeromagnetic traverses not shown)
200m Bathymetric contour
14
13
12
8
1000m
200m
Monte Bello Islands
AREA 6
BARROW ISLAND
Dampier
Port Hedland
Yule River
Turner River
Record No 1978/47
XAUS-7-37
112°
113°
114°
115°
116°
117°
118°
119°
18°
19°
20°
21°

PLATE 3B
AREA 6
AREA 4
AREA 1
AREA 3
AREA 1
AREA 2
AREA 7
AREA 1
AREA 2
AREA 1
AREA 3
AREA 4
AREA 5
AREA 9
Thevenard Island
Long Island
Onslow
Muiron Island
North West Cape
EXMOUTH GULF
Robe River
Ashburton River
LAKE McLEOD
BERNIER ISLAND
DORRE ISLAND
Carnarvon
GASCOYNE RIVER
SHARK BAY
DIRK HARTOG ISLAND
PERON PENINSULA
Faure Island
MURCHISON RIVER
Kalbarri
HOUTMAN ABROLHOS
Wallabi Group
Easter Group
Pelsart Group
GERALDTON
14
12
8
7
5
11
10
4
1000m
200m
CARNARVON BASIN SOUTH
MAGNETIC TRAVERSES AND AEROMAGNETIC COVERAGE
1:1000 000
0 20 40 60 80 100 km
Survey numbers: For key to names see Appendix 2
Area bounded by hatching represent aeromagnetic surveys
(aeromagnetic traverses not shown)
—200m— Bathymetric contour
Record No 1978/47
X AUS-7-38
111° 112° 113° 114° 115° 116° 117°
21° 22° 23° 24° 25° 26° 27° 28° 29°

PLATE 4

CARNARVON BASIN SOUTH

MAGNETIC BASEMENT DEPTH CONTOURS

1:1000 000

Record No. 1977/21 & 1978/47

XAUS-7-43


PLATE 5A
CARNARVON BASIN NORTH
SEISMIC SURVEY AND LINE LOCATIONS
1:1000 000
0 20 40 60 80 100km
Survey names: For key to numbers see Appendix 2
—200m— Bathymetric contour
112° 113° 114° 115° 116° 117° 118° 119°
18° 19° 20° 21°
1000m
200m
Monte Bello Islands
BARROW ISLAND
Dampier
Port Hedland
Yule River
Turner River
Record No 1978/47
XAUS-7-35


PLATE 5B
CARNARVON BASIN SOUTH
SEISMIC SURVEY AND LINE LOCATIONS
1:1000 000
0 20 40 60 80 100km
Survey names: For key to numbers see Appendix 2
200m Bathymetric contour
Record No 1978/47
XAUS-7-36
111° 112° 113° 114° 115° 116° 117°
21° 22° 23° 24° 25° 26° 27° 28° 29°
Thevenard Island
Long Island
Onslow
Muiron Island
North West Cape
EXMOUTH GULF
Robe River
Ashburton River
LAKE McLEOD
BERNIER ISLAND
DORRE ISLAND
Carnarvon
GASCOYNE RIVER
SHARK BAY
DIRK HARTOG ISLAND
PERON PENINSULA
Faure Island
MURCHISON RIVER
Kalbarri
Wallabi Group
HOUTMAN ABROLHOS
Easter Group
Pelsart Group
GERALDTON
1000m
200m

