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An analysis of the petroleum prospectivity of vacant areas overlying the Ashmore Platform, Vulcan Sub-basin, Jabiru Terrace and northern Browse Basin

by

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Petroleum exploration and resource potential

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Abstract

This report examines areas currently vacant or likely to become vacant in the Ashmore-Cartier region. They contain features which represent significant exploration opportunities. Parts of the vacant acreage are expected to be available for application(s) in Release 2 of 1991 under the Petroleum (Submerged Lands) Act, in particular areas covering parts of the Ashmore Platform, Vulcan Sub-basin, northern Browse Basin and Jabiru Terrace.

As at 1 January 1991 the Bonaparte Basin in northwestern Australia contained five major and nine minor discoveries and over twenty shows or significant indications of hydrocarbons, including some residual or biodegraded accumulations. All the major oil accumulations, such as Jabiru, Challis/Cassini, Skua and Talbot, are reservoired in traps comprising Triassic and/or Jurassic reservoir which are sealed by Cretaceous marine shale sequences. The estimated recoverable petroleum reserves in the Bonaparte Basin as at 31 December 1990 comprised 5.992 x 10^6 m ^{3} of oil, 18.60 x 10^6 m^3 of natural gas liquids, and 111.189 x 10^9 m^3 of sales gas (BMR, 1991).

The vacant areas in the Ashmore-Cartier region offer the opportunity to identify additional leads and prospects or test known prospects likely to have potential for petroleum trapped in Triassic, Jurassic and Cretaceous sequences, as well as offering an opportunity to develop and test innovative new play concepts. The Vulcan Sub-basin and Jabiru Terrace areas offer typical Timor Sea plays with the Jurassic or Triassic as the major targets and a wide scope to identify and evaluate a variety of stratigraphic and structural leads and prospects.

This report examines the information available in vacant areas of the Ashmore-Cartier region and provides an outline of potential prospects and leads, as well as play concepts. It suggests that considerable potential exists for the development of additional prospects in all vacant areas with broad scope for the successful discovery of additional petroleum accumulations.

The report covers areas recently relinquished and likely to be included in forthcoming rounds of the acreage release process determined by the Joint Authority. As such. the actual areas released may be subject to changes in configuration and boundary because of considerations undertaken as part of the release process.

1.0 Introduction

This report examines and comments on the potential petroleum prospectivity of a major group of areas in the Ashmore-Cartier region which could be suitable for inclusion in future rounds of the process of release of vacant acreage under the Petroleum(Submerged Lands) Act. The region is part of the offshore Bonaparte Basin (Fig. 1) which extends offshore from near Kununurra in the south, northwest to Ashmore Reef and covers an area of approximately 281 000 sq kms.

A number of summaries have been published by the BMR (Williams & others, 1973; Branson, 1974; Brown, 1979). This report is based on a review of the offshore part of the basin by the Petroleum Resource Assessment Branch of BMR as part of the assessment of areas put forward for consideration for release under the terms and conditions of the Petroleum (Submerged Lands) Act.

This report summarises information on the petroleum prospectivity and exploration results of vacant areas in the Territory of Ashmore and Cartier Islands (Fig. 1). The report also suggests potential areas which could be included for future releases under the P(SL)A.

The report describes the regional stratigraphy, structure, traps, reservoirs, source rocks and the nature of known petroleum accumulations. The main focus of the report is however, an examination of the petroleum prospectivity of the vacant areas including the available seismic and drilling results, the location and nature of leads and prospects as well as the potential for new and as yet unknown play types.

The objectives of the report are:

- to provide details of the characteristics and petroleum prospectivity of the vacant areas in the region;

- to provide significant background data which will be of assistance in exploration for additional petroleum reserves in these and adjacent areas; and

- to document basic geological, geophysical and geochemical data for use in future exploration programmes.

For specific information on the general stratigraphy, structure and geological evolution of the Bonaparte Basin, outlines provided on these topics by Mory (1988) and Lavering & Ozimic (1988, 1989) and other papers in the APEA Journal should be consulted.

2.0 Bonaparte Basin

2.1 Basin setting

The Bonaparte Basin (Fig. 1) covers an area of approximately 263 000 square kilometres offshore, and 18 000 square kilometres onshore between the Kimberley and Sturt basement blocks. The basin contains a cumulative sedimentary sequence over 17 kilometres thick comprising Palaeozoic to Cainozoic sediments, deposited in a series of sub-basin, graben and platform areas (Edgerley & Crist, 1974; Laws & Kraus, 1974).

The oldest sediments which can be positively identified in the offshore parts of the Bonaparte Basin, including those within the vacant areas of the Ashmore Platform, Cartier Trough and Vulcan Sub-basin are Late Devonian, although Cambrian volcanics and sediments are present in the onshore part of the basin. The Palaeozoic sediments, where they are present in well intersections in the Timor Sea area, belong to a phase of Silurian to Carboniferous northwest rifting. New depocentres such as the Vulcan Sub-basin, developed along the northwest margin of the basin when Mesozoic northeast-trending rifting and breakup commenced. Subsequent Cainozoic sedimentation consists largely of carbonate shelf progradation, particularly in the outer part of the basin (Lavering & Ozimic, 1989; Mory, 1988).

The Petrel Sub-basin (Laws & Kraus, 1974) (Fig. 1) is the largest part of the basin and contains a Cambrian to Triassic sequence which is overlain by a thin veneer of Jurassic and Cretaceous sediments. Faulted shelf margins are developed in the southern part of the sub-basin adjacent to the Kimberley and Sturt basement blocks (Laws & Kraus, 1974; Warris, 1973). Offshore the Petrel Sub-basin passes into a series of grabens containing a Mesozoic sequence, up to four kilometres thick, which onlaps and thins onto adjacent platform areas (Edgerley & Crist, 1974; Laws & Kraus, 1974).

The Bonaparte Basin passes into the Browse Basin along the southwest margins of the Ashmore Block, Vulcan Sub-basin and Londonderry High (Fig. 1). In the northeast the Bonaparte sequence adjoins sediments of the Arafura and Money Shoal Basins beyond the limits of the Darwin Shelf. The northern margin of the basin is the lower continental slope along the Timor Trough where water depths exceed 3000 metres (Lavering & Ozimic, 1989).

There are few difficulties in defining the Bonaparte Basin onshore: it is flanked by Proterozoic rocks of the Kimberley and Sturt blocks. There are, however, a number of problems in defining the precise limits of the basin offshore .

Early workers extended the offshore Bonaparte Basin to the edge of the Timor Trough: they used a seafloor feature (the Londonderry Rise), and the presence of shallow basement (the Sturt Block) to define the southwestern and northeastern limits of the basin respectively (e.g., Williams & others, 1973). Since the 1970s however, extensive seismic surveys and drilling throughout the basin have revealed the arbitrary nature of this basin definition (Mory, 1988).

The southwestern margin of the basin, as defined by Mory (1988) crosses the shelf adjacent to the Kimberley Block, and the Vulcan Sub-basin to link the northern side of the Kimberley Block with the southern side of the Ashmore Platform. Similarly, the eastern margin of the basin crosses the Malita Graben to link the eastern margin of the Sahul Platform with the western limit of Permian and Triassic sediments on the Darwin Shelf. As a consequence, Triassic to Mesozoic sediments in the Browse Basin, and Jurassic to Cainozoic sediments in the Money Shoals Basin are continuous with sediments in the Bonaparte Basin. The reasons for this basin definition are not only historical, but are also a function of the sequence and structure becoming younger to the northwest (Mory, 1988).

In contrast to the approach employed by BMR workers, MacDaniel (1988) assigned the post-Palaeozic sequence in the Vulcan Sub-basin and Ashmore Platform to the Browse Basin, he restricts the Bonaparte Basin to the underlying Palaeozoic sequence (Mory, 1988).

2.2 Stratigraphy

Sediments of the Bonaparte Basin range in age from Cambrian to Tertiary (Fig. 2). Understandably, the oldest parts of the sequence are currently thought only to be relevant to the petroleum potential of the Petrel Sub-basin. For the sake of completeness they are outlined in this initial chapter of the report - future exploration in shallow basement areas, including parts of the Ashmore Platform may yet concentrate more on this part of the overall sequence.

The Cambrian to Permian part of the sequence is known from outcrop and well intersections in the Petrel Sub-basin (Laws & Kraus, 1974; Laws & Brown, 1976). The lowermost part of the Cambrian sequence unconformably overlies Precambrian basement and comprises the Antrim Plateau Volcanics, which is a subaerially-deposited volcanic sequence (Veevers & Roberts, 1968). Unconformably overlying the volcanic sequence is the Tarrara Formation which is overlain conformably by the Carlton Group. Both formations comprise a sequence of shallow marine clastic and carbonate sediments of Cambrian to Early Ordovician age.A major unconformity separates the Cambro-Ordovician sequence from overlying younger units. Interpretation of geophysical and well data

suggests that an evaporitic sequence was deposited in the basin during the Late Silurian and Early Devonian periods, and that this sequence has subsequently formed into a number of salt diapirs (Edgerley & Crist, 1974). From study of outcrop and well intersections the Middle Devonian to Early Carboniferous sequence has been classified into basinal marine, and shelfal carbonate and clastic units. The Bonaparte Beds comprises the basinal sequence of shale and siltstone, dated as Middle to Early Carboniferous in age and possibly Early Devonian. The shelfal sequence consists of a basal unit, the Cockatoo Formation, which is a clastic sequence deposited close to the faulted eastern margin of the sub-basin. A reef complex developed along a western shelf in the Late Devonian forming the Ningbing Limestone, a massive algal reef with horizontally-bedded back reef deposits.

The Keep River Group conformably overlies the reef complex along the western shelf area and comprises a sequence of carbonate, siltstone and shale which passes offshore, in the central part of the Petrel Sub-basin, into clastic sediments of the Bonaparte Beds. The Keep River Group is apparently Early Carboniferous (Tournasian) in age. The Early Carboniferous Milligans Formation unconformably overlies the Keep River Group and is a sequence of marine shale, siltstone and sandstone of Visean age. A major unconformity in the middle of this sequence separates a lower alluvial-fan sequence from an overlying prograding deltaic sequence.

The Tanmurra Formation disconformably overlies the Milligans Formation and is a transgressive unit which comprises near-shore sandstones and carbonates. A prominent seismic horizon evident in the southern part of the Petrel Sub-basin is correlated with the top of this formation. The Early Carboniferous Tanmurra sequence is late Visean to Late Carboniferous in age (Veevers & Roberts, 1968).

The Kulshill Group conformably overlies the Tanmurra Formation and is a sequence of fluvial to shallow marine sediments which range in age from Late Carboniferous to Early Permian (Sakmarian). The Kulshill Group has been informally divided into upper and lower units; the lower comprising a regressive sequence of alluvial fan, fluvial, deltaic and tidal clastics, and the upper a sequence of marginal marine, estuarine and tidal clastics. Onshore, the lower regressive sequence passes laterally into the Border Creek Formation, a clastic fluvial sequence restricted to the southern part of the Petrel Sub-basin.

The Fossil Head Formation, a transgressive sequence of marine siltstone and shale, conformably overlies the Kulshill Group (Laws & Brown, 1976). This unit is Early to Late Permian in age (Sakmarian to Kungurian) and comprises estuarine to tidal shelf sediments.

The Permian Hyland Bay Formation conformably overlies the Fossil Head Formation and consists of sandstones, shales, coal and limestone. It is Late

Permian in age (Kazanian and Tartarian) and contains three major lithological elements: a basal sequence of dense limestone and shale, a middle tidal clastic sequence, and an upper sequence of mudstone and sandstone, deposited as a coarsening-upwards deltaic sequence. The Port Keats Group comprises largely non-marine sediments deposited proximal to the eastern basin margin.

The Mount Goodwin Formation, a transgressive marine sequence of shale and siltstone, conformably overlies the Hyland Bay Formation. The Mount Goodwin Formation thickens towards the centre of the Petrel Sub-basin and is Early Triassic in age. It is conformably overlain by the Sahul Group, a Middle Triassic regressive sequence of fluvial sandstone. Late Triassic uplift and erosion is reflected in some instances by an unconformity. The overlying Malita Formation is Late Triassic to Early Jurassic in age.

The overlying Early Jurassic to Early Cretaceous sequence consists of the Plover Formation and Flamingo Group which are separated by a Late Jurassic unconformity (Mory, 1988.). The Plover Formation comprises deltaic sandstone, siltstone and some coal. The Flamingo Group comprises glauconitic shale overlain in places by coastal to barrier-bar sandstone.

Unconformably overlying the Flamingo Group, or older units, is the Early to Late Cretaceous marine shelf sequence of the Bathurst Island Group. This group comprises a sandstone and shale sequence which is Neocomian in age and is overlain by Aptian to Cenomanian claystone, siltstone and sandstone. The Late Cretaceous sequence comprises a younger part of the Bathurst Island Group and consists of marl and claystone.

The Early Tertiary Hibernia Formation comprises open marine siltstone, shale and mudstone. It is overlain by a Late Tertiary carbonate shelf sequence of marl, shale and sandstone. An unconformity at base Miocene level is related to basin-wide uplift and erosion in response to regional tectonism. Calcareous sandstone overlying the unconformity is succeeded by a major Pleistocene barrier-reef complex that rimmed the northern flanks of the Cartier Trough and Ashmore and Sahul Platforms.

2.3 Reservoirs

Potential reservoirs occur in all of the major stratigraphic sequences, although reservoir quality tends to vary and deteriorate with increasing geological age, depth of burial and depositional environment. Outside the Petrel Sub-basin sediments older than Permian are thought to have limited reservoir potential because of deep burial. Potential Palaeozoic hydrocarbon reservoirs include the Devonian Ningbing Limestone, and the Carboniferous Milligans Formation, Tanmurra Formation and Bonaparte Beds. Traces of oil and gas were recorded in these units during drilling of the Keep River-1 (A.A.P., 1969), Spirit Hill - 1 (A.O.D., 1961), Bonaparte - 2 (A.O.D., 1965) and Lesueur - 1 (A.A.P., 1981) wells. Reservoir properties of

these units appear to deteriorate rapidly at burial depths greater than 2000 metres.

Potential reservoirs of Late Carboniferous and Permian age include the Kulshill Group, Fossil Head and Hyland Bay Formations. Several wells drilled in the Petrel Sub-basin have recorded both live and residual oil indications in the Kulshill Group including Turtle - 1 , Bougainville - 1 (A.A.P., 1972), Barnett - 1 (A.A.P., 1985), Lacrosse - 1 (ARCO, 1969), Kinmore - 1 (A.A.P., 1974), Kulshill - 1 (A.A.P., 1966), and Pelican Island - 1 (ARCO, 1972). In these wells up to 20 per cent porosity is evident in the lowermost parts of the Kulshill Group. Permeability is low however, and most of the hydrocarbon indications are in tight intervals.

The uppermost part of the Fossil Head Formation has some reservoir potential over a limited area of the Petrel Sub-basin. Indications of gas were recorded during drilling of the Penguin - 1 well in a tight sandstone interval at the top of the formation (ARCO,1972). The uppermost Permian unit, the Hyland Bay Formation, is a major petroleum-bearing sequence in the Petrel Sub-basin. The Petrel anticline in the centre of the sub-basin was tested by the Petrel - 1A well in 1969. The well intersected gas-bearing reservoirs of a major delta complex and carbonate unit. The Tern - 1 well intersected gas-bearing reservoirs in the upper part of the formation within a coastal barrier island reservoir system overlying the delta complex (ARCO, 1971).

Overall, the Permian fluvio-deltaic reservoirs of the Bonaparte Basin are noted for a marked deterioration in quality where they are deeply buried. Shaly sandstone commonly retains porosity, as clay has an inhibiting effect on some diagenetic changes (Bhatia & others, 1984).

Reservoirs of the Triassic Malita and Sahul Group are important potential exploration targets in the offshore part of the basin. Porosity readings of between 13 and 29 per cent are evident from these groups in wells such as Osprey - 1 (ARCO, 1972), Tamar - 1 (Getty, 1979) and Turnstone - 1 (ARCO, 1975). The Challis - 1 well drilled in the Vulcan Sub-basin during 1984, intersected an oil accumulation within the Sahul Group (BHP, 1984). Flow rates recorded during production testing of wells drilled on the Challis structure indicate good to moderate reservoir parameters.

