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DEPARTMENT OF
MINERALS AND ENERGY



BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

AN APPRAISAL OF PETROLEUM EXPLORATION TITLE AREAS

WA-23-P, WA-24-P, WA-25-P

055280

OFFSHORE NORTHERN CARNARVON BASIN,

August 1974

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by

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SUMMARY

This Record is the result of a brief examination of all available data, including confidential company reports. No original interpretation has been made.

Summaries are given of the geophysical results, and of the regional geology, drilling results, and hydrocarbon potential of the tectonic units covered by the three title areas.

Summary assessments of the three individual title areas are presented in Appendices 2, 3, and 4.

The area includes the Barrow, Exmouth, and Gascoyne Sub-basins of the offshore Carnarvon Basin. A commercial oil and gas field on Barrow Island is located centrally in the title areas. Offshore, one gas field, West Tryal Rocks, has been located on the southern extension of the Rankin Trend, on the Rankin Platform.

The more prospective part of the area has been covered by modern deep-water and shallow-water seismic exploration. This work indicates that the most prospective part of the title areas is the Barrow Sub-basin, especially the outer deeper-water trend, where a number of leads are known.

INTRODUCTION

The following report and maps give a reconnaissance review of Petroleum Exploration Title Areas WA-23-P, WA-24-P, and WA-25-P. One month was allotted for the review. All available data received in the Petroleum Exploration Branch under the Petroleum Search Subsidy Act and the Petroleum (Submerged Lands) Act were studied, together with confidential company reports and files. No time was allowed for interpretative work: the interpretations presented are those of contractors and title holders.

This Record is classified as 'In Confidence' because it contains information derived from confidential company reports and files.

REGIONAL SETTING

Petroleum Exploration Title Areas WA-23-P, WA-24-P, and WA-25-P lie adjacent to the northwest coast of Western Australia and stretch from Port Hedland to Carnarvon (Fig. 1). To the north they are bounded by WA-28-P and WA-1-P and to the south by WA-26-P and WA-27-P. WA-23-P and WA-24-P lie adjacent to the coastline; WA-25-P does not have any petroleum exploration title areas along its seaward extremity.

WA-23-P and WA-24-P lie in water depths varying from high-tide mark at the coast to 200 m off the North West Cape. Over 50 percent of WA-25-P lies in water depths in excess of 200 m, and water depths vary from less than 200 m to 1400 m along its seaward extremity.

The title areas cover the northern part of the offshore Carnarvon Basin, a complex Phanerozoic basin lying to the west and southwest of the Precambrian Pilbara Block.

GEOPHYSICS

Regional information on structural configuration, basement depths and fault patterns of the offshore Carnarvon Basin were derived from aeromagnetic surveys flown by Adastral Hunting for the West Australian Petroleum Pty Limited (WAPET) in 1967 (Offshore Onslow, 67/4628), and in 1969 (Offshore Bernier, 69/3031). Shallow basement was indicated in WA-23-P over the Pilbara Shelf, and between Long Island and Point Locker (Plate 1); up to 8000 m of sediments was indicated over much of WA-24-P and WA-25-P.

Gravity surveys have been carried out on Barrow Island and over North West Cape for WAPET. Marine gravity data were recorded during the 1968 BMR Continental Shelf survey. This gravity work contributed to the delineation of the offshore basins and revealed a significant positive anomaly associated with the Rankin Platform. Gravity readings have been recorded on most WAPET marine seismic surveys since late 1969, and magnetic readings since 1971.

Since 1961, the area extending from North West Cape through Barrow Island to the Rankin Platform has been extensively investigated by marine seismic and drilling operations. Individual surveys are listed in Appendix 1, and the coverage is shown in Plates 2 and 3. The coverage available to B.M.R. is not complete: geophysical surveys carried out from 1964 to 1973 within 50 miles of the Barrow Island oilfield and 30 miles of Rough Range-1 were not eligible for subsidy, although the results of those surveys carried out from 1968 to 1973 are available under the terms of the

Petroleum (Submerged Lands) Act (1967-73). Quality of the early surveys was adversely affected by multiples and other interfering energy and little useful deep information was obtained. Since 1968, the use of digital recording techniques and a variety of modern energy sources (Aquapulse, Maxipulse, and air-gun) has greatly improved seismic data.

Geophysical and drilling investigations have established the presence of Mesozoic and Tertiary sediments resting unconformably on older sediments in the central basinal areas and onlapping metamorphic and igneous basement along the continental margins.

As a result of extensive faulting during the Mesozoic, a number of sub-basins were formed - the Exmouth, Gascoyne, Barrow, and Dampier Sub-basins. The western margin of the Barrow and Dampier Sub-basins is formed by the Rankin Platform consisting of Triassic and Lower Jurassic block-faulted sediments unconformably overlain by Cretaceous and Tertiary sediments. Sedimentary thicknesses and fault configurations can be inferred from the seismic data, except in zones of poor deep data.

Pilbara Shelf

Sparse seismic data and the one well drilled near this area (Haury-1 in WA-1-P) confirm aeromagnetic and gravity indications of a thin sedimentary section onlapping very shallow basement less than 300 m. Seaward margins of the shelf are formed by the Sholl Island Fault System and the Enderby Trend. A BMR refraction probe in an inshore part of the Pilbara Shelf recorded 6100 m/sec refractor at a depth of 30 m.

Barrow Sub-basin

Although the Barrow Sub-basin has been covered by an extensive network of seismic lines, only basic data from outside the 50-mile-radius excluding circles were provided to BMR under the subsidy scheme. High-quality seismic work using modern techniques has been recorded in the more recent Hilda-Sultan and Barrow 3 and 4 seismic surveys (unsubsidized). Seismic record sections and contour maps on the Base Toolonga (Upper Cretaceous) and Base Muderong (Lower Cretaceous) horizons confirm the sub-basin as a Tertiary-Cretaceous-Jurassic downwarp containing a maximum of over 10 000 m of sediments. The basin limits to the south and east, the Long Island/Flinders Fault System, are clearly defined on the seismic sections; to the north, there is little seismic confirmation of any structural separation from the Dampier Sub-basin.

The most northwesterly component of the Barrow Sub-basin is the Rankin Platform, which was recognized as a prominent north-east trending gravity positive anomaly in the 1968 BMR Marine Geophysical Survey of the Northwest Continental Shelf. The seismic expression of this feature was obscured in early surveys by multiples of a high velocity marker in the Tertiary; lateral velocity variations in the area have further complicated seismic mapping.

Peedamullah Shelf

Fairly extensive seismic coverage and seven stratigraphic wells have confirmed the Peedamullah Shelf as a northwest-dipping block of Palaeozoic and Triassic sediments limited by the down-to-the-northwest Flinders and Sholl Island Fault Systems.

Gascoyne Sub-basin

Moderate-density seismic coverage and three stratigraphic wells show the Gascoyne Sub-basin as trending northeast between the Exmouth Sub-basin to the west and the Ashburton Sub-basin to the east. Contours on the Base Muderong horizon show sediments thickening off the Yanrey Ridge across Exmouth Gulf to the west. Three structural features at Long Island, Observation Island, and Locker Island have been drilled without success.

Exmouth Sub-basin

The Exmouth Sub-basin, extending westwards from the Rough Range Fault system across Cape Range into deep water offshore, has been extensively covered by seismic work. Much of the early seismic data were poor because of multiple interference caused by a strong shallow reflector.

Only poor data have resulted from onshore exploration on Cape Range because of adverse surface conditions. Recent marine data using an air-gun energy source and a 2400-metre cable are of good quality.

Structural closures are associated with the Cape Range and Rough Range anticlinal trends and with NNE-trending fault systems.

REGIONAL GEOLOGY, DRILLING RESULTS, AND HYDROCARBON POTENTIAL

The northern margin of the Carnarvon Basin is the North Turtle Arch, which separates the basin from the Bedout Sub-basin of the offshore Canning Basin; the Yandi-Madeline Hinge separates it from the Perth Basin to the south. The basin extends offshore at least as far as the margin of the continental shelf; the onshore eastern margin is either a sedimentary onlap onto, or a faulted contact with, rocks of the Precambrian Shield.

The offshore northern Carnarvon Basin has a number of significant and tectonically distinct features. These are the Beagle Sub-basin, Dampier Sub-basin, Pilbara Shelf, Peedamullah Shelf, Barrow Sub-basin, Exmouth Sub-basin, and Gascoyne Sub-basin. The title areas cover parts of all of these subdivisions except the Beagle and Dampier Sub-basins.