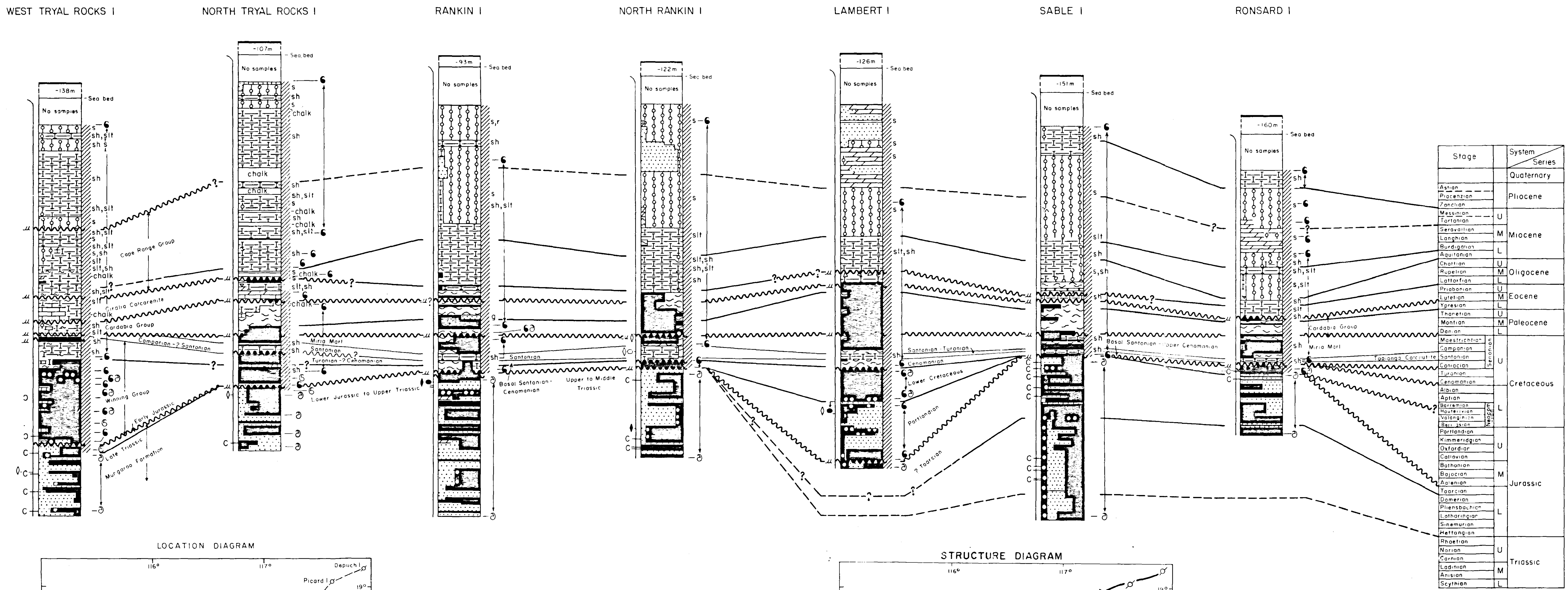
PLATE 6A


CARNARVON BASIN NORTH
REGIONAL SEISMIC DEPTH CONTOURS
1:1000 000
0 20 40 60 80 100 km
Fault
Seismic horizon change
3000 Depth below sea level (metres)
200m Bathymetric contour
STEAMBOAT Structure mapped by seismic
112° 113° 114° 115° 116° 117° 118° 119°
18° 19° 20° 21°
1000m
200m
Near base of Cretaceous
Near base of Cretaceous
Minor horizon change
Correlation doubtful
EAGLEHAWK
EGRET
LAMBERT
ANGEL
NTH RANKIN
GOODWYN
RANKIN
MALUS
BANK
STEAMBOAT
FINUCANE
SABLE
RONSARD
JARMAN
PICARD
DEPUCH
NORTH TURTLE
Monte Bello Islands
BARROW ISLAND
Dampier
Port Hedland
Yule River
Turner River
Record No 1978/47
XAUS-7-44

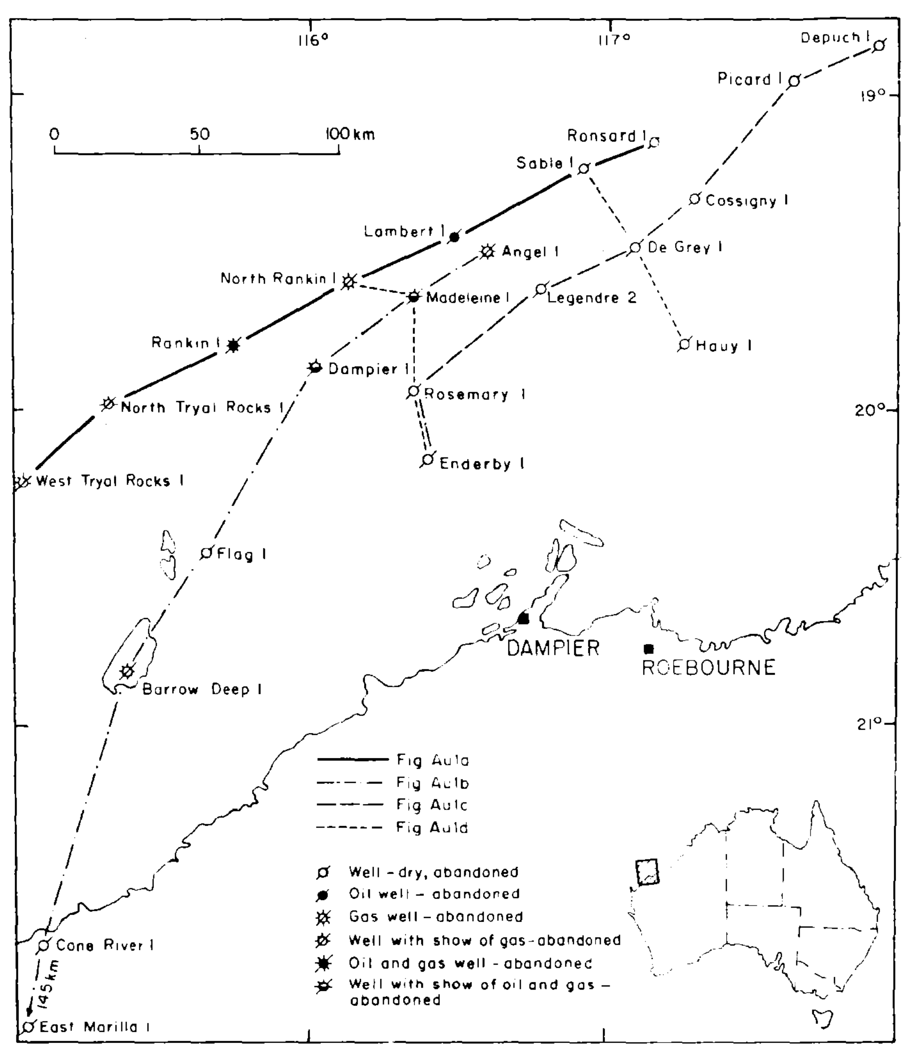

PLATE 6B
Near base of Cretaceous
Horizon truncated
Thevenard Island
Long Island
Onslow
Muiron Island
North West Cape
EXMOUTH GULF
Ashburton River
Robe River
Lower Palaeozoic
PENDOCK
FAULT ZONE
LAKE McLEOD
Top of Tumblagooda Sandstone (Silurian)
GASCOYNE RIVER
BERNIER ISLAND
Carnarvon
DORRE ISLAND
SHARK BAY
Correlation doubtful
DIRK HARTOG ISLAND
PERON PENINSULA
Faure Island
MURCHISON RIVER
Possible Mesozoic
Kalbarri
? Jurassic
Wallabi Group
HOUTMAN ABROLHOS
Easter Group
Pelsart Group
GERALDTON
CARNARVON BASIN SOUTH
REGIONAL SEISMIC DEPTH CONTOURS
1:1000 000
0 20 40 60 80 100 km
Fault
Seismic horizon change
3000 Depth below sea level (metres)
—200m— Bathymetric contour
PENDOCK Structure mapped by seismic
Record No 1978/47
XAUS-7-45

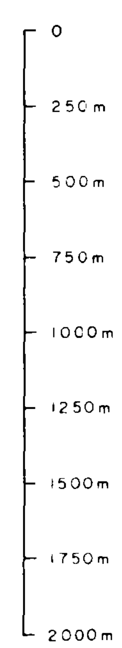
CARNARVON BASIN : WESTERN AUSTRALIA

ESCAP ATLAS OF STRATIGRAPHY (IGCP PROJECT No.32)