Fluvio-deltaic and marine sandstone in the Plover Formation are important potential reservoirs in the offshore parts of the Bonaparte Basin. Braided-fluvial sandstone units at the base of the sequence were succeeded in the Petrel Sub-basin by a wave-dominated delta system. Marginal to the delta, on the Londonderry High, a barrier bar system formed by longshore drift of sand from the delta, and a coal swamp developed landwards behind the barrier bar. The Flamingo Group comprises a sequence of marine shale overlain by barrier bar sandstone, or in some instances submarine fan deposits.

The excellent reservoir potential of the Flamingo Group is evident from results of the Jabiru - 1A well which was drilled on the Jabiru Terrace (BHP, 1983). The well intersected an oil-bearing reservoir at the top of the Flamingo Group. Flow rates of up to 7509 barrels of oil per day were measured during production testing of the reservoir. The oil column extends into the underlying Plover Formation.

Reservoir potential is also evident in the marine Cretaceous sequence. Restricted marine shelfal sandstone, was intersected in the upper part of the Bathurst Island Group by Skua - 2 (BHP, 1986), Tamar - 1 (Getty, 1979) and Lynedoch - 1 . Maastritchian sandstone reservoirs host the Puffin oil accumulation. Carbonate sequences in the Cretaceous and Tertiary succession have limited reservoir potential but a calcarenite intersected by the Puffin -1 well contained residual traces of oil (ARCO, 1972).

2.4 Source rocks

The fine grained sediments of both the Palaeozoic and Mesozoic sequences have poor to good potential as petroleum source rocks. Kraus and Parker (1979) suggest that the Upper Permian to Middle Jurassic sequences contain source rocks of sufficient maturity to generate hydrocarbons.

The onshore Palaeozoic sequence is the host of numerous oil shows encountered by shallow mineral exploration coreholes, particularly in the Ningbing Limestone and Cockatoo Formations. Parts of the Bonaparte Beds or Milligans Formation contain some oil-prone organic source rock.

Organic matter present in the Bonaparte Beds away from the basin margins is largely gas-prone but some oil potential is evident in the basal part of the sequence. The Keep River Group contains some oil-prone source material (Laws, 1981).

The source potential of the Palaeozoic sequence outside the Petrel Sub-basin is not well known. Bonaparte Beds, and Milligans and Tanmurra Formations are considered to have some source potential (Jackson & others, 1983).

Fair to good source potential for both oil and gas is evident in the upper part of the Kulshill Group (Laws & Brown, 1976). The Fossil Head Formation has little source potential as much of the organic matter present in this sequence is oxidised and has little generative potential (Jackson & others, 1983).

The Hyland Bay Formation has source potential which ranges from poor, in the middle and lower parts of the sequence to fair in the upper interval where marine influence is restricted (Laws & Brown, 1976).

The Mount Goodwin Formation in the Petrel Sub-basin contains organic matter but appears to have low generative potential. Similar trends appear in the overlying Sahul Group and Malita Formation. The entire Triassic sequence is likely to be gas-prone where generative potential exists (Jackson & others, 1983).

A glauconitic marine shale sequence near the base of the Flamingo Group is considered to be a fair source for both oil and gas (Laws & Brown, 1976). Minor to fair source potential for gas is indicated in the Plover Formation where organic matter is preserved. The Flamingo Group contains paralic to marginal marine sandstone and shale exhibiting mixed gas and oil potential.

The Bathurst Island Group contains moderate amounts of organic material, largely of humic composition, which is a poor to fair source (Laws & Brown, 1976). The Late Cretaceous and Tertiary sequences are largely immature for hydrocarbon generation and contain limited quantities of organic material which is mainly humic in composition.

2.5 Structural framework

The major structural elements in the offshore basin are broadly similar to those of other basins along Australia's northwest margin (Crist & Hobday, 1973). As noted by Laws and Kraus (1974), the northern offshore part of the Bonaparte Basin displays similarities to the Carnarvon Basin with outer platform areas (Ashmore and Sahul), central northeast trending graben structures (Vulcan Sub-basin) and inshore shallow basement areas: Darwin Shelf, Londonderry Arch (Fig. 3). These features, as shown on Figure 1 can be further subdivided. The northern part of the Vulcan Sub-basin has been subjected to major post-Miocene subsidence and as a result is identified as the Cartier Trough. The Londonderry High is an area of faulted horst and graben development and the northern flank of this area, with the Vulcan Sub-basin and Cartier Trough, has been identified as the Jabiru Terrace. A trough feature on the northeast flank of the Londonderry High is identified as the Sahul Syncline. Further discussion of the origins of each of these features is given in following sections of the report.

Fault and horst block trends within the offshore part of the Bonaparte Basin appear to be related to two separate structural origins (Warris, 1973). A northwest-oriented structural trend is evident in the Petrel Sub-basin. This has been related to the middle Palaeozoic development of the region, mainly to Devonian and Carboniferous rifting (Warris, 1973). A second, northeast-oriented structural trend is evident in the outer offshore parts of the basin. This trend is related to Mesozoic, mainly Jurassic, tectonic movements.

Renewed tectonism during the Miocene is reflected in additional fault

development, as well as the reactivation and tilting of existing fault blocks. Major tectonic events within the basin have determined the type, size and number of potential traps, which are mainly anticlines, faulted anticlines, fault and diapiric structures. In the offshore platform and sub-basin or graben areas, faults and faulted anticlines are the major potential traps. A major risk with such features is whether fault seal has been maintained during Miocene tectonic movement. Residual hydrocarbons observed in faulted anticlinal traps such as that tested by the Eider - 1 (ARCO, 1973) well, could be interpreted as being due to a failure of fault seal during the Tertiary, allowing previously entrapped hydrocarbons to escape.

3.0 Petroleum accumulations

3.1 Exploration History

During the 1960s and 1970s the Ashmore Cartier region was initially explored by the ARCO and Burmah/Woodside groups who controlled permit areas on the Northwest Shelf. During the late 1960's and early 1970s, ARCO undertook a number of reconnaissance seismic surveys over the Ashmore Cartier area. These lines are generally of fair to good quality down to the base Cretaceous. However, below this level, data quality is poor. The early ARCO wells were drilled on these regional seismic grids of 2 to 5 km maximum density. This factor, combined with the absence of clear deep reflectors, lead to the drilling of wells in less than optimal locations and it is believed that many were drilled off structural crests. The position of these early lines in relation to later surveys is suspect due to navigation and positioning techniques.

The first successful well, drilled by ARCO was Puffin-1 in 1973 (Fig.4). Puffin-1, east of the vacant Ashmore Platform area, discovered oil in Late Cretaceous sands draped over an older horst block. Puffin-2 which tested a separate fault block, flowed 4,608 BOPD from a 5 metres Cretaceous sand. Puffin-3 encountered 3 metres of oil bearing sandstone of Late Cretaceous age. Total reserves at Puffin are estimated at 9 MMSTB OIP . Puffin is now part of the Puffin Block of AC/P2 operated by BHP.

In AC/P4 to the north of AC/P2, the 1983 drilling of the Jabiru 1A well recorded a flow of 7,033 BOPD from a net pay column of 57 metres and sparked a renewed interest in the Timor Sea area, now regarded as the most prospective offshore area in Australia outside of the Gippsland Basin. Unfortunately, the three follow-up wells were disappointing and Jabiru recoverable reserves estimates did not meet initial expectations of 200 MMBBL. Ultimate recoverable reserves in Jabiru are now estimated to be 89 MMBBL. The follow-up Jabiru wells encountered a much shalier section above the oil water contact than did the initial well because of steeply dipping Early to Middle Jurassic reservoir beds beneath the Callovian unconformity. However, because of expected high flow rates, Jabiru-1A was developed using a floating production system and production commenced in August, 1986 (Lavering & Ozimic, 1989) .

Twenty kilometres to the south of Jabiru, in AC/P4, the Challis-1 well was drilled on a Jabiru-like horst block in 1984. The well encountered Triassic reservoir directly beneath the basal Cretaceous unconformity and production tested over 6,000 BOPD. Challis-2A drilled in 1986, flowed a stabilised 8,480 BOPD with 26 MMCFD (740,000 m /d) gas from a 15 metre "lower" zone and 4590 BOPD with 1.6 MMCF/D (45 400 m3/d) from a 7 metre "upper"zone. Challis-3 flowed 9989 BOPD and estimates of recoverable reserves are of the order of 80 MMSTB.

In late 1985, BHP drilled Skua-2, 20km to the southeast of the Puffin accumulation and 15km east of the margin of the Ashmore Platform vacant acreage. Although, this well tested only 440 BOPD from Early Jurassic(?) sands it showed that other liquid hydrocarbon accumulations are present in the area. In the late 1980s Santos drilled the Talbot-1 well on the Londonderry High, east of the Skua discovery, and intersected an oil-bearing Triassic sequence.

3.2 Petroleum accumulations

Petroleum has therefore been discovered in several major and minor accumulations, as well as being recorded as significant shows, including residual accumulations, during the drilling of a growing number of other petroleum exploration wells. Petroleum was first discovered in 1959 when traces of oil were noted during drilling of the onshore well Spirit Hill-1 (A.O.D., 1961). Since then over 100 petroleum exploration wells have been drilled, resulting in the discovery of the following growing list of petroleum accumulations (Lavering & Ozimic, 1989).

The definitions of these discoveries are given in the Lavering & Ozimic (1989).

Major accumulations

- Jabiru (oil)*
- Challis (oil)*
- Cassini (oil)*
- Skua (oil and gas)
- Talbot (oil)

* currently producing

Minor accumulations

- Petrel (gas/condensate)
- Tern (gas/condensate)
- Penguin (gas)
- Oliver (oil and gas)
- Montara (oil and gas)
- Troubadour (gas/condensate)
- Puffin (oil)
- Bonaparte (gas)
- Sunrise (gas/condensate)
- Bilyara (oil/gas)

Significant shows/residual accumulations

- Avocet (oil and gas)
- Eider (oil)
- Flamingo (gas)
- Keep River (gas)
- Kulshill (oil and gas)
- Swan (gas)
- East Swan (oil and gas)
- Lesueur (gas)
- Spirit Hill (oil)
- Swift (oil)
- Curlew (gas)
- Weaber (gas)
- Eclipse (oil)
- Sahul Shoals (oil)

- Pelican Island (oil)
- Lacrosse (oil)
- Barnett (oil and gas)
- Turtle (oil)
- Lynedoch (gas)
- Dillon Shoals (oil)
- Barita (oil)
- Ningbing (oil)

(modified after Lavering & Ozimic, 1989).

3.3 Petroleum type(s)

The gravities of Bonaparte Basin oils range from 21 to 49 °API depending on original composition and degree of biodegradation. Oils in the Palaeozoic sequence of the Petrel Sub-basin have gravities ranging from 21 to 31.3 °API and are interpreted to be heavily biodegraded or residual accumulations. Oils reservoired in Mesozoic reservoirs in the Ashmore Cartier region have gravities which range from 33 to 49 °API and are highly paraffinic to paraffinic in composition (Table 1). Condensates appear to be ultraparaffinic to highly paraffinic in composition The composition of natural gases varies from dry to wet with a significant increase in nitrogen, up to 45 percent, in Palaeozoic reservoirs .

Table 1 - Crude oil properties, Bonaparte Basin accumulations.

Accumulation	**Challis**	**Jabiru**	**Puffin**	**Skua**
Petroleum-bearing unit	Sand 'A'	Multiple	Upper Cret.	Jurassic
Gravity °API	39.9	41.6	43.5-47.5	44.3
Base	n.d.	n.d.	paraffinic	paraffinic
Sulphur (%wt)	n.d.	0.06	n.d.	n.d.
Wax content (%wt)	n.d.	n.d.	9.9-22.5	n.d.
Initial gas/oil ratio	390	348	n.d.	663
Pour point	n.d.	15	n.d.	n.d.
Viscosity	n.d.	2.5	n.d.	n.d.

(n.d.: not determined)

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3.4 Developments and production

Petroleum has been produced from three accumulations in the Bonaparte Basin but principally from the Jabiru field. Production from the Challis/Cassini accumulation(s) uses a similar but larger floating production facility which is permanently moored to a fixed point mooring system.

The Jabiru project was first bought on stream in August 1986 following installation of the floating production facility (FPF) using a converted tanker. The 'Jabiru Venture', of approximately 140 000 DWT is moored to a single point system of catenary design. Oil and associated gas is produced from subsea completed wells (Jabiru - 1A, 5A, 6 and 7) via flowlines to the

mooring system and hence to the tanker where the oil is stabilised and stored. A connect/disconnect system is incorporated into the facility to allow the tanker, and elements of the mooring system, to disengage in the event that system loads exceed preset criteria, or upon warning of an approaching cyclone. Rapid reconnection is possible.

The FPF is located in approximately 119 metres of water 900 metres from the Jabiru - lA subsea well head. Crude oil is transferred from the FPF to a shuttle tanker moored in tandem. Oil is produced from the Jabiru Venture via a floating hose at rates of up to 3 000 m^3 per day.

Up until 31 December 1990 the cumulative oil production in the Bonaparte Basin was over 1.528 x 10^6 m^3 . Cargo volumes of approximately 60 000 m^3 are lifted from the 'Jabiru Venture' once every six to eight weeks.

The Petrel and Tern accumulations in the Petrel Sub-Basin are currently under consideration for possible future development based on a perceived potential market for 2.3 x 10^6 tonnes per year of LNG, requiring an annual field production of 3.5 x 10^9 m^3 of natural gas (NTDME, 1985).

Development options proposed for Petrel and Tern include a ten-well platform and treatment plant on Tern with a 65 km pipeline to the Petrel platform which could have space for up to 50 wells. A 185 km pipeline from Petrel to shore would be linked to a 110 km of onshore pipeline and a liquefaction plant located near Port Darwin (NTDME, 1985).

4.0 Ashmore -Cartier region

4.1 Structural features

The Ashmore-Cartier region covers the Vulcan Sub-basin, the Ashmore Platform, Londonderry High and the northernmost part of the Browse Basin (Figures 1 & 3). The major part of petroleum exploration in the Timor Sea has been undertaken in the Vulcan Sub-basin (or Vulcan "Graben") feature which comprises a complex structure between the Londonderry High to the east and southeast and the Ashmore Platform to the west. Within the Vulcan Sub-basin are a series of southeast-northwest oriented grabens such as the Paqualin, Swan and Heywood Grabens. These are flanked by horst-like features which have been major target areas for prospective petroleum-bearing structures such as those along the Jabiru and Skua horsts(Fig.3). On the eastern side of the Vulcan Sub-basin are a series of fault-related features which comprise the Jabiru terrace.

The Ashmore Platform is on the western side of the Vulcan Sub-basin and also immediately adjacent to the northern extension of the Browse Basin (to the south) . The Browse Basin is a northeast-southwest trending Triassic-Cretaceous basin formed along the northwest margin of the Australian Continent. The Ashmore Platform is a basement 'high' feature which lies between the western margin of the Vulcan Sub-basin and the edge of the continental shelf. Data from two wells on the western edge of the platform, North Hibernia-1 and Ashmore Reef-1, indicate that a western land mass may have shed sediment across the Ashmore Platform during the Triassic and Jurassic prior to break-up. Late Jurassic volcanics penetrated in Ashmore Reef-1 attest to the close proximity of the well location to the original spreading centre. Oceanic crust now lies to the west of the Ashmore Platform.

Previous interpretations (e.g. Allen & others, 1978) have shown the Ashmore Platform, which is a block fault high area of Triassic and older rock, is only overlain by thin Late Cretaceous and Tertiary cover. However, new seismic suggests that significant Mesozoic section, possibly including Late Triassic, Jurassic and Early Cretaceous sediments, is present within small graben features within the Ashmore Platform.

The Ashmore Platform and Londonderry High became emergent and remained largely so until the Late Cretaceous. The transgression which followed rifting saw the deposition of thick Late Jurassic and Early Cretaceous marine shales over an irregularly faulted surface in the main Vulcan Sub-basin and Cartier Trough. The progression to an open marine mature stage of continental margin evolution was interrupted in the Late Cretaceous by a period of marine regression. Following this, from the Late Cretaceous onwards, a westward thickening wedge of predominantly carbonate sediments covered the area. Faulting continued throughout the Tertiary as old faults were reactivated and antithetic faults developed due to

extension and sediment loading.