PILBARA SHELF

The Pilbara Shelf forms the southeastern margin of the Dampier Sub-basin, lying immediately offshore from the Pilbara Block. The shelf area is limited seawards by the Enderby Trend, a northeast-trending fault complex in which downthrow is to the northwest. The western limit of the shelf is the down-to-the-basin Sholl Island Fault System.

Within the title areas the sedimentary section gently onlaps basement and varies in thickness from nil at the coastline to less than 300 m farther offshore. It seems likely that only Tertiary and Cretaceous sediments occur in this area although Jurassic sediments could exist farther offshore.

Only one well, Haug-1, has been drilled near the Pilbara Shelf; it was located northwest of the WAPET title areas in WA-1-P. Haug-1 drilled Tertiary, (?)Cretaceous, and Triassic sediments to 805 m where metamorphosed basic igneous rock was encountered. Although no hydrocarbons were encountered the stratigraphic section penetrated was favourable for the accumulation of hydrocarbons. Below 592 m an interbedded sequence of claystones, siltstones, and sandstones with extremely good reservoir characteristics was penetrated.

No offshore wells have been drilled on the Pilbara Shelf within the title areas under consideration.

Hydrocarbon Potential

Within the title areas the shallowness of basement and the thinness of the sedimentary section gives little encouragement for petroleum exploration. However, frequent unconformities are present, and stratigraphic trapping is a possibility where units have thinned considerably and rapid changes in lithology may have occurred.

PEEDAMULLAH SHELF

The Peedamullah Shelf lies to the southwest of the Pilbara Shelf and extends both onshore and offshore. The shelf forms the southeastern margin of the Barrow Sub-basin, from which it is separated by the Flinders Fault System. The shelf consists of a Tertiary/Cretaceous section which gently onlaps, towards the east, a northwest-dipping block of Palaeozoic and Triassic sediments down-faulted by the Sholl Island Fault System which forms the eastern margin of the block.

Although the stratigraphy is fairly well known down to the base of the Cretaceous, the subcropping units are not well known. Well data indicate that they become younger to the north.

Seven stratigraphic wells have been drilled on islands in the offshore area. These wells, Sholl-1, Fortescue-1, North Sandy-1, Mangrove-1, Beagle-1, Mary Anne-1, and Direction-1 were drilled by WAPET in their 'Island Stratigraphic Drilling Programme'. None of these wells was subsidized and therefore only a little information is available - a Tertiary, Cretaceous, Triassic, and Lower Permian section was proved in the area. Available control suggests that the Ordovician-Silurian rocks of the Gascoyne Sub-basin are absent. Onshore, the oldest rocks encountered on the Peedamullah Shelf are Devonian/Carboniferous sediments.

To date no commercial hydrocarbon discoveries have been encountered on the Peedamullah Shelf, although numerous shows have been reported.

Hydrocarbon Potential

The Peedamullah Shelf lies updip from a proved hydrocarbon province in the Barrow Island Oil Field. Numerous gas shows from the shallow bores on the onshore shelf area indicate the distinct possibility of hydrocarbon accumulations on this southeastern margin of the Barrow Sub-basin.

The Cretaceous section, especially the Windalia Sand Member of the Winning Group (the main producing horizon at Barrow Island) and the basal sand (Birdrong Sand Member of the Winning Group/Yarraloola Conglomerate), are regarded as primary objectives in this area.

BARROW SUB-BASIN

The Barrow Sub-basin lies to the north of the Exmouth and Gascoyne Sub-basins and west of the Peedamullah Shelf. It is a Jurassic-Cretaceous sub-basin containing over 10 000 m of prospective sediments in a downwarp bounded to the south and east by the Flinders and Sholl Island Fault Systems and to the west by the Rankin Platform. The Rankin Platform is the most northwesterly known component of the Sub-basin. WAPET regards the De Grey Nose as the northeastern limit of the Barrow Sub-basin, whereas B.O.C. of Australia Ltd consider that another distinct Sub-basin, the Dampier Sub-basin, exists between the De Grey Nose and the Barrow Sub-basin. In this report, the boundary between the Barrow and Dampier Sub-basins is arbitrarily regarded as a seaward extension of the Rankin-Preston Arch.

The boundary between the Barrow and Exmouth Sub-basins is not well documented. It is regarded as the southern limit of the Barrow Group although pre-Cretaceous deposition may have been continuous across the boundary.

All the offshore wells drilled in the WAPET title areas around Barrow Island have been drilled within the Barrow Sub-basin and, together with extensive geophysical coverage, provide much structural and stratigraphic control. Additional control is also provided by wells drilled in the Island Stratigraphic Drilling Programme (most of these were unsubsidized), and by the extensive drilling programme carried out on Barrow Island.

The Rankin Platform was originally recognized as a pronounced gravity anomaly extending southwestwards from the Dampier Sub-basin. Drilling by B.O.C. on the Rankin Trend (part of the Rankin Platform) and more recently by WAPET has demonstrated that the platform consists of Cretaceous and Tertiary sediments draped over block faulted Triassic-Jurassic highs. Wells drilled to the southeast of the Rankin Trend, in the Dampier and Barrow sub-basins, penetrated thick Neocomian and Jurassic sediments, indicating that the down-to-the-basin faults separating the Trend from the rest of the two sub-basins have a pre-Cretaceous throw somewhere in the order of 2500 m.

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Hydrocarbon Potential

The Barrow Island oil and gas-condensate field, which was discovered by the drilling of Barrow-1 in 1964, was declared commercial in 1966. Since then, 520 development wells have been drilled, resulting in 309 producers from the Albian-Aptian-Windalia Sand Member of the Winning Group (average depth about 670 m), 8 from the Lower Cretaceous Muderong Greensand (850 m), 5 gas and oil producers from reservoirs of Neocomian to Upper Jurassic age (2040 m), 8 water source wells from the Barrow Group (Neocomian), and 157 water injection wells.

Production averages 41,200 BOPD, of which 98 percent is from the shallow Windalia Sand Member. The Member is a high-porosity, low-permeability sand which is only found on Barrow Island.

At the Barrow Island field the sands of the Dupuy Member which is the uppermost sandy facies of the Upper Jurassic Dingo Claystone, have an average porosity of 20 percent and normally 10 to 100 millidarcies permeability, while the overlying Barrow Group sands (Neocomian) have an average porosity of 23 percent and normally 10 to 1000 md permeability. Hydrocarbons have been produced from several intervals in the Dupuy Member, notably 980 BOPD from a sand at 2040 m in Barrow-1, and from six separate intervals in the Barrow Group.

Within the offshore Barrow Sub-basin the primary objectives for exploration to date have been the sands of the Barrow Group and of the underlying Dupuy Member. The Dupuy Member consists of very fine to fine-grained variably argillaceous sands, interbedded with marine shales. The Barrow Group and Dupuy Member are interpreted as being part of a deltaic complex deposited in a near-shore to restricted marine environment.

The Barrow Group objectives have proved disappointing in the offshore wells drilled to date. A few minor shows were encountered in Anchor-1 and Flag-1 and 3 m of net gas pay was encountered at the top of the Barrow Group at Pepper-1.

On the Rankin Platform, the proved reservoirs are Jurassic-Triassic sands beneath the basal Cretaceous (Neocomian) unconformity.

To date, no commercial hydrocarbons have been encountered in WA-23-P, WA-24-P, and WA-25-P although West Tryal Rocks-1 still remains to be tested (Barrow Island oilfield is in a land permit).

The prospective horizons in the Barrow Sub-basin are numerous, and potential reservoirs occur throughout the section.

EXMOUTH SUB-BASIN

The Exmouth Sub-basin lies immediately to the west of the Gascoyne Sub-basin and is separated from it by the Rough Range Fault System. The western and southwestern boundaries are poorly understood and have not been defined.

To the north the Exmouth and Barrow sub-basins probably formed a single depositional area during and before the Jurassic. The Exmouth Sub-basin is distinguished from the Barrow Sub-basin by the absence of widespread Neocomian sediments; the boundary between them is arbitrarily placed at the present southern limit of extensive development of the Barrow Group, at or near the Long Island Fault System.

The structure of the offshore part of the Exmouth Sub-basin is complex and incompletely known. The Sub-basin is interpreted as a narrow, generally northward-plunging half-graben, containing in excess of 6000 m of Triassic and Jurassic sediments, which is overlain by a relatively thin sequence of Cretaceous and Tertiary sediments.

Hydrocarbon Potential

Two island stratigraphic wells, Muiron-1 and Peak-1, have been drilled in the offshore portion of the sub-basin. Both wells terminated in Upper Jurassic Dingo Claystone at 1785 m and 2142 m respectively. No shows of hydrocarbons were encountered in these wells and to date no commercial hydrocarbon discoveries have been encountered in the sub-basin.