LOCATION DIAGRAM

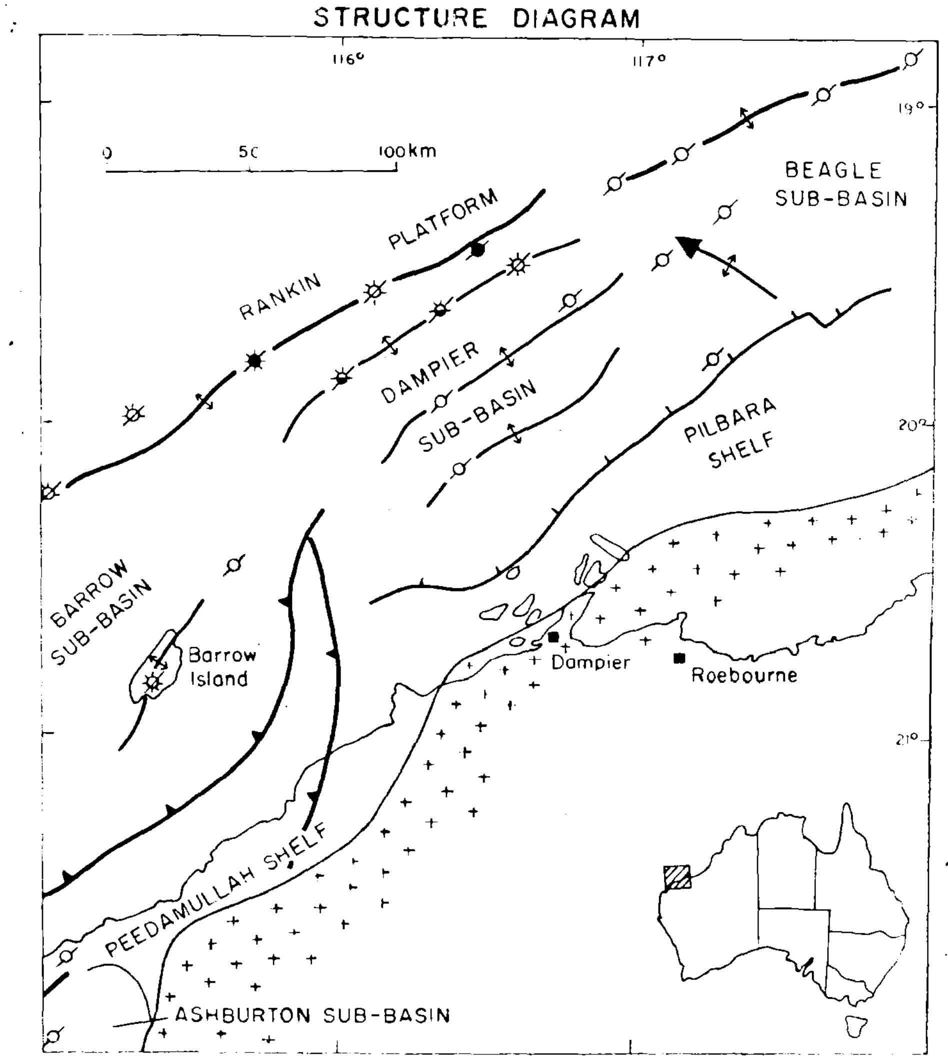




Vertical Scale
1 : 25000

● Oil discovery
♦ Gas discovery

STRUCTURE DIAGRAM



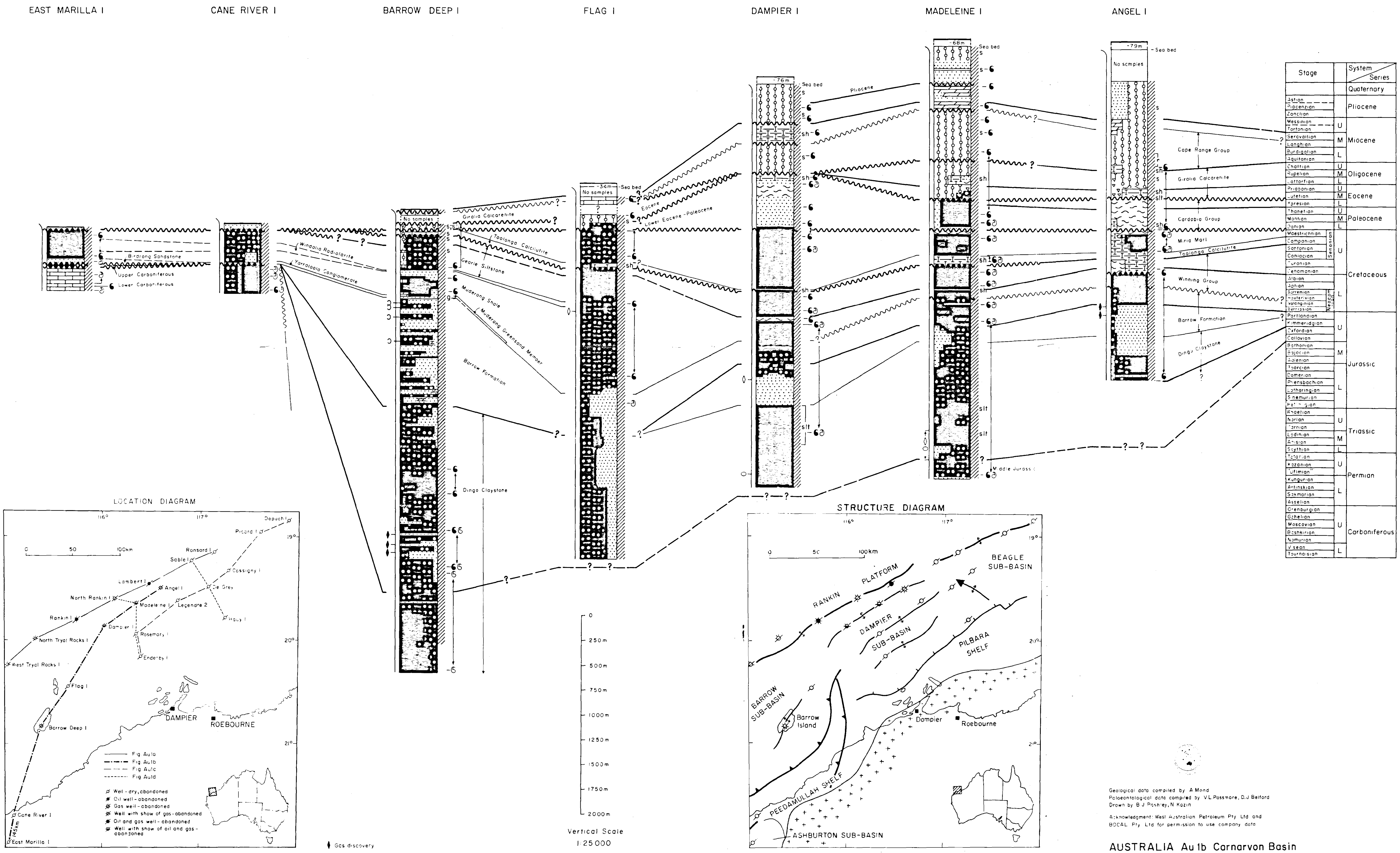
Geological data compiled by A Mond
Palaeontological data compiled by V.L Passmore, D.J Belford
Drawn by B.J Pashley, N Kozin