The Vulcan Sub-basin is effectively a northern extension of the Browse Basin, one of a series of features along the northwest continental shelf of Australia which generally parallel the present coastline. A prospective sedimentary sequence, ranging from Late Triassic to Tertiary, is present within the Vulcan Sub-basin. Block-faulting with associated uplift and erosion accompanying and following break-up of the Australian continental margin in the Mid-Jurassic resulted in the creation of a diverse array of prospective structures in the Ashmore-Cartier region. Restricted marine circulation in the Late Jurassic resulted in the deposition of thick sequences of organic rich shales within the Vulcan Sub-basin. These are generally regarded as the primary oil source for the region although older sequences also contain less-well recognized potential sources.

The Londonderry High is a northerly plunging extension of the Precambrian Kimberley Block which separates the Vulcan Sub-basin from the Bonaparte Basin. The Kimberley Block and Londonderry High (when emergent) have been the main sediment source for the Vulcan Sub-basin and Ashmore Platform. Along the western margin of the Londonderry High, a series of down-to-basin block faults marks the boundary with the Vulcan Sub-basin.

4.2 Geological evolution

The main phase of deposition in and around the Ashmore-Cartier region commenced in Early Triassic with a regional marine transgression into a pre-existing intra-cratonic Palaeozoic Basin. The Palaeozoic sediments comprise mainly limestone with minor shale and sandstone of the Hyland Bay Formation which probably overlies older Carboniferous-Devonian age sediments (Osprey - 1), including evaporites.

The regionally extensive and uniform sequence of marine claystone and siltstone of the Early Triassic Mt Goodwin Formation disconformably overlie the Permian sediments. The Early Triassic transgression gave way to a major regression in mid-Triassic resulting in deposition of the extensive shallow marine to fluvio-deltaic sandstone, siltstone and shale of the Sahul Group. The regression continued until Late Triassic and Early Jurassic during which the red-beds of Malita Formation was deposited. The regional regression was interrupted by episodic and localised marine transgressions, particularly during Late Ansian and Carnian times. During each incursion extensive carbonate was deposited throughout the Ashmore-Cartier area. The proportion of carbonate, however, increases drastically toward west and northwest indicating a westward domination of marine conditions. During Late Triassic time, several individual depocentres formed in the Ashmore-Cartier region which controlled the nature and style of deposition.

Good reservoir quality sandstones are associated with the Late Triassic sediments, particularly along east and southeast portion of Vulcan Sub-basin. Over the Ashmore Platform, however, the Late Triassic reservoirs are often eroded or relatively poorly developed.

A regressive environment resumed during Lower and Middle Jurassic before being terminated by the onset of tectonic activity related to mid-Jurassic rifting and sea-floor spreading. These movements which were initiated in the Late Triassic resulted in erosion of many uplifted areas and deposition of sand, shale and coal sequences of the Plover Formation in nearby sag basins. Such sequences are excellent potential reservoirs where they subcrop under the Mid-Jurassic (Callovian) unconformity.

Continuous rifting and uplifting during Middle Jurassic eventually formed the major northeast-southwest oriented structural elements of the Ashmore-Cartier area and subsequently the regional Callovian unconformity. The Vulcan Sub-basin, Cartier Trough, Ashmore Platform and Londonderry High features were all gained their current shape at this time. Extensive erosion occurred over uplifted areas especially over the Ashmore Platform and Londonderry High. Deposition recommenced in the Late Jurassic with a regional marine transgression into the rifted areas and depressions formed during Jurassic tectonic activity. Transgression continued until the Early Cretaceous and thick restricted marine shale and minor siltstone and sandstone of the Flamingo Group progressively onlapped the Callovian unconformity surface, covering most of the areas except the highest uplifted blocks. The Flamingo Group is considered as the main potential source-rock and often provides an excellent seal for Middle and Lower Jurassic reservoirs. The thickness of Upper Jurassic sediments varies considerably within the Ashmore-Cartier area, ranging from a few metres at the Jabiru-1A well to 2000 m in the Vulcan Sub-basin. Upper Jurassic sediments were probably restricted to a few, if any, graben features within the confines of the the Ashmore Platform, and are probably thinner in Cartier Trough than in Vulcan Sub-basin.

Fluctuation of the sea level during the Valanginian interrupted the transgression and resulted in the formation of a regional intra-Valanginian unconformity overlying the Late Jurassic-Early Cretaceous sequence. After a minor hiatus, a more extensive transgression prevailed and open marine conditions dominated the entire region when marl and carbonate of the Bathurst Island Group were deposited throughout Cretaceous times. The thickest section of the Bathurst Island Group occurs in the central Browse Basin. Within the Ashmore-Cartier region the group thins and gradually grades to predominantly carbonate toward west and northwest. The marl and claystone of Bathurst Island Group is generally considered as a regional seal for intra and pre-Cretaceous reservoirs. A relative fall of sea level during the Campanian and Maastrichtian is considered to be responsible for deposition of an extensive sand sequence (Puffin Sand sequence) in the northern Browse Basin, as well as southeast of the Vulcan

Sub-basin and in the southern part of the Ashmore Platform. These sandstones are well developed in the central Browse Basin and they provide excellent potential reservoirs and in some places could form the main exploration objective.

The overlying Tertiary sediments were deposited on a subsiding and prograding continental margin and comprise predominantly carbonates, interupted by regional sand units at the base of Miocene and the base of Eocene. The basal Eocene sand generally thins toward the west-northwest and changes facies to marl over the Ashmore Platform. A period of non-deposition during Oligocene resulted in a widespread disconformity throughout the Ashmore-Cartier region, except in the northwestern portion of the Ashmore Platform.

4.3 Structural development

The Vulcan Sub-basin, Ashmore Platform and Londonderry High are all major features of the Ashmore-Cartier region and they comprise the major structural elements formed during the Mesozoic breakup of Gondwanaland. These features, were formed by extensional deformation primarily during the Middle and Late Jurassic.

The Vulcan Sub-basin incorporates several troughs and a horst and graben terrane and lies between the Ashmore Platform and the Londonderry High. The northern part of the Vulcan Sub-basin has been subjected to significant post-Miocene subsidence forming the Cartier Trough (Fig. 5). Thick Late Jurassic sediments occur in the Vulcan Sub-basin which appear to be thin or non-existent on the more elevated features of the adjacent Ashmore Platform and Londonderry High. Early Cretaceous and younger sediments onlap onto and extend over the entire extent of the region, including the elevated platform and high areas.

Periodic rifting has caused the majority of structural features evident on existing seismic data over the Ashmore Cartier region (Wormald, 1988; Woods, 1988). These rifting episodes controlled the pattern of fault formation and, as a result, the extent and areas of sedimentation and erosion. The development of intense block-faulting and graben formation was initiated towards the end of the Middle Jurassic (Callovian), and established the dominant southwest-northeast tectonic grain evident throughout much of the Ashmore-Cartier region, particularly the Vulcan Sub-basin and its surrounding terraces.

The Jabiru Terrace has been subjected to the most detailed seismic coverage of any area within the Ashmore-Cartier region. Seismic sections illustrated in the literature describing this region commonly resembles the tensional faulting and extension models outlined in an experimental studies by Woods(1988).

The collision between the Australian and Asian plates during the Early Miocene subsequently reactivated the older Mid-Jurassic fault systems. This tectonic event has overprinted an east-northeast to west-southwest fault orientation on the Ashmore-Cartier region with many faults penetrating up to or close to the sea floor. A significant question must remain as to the local expression of this event (tensional or compressional) as few features indicative of purely compressional forces are evident from available data.

Indeed, according to the data relating to structural interpretations models identified by Woods (1988), the dominant horst and graben features present in the Ashmore-Cartier region are a distinct indication of tensional and extensional tectonics rather than the compressional regime previously invoked in the literature. A further major episode of renewed subsidence in the Cartier Trough commenced in the Cainozoic and continues to the present day - a further feature which a purely compressive regime would be unlikely to produce.

Woods (1988) indicates that a combination of periodic extensional faulting can be related to Permian normal faults, subsequent Jurassic faulting and Miocene reactivation of these older systems under a tensional regime. The implications of the latter tectonic regime are simple even if the nature of the structures they have produced are not. The commonly evident features are as shown in Figure 5 and include horst features in the Permian, Triassic and Jurassic sequences, caused by the development of converging normal faults. The apex of closures at the top of the Jurassic, or older sequences, provides much of the trap potential for petroleum exploration. Subsequent Miocene extension often produced graben or 'keystone' features in the overlying Cretaceous and Tertiary section and have resulted from rejuvenation of the older underlying fault patterns.

Woods (1988) concludes that the presence of a localised graben feature in the Tertiary part of the section is often a good indicator of an underlying horst. The throw of faults on the graben faults is often less than that of the faults on the underlying horst in the Jurassic or older sequence. The Miocene extension may have rejuvenated some older faults but not all will be so affected.

The results of this analysis confirm such results, as is outlined in the following regional review of the petroleum exploration results, prospects, leads and petroleum prospectivity of each of the vacant areas in the Ashmore-Cartier region..

4.4 Petroleum plays

The major petroleum play concept which has been successfully tested in the Ashmore-Cartier region is one where tilted horst fault-blocks comprising Plover Formation, Flamingo (Jurassic) and Sahul (Triassic) Group

reservoirs are sealed by the overlying base Cretaceous regional seal of the Bathurst Island Group. Closure is fault-dependant , the faults being Late Jurassic in age with some post-Miocene reactivation which can cause trap destruction. Faulting is very complex and difficult to resolve with regional seismic coverage alone.

Significant additional potential exists to test further valid play concepts which may involve some elements from the successful play type noted above. Submarine fan complexes in the Flamingo Group provide a significant play concept with very large potential trap sizes. They would be located on the downside of (generally) Oxfordian fault-scarps and rely on source and migration from downdip Jurassic source rocks.

Maastrichtian (Late Cretaceous) turbidite sands (Puffin play) provide a further play type which has demonstrated potential, as illustrated by the discovery of oil in the Puffin -1 and - 2 wells.

The results published in industry journals illustrate that the known oil accumulations such as Jabiru, Challis, Talbot, Skua and Puffin are all located on structurally high features up-dip of or proximal to major fault systems along which oil has migrated out of mature Jurassic source-rock sequences. It is the connection between the fault system, the strucural high and source sequences which the majority of unsuccessful exploration wells in the Ashmore Cartier region have visibly lacked.

There still exists significant potential for a wide variety of play types to be successfully developed, some of which may comprise some of the extensive array of plays outlined in detail by Botten & Wulff (1990).

5.0 Ashmore Platform

The most recent exploration within the available vacant area(s) on the Ashmore Platform was undertaken while much of it was held under the recently vacated permits AC/P1 and AC/P9 (Fig. 6). AC/P1 was located in the central and southern portion of the Ashmore Platform - it covered an area of 9835 km (Fig.6). Permit AC/P9 was immediately east of AC/P1 and occupied the southeast portion of the Ashmore Platform and an adjacent part of the Vulcan Sub-basin.

Recent exploration activity in the two permit areas prior to their recent surrender was as follows:

Seismic surveys	Petroleum exploration wells
AC/P1 (1985-1991)	
1986 86.01 Survey (2171 km) (reprocess 710 km)	
1987 87.01 Survey (372 km)	
1988 88.01 Survey (310 km)	1988 Delta-1
AC/P9 (1986-1991)	
1987 Johnson Bank (1514 km)	1988 Cartier-1
1989 Bishops Rocks (322 km)	1990 Lucas-1
1990 Osborn (326 km)	

Seismic survey coverage for AC/P1 is concentrated in the southern half of the permit area, much of it over undrilled structural features which appear to contain potential Triassic reservoirs overlain by base Cretaceous regional seal units, as well as potential Late Cretaceous reservoirs sealed by younger units. Some of these features are faulted horst blocks and few appear to have independent four-way dip closure. The feature tested by Delta-1 appears to be one of the few with four-way dip closure.

Source, migration and seal are perhaps the most critical factors affecting the explorations results available to date. Previous wells such as North Hibernia - 1, Brown Gannet-1, Grebe-1 and Prion-1 recorded results indicating that excellent clastic Triassic reservoirs (sandstone) are present in the Ashmore Platform sequence, with additional potential for reservoirs in carbonate (reef-like) sequences. Source, maturation and migration are elements which to date have proved disappointing. Lack of adequate source and maturity have pointed to a need to rely on migration from mature oil-generating sequences in the northern Browse Basin. Potential does exist however for the identification of graben features within the recognized confines of the Ashmore Platform which may contain mature sources

rocks within the Jurassic as well as Triassic sequence.

5.1 Hydrocarbon potential

As this part of the vacant acreage (Ashmore Platform) is adjacent to the Vulcan Sub-basin (to the east) and the Browse Basin (to the south), much of the focus of interest in the areas will be on petroleum plays which are similar or incorporate elements of plays which have proved successful in the Vulcan Sub-basin or Jabiru Terrace. The Jurassic reservoired Skua oil discovery lies 20 km to the southeast and the Cretaceous Puffin oil accumulation lies 10 km to the east of the Ashmore Platform. The Jabiru field which is currently producing from the Jurassic is located 85 km away to the east.

The Ashmore Platform contains over 3000 m of Triassic, and possibly Jurassic, pre-breakup sediments overlying the Permian Hyland Bay Formation which is generally considered economic basement. This pre-breakup sequence is abbreviated by the Callovian to Valanginian age breakup unconformity. This event forms the base of a Late Jurassic to Cretaceous sequence of shale, marl and calcilutite up to 650 m thick. The Cretaceous also contains a Maastrichtian-aged turbidite sand unit in the southeastern part of the area. Over 2000 m of Tertiary calcarenite, calcilutite and some sandstone overlie the Cretaceous sequence.

Structurally the Ashmore Platform area is broken by a set of NE-SW trending faults in the pre-breakup sequence (Fig. 7). These faults relate to the Middle Jurassic rifting phase and generally terminate at the Callovian breakup unconformity. The second major set of faults dates from Miocene. On the Ashmore Platform these faults are generally ENE-WSW trending and overprint and in some cases re-activate the earlier faulting. In some cases the younger faults appear to offset the deeper faults in a strike slip movement. This results in a highly structured area with several potential hydrocarbon traps. It is also likely that these elements are influenced by an underlying NE-SW Palaeozoic lineament similar to that seen in the Bonaparte and Canning Basins. These older faults are thought to form transfer faults offsetting rift-phase structures. The primary reservoir targets in Ashmore Platform vacant area(s) are sandstones of the Late Cretaceous and Triassic.

Triassic Play

The Triassic sandstones exhibit variable reservoir quality. In the southeast at Grebe-1 and at Lucas-1 porosities of 23% are evident. There are potential structural/stratigraphic traps that involve this high-quality Triassic reservoir in the southeast corner of the Ashmore Platform, eg. the Grebe updip lead. Good Triassic potential is evident in the northern part of the

platform, as evidenced at Rainbow-1 which had porosities of 20% in sands below the Carnian age limestones.

The Triassic targets are expected to be sealed by shale and marl at the base of the overlying Cretaceous sequence as they are at Skua and Challis or by Upper Jurassic shale in a trough feature west of Lucas-1. The main potential oil source for Ashmore Platform prospects lies to the east in the Vulcan Sub-basin area where mature oil-prone source rocks have been identified (eg. Swan-2). The Upper Jurassic (restricted marine) shales in Vulcan Sub-basin are considered the main source-rock for the Ashmore-Cartier Region, although terrestrial to shallow marine sediments of the Mid-Early Jurassic also have source potential. Prospects on the Ashmore Platform are in a position to trap hydrocarbons migrating from the Vulcan Sub-basin, as well as from the Browse Basin to the south. This is the main play in the southeastern portion of the Ashmore platform. Sourcing is most likely from the Triassic or Late Jurassic sediments in the Browse Basin. Long-distance migration is required to charge these structures. The Triassic reservoir is predicted to contain stacked, 5-10 m thick fine to very fine grained sandstones deposited in a fluvio-deltaic environment.