No offshore wells have been drilled in the Exmouth Sub-basin; however, the non-commercial oil discovery made onshore in Rough Range-1 in 1953 points to the possible potential of the offshore areas. Of prime interest will be the Lower Cretaceous Birdrong Sand Member of the Winning Group - the producing horizon at Rough Range; other sands within the Jurassic and Triassic(?) will be secondary objectives.

To date the hydrocarbon potential of the offshore Exmouth Sub-basin remains untested. Well over half the offshore area lies in water depths in excess of 200 m.

GASCOYNE SUB-BASIN

The Gascoyne Sub-basin is a generally north to northeast-dipping block of pre-Cretaceous sediments overlain by a veneer of Cretaceous and younger sediments. Subcrop at the Lower Cretaceous unconformity becomes younger to the north, ranging in age from Ordovician(?) in the south to Upper Triassic in the north.

The Gascoyne Sub-basin is essentially a northeast-trending horst-like platform between the Exmouth Sub-basin to the west and the Ashburton Sub-basin to the east. The bounding faults are the complex Wandagee Fault System in the east and the Rough Range Fault System in the west. The northern boundary of the sub-basin is the Long Island Fault System.

Three island stratigraphic wells, Observation-1, Locker-1, and Long Island-1 are the only control offshore from the mainland, and together with seismic, give a reconnaissance coverage of the area. These wells encountered a Tertiary-Cretaceous section unconformably overlying Upper Triassic Mungaroo Formation. Observation-1 and Long Island-1 terminated in Lower Triassic Locker Shale. The Lower Cretaceous-Upper Jurassic section was absent in these wells: the Long Island Fault System is thought to have controlled sedimentation, and to have restricted it to the north during this period.

Hydrocarbon Potential

No hydrocarbons were encountered in any of the island stratigraphic wells, but these wells were probably not located on structures.

The prospective section must be regarded as the Cretaceous especially the Birdrong Sand Member. The Triassic Mungaroo Formation may have some potential.

APPENDIX 1

GEOPHYSICAL SURVEYS, WA-23-P, WA-24-P, WA-25-P

Survey	Dates	Company	Contractor	Title	Seismic Source	Cable	Recorder	Coverage	Line Kilometres	Quality	Remarks
<u>SUBSIDIZED</u>											
<u>Marine Seismic</u>											
Exmouth Gulf	62/1563	7/61-8/61	WAPET	G.S.I.				100%	1212	P	Mapped Cape Range and Rough Range anticlines.
Barrow	65/11031	4/ 9/65-23/10/65	"	G.S.I.	PE 28H, 217H, 233H	Expl.			789	P	Indications of structure.
West Carnarvon	66/11089	29/ 6/66-24/ 9/66	Canadian Superior	G.S.I.	PE 235H	"	1600 m	300%	2302	P	
								600%			
Long Island	67/11153	5/ 3/67-14/ 4/67	WAPET	Western	PE 28H, 217H, 233H	"			304	F	Structure complex. Jurassic absent.
Muiron	67/11167	25/ 5/67-30/ 6/67	"	G.S.I.	PE 28H, 217H, 233H	"			654	F	Defined structures.
Table	68/3001	29/12/67- 5/ 6/68	"	G.S.I.	"	Air-gun			813	F	Mapped six structures.
						Expl.					
Mandu & Jurabi	68/3042	15/10/68-18/ 1/69	"	G.S.I.	PE 28H, 24P, 25P	Expl.		600%	86		
Helby	68/3045	26/10/68-29/10/68	"	Western	WA-24P, WA-25P	Aquapulse		1200%	132		Defined Visming & Yardie anticlines
Fraser	69/3015	15/ 3/69- 2/ 4/69	"	G.S.I.	WA-24P, 25P & 28P	Air-gun	2400 m	1200%	528	F-P	Located two drillsites & several closures.
						Expl.					
Barrow Waters	70/127	5/ 2/70-11/ 2/70	"	G.S.I.	WA-24P, 25P		1600 m	2400%	214	P-F	No new structural leads.
							2400 m				
Bernier	71/722	31/10/71- 8/12/71	Ocean Ventures	Western	WA-26P	Expl.	2400 m	4800%	1476	P-G	
Ronsard	71/79	5/ 3/71-14/ 3/71	Endeavour Oil	G.S.I.		Air-gun	2400 m	2400%	341	P-F	
<u>Aeromagnetic</u>											
Offshore Onslow	67/4628	7/ 9/67- 5/12/67	WAPET	Adastral H.	WA-23P, WA-25P				3920		7500 m of sediments. Basement ridge between Long Island and Point Locker.
					PE's 28H, 217H, 233H						
Offshore Bernier	69/3031	2/ 6/69-30/ 6/69	"	Hunting	WA-24P, WA-25P				4669		Suggests that Rough Range structure extends offshore to southwest.
<u>UNSUBSIDIZED</u>											
<u>Marine Seismic</u>											
Tryal Rocks	68/2	29/10/68- 1/11/68	WAPET	Western	WA-25P	Aquapulse	5290 ft	SDS-1010	1200%	86	F
North Tryal Rocks	71/11	28/ 8/71- 3/ 9/71	"	Western	WA-25P, WA-28P	Maxipulse	7590 ft	SDS-1010	2400%	563	F
Flag, East Flank	71/15	11/10/71- 1/12/71	"	G.S.I.	WA-23P	Air-gun	2400 m	DFS-111	2400%	114	F
Mermaid, North Sholl	71/18	14/ 3/71- 5/ 4/71	"	G.S.I.	WA-23P	Air-gun	2400 m	DFS-111	2400%	114	F
West Flank, Tauton										707	F
Muiron, SW Cape										419	F
Gulfrex Reconnaissance	72/9	28/ 5/72- 6/ 7/72	Aust. Gulf Oil	Aust. Gulf Oil	WA-25P	Aquapulse	5280 ft	DFS	2400%	121	F
Alpha	72/24	14/ 8/72-20/ 8/72	WAPET	G.S.I.	WA-24P, WA-25P	Air-gun	3200 m	DFS-111	4800%	612	F
Murat, Sunday Is, Yardie 2	72/26	28/ 2/72-28/ 3/72	"	Western	WA-24P, WA-25P	Maxipulse	3200 m	DCS-777	4800%	2252	F
Barrow 3											
Onslow											
Barrow 4	72/34	29/12/72-11/ 1/73	WAPET	G.S.I.	WA-23P, WA-24P, WA-25P	Air-gun	3200 m	DFS-111	4800%	1488	G
(Hilda	73/23	15/ 7/73- 8/ 8/73	"	G.S.I.	WA-24P, WA-25P	Air-gun	3200 m	DFS-111	4800%	2143	G
(Sultan	73/24										Extensive, high-quality coverage of WA-25P

APPENDIX 1

Title Assessment WA-23-P

Title holder: West Australian Petroleum Pty Limited
No. of blocks: 398
Expiry date: 3.10.74
Farmout negotiations: Nil
Expenditure conditions:

<u>Year</u>	<u>\$A</u>	<u>\$A/block/year</u>
1 (1968-69)	1,985,000	4,987.43
2 (1969-70)	1,945,300	4,887.68
3 (1970-71)	60,344	151.61
4 (1971-72)	60,344	151.61
5 (1972-73)	60,344	151.61
6 (1973-74)	60,344	151.61
	<u>4,171,676</u>	<u>10,481.55</u>

(average 1746.92/block/year)

Regional setting

Title area WA-23-P lies adjacent to and along the northwest coast of Western Australia from Port Hedland in the east to Onslow in the west. Water depths vary from nil to 60 m.

Wells drilled

Refer to Tables 1 and 2. Four offshore wells, Flinders Shoal-1, Flag-1, Ripple Shoals-1, and Pepper-1 have been drilled, all within the Barrow Sub-basin. Flag-1 is northeast of Barrow Island, and the other three wells are south of the island.

Flinders Shoal-1 was the first offshore well to be drilled in the Barrow Sub-basin. The only significant hydrocarbon show was encountered in the Lower Cretaceous Birdrong Sand Member; a DST in this formation over the interval 792 m - 799 m yielded gas at a rate 2.8 MMcf/d but was not considered of economic significance.

Flag-1 was drilled to test a seismic anomaly just east of the Monte Bello Islands. The well was originally programmed to 2896 m (9500 ft) but was deepened to 3810 m to test the possible occurrence of older Jurassic sands. No economically significant hydrocarbon shows were recorded, the only producing zone being in the Windalia Sand Member of the Winning Group which on DST produced gas at 1.1 MMcf/d.