Acknowledgment: West Australian Petroleum Pty Ltd and BOCAL Pty Ltd for permission to use company data

AUSTRALIA Au 1a Carnarvon Basin

CARNARVON BASIN : WESTERN AUSTRALIA

ESCAP ATLAS OF STRATIGRAPHY (IGCP PROJECT No.32)



Geological data compiled by A.Mond
Palaeontological data compiled by V.L.Passmore, D.J Belford
Drawn by B J Pashley, N Kozin

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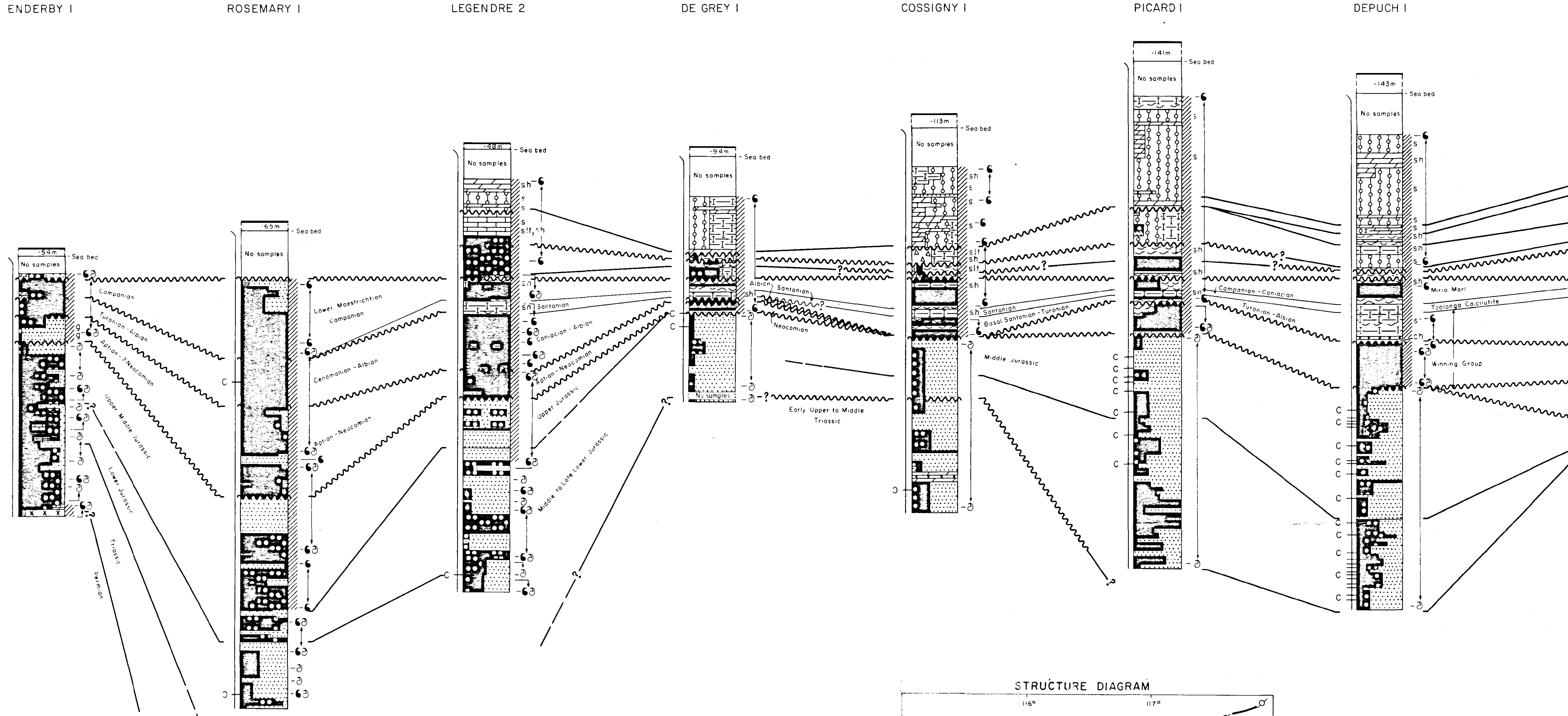
AUSTRALIA Au 1b Carnarvon Basin