The Triassic sequence intersected by Prion-1 (Challis and Pollard Formations ?)contains low concentrations of organic matter (0.1 to 0.46% Total Organic Carbon, TOC) indicating limited local source potential out of this mixed carbonate and shale sequence, while a vitrinite reflectance level of 0.64% indicates that it is moderately mature for hydrocarbon generation. In Sahul Shoals-1 similar low levels of organic carbon are evident in the Triassic sequence (0.58 to 0.89% TOC) with a slightly lower level of maturity (vitrinite reflectance of 0.56%). Brown Gannet-1 reveals about 0.6% TOC and 0.56% vitrinite reflectance in the Triassic sequence. In contrast, North Hibernia-1 intersected delta and lower delta-plain sediments of the Nome Formation which contain TOC values of 2.98 to 10.79% (2245-2360 m KB) at a vitrinite reflectance level of 0.6% or the mid-maturity for liquid hydrocarbon generation . These results indicate some potential for oil generation from the Triassic in the Ashmore Platform, potential which tends to be overshadowed by the more favoured plays in and around the Vulcan Sub-basin.

Calcareous Triassic shales should provide good local interbedded seals. Aptian shales provide a regional seal. The Aptian onlaps the Ashmore Platform. It is thickest in troughs and may be absent on some horsts. The Aptian also becomes thinner and more calcareous towards the northwest. Albian-Cenomanian marls overlie the Aptian shales and they also have sealing capacity but also become more calcareous towards the northwest.

Cretaceous Play

The Cretaceous sands have flowed 4608 BOPD at Puffin-2, 10 km east of the Ashmore Platform. These sands have porosities of 28% and excellent

inferred permeabilities at Lucas-1. The Cretaceous sands are not present throughout the area, but well control, together with seismic interpretation, indicates that this reservoir is present in the southeastern part of the Ashmore Platform. Cretaceous leads are sealed by shales within the same sequence as evidenced at the Puffin Field. Sourcing would be from the same units as for the Triassic play as well as Lower Cretaceous shales. Excellent reservoirs are provided by medium to fine grained sand of Maastrichtian age. These sands were the primary objective in Delta - 1. Good seals are generally provided by the Upper Cretaceous marine shales which onlap the reservoir.

5.2 Seismic results

The seismic data from AC/P1, and data from the immediate vicinity, contains in excess of 5,000 km of seismic coverage. A regional seismic survey (86.01) identified numerous structural closures, with the most prospective being located in the southern part of the the Ashmore Platform (Fig.7) - one, a lead/prospect, is named here in accord with the earlier established tradition of bird groups (*Albatross*), and the second is the Delta feature (drilled by Delta-1). Both were covered by more detailed coverage in the 87.01 seismic survey program. The follow-up 88.01 seismic survey was recorded in January 1989 and totalled 310 km. This survey was designed primarily to infill the grids over other prospects which are here named from those groups available in Slater & others (1986) - the *Booby* and *Goose* prospects (refer Fig. 6). In addition, one line was recorded between Delta-1 and the *Albatross* feature. This line provides a direct seismic tie from Delta-1 as well as a line perpendicular to the structural orientation of the *Albatross* prospect.

The 88.01 survey contains 310 km of data located in the southern portion of AC/P1 over the known *Booby* and *Goose* feature with one line over the *Albatross* feature. On the *Booby* feature, 12 lines were recorded totalling 159.6 km of coverage, which produced a 1 km x 1.5 km grid. On the *Goose* prospect, 9 lines were recorded totalling 85.3 km, a 1 km x 1.5 km grid. A line recorded from *Albatross* to tie with Delta - 1 contains 26.5 km of multi-fold coverage.

Approximately 2000 km of seismic data is available from the AC/P9 work program, comprising 1500 km of 1987 Johnson Bank seismic survey lines acquired in 1987 and about 500 km of Vulcan Shoals (VS) lines, acquired in the early 1980s as part of a speculative survey program, 240 km of which were reprocessed in 1987. The total data set form a grid of 1 km spaced dip lines and 2 km spaced strike lines over the structure drilled by the Cartier-1 well and the *Coot* feature, with a 2 km dipline grid over most of area of AC/P9.

Well control in the area of AC/P9 is available on lines 87JB-3 and VS-ll which pass through Brown Gannet-l, lines 87JB-60 and 87JB-40 pass

through Rainbow-1, lines VS-10A and 87JB-27 pass through Prion-1, lines 87JB-37 and VS-10A pass through Grebe-1 and line 87JB-45 passes through Puffin-2 to the east.

5.3 Seismic data

The 85.01 and 86.01 seismic data from AC/P1 can be calibrated from well ties with the Prion-1, Brown Gannet-1 and North Hibernia-1 wells. In addition, well ties can be made on data at Ashmore Reef-1, Mount Ashmore-1, Grebe-1 and Woodbine-1, all in the immediate vicinity of AC/P1. The 88.01-1 line is tied directly to Delta-1, as shown in Plate 1. Nine or more major seismic horizons can be picked and tied over much of the Ashmore Platform area, based on the results available from seismic collected in AC/P1 and AC/P9.

All of the horizons identified in AC/P1 can be correlated to the *Albatross* feature and tied from the Delta-1 well. Many are also traceable over the *Booby* and *Goose* features. Over the *Booby* feature the higher horizons could be correlated with reasonable reliability. The base Cretaceous is difficult and low certainty must be attached to maps at this level. The top Permian is not accurate and is only indicative.

Over the *Goose* feature, seismic data quality is considerably reduced due to the effect of surface reefs. The top Palaeocene, top Cretaceous and top Bathurst Island Group have been mapped with reasonable reliability. As with the *Booby* feature the base Cretaceous is a difficult pick and the top Permian horizon is only used to indicate approximate structure at depth.

The Johnson Bank seismic survey and associated reprocessing allowed the first detailed structural mapping of the AC/P9 area. With a 1 to 2 km dip-line grid over most of the permit, all sizeable Callovian unconformity structures can be identified, the two largest structures being Cartier and *Coot*, both have been detailed with 1 km dipline grids. The Cartier structure was tested by drilling of the Cartier-1 well, drilled during August-September 1988. The well was plugged and abandoned as a dry hole.

5.4 Prospects and leads

Albatross (Plate 1, Figs 7 & 8)

The *Albatross* feature is associated with a NNE-trending horst block. Line 88.01 runs perpendicular to the structure (Plate 1). The major objective of the *Albatross* feature is considered to be Triassic sands immediately beneath the regional unconformity. Secondary objectives are the Late Cretaceous sands.

Closure is largely fault-dependant at both major objectives though there is

also a small component of fault-independent closure (Fig. 8). The northern closure is formed by the subordinate E-W cross fault trend down-faulting to the north which reverses the southerly regional dip. The NNE fault trends bounding the horst form the eastern and western closures and the regional dip forms the southern closure.

There is a risk that the main Triassic objective will not have an effective seal. The main seal for this play is the Aptian shale which is overlain by Albo-Cenomanian marls. The top Bathurst Island to base Cretaceous interval (containing the Aptian shales and Albian-Cenomanian marls) may thin onto the *Albatross* structure. There is a risk that this sealing unit will be breached by the E-W fault. The base Cretaceous is difficult to identify on seismic and may be deeper than expected. A deeper base Cretaceous would decrease the sealing risks for the structure. As *Albatross* is such a large structure, an effective seal would make it attractive.

The main risks of the *Albatross* structure are sourcing - long distance migration is probably required to charge the reservoirs and no source rocks have been specifically identified to date in the vicinity. Sealing is a further problem - the fault-dependant closure (*Albatross*) is delineated by several major faults which may breach the structure; the regional seal over the Triassic play is thin or possibly absent .

Booby (Plate 2, Fig. 7)

Booby is a trap-door style trap located at the intersection of two major faults, one trending E-W the other trending NE-SW. The primary target is the base Cretaceous and at this level the spill point is located in the ENE corner of the structure. The vertical relief of the structure is equivalent to the throw of the fault, that is, there is no fault-independent closure. At the top Cretaceous level there is no significant closure and there is little chance the secondary Cretaceous play will be successful. The top Bathurst Island Group to base Cretaceous interval appears to thin or be absent over the crest of the structure and as such the Triassic play will have major sealing risks due to the unreliable nature of the base Cretaceous mapping.

The main risks for the *Booby* feature are migration and seal. The most likely source is from the Browse Basin. Long distance migration is therefore necessary, unless sourcing can and has occurred from Jurassic sequences in grabens within the Ashmore Platform. There is some risk that the seals will not be effective and the faults may breach the structure.

Goose (Plate 3, Fig. 7)

Goose is the more western prospect of the two detailed by the 88.01 seismic survey in AC/P1 . The structure appears to have been formed by the convergence of two major faults, as with the *Booby* feature. The presence

of surface reefs dramatically effects this prospect. Such reefs cause time pull-ups and ray path distortions which degrade the seismic quality giving the data a broken appearance. The time pull-ups also have the effect of distorting the real depth picture for a given horizon. Depth conversion may therefore be necessary. The seismic data indicates the prospect has two separate culminations separated by a saddle. The culmination to the west appears to be largely effected by the presence of a reef. The culmination to the east is also affected by water bottom variations though to a lesser degree. The eastern culmination is sufficiently robust to survive depth conversion and may increase in size.

The primary target is the base Cretaceous. The top Bathurst Island Formation to base Cretaceous interval appears to thin onto the structure, as at *Booby*. This results in a potential seal risk and will require further investigation. Closure exists at the top Cretaceous and therefore the Maastrichtian sands can be considered a secondary target.

Additional structures identified during this review of available information include the following features (Fig. 7) which have as their main potential reservoir sequences, the following intervals;

Feature	**Main potential reservoir(s)**
Coot	Cretaceous & Triassic
Thickhead	Cretaceous & Triassic
Mallard	Cretaceous & Triassic
Lapwing	Triassic
Noddy	Cretaceous
Ostrich	Triassic
Owl	Cretaceous & Triassic

Names given above are taken from those present in Slater & others (1986) and not used for naming features in other parts of the Bonaparte Basin.

The quality of seismic data coverage and potential for up-dip drilling on known prospects and structures can be determined by closer examination of the following seismic lines.

Exploration well	**Seismic line**	**Extent of structure**
Delta-1	8801-001	SP 1000-1200
	8601-47	SP 500-600
	8701-30	SP 200-300
Grebe-1	WB-1A	SP 01-97
	VS-1	SP 01-100
	VC-10	SP 180-200
Prion-1	VS-1OA	SP 1200-1400
	HP-25	SP 01-96
	8501-45	SP 01-100

	HP-8	SP 200-250
Cartier-1	LR-103	SP 40-120
	VS-9	SP 100-400
Brown Gannett-1	8601-26	SP 01-200
	VS-11	SP 50-90
	BB-49	SP 50-90
Ashmore Reef-1	71-760	SP 30-40
Mount Ashmore-1	76-1736	SP 75-90

A representative set of seismic lines over the southern and southeastern parts of the Ashmore Platform are included as Plates 4 to 8. They comprise lines 1, 7, 8, 10A and 11 of the Vulcan Shoals (VS) scientific survey acquired in 1983 by Geophysical Service International. The location of each seismic line is shown on the panel of each section display.

6.0 Vulcan Sub-basin

The most recent exploration within the available vacant area(s) in the Vulcan Sub-basin was undertaken while the area(s) were held under the AC/P2 permit (Fig. 9), located in the central and southern portion of the Vulcan Sub-basin.

Recent exploration activity in the AC/P2 permit areas prior to the recent partial surrender was as follows:

	Seismic surveys	**Petroleum exploration wells**
1985	HV3 Survey (1314 km)	Skua-2 (oil)
	HV4 Survey (318 km)	Eclipse-2 (shows)
1986	HV5 Trials (352 km)	Skua-3 (oil/gas)
	HV6 Survey (5823 km)	
1988		Skua-4, Puffin-4, Parry-1, Allaru-1
1989	HV7 Survey (809 km)	Paqualin-1
1990	XV10 Survey (55 km)	Rowan-1, Maple-1, Pascal-1, Birch-1
	HV11 Skua 3D survey (5376 km)	

The vacant areas in the Vulcan Sub-basin made available as a result of relinquishments from AC/P2 are located on the western and central parts of the sub-basin. The western area ('Pascal' area) overlies one feature previously tested by the drilling of the Pascal-1 well, the northern two areas are near to the Maple-1 and Paqualin-1 wells drilled on structures in the western part of the Vulcan Sub-basin - these are termed the 'Paqualin' and 'Maple' areas, as shown in Figure 9.

A detailed outline of the play types known to occur in the Vulcan Sub-basin has been outlined in Patillo & Nicholls (1990). As such only the simplest details of the of the features of the sub-basin are repeated here.

6.1 Geological evolution

Deposition in the Vulcan Sub-basin during the Early Triassic comprised a major marine transgression over the Late Permian Hyland Bay Formation. This transgression deposited the Mt. Goodwin Formation which consists of marine siltstone, claystone and grades vertically into regressive pro-delta claystone and deltaic sandstone. An extensive marine transgression followed and marks of a second (Triassic) depositional cycle, it deposited carbonate and claystone. A regressive component commenced in the Middle Triassic and into the Late Triassic, resulting in the deposition of deltaic and fluvial sandstone, siltstone and claystone, with some shallow-marine sandstone and limestone. Reservoir quality is good in Middle-Late Triassic sediments. Tectonic movement at the end of the Triassic period was characterised by regional block faulting, uplift and erosion. The Triassic/Jurassic boundary appears to be marked by a regional

unconformity related to the initial onset of rifting which continued into the Late Jurassic.

The Early to Middle Jurassic Plover Formation is characterised by massive sandstones deposited in a fluvial-braided stream environment. They pass laterally into more deltaic and marginal marine environments and the formation forms part of the producing reservoir in the Jabiru field.

Widespread uplift and block-faulting commenced towards the end of the Middle Jurassic and continued to the Late Jurassic and imprinted a NE-SW structural grain onto the region, characterised by by horsts, grabens and tilted fault blocks. Associated uplift and erosion produced the regionally pervasive "break-up"-related unconformity of approximate Callovian age. In places extensive erosion occurred particularly over the Ashmore and Sahul Platforms and Londonderry High, removing Lower to Middle Jurassic sediments and exposing the Triassic sequence on some of the more elevated blocks.

Graben collapse followed and allowed the incursion of the Late Jurassic seas into graben areas which filled with sequences of restricted marine mud and claystone whilst shallow marine clastic environments developed along adjacent high areas. Deep-water clastics episodically prograded from the flanks of these basins. Tectonic rejuvenation of the region during the Kimmeridgian uplifted intrabasinal areas forming additional high trends i.e. Jabiru/Eclipse. Adjacent grabens filled with Tithonian to Berriasian claystones with marginal clastics again developed along basin flanks and around intrabasinal highs.

Deposition continued into the Early Cretaceous, before being interrupted in the Neocomian by a major transgressive event commencing in the Valanginian. Deposition of the Cretaceous-aged Bathurst Island Formation was controlled initially by continuing post-break-up regional subsidence. As subsidence slowed, extensive progradation and basinward growth of the shelf occurred. Neocomian restricted marine glauconitic claystone deposition gave way in the Early Albian to extensive open marine marls and carbonate deposition which continued throughout the Cretaceous and Tertiary. These claystones and marls provide the regional seal to the underlying Jurassic and Triassic reservoirs. Local stratigraphic names for the sequences are listed in Patillo & Nicholls (1990).

6.2 'Pascal' area

A stratigraphic section ranging from Recent down to Middle Triassic occurs within drillable depths in the three vacant areas overlying the Vulcan Sub-basin, including the 'Pascal' area. No source intervals are yet evident but potential reservoir intervals are present and include; Oliver Sandstone, Puffin Sandstone (if present), possible Oxfordian fan-sands in the Jurassic Vulcan Formation and Triassic sandstones (Nome & Pollard

Formations). No structural closure or overlying seal is yet evident in the Oliver Sandstones. The Puffin sandstones are expected to be present in part of the 'Pascal' area. The depositional edge of the Puffin-fan sandstones is interpreted to trend E-W through the northern part of the area. The depositional edge is marked by thinning of the Cretaceous interval northward of Pascal-1 and Parry-1. The clastic fan units are replaced by lateral and distal claystones of the Puffin Formation. Further north a transition to the Borde Formation facies occurs.