Ripple Shoals-1 was drilled to test a fault closure on the downthrown side of the Flinders Fault System. The well was plugged and abandoned without finding any hydrocarbons.

Pepper-1 was drilled on an anticline to test the top of the Barrow Group and the Dupuy Member. The well encountered 3 m of gas at the top of the Barrow Group and a further 11 m of gas and 17 m of questionable gas in the interbedded siltstones and sandstones of the Dupuy Member.

Geophysical coverage

See Plates 2 and 3 and Appendix 1.

Prospectivity

Refer to Plate 1. The title area can be conveniently divided into three separate regions: Pilbara Shelf and margins, Peedamullah Shelf, and Barrow Sub-basin.

Pilbara Shelf and Margins

The northern limit of shallow Precambrian is shown on the map. South of this limit the thinness of the sedimentary section downgrades the petroleum potential of the area.

Although the sedimentary section thickens off the shelf, the only appreciable thickness of sediments on the Pilbara Shelf within the title area occurs in the northwest corner of the shelf, adjacent to the Sholl Island Fault System. Here seismic data indicate up to 1500 m of Tertiary-Cretaceous sediments.

Recommendation. No further work at this stage.

Peedamullah Shelf

The prospective section is sands within the Cretaceous, especially the Windalia Sand Member of the Winning Group and the basal Cretaceous sand (Birdrong Sand Member of the Winning Group/Yarraloola Conglomerate). As the area is located updip from a known petroliferous province it must have some prospects. The better prospects may be located on the downthrown side of the Flinders Fault System and one such structural lead on the title boundaries between WA-25-P and WA-23-P has been delineated.

Recommendation. Further seismic detailing to confirm closure on the structural lead followed by a test well. Further reconnaissance seismic work to delineate any other closures associated with the hinge line.

Barrow Sub-basin.

The prospective section is sands within the Lower Cretaceous and Jurassic (and possibly Triassic?). All of this area lies within the Barrow Island excludng circle and pre-P(SL)A data are extremely sketchy. Four offshore wells have been drilled within the title area without discovering any commercial hydrocarbons. Two structural leads have been delineated in the vicinity of the Monte Bello Islands, one of which is the southwest extension of the Flag structure. There may be possibilities of structural or stratigraphic trapping or both along the downthrown side of the Flinders and Sholl Island Fault Systems.

Recommendation. Both structural leads are poorly controlled and further detail work is required, although this may be impracticable because of shallow water. More modern seismic detailing may uncover deep structural closures not evident on existing coverage.

APPENDIX 2

Title Assessment WA-24-P

Title holder: West Australian Petroleum Pty Limited
No. of blocks: 208
Expiry date: 17.10.74
Farmout negotiations: Nil
Expenditure conditions:

<u>Year</u>	<u>\$A</u>	<u>\$A/block/year</u>
1 (1968-69)	145,600	700
2 (1969-70)	187,200	900
3 (1970-71)	1,040,000	5,000
4 (1971-72)	35,568	171
5 (1972-73)	728,000	3,500
6 (1973-74)	32,032	154
	<u>2,168,400</u>	<u>10,425.00</u>

(average \$1737.50/block/year)

Regional setting

Title area WA-24-P lies adjacent to and along the northwest coast of Western Australia extending from the town of Onslow in the north to the town of Carnarvon in the south. Water depths range from nil at the coast to 800 m at the western extremity of the title area, although only a few blocks lie in water depths greater than 200 m.

Wells drilled

Refer to Tables 1 and 2. Only one offshore well, Anchor-1, has been drilled in WA-24-P. The well was drilled to investigate the hydrocarbon potential of the Lower Cretaceous Barrow Group sands and the sands of the Upper Jurassic Dupuy Sand Member on a structure on the downthrown (northern) side of the Long Island Fault System. Although the well did not encounter any hydrocarbon accumulations it did show the presence of sands with good reservoir properties and potentially good source rocks.

Geophysical coverage

Plates 2 and 3 and Appendix 1.

Prospectivity

Refer to Plate 1. The title area covers parts of four tectonic sub-units: Peedamullah Shelf, Barrow Sub-basin, Exmouth Sub-basin, and Gascoyne Sub-basin.

Peedamullah Shelf

Only the southern extremity of the Peedamullah Shelf lies in WA-24-P. One structural lead straddling the boundary of WA-23-P and WA-24-P has been delineated. The prospective section is sands within the Cretaceous, especially the Windalia Sand Member of the Winning Group and the basal Cretaceous sand (Birdrong Sand Member of the Winning Group/Yarraloola Conglomerate).

Recommendation. Further seismic detailing to confirm closure on the structural lead, followed by a test well.

Barrow Sub-basin

Only the southern extremity of the Barrow Sub-basin lies in WA-24-P. Prospective horizons are sands in the Lower Cretaceous and Jurassic. Seismic detailing has revealed two structural leads on trend with the Long Island Fault System. These partly lie in WA-24-P. In 1972, several attempts at drilling a well on the larger of these leads, the West Muiron Structure, were abandoned due to mechanical difficulties in drilling Tertiary limestones. The drilling attempts (West Muiron-1 and 1A) were all made in WA-25-P. Another attempt at drilling a well on this structure is programmed (West Muiron No. 2). The other structure is a rollover onto the downthrown side of the Long Island Fault System.

Recommendation. Should drilling of West Muiron No. 2 prove encouraging a test of the smaller associated feature is recommended. Modern high-effort seismic work may mature further closures in the thick sedimentary sequence north of the Long Island Fault System.

Exmouth Sub-basin

About six blocks of this sub-basin, within the title area, lie in water depths in excess of 200 m. The portion of WA-24-P in the Exmouth Sub-basin extends from Muiron Islands along the west shore of Cape Range south to Chabiuwardoo Bay. The prospective section is sands within the Lower Cretaceous, Jurassic, and possibly Triassic.

The West Muiron structure may lie partly in the Exmouth Sub-basin, but until the West Muiron-2 well is drilled this will not be resolved.

A small structural lead off the Northwest Cape, the Vlaming Structure, has been delineated. This structure occurs partly onshore and could be tested with an onshore well at Vlaming Head.

Another structural lead investigated is the Yardie feature, a basement high, located off the western shore of Cape Range. The structure appears to have been downgraded because of the expected lack of suitable reservoir rocks in the area.

Recommendation. At this stage the area appears to have low prospectivity, but should the drilling of West Muiron-2 prove encouraging further work is recommended in this coastal region.

Gascoyne Sub-basin

The prospective sediments are sands within the Lower Cretaceous, especially the Birdrong Sand Member. The Gascoyne Sub-basin can be divided into two areas - that northeast of Cape Range and the coastal section south of Chabiuwardoo Bay. To date no structural leads are known except perhaps for the Sunday Island structure, which requires further detailing.

Little is known of the southern offshore strip and seismic and stratigraphic control in this area is sparse. Two speculative fault-controlled leads are known, but as several similar leads have been tested onshore without encountering commercial hydrocarbons, their prospects seem poor.

Limited geophysics indicates that the Cretaceous section gently thickens seawards to approx 900 m at the western boundary of the title area.

Recommendation. Depending on the results of the Sunday Island seismic survey (72/76), test drilling and further seismic detailing may be warranted.

Prospects of the southern area are not rated highly, but should evaluation of either of the two existing structural leads give any encouragement, upgrading of the area's prospects would result and further work would be justified. At this stage however, the only work recommended is seismic detailing of either of the structural leads.

APPENDIX 3

Title Assessment WA-25-P

Title holder: West Australian Petroleum Pty Limited
No. of blocks: 256
Expiry date: 16.10.74
Farmout negotiations: Nil
Expenditure conditions:

<u>Year</u>	<u>\$A</u>	<u>\$A/block/year</u>
1 (1968-69)	38,400	150.00
2 (1969-70)	38,400	150.00
3 (1970-71)	352,000	1,375.00
4 (1971-72)	38,400	150.00
5 (1972-73)	358,400	1,400.00
6 (1973-74)	1,843,200	7,200.00
	<u>2,668,800</u>	<u>10,425.00</u>

Regional setting

Title area WA-25-P is located off the northwest coast of Western Australia and extends from approximately 130 km north of Barrow Island along the western boundaries of WA-23-P and WA-24-P to approximately 150 km southwest of North West Cape. Over half of the title area lies in water depths in excess of 200 m; water depths range up to 1400 m.