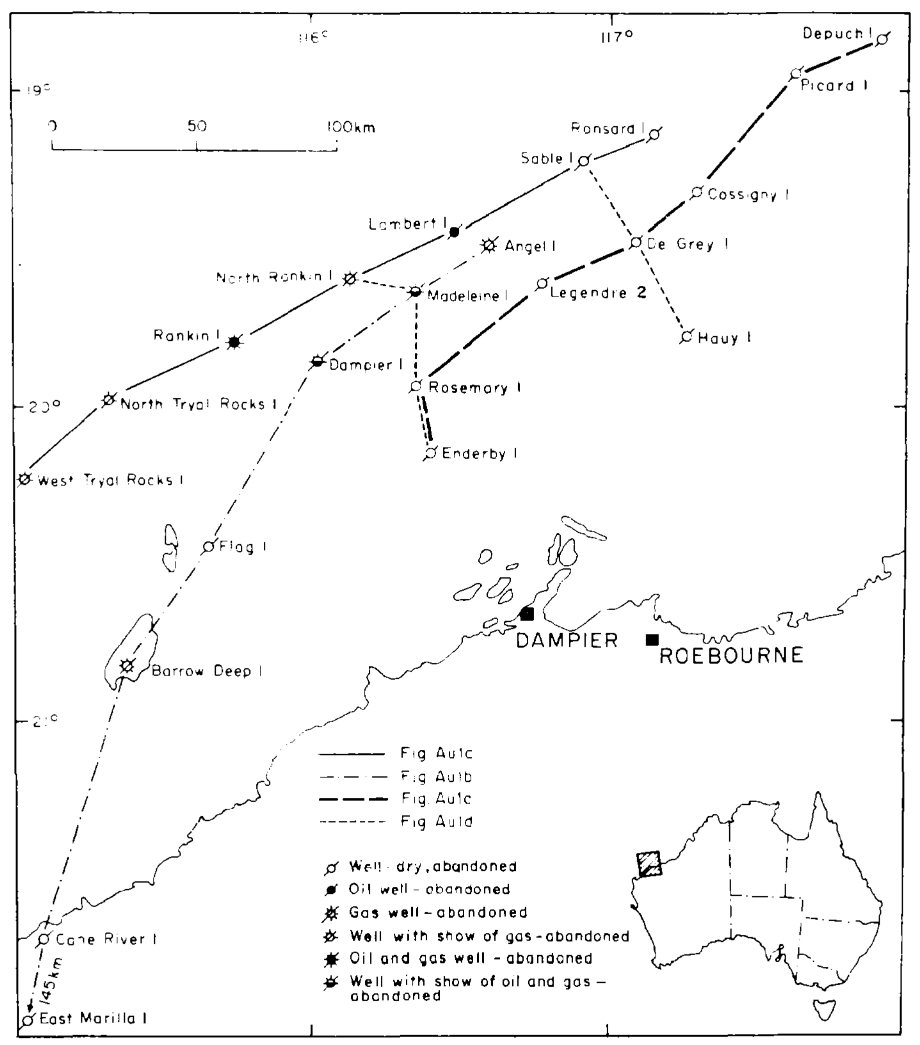
CARNARVON BASIN : WESTERN AUSTRALIA

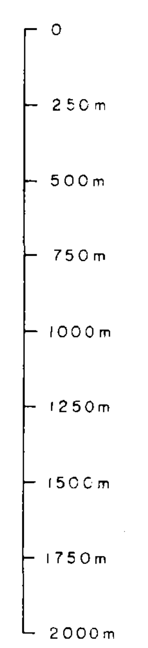
ESCAP ATLAS OF STRATIGRAPHY (IGCP PROJECT No.32)



Stage	Subdivision	Series	System
			Quaternary
Astian			Pliocene
Piacenzian			Pliocene
Zanclian			Pliocene
Messinian		U	Miocene
Tortonian		U	Miocene
Seravallian		M	Miocene
Langhian		M	Miocene
Burdigalian		L	Miocene
Aquitanian		L	Miocene
Chattian		U	Oligocene
Rupelian		M	Oligocene
Lattorfian		L	Oligocene
Priabonian		U	Eocene
Lutetian		M	Eocene
Ypresian		L	Eocene
Thanetian		U	Paleocene
Montian		M	Paleocene
Danian		L	Paleocene
Maestrichtian	Senonian	U	Cretaceous
Campanian	Senonian	U	Cretaceous
Santonian	Senonian	U	Cretaceous
Coniacian	Senonian	U	Cretaceous
Turonian		U	Cretaceous
Cenomanian		U	Cretaceous
Albian		L	Cretaceous
Aptian		L	Cretaceous
Barremian	Neocomian	L	Cretaceous
Hauterivian	Neocomian	L	Cretaceous
Valanginian	Neocomian	L	Cretaceous
Berriasian	Neocomian	L	Cretaceous
Portlandian		U	Jurassic
Kimmeridgian		U	Jurassic
Oxfordian		U	Jurassic
Callovian		U	Jurassic
Bathonian		M	Jurassic
Bajocian		M	Jurassic
Aalenian		M	Jurassic
Toarcian		L	Jurassic
Domerian		L	Jurassic
Pliensbachian		L	Jurassic
Lotharingian		L	Jurassic
Sinemurian		L	Jurassic
Hettangian		L	Jurassic
Rhaetian		U	Triassic
Norian		U	Triassic
Carnian		U	Triassic
Ladinian		M	Triassic
Anisian		M	Triassic
Scythian		L	Triassic
Tatarian		U	Permian
Kazanian		U	Permian
"Ufimian"		U	Permian
Kungurian		L	Permian
Artinskian		L	Permian
Sakmarian		L	Permian
Asselian		L	Permian