Intra-Triassic seismic mapping and correlations have not been improved by results in Pascal-1 where Triassic reservoirs proved to be of poor quality. Scarce seismic data of moderate to poor quality does not allow mapping of the Triassic Nome, Challis and Pollard Formations. Any of these could potentially subcrop the main unconformity within low relief closures. The Challis Formation occurs in the Triassic section at both Rainbow-1 and Pascal-1 but has poor reservoir quality .

If good-quality Nome Formation sands subcrop any valid closures at the main unconformity, seal would be provided by a condensed sequence (Echuca Shoals to Gibson/Fenelon) of claystones, calcilutites and marls.The Hibernia and Grebe Sandstones are not expected to be present in the sequence. The absence of proximal source intervals adds a large hydrocarbon charge risk to the 'Pascal' area.

The 'Pascal' area overlies the edge of the Ashmore Platform. The Ashmore Platform has been a positive feature since at least the inception of rifting (approximate Callovian age). The main unconformity mapped represents a composite surface of several erosional events resulting from structural uplift as well as long periods of non deposition and/or very low rates of deposition. The major hiatus spans the Mid./Late Triassic to Early Cretaceous. The main structural (erosional) episodes are the Callovian and Intra-Kimmeridgian. The high blocks were eventually submerged and covered by marine restricted basin claystones in the Mid.-Late Valanginian transgression .

Several fault trends are evident on the seismic data. Older pre-Valanginian faults trend SSW-NNE and SW-NE, more than one episode being present. Post-Valanginian fault trends are WSW-ENE and relate to the Late Miocene structuring. Some older faults were reactivated by the Miocene event but often Miocene faulting cross cuts the older trends.

Poor quality and sparse seismic data allows mapping of several modest low- relief time closures at the main unconformity and top Cretaceous levels. Any Puffin sands present are expected to be thin (5-15m) and reservoir quality average to good, though probably inferior to Pascal-1 and Parry-1. Potential Triassic reservoir section is not confidently known but Nome, Challis or Pollard Formations may subcrop. Vertical seal to the Puffin

sandstones (if present) would be provided by calcareous claystones commonly present in the Late Cretaceous sequence.

Breaching of any Cretaceous oil accumulation by Miocene faulting is a possibility in the north of the area as young faults are evident in the Cretaceous and younger parts of the section..

Vertical seals to the Triassic section subcropping the main unconformity are likely to be the Fenelon to Echuca Shoals Formations. This section is present immediately above the main unconformity in Rainbow-1, Pascal-1 and Parry-1. Intraformational seals are possible in the Triassic, particularly in the Challis Formation. The structural style beneath the main unconformity is characterised by a series of SSW-NNE and SW-NE trending faults downthrown to the NW.

The Swan graben is considered too distant to supply hydrocarbons to the northern 'Pascal' area, particularly as the presence of the Puffin horst between the Swan Graben and the 'Pascal' area creates a migration shadow zone NW of the Puffin horst. A thick section of Late Jurassic source-rocks that are possibly mature enough to generate and expel hydrocarbons are possibly present in the Paqualin graben north of the 'Pascal' area . Migrating hydrocarbons would follow the steepest dip along Late Jurassic carrier beds (if any are present), tending to move NW and SE out of the graben axis. Any hydrocarbons accessing the SW end of the Paqualin Graben must migrate to the 'Pascal' area by means of a complicated pathway.

Structural leads present in the 'Pascal' area are mapped on moderate to poor quality seismic data at main unconformity and top Cretaceous levels. The Puffin Sandstone is expected to pinchout to the northwest in the 'Pascal' area - if present, it may not be strictly conformable to the top Cretaceous horizon. An unknown Triassic reservoir section would occur beneath the main unconformity in the northern 'Pascal' area but closures are modest, low relief and high risk.

The Pascal structure comprises a strongly eroded Late Triassic tilted fault-block. Pascal-1 drilled a fault-closed feature on the margin of the Ashmore Platform and Vulcan Sub-basin but failed to encounter any hydrocarbon shows. Complex Triassic lithologies are likely to subcrop the regional unconformity across the 'Pascal' area, making reservoir predictability difficult.

The nearest well to the' Pascal' area which recovered oil was on the Puffin High which encroaches into the eastern part of the 'Pascal' area (Fig. 9).
A total of five wells have been drilled on the Puffin horst trend; Puffin 1 to 4 and Parry-1. Puffin-1 contains a 1.5 m oil column and Puffin 2 flowed 4608 BOPD, both from the Maastrichian Puffin Formation. A small oil accumulation may occur updip of Puffin-3 and 4 within the similar

stratigraphic sequence. Triassic underlies the basal Cretaceous on the Puffin High.

Plate 9 is an interpreted section acquired in mid-1988 in the southeast part of the easterly 'Pascal' Block and shows the eastern edge of the Puffin High and the faulted margin of this feature and the Swan Graben. The section indicates that a considerable thickening of the sediments in the Cretaceous sequences takes place in the Swan Graben with displacement which has taken place within faulted parts of the Tertiary sequence being accommodated in underlying sequences by compaction.

6.3 'Paqualin' area

The Ashmore Platform also extends into the northwest corner of the 'Paqualin' area but is offset en-echelon by the Paqualin Graben. Detailed seismic coverage in the form of the 1987 HV6 3D survey provides as much as a 50 m line spacing between major diplines. The least well covered parts of the area have grid coverage of the order of 2 x 1 km.

The Paqualin-1 well appears to have intersected two Upper Vulcan Formation fan-sands deposited in the Paqualin Graben. As the Paqualin feature appears to be related to salt piercement the timing of potential generation and entrapment is not clear at present.

Similar Triassic-aged reservoirs to those encountered in the Puffin/Parry wells are interpreted to subcrop the regional unconformity in this area. The shallower depth of burial gives this area some likelihood of improved reservoir quality in the Triassic sequence. In the 'Paqualin' area, three small leads are identified at Triassic levels in the northwest along the flank of the Ashmore Platform. Such features would however, require source and migration from the Paqualin Graben to the east . Significantly more seismic control is required to fully evaluate the leads but their major weakness are the need for external migration and (Triassic) reservoir quality.

To date two wells, Maple-1 and Paqualin-1, have been drilled in this region. Paqualin-1 was drilled adjacent to the salt diapir and encountered low-quality Triassic oolitic limestone and sandstone reservoirs beneath a thick sequence of Late Jurassic claystones. Thin distal turbiditic sandstones at the base of the Upper Vulcan formation contained a 2 m column of gas on 1 m water, based on RFT data. Maple-1 tested an intra-Kimmeridgian aged tilted fault-block adjacent to the Paqualin central graben region. The well tested gas (9.1 MMCFD) and condensate (270 - 250 BBls/MMCFD) from a tight calcareous/siliceous cemented Late Triassic sequence (Challis formation). Log analysis indicates the entire Triassic section penetrated to be of extremely poor reservoir quality.

The NW margin to the Paqualin Graben is defined by the boundary with the

Ashmore Platform. The Paqualin Graben plunges NE out of the vacant area, whereas towards the SW it rises into the AC/P13 permit where it appears to die out. Thick Late Jurassic claystones fill the main graben axis which has been pierced by a major salt diapir originally of Palaeozoic age. Across the entire region Late Jurassic Lower Vulcan formation claystones are interpreted to unconformably overlie Triassic pre-rift sequences. These units are truncated towards the SW due to uplift and erosion related to intra Kimmeridgian tectonism. Upper Vulcan Formation claystones unconformably overlie the older Late Jurassic sequences. A major erosional scarp is interpreted to have developed along the edge of the Ashmore Platform during the Late Jurassic. Thick oil-prone and generative Late Jurassic source rocks are thought to occur in the Paqualin Graben.

Plates 10, 11 and 12 are seismic sections which traverse parts of the 'Paqualin' area. Plate 10 crosses the flank of the Paqualin diapir, while Plate 11 is an oblique section of the Paqualin Graben and Plate 12 is a cross-section of the graben.

6.4 'Maple' area

The 'Maple' area comprise a series of en-echelon ENE trending intra-Kimmeridgian fault-blocks which appear to progressively downstep into the Paqualin Graben. Structural and stratigraphic trends cannot be defined with certainty beyond the Maple Horst as the Paqualin salt diapir is approached. These structures plunge towards the NE and beyond into AC/P4. Late Jurassic claystones overlie Triassic pre-rift sequences within the 'Maple' area.

The main prospective level in the 'Maple' area is in Late Jurassic fan plays adjacent to the Ashmore Platform and structural traps related to salt piercement. Late Miocene faulting has reactivated some Late Jurassic faults across the Vulcan Sub-basin, setting-up additional structural plays in the overlying Puffin Formation.

Allaru-1 was drilled southeast of the 'Maple' area. The well encountered hydrocarbon shows in thin early Cretaceous Berriasian sandstones, but failed to intersect Plover Formation reservoirs. Additional potential is is possible in plays associated with either subcrop of late Jurassic sandstones beneath the intra-Kimmeridgian unconformity or thin Early Cretaceous sandstones which onlap the dip slopes of the main tilted fault blocks.

Although no prospects are evident in the Swan Graben where it extends into in the southern part of the 'Maple' area, potential fan plays appear to occur on graben flanks in Late Jurassic sequences. Uplift during the Late Jurassic or regional lowstands during the Valanginian and Mid. Aptian are likely times for lowstand clastic (fan) development. Low-relief,

mounded features are apparent on some seismic sections in the Swan Graben and with improved data quality, further similar features may be found.

Four wells have been drilled in the Swan Graben south of the 'Maple' area; Swan-1 and 2, Vulcan-1B and Rowan-1. Swan-1 and 2 and Vulcan-1B penetrated thick sequences of Late Jurassic claystones but both wells failed to encounter pre-rift reservoir sequences within the deep graben axis. They did have significant hydrocarbon shows in thin sandy turbidites, but did not encounter reservoirs in the syn-rift Vulcan Formation. Geochemical data indicates the Swan Graben has been a significant source 'kitchen' and - and, in addition, the Late Cretaceous Puffin sandstones in Swan-1 and 2 are oil-bearing.

The 'Maple' area overlies the extension of the Puffin Horst and lies between the Paqualin Graben and Swan Graben. The horst is tilted away from the high point adjacent to the Paqualin Graben down to the southeast towards the Swan Graben. To date no wells have been drilled in the area however, Paqualin-1 to the west , Maple-1 in the adjacent block to the southwest , and Allaru-1 provide some well control.

Seismic control is only moderate. The HV6 3D survey extends into the area and has a dip-line seismic spacing of approximately 1km and sparse strike-line control. The available seismic data is from several vintages: HV3 in 1986 and HV7 in 1989. Data quality is generally poor with data beneath the intra-Valanginian event being very difficult to identify. Key horizons are shown in Plate 13 which traverses the southeast part of the 'Maple' area. The base Miocene, top Palaeocene, top and base Cretaceous horizons shown evidence of normal faulting and the development of small graben-like features. The pre-Cretaceous section is less distinct. The Triassic marker and Callovian unconformity horizons are poorly-defined as a result of the poor data-quality. The Callovian unconformity is the upper surface of the main target horizon.

The only prospect or lead previously identified is the Maple prospect which was drilled in late 1989/early 1990 and discovered a sub-economic gas accumulation. The northeastern extension of the Maple rotated fault-block structure lies in the western part of the area. Seismic data quality precludes the confident mapping of the northeastern extent to the Maple structure, however, it is possible that closure extends considerably further across the 'Maple' area.

A stratigraphic section ranging in age from Triassic through to Recent is interpreted to be within drillable depths in the 'Maple' area. The Challis Formation is interpreted as subcropping the Callovian unconformity over most of the area. Thin units of Triassic Nome Formation may be preserved and they are potentially a hydrocarbon source in addition to that provided by the Jurassic of the Swan Graben.

The distribution of the Plover Formation is interpreted as having been controlled by the bounding fault on the Swan Graben, with only minimal Plover Formation being deposited west of the graben.

Overlying the Callovian unconformity is the Late Jurassic Vulcan Formation, in which an intra-Kimmeridgian unconformity is evident. At Allaru-1 the lower part of the Vulcan Formation - marine claystone, a mid-upper shoreface basal sand and discrete interbeds of submarine fan sands are present.In the 'Maple' area the (Lower) Vulcan Formation marine claystone with a basal sand should be present. The submarine fan sands which were present at Allaru-1 are expected to extend into the southeastern part of the 'Maple' area. Overlying the intra-Kimmeridgian unconformity a section of (Upper) Vulcan Formation silty marine claystone may be present. The Late Cretaceous Puffin Formation sands are expected in the southern part of the 'Maple' area.

A Tertiary section of bioclastic calcarenite, calcilutite, and quartz sandstone with minor calcareous claystone and limestone overlies the Cretaceous.The broad, low-relief extension of the Puffin Horst is a significant feature of the 'Maple' area. The horst lies between the NE-SW trending Paqualin and Swan Grabens. The Paqualin Graben cuts through the northwestern corner of the area.

The northeast extension of the Puffin Horst is made up of a series of rotated fault-blocks and small horst-blocks, which dip away from the Paqualin Graben towards the Swan Graben . Throws on faults of the rotated blocks and horsts tend to be small, apart from the main bounding fault. These faults appear to die out within the upper part of the Vulcan Formation.

The horst was initially on the margin of a broad graben which developed in response to Callovian tectonism. Subsequent intra-Kimmeridgian tectonism resulted in the broad uplift of the Puffin Horst trend and the further collapse of the Swan and Paqualin Grabens. Despite significant uplift at this time the area remained sufficiently submergent for a thick sequence of (upper) Vulcan Formation marine claystone to be deposited.

Further structuring occurred in the Late Miocene, with the trend of the faults being more east-west. This faulting appears to be independent of the pre-existing structure and generally does not penetrate the intra-Valanginian event.

The Challis and Nome Formations are potential reservoirs beneath the Callovian unconformity, as intersected by Maple-1. The section comprised thinly interbedded sandstones, claystones and minor limestones. The sandstones were heavily cemented with abundant silica cement and minor amounts of carbonate cement.

The Nome Formation is generally good-quality reservoir when preserved at shallow depths. Analysis of the Triassic sections in Paqualin-1 and Maple-1 indicate that porosity occlusion due to silica cementation is widespread at depth. The Nome Formation is only predicted to be of moderate reservoir quality within the area despite its excellent reservoir characteristics when preserved at shallower depths. Geochemical data from the North Hibernia-1 well indicates some potential within the Nome Formation for hydrocarbon generation.

The interbedded sandstones of the lower and upper parts of the Vulcan Formations, which are potential reservoirs elsewhere, are absent due to the lack of a clastic sediment source. The Grebe Formation sand is also potential reservoir over the whole of the 'Maple' area and is expected to have excellent porosity and permeability due to shallow depth of burial. The marine claystone of the lower Vulcan Formation are expected to provide seal over the Triassic-aged units which subcrop the Callovian unconformity. The seal potential of the Tertiary carbonate which overlies the Grebe Formation sands is considered high-risk.

The upper and lower Vulcan Formation, which are present in the Paqualin Graben are the main potential source sequence in the 'Maple' area. Geochemical analysis of the section indicates that it is moderately rich in Type II/III kerogen with the upper half of the lower Vulcan Formation and this interval is currently in the oil generation window.The low relief horst trend drilled by Maple-1 has a thick covering of potential source-rock. The horst is also well located to receive hydrocarbons migrating out of the Swan and Paqualin Grabens.

Migration of hydrocarbons into any Grebe Formation closures would be difficult as hydrocarbons would have to rely on conduits via fault systems. There are few faults evident from available seismic which cut both the shallow horizons and down into the deeper source sequences. The prospectivity of structural closures at Callovian unconformity level is lower because of difficulty in mapping closures with confidence. Apart from the existing Maple structure there are no readily evident closures at the near top Permian level. In addition to lack of structural closure, the quality of the expected reservoir in the pre-Callovian sequence is likely. The potential for stratigraphic plays within the upper or lower Vulcan Formations is also hindered by lack of a nearby clastic source which could provide the necessary reservoir in fan-like complexes derived from eroding blocks.

A Grebe Formation sand play could be present in the area if closure is developed at this level however, no shows have been identified in the Grebe Formation in any of the nearby wells. Seal is a high risk at such a stratigraphic level and migration is also difficult although not impossible for such a play. No significant Tertiary leads have been identified.