Wells drilled

Refer to Tables 1 and 2. Four offshore wells, Tryal Rocks-1, North Tryal Rocks-1, West Tryal Rocks-1 and West Muiron-1/1A have been drilled in the Barrow Sub-basin within WA-25-P. Hilda-1 was drilling at 8832 ft (2692 m) on 15 August 1974.

Tryal Rocks-1 was drilled on a large anticlinal structure 50 km northwest of Barrow Island. The well drilled a Tertiary-Cretaceous section and terminated in Jurassic siltstones and sandy siltstones. No significant hydrocarbon zones were encountered.

North Tryal Rocks-1 and West Tryal Rocks-1 were drilled on a southern extension of the Rankin Platform into WA-25-P. Both wells were drilled on horst blocks with Tertiary-Cretaceous sediments draped over them. North Tryal Rocks-1 encountered 3 m of Jurassic sediments overlying Upper Triassic, and West Tryal Rocks-1 passed straight into Upper Triassic below the Neocomian unconformity.

North Tryal Rocks-1 encountered numerous shows, and logs and FIT's indicate that the interval 3053-3142 m is gas-bearing, with 3 m of potential pay from 3139 to 3142 m. An FIT at 3142 m gave an estimated gas flow rate of 3.2 MMcf/d.

West Tryal Rocks-1 was suspended due to mechanical difficulties before the well was tested. Wireline log evaluation indicates the presence of 90 m of possible hydrocarbon pay. The hydrocarbon column extends over a gross interval of 265 m, and the hydrocarbon-water contact is transitional from 3498 m to 3501 m. The exact net pay and nature of the hydrocarbons have yet to be verified by a testing programme.

In 1972, several attempts were made to drill a well on the West Muiron structure in the southern part of the Barrow Sub-basin. These were all abandoned due to mechanical difficulties in drilling the Tertiary limestone section. A further well, West Muiron-2 is programmed.

Geophysical coverage

Refer to Plates 2 and 3, and Appendix 1.

Prospectivity

Refer to Plate 1. Over half of the title area lies in water depths in excess of 200 m. The remainder can be conveniently divided into two regions - the Rankin Trend and the Barrow Sub-basin.

Rankin Trend

The prospective sediments are sands within the Jurassic (if present), Triassic, and possibly the Lower Cretaceous. Two horst blocks with Cretaceous sediments draped over them remain to be drilled. The major risk on both features is that there will be shale instead of sandstone directly under the critical base Muderong unconformity. Another small structural lead is located southwest of West Tryal Rocks-1 well.

Recommendation. First, West Tryal Rocks-1 should either be tested, or redrilled and tested. The two horst blocks appear to have been sufficiently detailed to enable well locations to be recommended.

Barrow Sub-basin

The prospective section is sands within the Lower Cretaceous and Jurassic. Five structural leads have been delineated, one of which (Hilda) was drilling ahead in mid-August. The West Muiron structure and the neighbouring structure to the east also straddle the boundary between WA-24-P and WA-25-P.

Recommendation. The area has been covered by modern seismic work in the Hilda-Sultan project. Some further detailing may be necessary to mature drill sites.

Deep Water area

The southern part of the title area south of 21°30'S mostly lies in water depths in excess of 500 m, which is beyond the reach of modern production techniques. Parts of the northern portion of WA-25-P are also in water depths greater than 500 m. In this area one structural lead has been delineated but outside the title area. Between the 200 and 500 m water-depth contours two fault-controlled structural leads have been detailed. One of these is a horst block on the southern extension of the Rankin Platform.

Recommendation. At this stage only seismic work is practicable because of excessive water depths.

Table 1. Details of offshore wells drilled in (depths in feet below K.B.)
 WA-23-P, WA-24-P, WA-25-P, WA-26-P

Table 1

	Cost \$M	File No.	Rig Released	TD/RT	Title	Sub-basin	Deepest horizon	Subsea Top Mudcrong	Rig	Potential trap	Status (all abandoned) ^a	Remarks
Flinders Shoal-1	?	P(SL)A	9.7.69	11861/80	WA-23-P	Barrow	Permian	2654	Jubilee	Anticline	Well with show of gas	Birdrong Sand Member. DST 1 2597'-2622'. Gas @ 2.8 MMcf/D
Anchor-1	0.92	69/2019	31.8.69	10000/80	WA-24-P	Barrow	L. Jurassic	3819	Jubilee	Fault	dry	Fault trap on downthrown side of Long Island Fault System. No shows.
Flag-1	?	P(SL)A	30.1.70	12500/80	WA-23-P	Barrow	Dingo	7030	Jubilee	Anticline	Well with show of gas	Drilled on flank shows of gas in Dupuy and Dingo. Windalia Sand DST 1, 4192'-4236'. Gas @ 1.1 MMcf/D
Ripple Shoals-1	?	P(SL)A	11.3.70	7476/79	WA-23-P	Barrow	Dingo	2813	Jubilee	Fault	dry	Fault trap on downthrown side of Flinders Fault System. No shows.
Pepper-1	?	P(SL)A	6.5.70	9000/89	WA-23-P	Barrow	Dingo	4123	Jubilee	Anticline	Well with show of gas	11' gas at top of Barrow Group. 35' gas 55' questionable gas in Dupuy.
Tryal Rocks-1	?	P(SL)A	23.8.70	12123/93	WA-25-P	Barrow	Dingo	9363	Jubilee	Anticline	dry	Weak mudlog gas show and minor oil in Barrow Group and Dingo Claystone. Dupuy absent.
N. Tryal Rocks-1	1.96	72/2069	5.8.72	12000/40	WA-25-P	Barrow	Mungaroo	9480	Navigator	Anticline	Well with show of gas	L. Jurassic 10086'-10096'. Logs and FIT's indicate 10016'-10310' is gas bearing; 10' potential pay 10300'-10310' - FIT 10307' est. gas 3.2 MMcf/D.
W. Muiron-1		72/2738	4.10.72	2562/40	WA-25-P	Barrow?	Toolonga	NR	Navigator	Anticline	dry	P/A due to mechanical difficulties.
-1A			21.10.72	1133/40	WA-25-P	Barrow?	Toolonga	NR	Navigator	Anticline	dry	P/A due to mechanical difficulties.
W. Tryal Rocks-1		72/3108	31.3.73	12685/40	WA-25-P	Barrow	Mungaroo	8168	Navigator	Anticline	Well with show of gas	Suspended with corrosion cap installed. Numerous shows not tested.
Hilda-1		73/288	Spud 29.4.74	14108/40	WA-25-P	Barrow			Dalmahey	Anticline		Still drilling (August 1974).
1A												
W. Muiron-2		73/287	To be drilled		WA-25-P	Barrow?			Dalmahey	Anticline		To be drilled (August 1974).
Pendock ID-1		69/2020	18.11.69	8205/34	WA-26-P	Gascoyne	Silurian	3268	Glomar Conception	Anticline	dry	Oil stain/fluorescence only in Devonian.

Table 2. Stratigraphy of offshore wells, NA-23-P, 24-P, 25-P

Table 2.

Barrow Sub-basin		Gascayne Sub-basin									
Age	Formation	Flinders Shoal-1	Anchor-1	Flag-1	Ripple Shoals-1	Pepper-1	Tryal Rocks-1	N Tryal Rocks-1	W Tryal Rocks-1	Pendeck-ID-1	
		RT (ft)	80	80	80	79	89	93	40	40	34
Quaternary	Coastal Limestone	Seabed	Seabed	Seabed	Seabed	Seabed	Seabed	Seabed	Seabed	Seabed	464
Tertiary	Undifferentiated	190	727						1900		685
	Miria Marl								8588		2490
	Upper Toolonga	?	1700	1600		900	4140		8810	7410	2605
Cretaceous	Lower Gearle Siltstone	1067	2155	2860	1302	1870	4422		9140	7520	2716
	Windalia Radiolarite	1938	3630	3048	2779	3231			9460	8495	3176
	Muderong	2038	3899	4094	2892	3408	6700		9520	8620	3302
	Birdrong Sand Member		4351		3456						3353
	Barrow Group	2817	4407	7030	3542	4123	9363	NP	NP	NP	NP
Jurassic	Upper Dingo Claystone	3485	5382	8420	6095	7536	11184		NP	NP	NP
	Lower								10086		
Triassic	Upper Mungaroo Beds	6208							10096	10608	NP
	Lower Locker Shale	7560									NP
Permian	unknown?	110247									NP
Carboniferous	Moogeorge Formation										3378
Devonian	Gneudna Formation										3632
	Manayarra Greynacke										5462
Silurian	Dirk Hartog Formation										6070
	Sandstone unit										7190
	Basal dolomite										7500
	T.D.	11861	10000	12500	7476	9000	12123	12000	12685		8205

Table 3. Island Stratigraphic Wells HA-23, 24, 25P

Table 3.