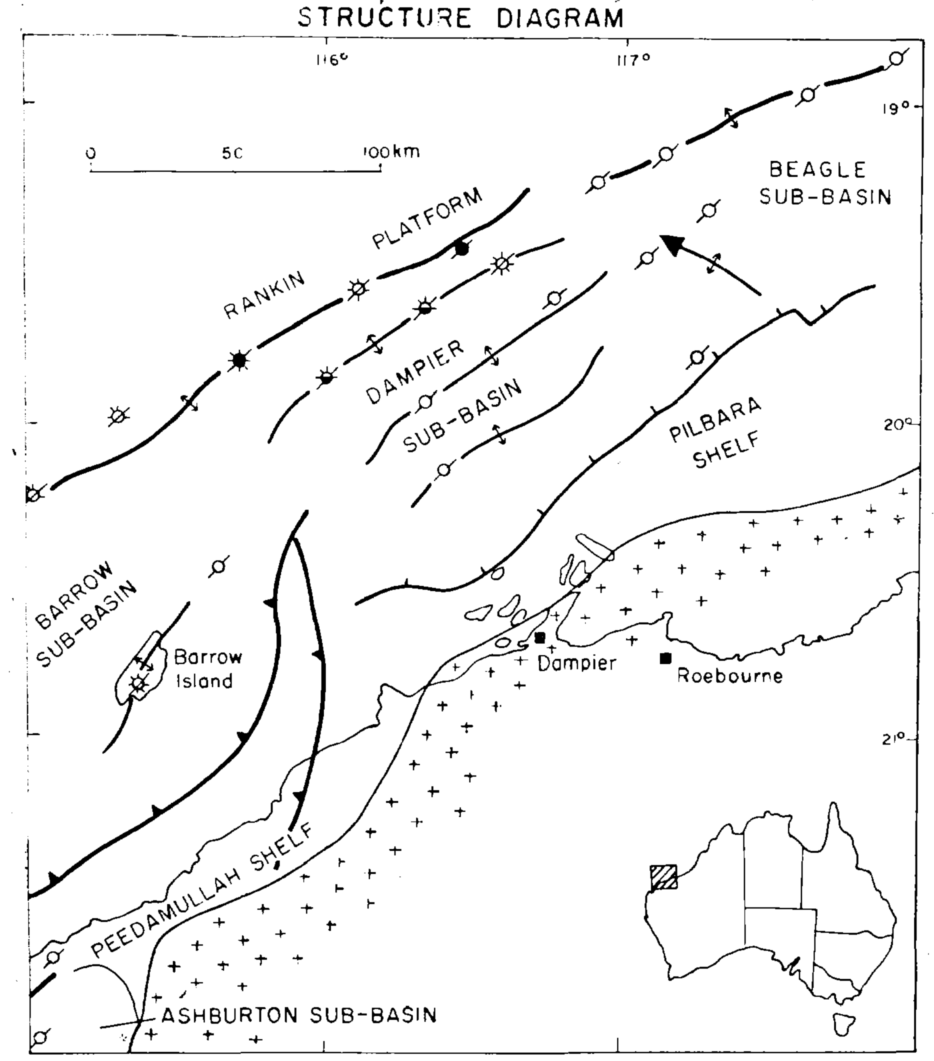
LOCATION DIAGRAM





Vertical Scale
1:25000

STRUCTURE DIAGRAM



1978/47
1978/33
Record No 1977/21

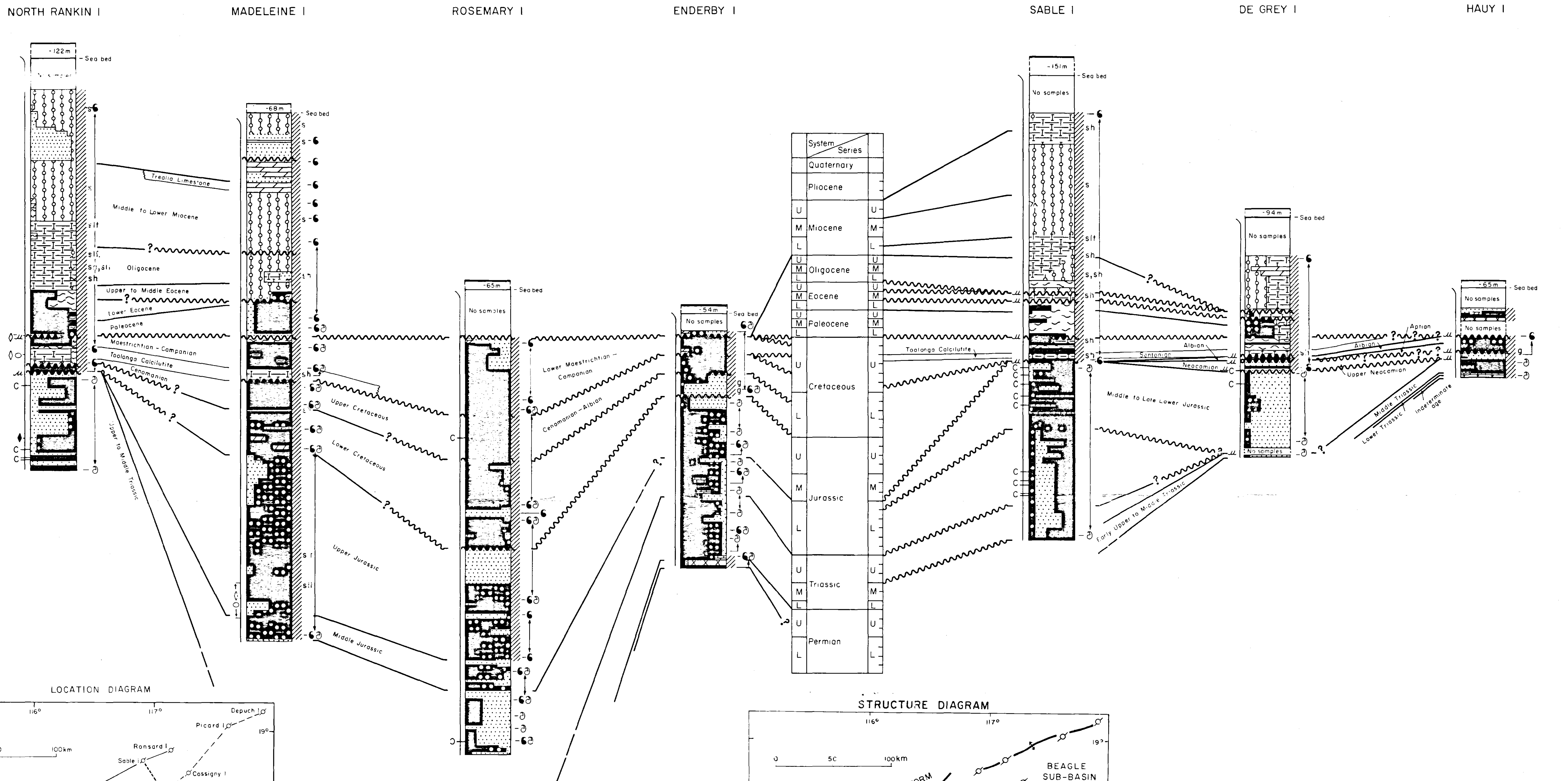
Geological data compiled by A. Mond
Palaeontological data compiled by V.L. Passmore, D.J. Belford
Drawn by B.J. Pashley, N. Kozin