7.0 Jabiru Terrace

The most recent exploration within the available vacant area(s) in the Cartier Trough and Londonderry Terrace areas was undertaken while the area(s) were held under the AC/P4 permit (Fig. 10), located in the eastern and northeastern portions of the Jabiru Terrace and adjacent parts of the Cartier Trough and Londonderry High.

Recent exploration activity in the AC/P4 permit area prior to the latest partial surrender was as follows;

Seismic surveys			Petroleum exploration wells
1986	HJ5	2597 km	Nome-1
	HJ6	454 km	Challis-2, 2A
			Challis-3
			Challis-4
1987	HJ9	4775 km	Challis-5
	XJ7	196 km	Snowmass-1
			Rainer-1
1988	HJ10	113 km	Lorikeet-1
		403 km	Tancred-1
			Pengana-1
			Cassini-1
1989		92 km	Arunta-1
1990	HJ11	444 km	Nancar-1
	XJ12	542 km	Willeroo-1
			Delamere-1
			Jarrah-1A
			Casuarina-1

The vacant areas in the Jabiru Terrace region which have been relinquished from AC/P4 are termed the 'Osprey', 'South Jarrah' and 'Nancar' areas to identify them using the location of existing petroleum exploration wells in or near their vicinity (Fig. 10). The features of each of these three areas is as follows.

7.1 'Osprey' area

The five blocks adjacent to the Osprey-1 well southeast of the Challis/Cassini oil field and an outlying block north of Ibis-1 comprise the 'Osprey' area. It overlies a series of northeast-trending tilted fault blocks which comprise the Jabiru Terrace of MacDaniel (1988). The Osprey-1 well intersected a tilted fault-block structure which as in most instances in this region the Late Jurassic to Mid Jurassic section is missing. As such the major reservoir targets are the Challis and Pollard Formations or a thin veneer of upper Vulcan Formation sand below the base Cretaceous unconformity.

The main potential plays in the 'Osprey' area are the Late Jurassic to Early Cretaceous upper Vulcan Formation and, where that has been eroded from rotated fault blocks, the Mid to Late Triassic Challis and Pollard Formations. Other older Triassic units are also potential reservoir targets where erosion has taken place down to that level.

The sands of the upper Vulcan Formation are good potential reservoirs with high sand/shale ratios and good porosity levels. The Triassic Challis and Pollard Formations are also suitable but generally less favourable than the Jurassic sequence. Where the Triassic is present on the upper part of fault blocks seal may be breached by the lateral positioning of Jurassic upper Vulcan Formation against the Triassic.

Traps in the 'Osprey' area are likely to be filled by hydrocarbons migrating from the Skua Graben to the southwest which can also supply hydrocarbons into the Challis Graben. Migration pathways may evidently be via the fault-block sequences as well as the fault systems themselves. Potential traps which have formed as a result of Miocene tectonism have post-dated the period of highest likely hydrocarbon migration.

The tilted fault-block systems provide the most likely traps and the presence of the Talbot oil field in a similar trap system approximately 25 km to the southwest of the southern part of the area offers some possibility of similar plays occurring in the 'Osprey' area.

In all, four wildcat wells (Talbot-1, Anderdon-1, Osprey-1 and Ibis-1) have been drilled in and around the 'Osprey' area. Of these, Talbot was a test of a horst block whereas the other three were tilted fault-blocks. Osprey-1 was a valid test at the intra-Valanginian level. A DST flowed 6000 BOWPD from fractured Permian carbonates. Anderdon-1 and Ibis-1 were apparently not valid closures at intra-Valanginian level.

The seismic grid in the 'Osprey' area is moderate to good. However, more infill seismic coverage is required to mature some of the known leads and define potential prospect closures. The data-quality is generally good.

7.2 'South Jarrah' area

Major structural elements in the northern part of this area are the Eider Graben and Sahul Syncline. In the southern part of this area, the graben opens out in a broad and shallow area which is bounded by other horsts and blocks to the northeast. Significant truncations at the Triassic and Jurassic levels are evident on seismic data. The Late Jurassic section is thin throughout The main plays in the area are the roll-overs along the young faults in the north (as was drilled by Jarrah 1A in the area to the north) and tilted fault- blocks in the south. The major targets in these plays

are the upper Vulcan and Plover Formations sands below the intra-Valanginian and intra-Kimmeridgian unconformities. These sandstones generally form good to excellent reservoirs. They are sealed by a condensed section of the Echuca Shoals Formation, which in turn is overlain by the radiolarite of the upper Jamieson Formation. Breaching of traps along the minor faults, because of a thin vertical seal, is the main problem in the area (e.g. Avocet 1A). Permeable radiolarites are expected to be present throughout the area.

The Late Jurassic section is thin, thus, long-distance migration, from the mature source rocks (e.g. Echo and Sahul Syncline) is required for traps to be filled. Traces of oil recovered from Avocet-1A are similar to that present in Late Jurassic sediments intersected by Flamingo-1 in the eastern part of the Sahul Syncline.

Leads are recognized in the area. These leads are on the same trend as the Avocet and Barita wells, where significant oil shows and residual oil accumulations have been observed. Major risks are the seal and lack of migration from the Late Jurassic 'kitchens'. Seismic data quality is generally good in the area and it is covered by a reasonably closely-spaced grid of seismic lines.

7.3 'Nancar' area

The 'Nancar' area is located in the northeastern part of the Territory of Ashmore and Cartier Islands. The structural trends in the area are oriented east-west. The area essentially forms part of the Sahul Syncline trend. It has a number of E-W oriented horsts and grabens along with the associated tilted blocks. Miocene tectonism has significantly altered the older structural trends in the area. At pre-Miocene times, the Nancar and Lorikeet structures were tilted blocks. Due to the Miocene faulting, they developed into horst blocks.

The main play in the area are structural closures on the upthrown side of major faults. These closures have been mapped at the intra-Valanginian levels. The main targets are Vulcan and Plover Formation reservoirs. The Plover Formation has not been intersected in any of the wells drilled in the northern area.

The upper and lower Vulcan Formation are moderate to good reservoirs in the area. The sands were deposited in a marine continental slope environment. The thickness of the Late Jurassic section increases north. The sand/shale ratio in the upper Vulcan Formation is high and the sands have an average porosity of 16%. Thick silty claystones of the upper and lower Vulcan Formation form an adequate seal over the reservoirs . However, where the Vulcan and the Echuca Shoals Formation section is thin, there is a major risk of breaching of traps through the radiolarites. Thick sections of LateJurassic are present in the graben areas . The source

rock quality of these claystones is good but they are lean in organic quantity . Because of low TOC, a higher degree of maturity is required before expulsion can take place. This maturity has been attained in the deeper parts of the Sahul Syncline, but probably not in the areas draining towards Nancar-1. The extra maturity required increases the risk of gas being the expelled hydrocarbon or gas flushing of oil generated at an early stage.

Two wells have been drilled close to this area, Nancar-1 and Lorikeet-1. Both had significant oil shows. The breaching of seal due to permeable radiolarites can be a problem in the southern part. In the northern part, the Late Jurassic claystones form a good seal over the Tithonian/Oxfordian sands. Major plays in the area are the tilted fault blocks and horsts. The plays rely on hydrocarbon generation and migration from the Sahul Syncline, although the generation capacity of the smaller grabens is unknown. In addition to the structural plays, there is potential for a number of stratigraphic plays in the area. Two such plays are: Late Jurassic pinchout and the Late Cretaceous fan play along major faults.

The seismic grid over the area is moderate. The data quality evident in Plates 17 to 22, below the intra-Valanginian unconformity is moderate - although sufficient to be able to infer, if not precisely identify, the top of Permian. More seismic data is required to mature the structural and stratigraphic plays in this area.

8.0 Northern Browse Basin

The northern part of the Browse Basin adjoins the southern margin of the Ashmore Platform, which consists of uplifted blocks of at least 3000 m of Triassic sediments and an unknown thickness of pre-Triassic sediments, unconformably overlain by Cretaceous and younger sediments. Wells drilled on the Ashmore Platform, with the exception of Ashmore Reef-1 all intersected Triassic below the Cretaceous. In Ashmore Reef-1 Lower Cretaceous and Upper Jurassic sediments and volcanics (300m) are underlain by Triassic rocks (Allen & others, 1978). Such results suggest that the western and southern parts of the Ashmore Platform may have a greater opportunity for Jurassic onlap than is apparent in and around the margins of the Vulcan Sub-basin where eroded and fault-controlled edges are apparent to date.

The Browse Basin sequence is distinguished by the thickened sequence of Tertiary and Cretaceous sediments which overlie Jurassic and older sequences which are markedly thicker than is apparent in the adjoining parts of the Bonaparte Basin to the north (Figs. 12 & 13). In the Browse Basin the sediment thickness totals up to 11 km of Carboniferous to Recent strata. Along the northern margin of the basin, where it underlies the Territory of Ashmore and Cartier Islands (Fig. 1), the main point of interest has been in the petroleum potential of Permian and younger sequences where they subcrop at depths of less than 4.5 km.

The Permian and Triassic sequences are the general lower limit of the prospective sequence in the northern part of the Browse Basin. Lower Permian sediments along the eastern flank of the basin comprise claystone, siltstone and some limestone bands. The presence of additional coal and microfossils indicate that it was deposited under paralic conditions (Allen & others, 1978). In the Later Permian along the eastern basin-margin non-marine clastic sediments were deposited but no information is available from the western part of the basin

During the Mid and Late Triassic the northern part of the basin received sediment which ranged from marine and paralic in the northwest, to fluvio-delatic in the northeast. This continued into Jurassic and by the Early Cretaceous marine shelfal sedimentation became widespread over all parts of the basin. Outer shelf and slope conditions developed by the Mid to Late Cretaceous (Allen & others, 1978). In the Early Tertiary the eastern part of the basin developed non-marine sediments in the form of clastic sequences with coal seams while lagoonal or inner shelf carbonates and sands were deposited offshore to the west. By the Oligocene the sea had withdrawn westwards. In the Miocene this was followed by a transgressive marine sand and a major carbonate wedge which is currently several thousand metres thick in the region of Scott Reef.

8.1 Petroleum plays

The major feature of the northern Browse Basin sequence is that the Early Jurassic sequence, the main potential petroleum-bearing unit, is at sufficient depth to be mature for generation of hydrocarbons. The Permo-Triassic and Early Jurassic sequences comprise a rift valley sequence of fluvio-deltaic and paralic sand with some carbonates - average porosities are up to 20% and permeability readings are fair (Allen & others, 1978).

Seal is provided by the marine claystone in Late Jurassic and Early Cretaceous sequences. Upper Tithonian and Lower Neocomian regressive sandstones associated with the claystone sequences also have good reservoir properties. Albian and Aptian sands which appear to locally derived along the eastern basin margin appear to have some reservoir potential.

The uppermost Cretaceous and Tertiary appear to contain the main reservoir units in the northern Browse Basin and the Maastricthian sands, in particular, are proven oil reservoirs in the Puffin Block of the Vulcan Sub-basin. A lack of potential top seal is a concern with this part of the sequence.

Water depths, seismic data quality and a lack of early success have all contributed to the perception of risk the exploration industry currently associates with the northern Browse Basin. Inspection of available information suggests that for the most part the resource potential of the region is worthy of more intensive evaluation.

9.0 Potential release areas

The review and analysis undertaken for this study was done so with the aim of determining potential boundaries for future release of areas. Such boundaries are identified in Figure 14 so that the areas defined contain a diverse array of potential leads and features which may develop into possible drilling targets.

A total of three areas are suggested, the largest covers the northern Browse Basin and southern Ashmore Platform, the second covers the Ashmore Platform and western Vulcan Sub-basin and the third the northeastern flank of the Vulcan Sub-basin, Jabiru Terrace and Sahul Syncline. Each area has a variety of potential leads and prospects, as well as nearby well control, and significant potential to evaluate and mature a wide variety of potential drilling targets.

As the process of selection and confirmation of vacant areas is subject to additional considerations involving State and Commonwealth agencies and Ministers, the areas shown here have no greater status than that represented by a BMR study of the region.

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Appendix 1

Vulcan Graben, Timor Sea; Regional Structure from a magnetic survey
by P. Wellman & G.W. O'Brien (modified from Wellman & O'Brien, 1991)

The BMR survey covered the Vulcan Graben region and part of the Eider Trough to the east of the Jabiru Terrace. The flight line spacing was 2.5 km, the tie line spacing was 15 km and the flight altitude was 150 m. The flight lines were oriented along 130°, at right angles to the known structure. An attempt was made to measure the anomalous magnetic field along flight lines to a precision of 0.1 nT. The survey (20 000 line-km) was flown by 'Austerix' under contract during November and December 1989.

The observed aeromagnetic anomaly map has anomalies with a wavelength of 50 to 100 km, amplitudes of 30 to 240 nT, and predominantly easterly trends. This trend may reflect dominant east-trending structuring, but it is more likely due to the preferential enhancement of east-trending structures relative to structures in other directions at low magnetic latitudes.

ARCO (1965) calculated depth to magnetic basement, apparently mainly using graphical methods. Their shallowest depths are about 3.5 km at the southern comer of the area while their greatest depths are about 6.6 km near the centre of the Vulcan Graben. New estimates of the depth to magnetic basement were made using the Vacquier method and our new aeromagnetic data. The two sets of depths are roughly consistent, with depths to magnetic basement of 6-7 km within the Vulcan Graben and 35 km on the graben margins.

Short-wavelength anomalies

The short-wavelength anomalies of greatest interest had wavelengths of 3 to 12 km and amplitudes of 0.2 to 2.0 nT. There is a major problem in separating these anomalies from the longer wavelength anomalies, not because the wavelengths were similar, but because the amplitude difference means that the leakage of long wavelength components must be 0.1% or less. The preferred filter was the residual to a mean of 6 km length:- this l-D filter was applied to the flight line profiles . A l-D band-pass filter was found to be unsatisfactory:- in order to get low leakage the filter length had to so long that much of the flight-line profile was lost. Filtering in 2-D was attempted using a ring filter of diameter 6 km, applied twice. Filtering of the grid gave unsatisfactory results because:- l) the errors in levelling (up to 0.2 nT) were about the same amplitude as the smaller short-wavelength

anomalies, so the effects of poor levelling tended to mask the effects of (interpreted) cross-strike faults; and 2) gridding destroyed the detailed information on anomaly shape that provided a major control on anomaly correlation.

The northeast-trending short-wavelength anomalies that are present over most of the area. These have been correlated between profiles on the basis of their amplitude and shape using the plan of the flight line profiles; adjacent anomalies are generally subparallel. Only the positive anomalies have been mapped over most of the area, because they have a greater or equal amplitude compared with adjacent negative anomalies. Negative anomalies have been mapped where they have greater than about 0.4 nT amplitude, or they are greater in amplitude than the adjacent positive anomalies. Anomaly amplitude is generally less in the centre of the Vulcan Graben than elsewhere. The correlations of the more prominent short-wavelength anomalies. Correlations were made primarily using flight-line profiles, though contour maps showing 6 km and 30 km wavelength anomalies were also used. The trend of the anomalies ranges from east to north, with the average near northeast. There are well-defined areas within which the trend is consistent for an area 30 to 50 km across.

The depth to source of the short-wavelength anomalies has not been calculated. Their wavelength ranges from 3 to 12 km, with what appear to be composite anomalies, suggesting that the magnetic sources are spread out vertically over a depth range between 0. 7 to 3 km. The dominant sources appear to be between a depth of 1 to 2 km. ARCO (1965) calculated the depth-to-source to be 0.6 to 2.3 km, with a mean of about 1 km.

If an average magnetic source depth of 1.0-1.5 km is assumed, then the source would lie within (i.) the pre-rift (predominantly Triassic) megasequence on the Ashmore Platform and Londonderry High. It could lie within the Permian over parts of the Londonderry High, (ii.) the Triassic to Late Jurassic on the terraces within the Vulcan Graben, (iii.) the post-rift megasequence in the sub-grabens within the Vulcan Graben.