		Peedamullah Shelf		Exmouth Sub-basin		Gascoyne			Barrow Sub-basin		
		Shall-1	North Sandy-1	Peak-1	Muiron-1	Observation-1	Locker-1	Long Island-1	Hope Island-1	Tortoise-1	Whaleback-1
<u>Quat.</u>	Coastal Limestone	16'	5'	16'	16'	16'	9'	16'	14'	16'	10'
<u>Tert.</u>	Undiff)	70'	164'	740'	1119'	950'	120'	70'	682'	100'	235'
	Miria Marl) Upper										
<u>Cret.</u>	Toolonga)			1840'	2973'	1680'	582'	1240'	1154'	747'	2136'
	Gearle		220'	2222'	3547'	1803'	735'	1411'	1428'	1280'	2277'
	Windalia	220'	443'	3496'	4193'	2616'	1512'	2103'	2580'	2668'	3511'
	Muderong	471'	660'	3678'	4303'	2793'	1750'	2356'	2757'	3246'	3631'
	Mardie Grn Sd. Member	830'	NP	NP		NP					
	Birdrong/Yaraloola	970'	1092'	NP		2997'	1980'	2582'	2920'	3730'	3805'
	Barrow Group	NP	NP	NP		NP	NP	NP	NP	NP	
<u>Jurassic</u>	Upper Dingo Claystone	NP	NP	3935'	4478'	NP	NP	NP	NP	4040'	4046' Learmonth Fm
	Lower	NP	NP			NP	NP	NP	NP		
<u>Triassic</u>	Upper Mungaroo	NP	NP			3052'	2081'	2605'	NP		
	Lower Locker	1110'	1210'			6535'		6535'	2989'		
<u>Permian</u>	Upper Kennedy	2890'							3502'		
	Lower Byre	3480'									4555' Callythara Fm
	Lyons ?	3670'									4828'

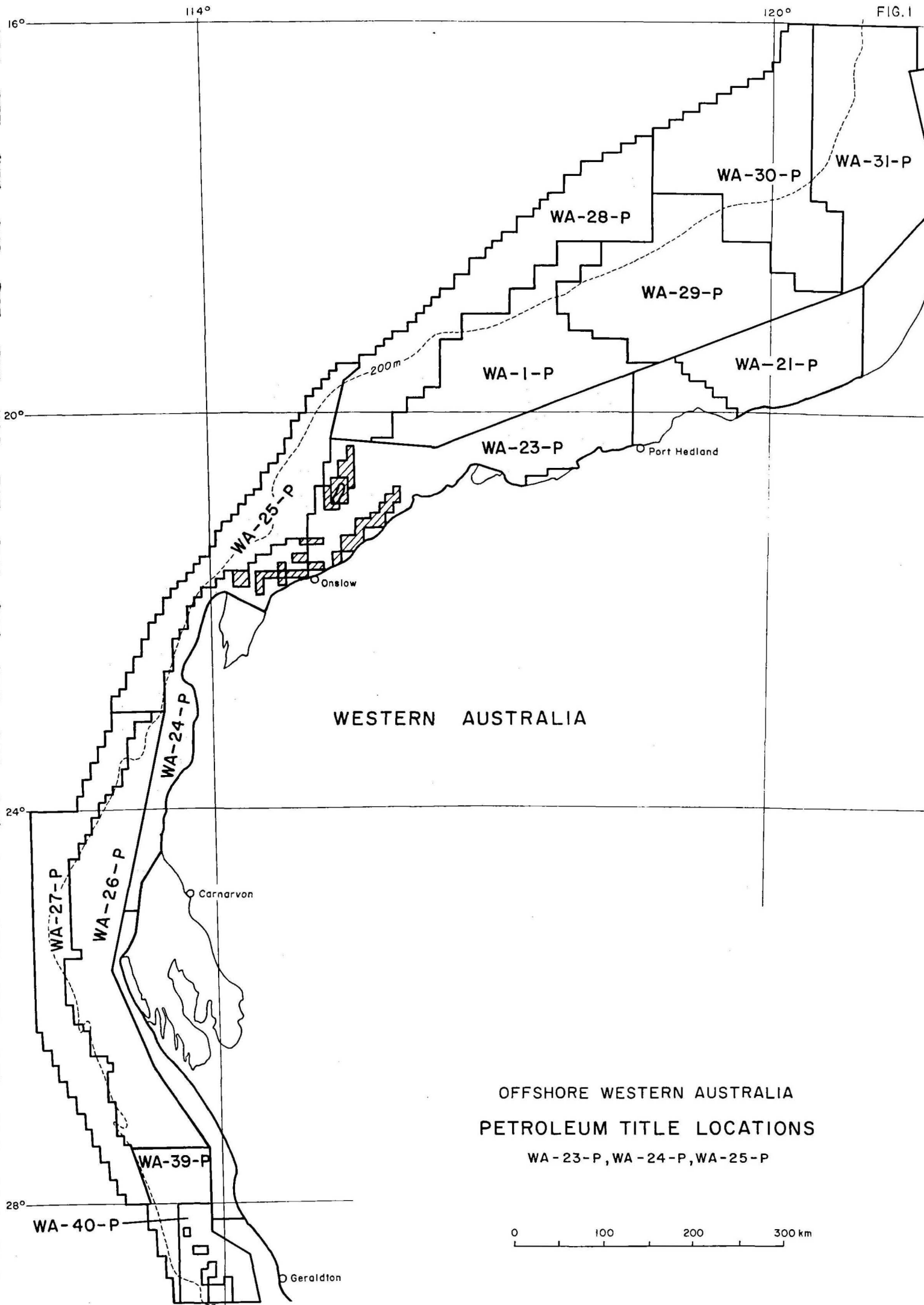
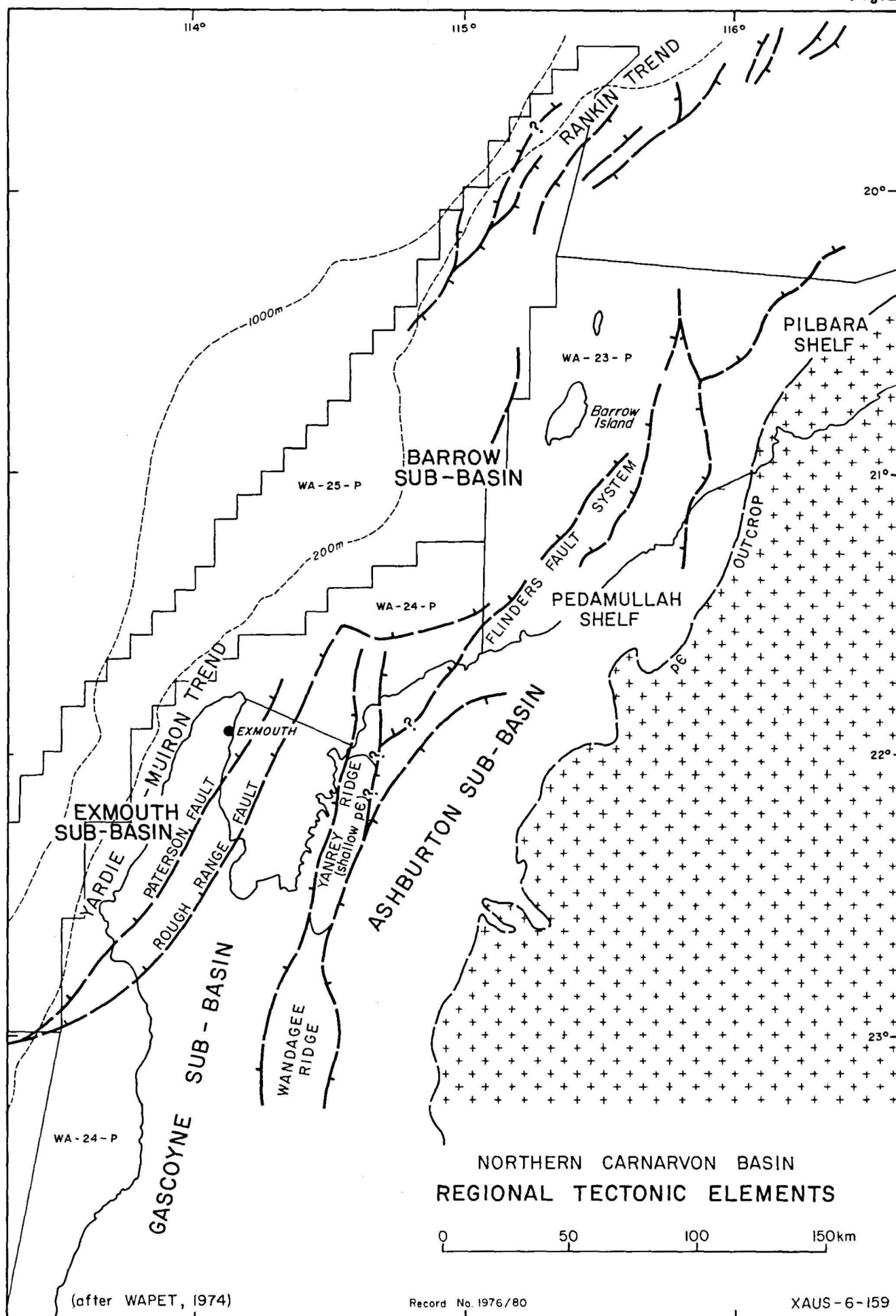
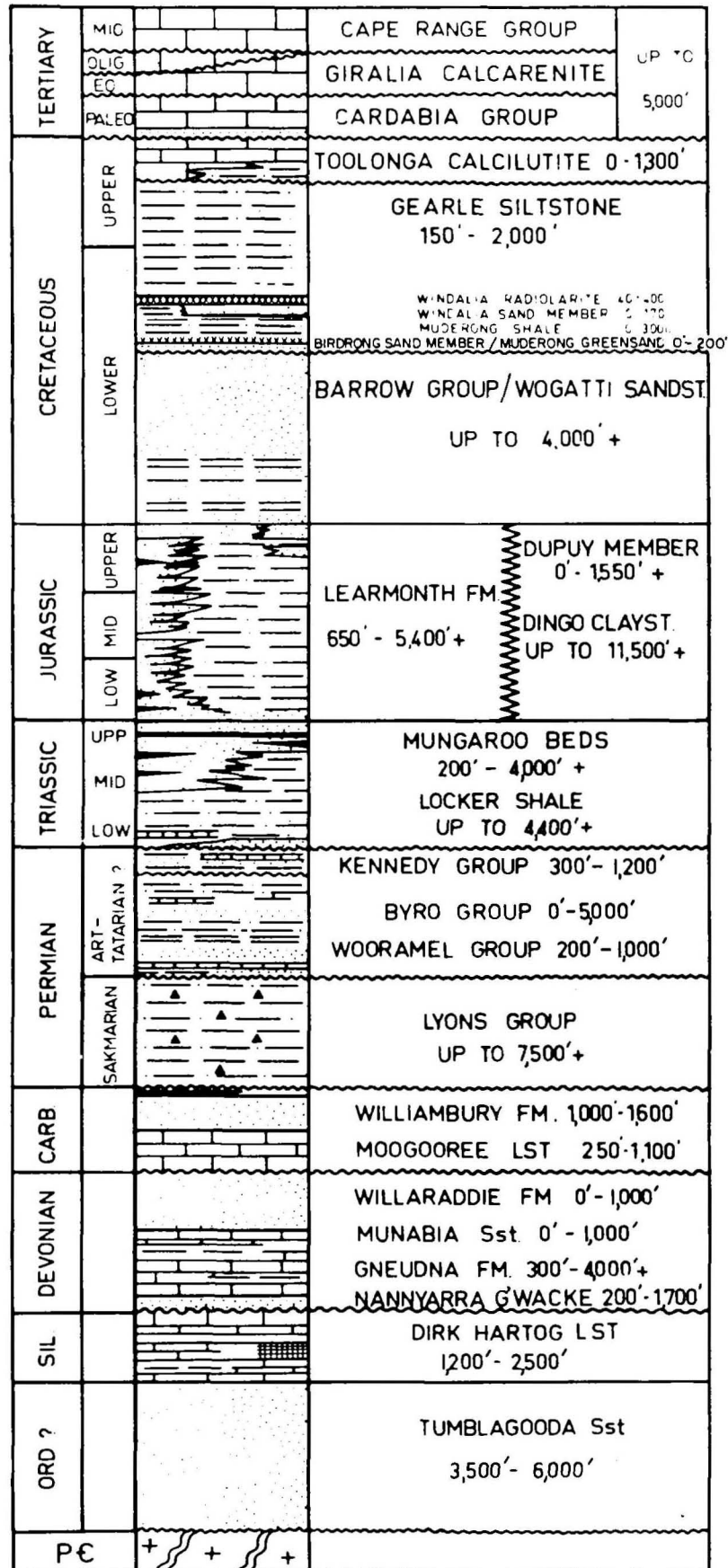