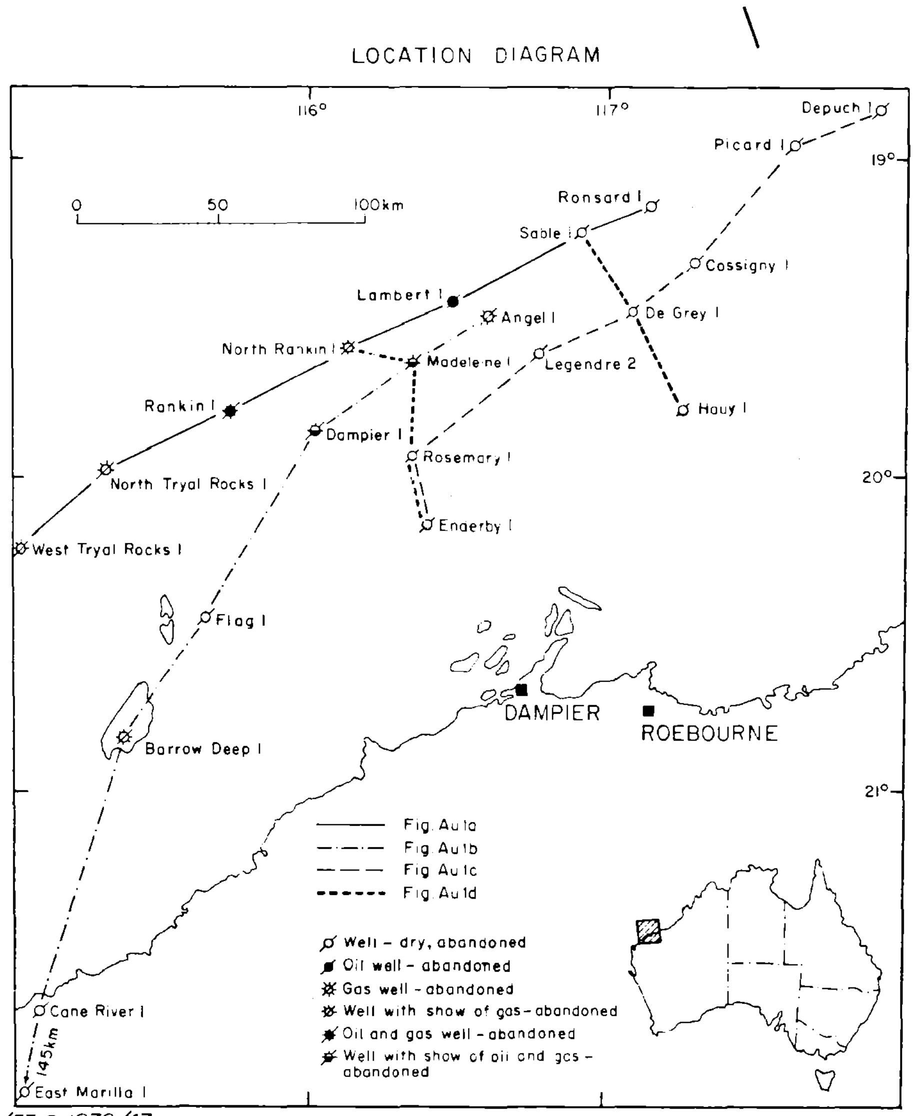
Acknowledgment: West Australian Petroleum Pty. Ltd and BOCAL Pty Ltd for permission to use company data

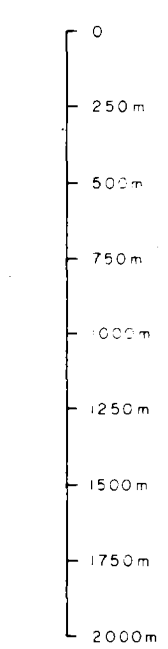
AUSTRALIA Au 1c Carnarvon Basin

CARNARVON BASIN : WESTERN AUSTRALIA

ESCAP ATLAS OF STRATIGRAPHY (IGCP PROJECT No.32)