The cause of the short-wavelength anomalies is difficult to determine and each anomaly may be due to a number of sources at a range of depths. The possible sources include:- latest Jurassic to earliest Cretaceous basalts and volcaniclastics on the Ashmore Platform (as penetrated in the Ashmore Reef 1 and Mt. Ashmore lB wells) (Patillo and Nicholls, 1990); laterization during deep weathering during Valanginan Unconformity time, as evidenced by probable laterites in the Triassic of the Challis field; magnetite, possibly associated with salt diapirism as seen in Paqualin 1 (Smith and Whitehead, 1989). As these types of sources result in irregular and short length anomalies, they are not thought to be the major cause of the more prominent anomalies, which are straight and very elongate.

The magnetic anomalies are interpreted to be caused by structures

associated with the NE faults which cut the pre-rift and syn-rift megasequences, since the anomalies correlate well with the faults shown on the structural elements map. Generally the magnetic and structural elements trends are consistent:- the major faults correlate with major magnetic anomalies and minor faults with minor anomalies . The major discrepancy is that no anomalies correlate with the SE-dipping faults along the northwest margin of the graben. The magnetic trends also correlate with the faults shown on the Valanginian and Callovian structure maps (see Figures 11 & 1 2 of Patillo and Nicholls, 1990), but not the ENE-trending faults which formed in response to the collision with Timor. This is somewhat puzzling, since the Valanginian (and deeper structure) would seem to be too deep to host the magnetic source in the grabenal areas within the Vulcan Graben. The preferred interpretation is that the northeast-trending anomalies are predominantly due to the truncation of sediments by unconformities and faults, and possibly to magnetite introduced by faults, specifically either the northeast-trending rift faults within the pre-rift and syn-rift megasequences, or faults in the post-rift megasequence caused by the reactivation of rift faults.

Northeast component of long-wavelength anomalies

Initially the contractor used a 30 km wavelength 1-D filter along the flight lines which did not sum exactly zero. Maps contouring this data give directionly filtered long-wavelength anomalies. The sources of these anomalies is inferred from their wavelength to be in the pre-rift megasequence or basement. The magnetic highs have directions and extent such that they generally overly the correlated and stronger short-wavelength magnetic anomalies . The positions of these magnetic highs are therefore consistent with the correlations between individual segments of the stronger short-wavelength anomalies and between these correlated anomalies and the major rift faults. Magnetic highs correlate with northwest-dipping normal faults whereas magnetic lows correlate with southeast-dipping faults.

Northwest-trending features

The northeast-trending anomalies are interrupted by northwest-trending features along which the amplitude of the anomalies is relatively low. These commonly offset the northeast-trending anomalies by between 2 and 5 km, and they are interpreted to be faults. These NW-trending faults have a spacing of 5 to 25 km and range from 10 to over 200 km long. The offsets are generally sinstral in the southwest of the area and generally dextral in the east. The direction of these faults is very consistent; most are straight and trend at about 305°.

The northwest-trending faults may be due to the reactivation of transfer faults that originally formed during Mesozoic extension, the reactivation of Palaeozoic trends, or possibly some may be late-stage and independent of

earlier faults. These northwest-trending faults have not been mapped on seismic profiles, although some northwest-trending zones of poor reflection/character change have been recognized that are presumed to be faults. The observation that the major northeast-trending anomalies end at these northwest-trending features is consistent with a transfer fault interpretation. Some of the northwest-trending faults appear to be the major boundaries between areas of different structure.

The northwest-trending faults may have a major role in the entrapment of major hydrocarbon accumulations in the Timor Sea, since all of the significant oilfields in the Vulcan Graben are located close to a northwest-trending fault or its extension.

On the basis of the short- and long-wavelength aeromagnetic data. the Vulcan Graben can be sub-divided into discrete tectonic provinces which have abrupt boundaries. Within each province, structure at both shallow and deep levels appears to be of a consistent trend and correlatable.

Discussion

This study shows that an aeromagnetic survey using a high resolution magnetometer can define the structural elements of an extensional basin, the Vulcan Graben. The short-wavelength anomalies map the main northeast-trending (rift-related) normal faults and other parallel structures. The shallow, more ENE Miocene fault trends associated with the collision with Timor are not evident in the magnetic trends.

Breaks in the northeast-trending anomalies define important northwest-trending faults which may be reactivated Palaeozoic faults, Mesozoic transfer faults, or younger faults. Our work suggests that aeromagnetics may be more efficient than seismic in delineating cross-cutting faults. The mapping of these strike slip fault systems is important for three reasons:- 1) Understanding the gross tectonic structure of the region. 2) Mapping the boundaries of continuous strata. 3) Determining their control on the migration and/or entrapment of hydrocarbons. In the Vulcan Graben, most of the significant oil discoveries are located close to one of these northwest-trending faults.

It is clear that in the Vulcan Graben, an area with extensive seismic control, that the interpretation of the pattern of magnetic anomalies both complements and supplements the seismic data in a cheap and cost effective way. A similar understanding should be achievable in other offshore areas with extensive seismic coverage. In offshore areas with poor seismic coverage, aeromagnetic surveys should allow the major normal and cross faults to be mapped, and thereby provide a framework for a more informed planning of seismic surveys. Onshore, the relevant small anomalies may be difficult to separate because of high-amplitude very short-wavelength anomalies due to regolith magnetisation.

Northwest trending features

The northeast-trending anomalies are interrupted by northwest-trending features along which the amplitude of the anomalies is relatively low. These commonly offset the northeast-trending anomalies by between 2 and 5 km, and they are interpreted to be faults. These NW-trending faults have a spacing of 5 to 25 km and range from 10 to over 200 km long. The offsets are generally sinistral in the southwest of the area and generally dextral in the east. The direction of these faults is very consistent; most are straight and trend at about 305°.

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Appendix 2 Formation fracture resistance

(from Lavering & Ozimic,1989)

In any basin, accurate formation fracture gradient and formation pore pressure prediction are the key parameters for adequate well design - they set the conditions for well operations. The formation fracture resistance, together with the formation pore pressure, control the well casing requirements. The formation below the casing seat is commonly tested to its leak-off pressure, which is generally lower than a fracture-initiation pressure but higher than a fracture-propagation pressure. The leak-off pressure gives an indication of formation strength.

There are several methods for estimating fracture gradients but actual data derived from hydraulic fracturing, leak-off or formation integrity tests in the same basin are the most accurate. Leak-off pressure data have been compiled from the wells drilled in the Bonaparte Basin until January 1988. The plot of leak-off pressures versus depth. data from non-typical lithologies were omitted, while leak-off pressures recorded in more than 200 m of water were corrected for water depth.

Breckels & von Eekelen (1982) have compiled leak-off and fracture propagation pressure data from sedimentary basins worldwide, and conclude that in normally-pressured formations leak-off and fracture-propagation pressures are predicted by the following empirical relationships.

$P_{fp}=0.197^{1.145}$ and $P_{lo} = 0\ 2lD^{l\ 145}$

where

D = Depth, ft

P_{fp} = Fracture propagation pressure, psi

P_{lo} = Leak-off pressure

The Breckels's & von Eekelen's (1982) curves (0.197 and 0.219) are less than that in the Bonaparte Basin. It is considered that in some cases the formation may have been inadvertently broken down during leak-off testing and the curve derived from the lower boundary of the observed data, represents fracture propagation pressure of the Bonaparte Basin. This curve is represented by:

$$P_{fp} = 0.185D^{1.145}$$

Breckels & von Eekelen (1982) state that leak off pressure is 11 per cent greater than fracture propagation pressure which gives the following correlation:

$$P_{lo} = 0.206D_{1.145} -$$

The above correlation gives a reasonable prediction of formation strength in less than 200 m (650 ft) water depth for the Bonaparte Basin. For water

depths in excess of 200 m(650 ft) (curve 0.185) should be reduced by 5.65 kpa/m (0.25 psi/ft) of water depth.

(see main text for references)

Figures

1. Location map of the Bonaparte Basin.
2. Stratigraphic position of Bonaparte Basin petroleum accumulations.
3. Major structural elements of the Ashmore-Cartier region.
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7. Ashmore Platform structural features.
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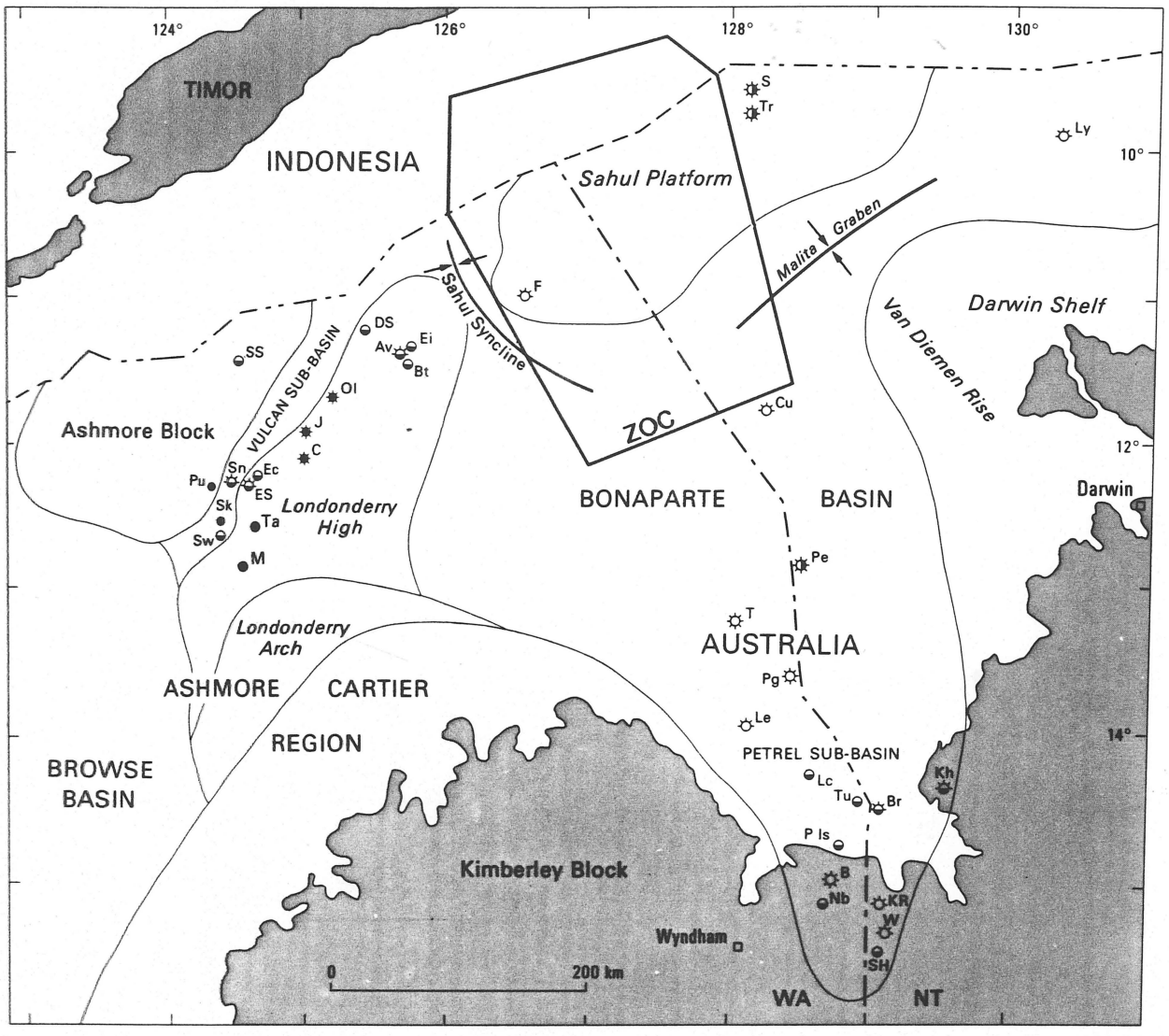
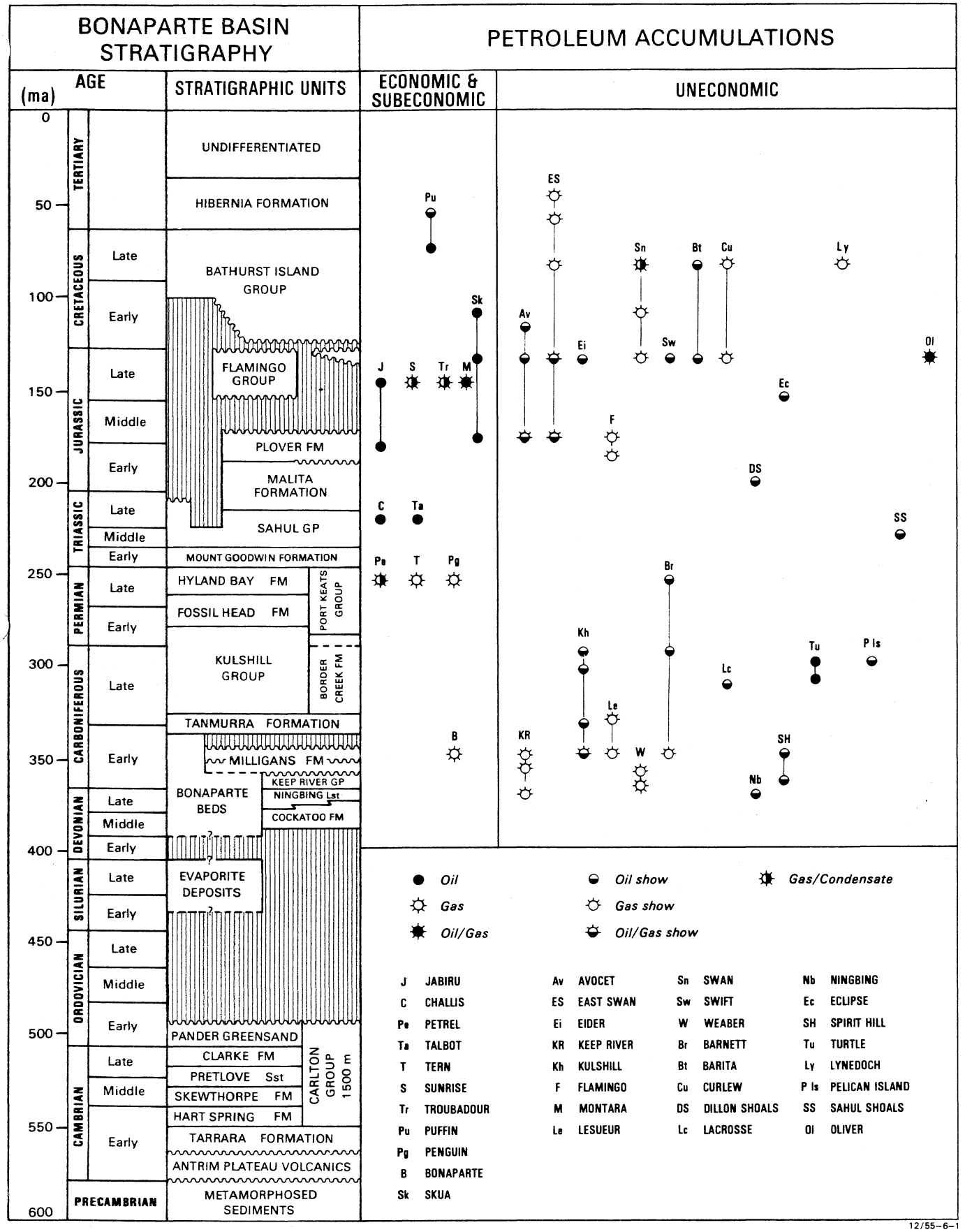
9. Vulcan Sub-basin structural features.
10. Vulcan Sub-basin and Jabiru Terrace seismic line locations.
11. Jabiru Terrace structural features.
12. Base Miocene two-way time map, after Patillo & Nicholls (1990).
13. Intra-Valinginian two-way time map, after Patillo & Nicholls (1990).
14. Potential release areas Ashmore-Cartier region.