Fig.2



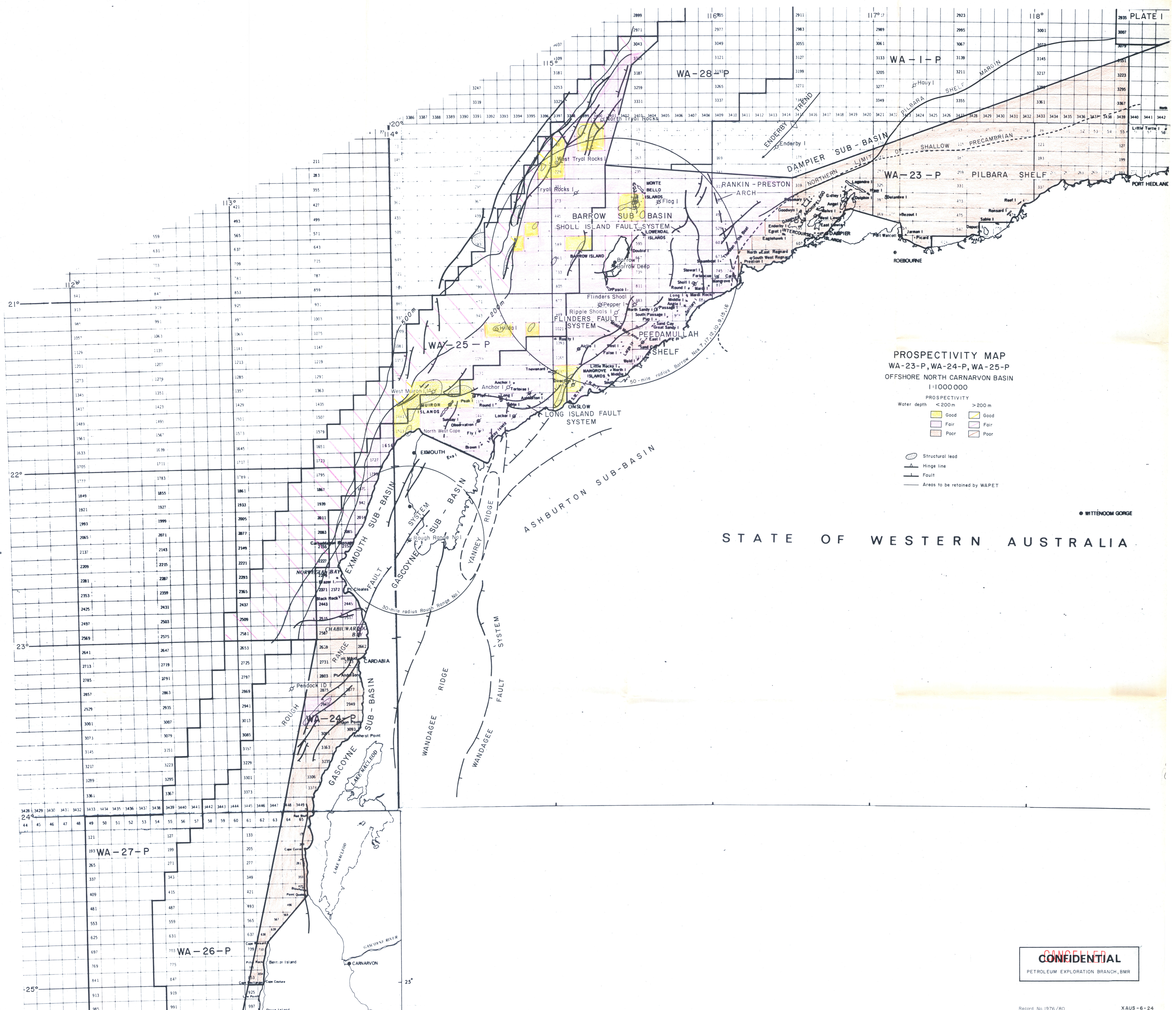
CARNARVON BASIN STRATIGRAPHY


 SANDSTONE

 SHALE
 SILTSTONE

 CARBONATES
 EVAPORITES

(after WAPET, 1974)