Vertical Scale
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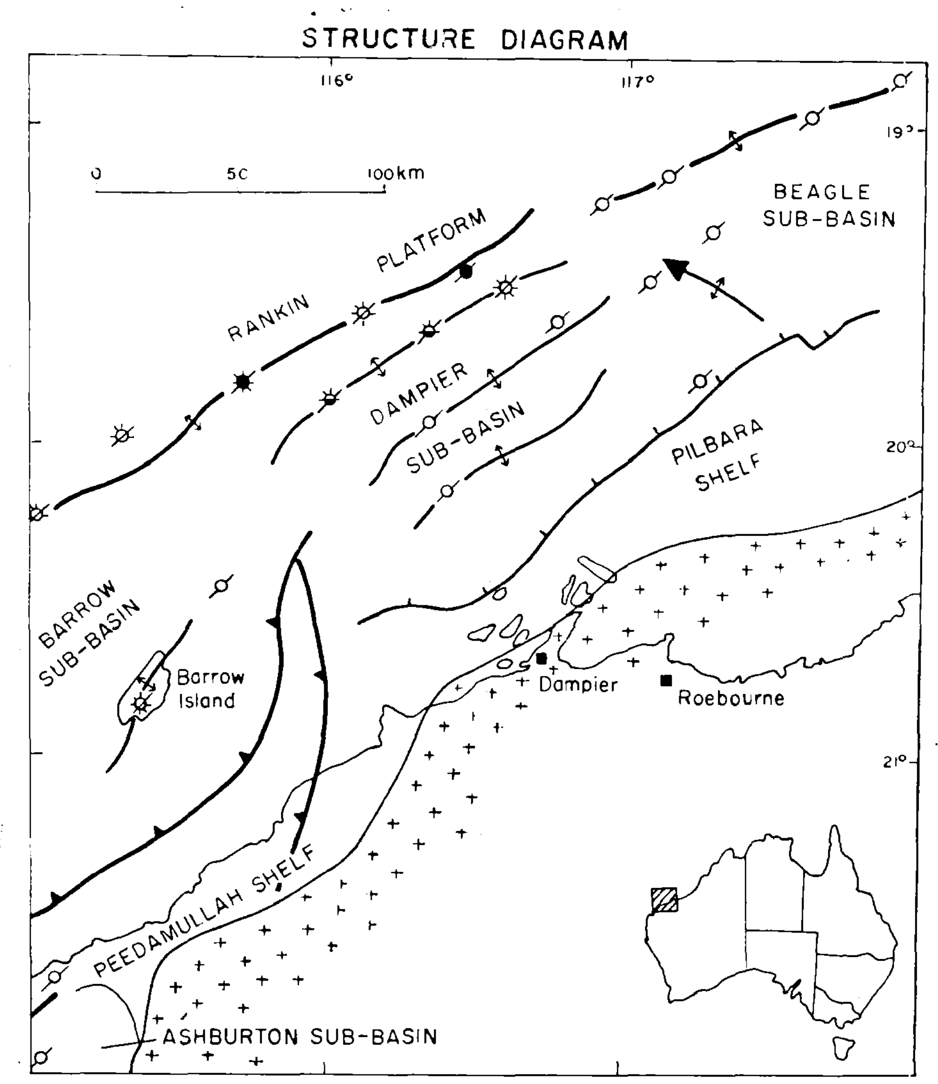
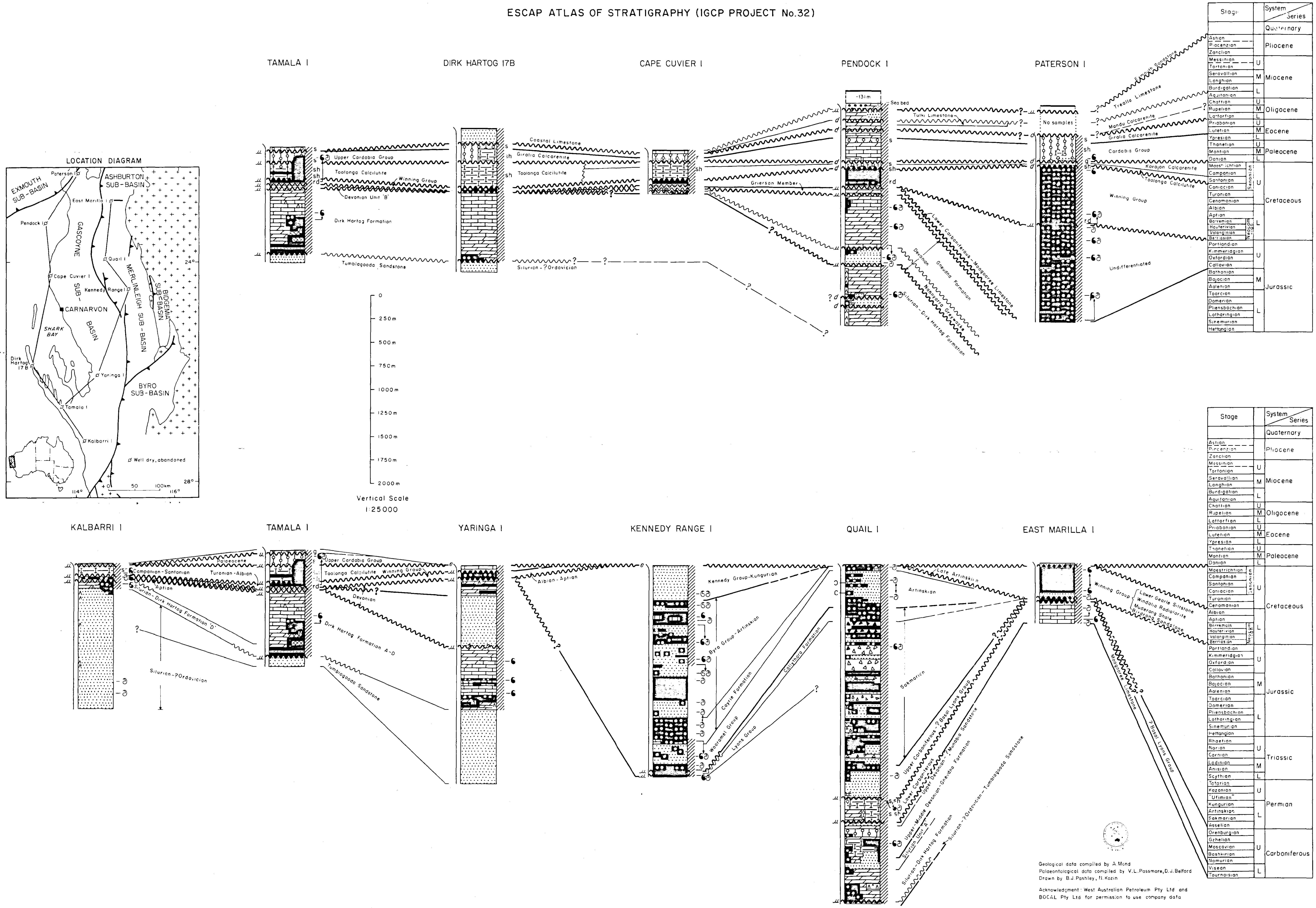


Geological data compiled by A. Mond
Palaeontological data compiled by V.L. Passmore, D.J. Belford
Drawn by B.J. Pashley, N. Kozin
Acknowledgment: West Australian Petroleum Pty Ltd and BOCAL Pty Ltd for permission to use company data

AUSTRALIA Au1d Carnarvon Basin

CARNARVON BASIN : WESTERN AUSTRALIA

ESCAP ATLAS OF STRATIGRAPHY (IGCP PROJECT No.32)



Geological data compiled by A. Mond
Palaeontological data compiled by V.L. Passmore, D.J. Belford
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AUSTRALIA Au 1e Carnarvon Basin