PROSPECTIVITY MAP
WA-23-P, WA-24-P, WA-25-P
OFFSHORE NORTH CARNARVON BASIN
1:1000000

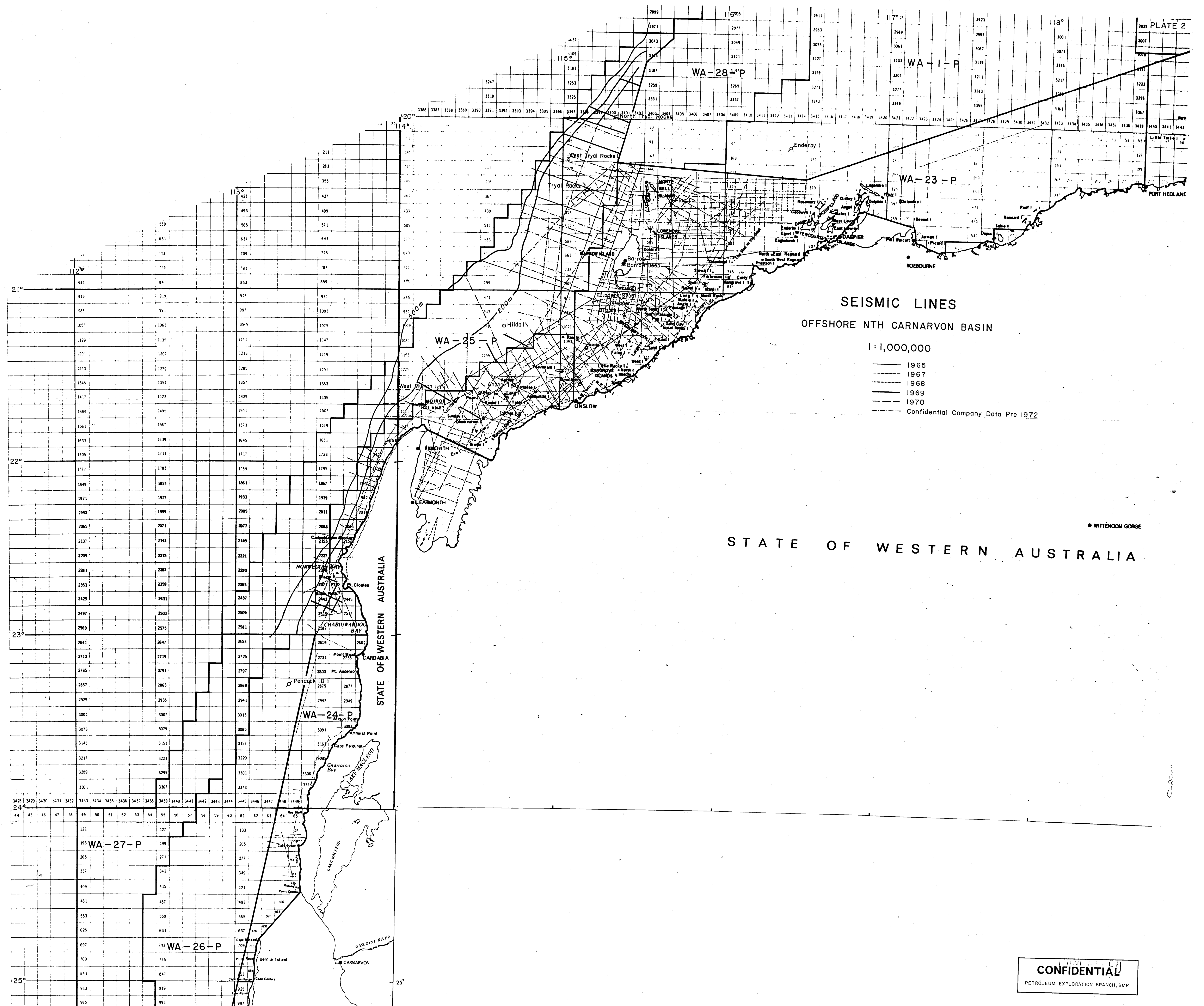
PROSPECTIVITY

Water depth	< 200m	> 200m
Good	[Yellow box]	[Yellow box]
Fair	[Light purple box]	[Light purple box]
Poor	[Pink box]	[Pink box]

Structural lead
Hinge line
Fault
Areas to be retained by WAPET

STATE OF WESTERN AUSTRALIA

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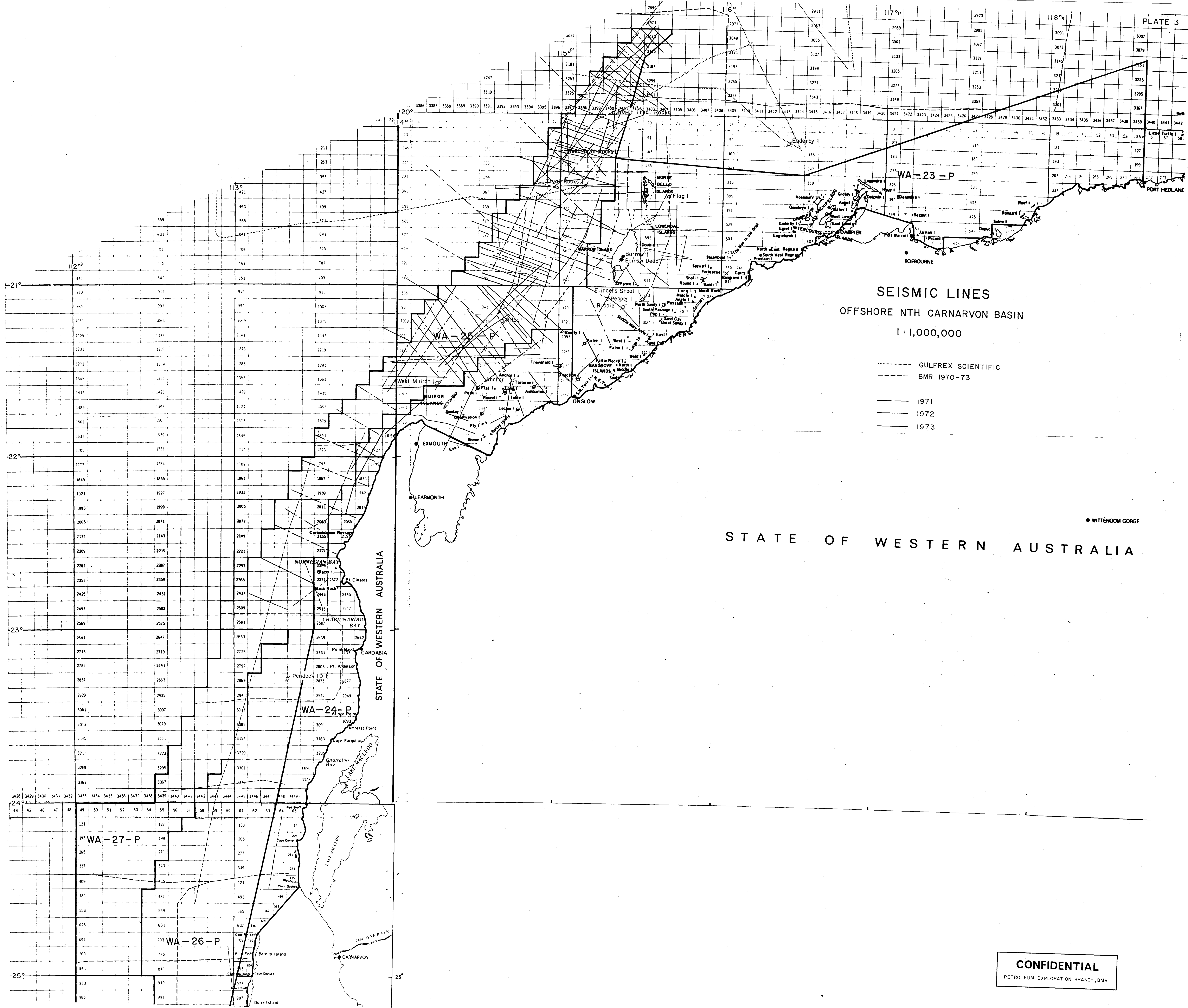


SEISMIC LINES
OFFSHORE NTH CARNARVON BASIN
1:1,000,000
— 1965
— 1967
— 1968
— 1969
— 1970
--- Confidential Company Data Pre 1972

WITTENOOM GORGE

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