12/55–8–1

- Oil
- Oil show
- Gas/Condensate
- Gas
- Gas show
- Oil/Gas
- Oil/Gas show

Av	Avocet	ES	East Swan	Lc	Lacrosse	Pg	Penguin	Sn	Swan
Bt	Barita	Ec	Eclipse	Le	Lesueur	Pe	Petrel	Sw	Swift
Br	Barnett	Ei	Eider	Ly	Lynedoch	Pu	Puffin	Ta	Talbot
B	Bonaparte	F	Flamingo	M	Montara	SS	Sahul Shoals	T	Tern
C	Challis	J	Jabiru	Nb	Ningbing	Sk	Skua	Tr	Troubadour
Cu	Curlew	KR	Keep River	Ol	Oliver	SH	Spirit Hill	Tu	Turtle
DS	Dillon Shoals	Kh	Kulshill	P Is	Pelican Island	S	Sunrise	W	Weaber


BONAPARTE BASIN STRATIGRAPHY
PETROLEUM ACCUMULATIONS
(ma)
AGE
STRATIGRAPHIC UNITS
ECONOMIC & SUBECONOMIC
UNECONOMIC
0
50
100
150
200
250
300
350
400
450
500
550
600
TERTIARY
CRETACEOUS
JURASSIC
TRIASSIC
PERMIAN
CARBONIFEROUS
DEVONIAN
SILURIAN
ORDOVICIAN
CAMBRIAN
PRECAMBRIAN
Late
Early
Middle
UNDIFFERENTIATED
HIBERNIA FORMATION
BATHURST ISLAND GROUP
FLAMINGO GROUP
PLOVER FM
MALITA FORMATION
SAHUL GP
MOUNT GOODWIN FORMATION
HYLAND BAY FM
FOSSIL HEAD FM
PORT KEATS GROUP
KULSHILL GROUP
BORDER CREEK FM
TANMURRA FORMATION
MILLIGANS FM
KEEP RIVER GP
BONAPARTE BEDS
NINGBING Lst
COCKATOO FM
EVAPORITE DEPOSITS
PANDER GREENSAND
CLARKE FM
PRETLOVE Sst
SKEWTHORPE FM
HART SPRING FM
CARLTON GROUP 1500 m
TARRARA FORMATION
ANTRIM PLATEAU VOLCANICS
METAMORPHOSED SEDIMENTS
Pu
Sk
J
S
Tr
M
C
Ta
Pe
T
Pg
B
ES
Av
Ei
Sn
Sw
Bt
Cu
Ly
Ol
Ec
F
DS
SS
Br
Kh
Le
Lc
Tu
P Is
KR
W
SH
Nb
Oil
Oil show
Gas/Condensate
Gas
Gas show
Oil/Gas
Oil/Gas show
J JABIRU
C CHALLIS
Pe PETREL
Ta TALBOT
T TERN
S SUNRISE
Tr TROUBADOUR
Pu PUFFIN
Pg PENGUIN
B BONAPARTE
Sk SKUA
Av AVOCET
ES EAST SWAN
Ei EIDER
KR KEEP RIVER
Kh KULSHILL
F FLAMINGO
M MONTARA
Le LESUEUR
Sn SWAN
Sw SWIFT
W WEABER
Br BARNETT
Bt BARITA
Cu CURLEW
DS DILLON SHOALS
Lc LACROSSE
Nb NINGBING
Ec ECLIPSE
SH SPIRIT HILL
Tu TURTLE
Ly LYNEDOCH
P Is PELICAN ISLAND
SS SAHUL SHOALS
Ol OLIVER

12/55–6–1

MAJOR STRUCTURAL ELEMENTS OF THE ASHMORE CARTIER REGION

123° 124° 125° 126°

10°

12°

13°

INDONESIA

AUSTRALIA

BOUNDARY NOT RESOLVED

Sahul Shoals 1

A

CARTIER TROUGH

JABIRU TERRACE

EIDER TROUGH

ASHMORE PLATFORM

VULCAN SUB–BASIN

JABIRU FIELD

CHALLIS/CASSINI FIELD

Osprey 1

A′

B

PUFFIN GRABEN

PUFFIN FIELD

SWAN GRABEN

SKUA FIELD

TALBOT FIELD

LONDONDERRY HIGH

SKUA TROUGH

Anderdon 1

B′

HEYWOOD GRABEN

ANDERDON GRABEN

WESTERN AUSTRALIA

NORTHERN BROWSE BASIN

TERRITORY OF ASHMORE & CARTIER IS

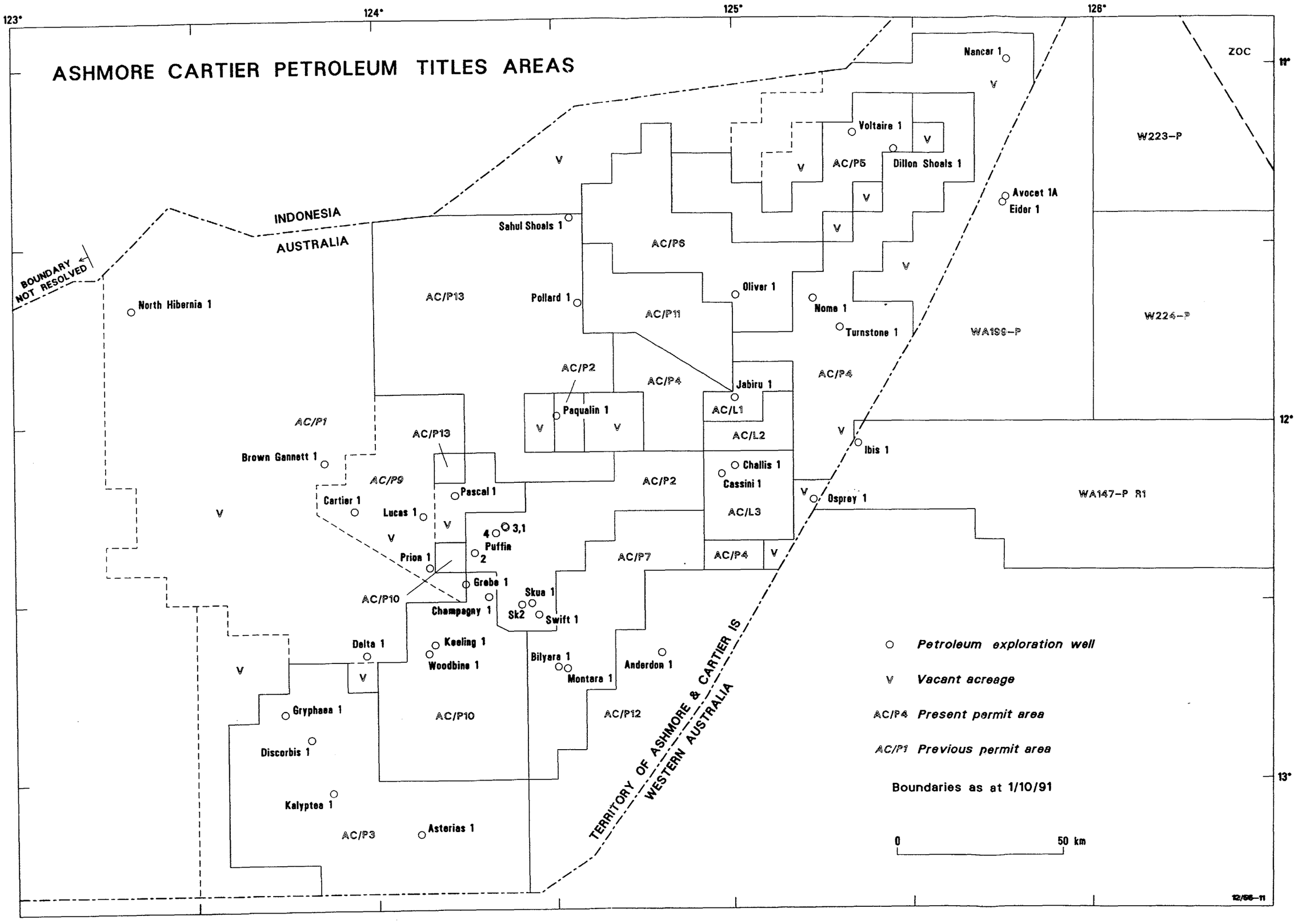
Cross sections (Figure 5)

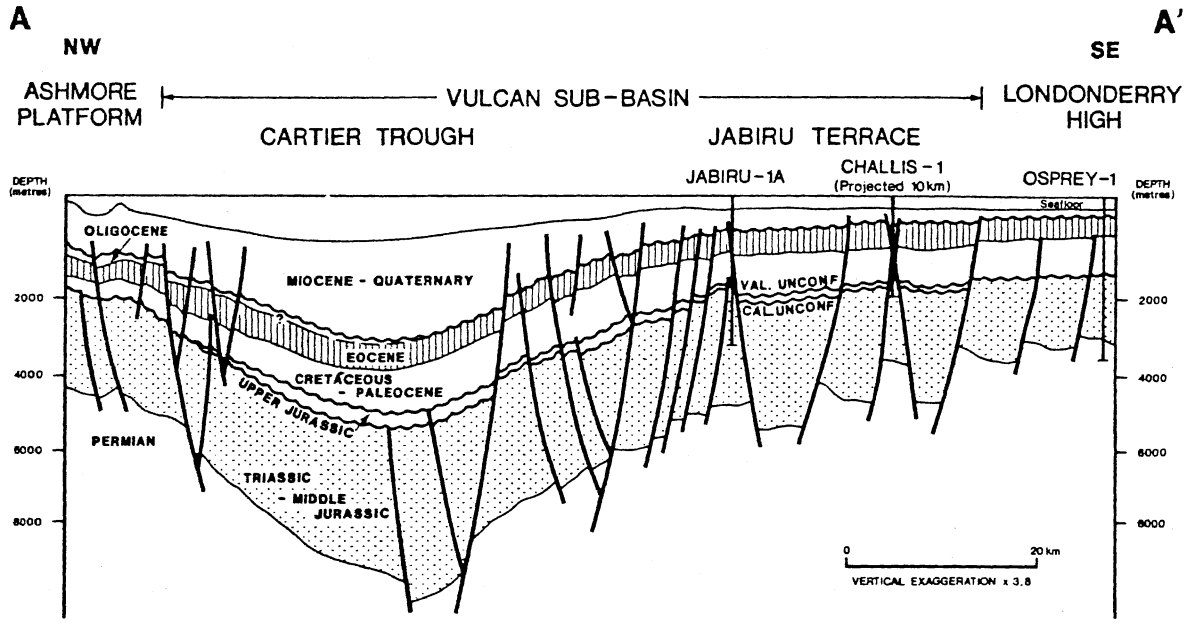
0 50 km

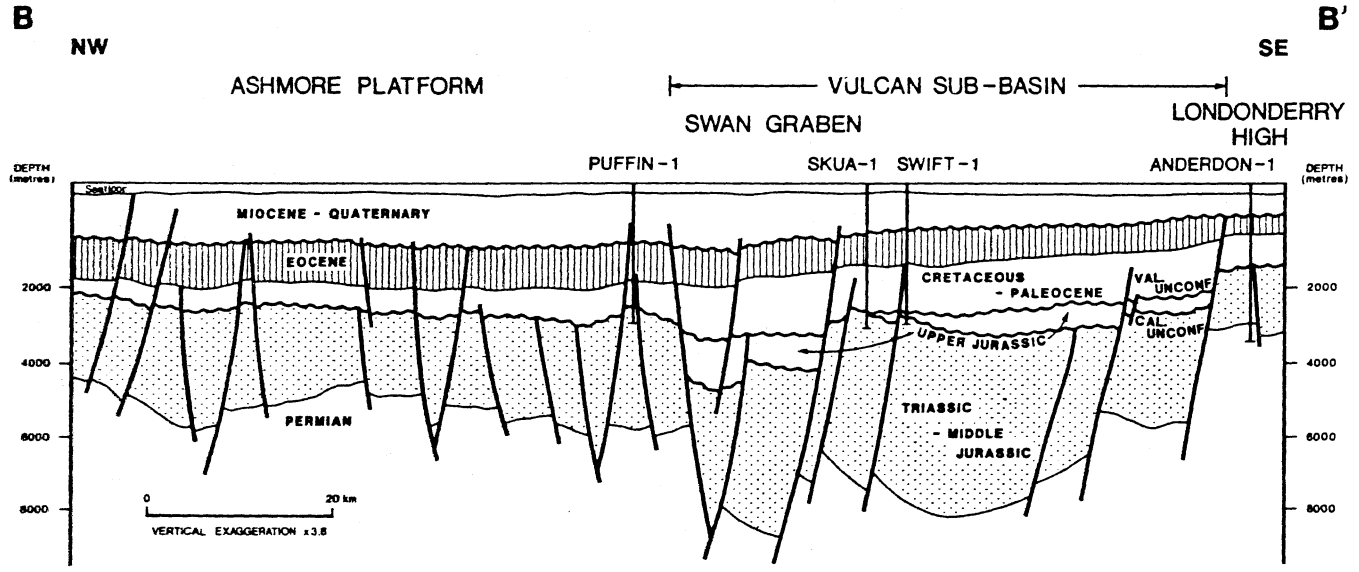
12/88–10

R9109002

ASHMORE CARTIER PETROLEUM TITLES AREAS




A
NW
A'
SE
ASHMORE PLATFORM
VULCAN SUB-BASIN
LONDONDERRY HIGH
CARTIER TROUGH
JABIRU TERRACE
JABIRU-1A
CHALLIS-1 (Projected 10km)
OSPREY-1
DEPTH (metres)
Seafloor
OLIGOCENE
MIOCENE - QUATERNARY
VAL. UNCONF.
CAL. UNCONF.
EOCENE
CRETACEOUS - PALEOCENE
UPPER JURASSIC
PERMIAN
TRIASSIC - MIDDLE JURASSIC
2000
4000
6000
8000
0
20 km
VERTICAL EXAGGERATION x 3.8


B
NW
B'
SE
ASHMORE PLATFORM
VULCAN SUB-BASIN
SWAN GRABEN
LONDONDERRY HIGH
PUFFIN-1
SKUA-1
SWIFT-1
ANDERDON-1
DEPTH (metres)
Seafloor
MIOCENE - QUATERNARY
EOCENE
CRETACEOUS - PALEOCENE
VAL. UNCONF.
CAL. UNCONF.
UPPER JURASSIC
PERMIAN
TRIASSIC - MIDDLE JURASSIC
2000
4000
6000
8000
0
20 km
VERTICAL EXAGGERATION x3.8

ASHMORE PLATFORM EXPLORATION

123° 124° 125° 126° 11° 12° 13°

INDONESIA
AUSTRALIA
BOUNDARY NOT RESOLVED

North Hibernia 1
Sahul Shoals 1
Pollard 1
Oliver 1
Rainbow 1
Jabiru 1
Paqualin 1
Brown Gannett 1
Challis 1
Pascal 1
Ashmore Reef 1
Cartier 1
Lucas 1
Prion 1
4
3,1
Puffin
2
Osprey 1
Grebe 1
Skua 1
Talbot 1
Champagny 1
Mt Ashmore 1
Delta 1
Keeling 1
Woodbine 1
Montara 1
Gryphaea 1
Discorbis 1
Kalyptea 1
Asterias 1

AC/P1 AC/P2 AC/P3 AC/P4 AC/P5 AC/P6 AC/P7 AC/P10 AC/P11 AC/P12 AC/P13
AC/L1 AC/L2 AC/L3 AC/P4
V
WA199–P
W223–P
W224–P
ZOC
WA147–P R1

TERRITORY OF ASHMORE & CARTIER IS
WESTERN AUSTRALIA

OSBORN 1990 seismic AC/P9
88.01 1988 seismic AC/P1
Pre–1985 AC/P1 seismic coverage
Ashmore Platform boundary

0 50 km

12/55–12

ASHMORE PLATFORM STRUCTURAL FEATURES

123° 124° 125° 126°

11° 12° 13°

INDONESIA

AUSTRALIA

BOUNDARY NOT RESOLVED

Owl

Noddy

North Hibernia 1

ASHMORE PLATFORM

Ostrich

Lapwing

Rainbow 1

Coot

Thickhead

Brown Gannett 1

Ashmore Reef 1

Mallard

Cartier 1

Lucas 1

Goose

Booby

Prion 1

Mt Ashmore 1

Albatross

Delta 1

Keeling 1

Woodbine 1

Gryphaea 1

Kalyptea 1

Asterias 1

AC/P1

AC/P2

AC/P3

AC/P4

AC/P5

AC/P6

AC/P7

AC/P8

AC/P10

AC/P12

AC/P13

AC/L1

AC/L2

AC/L3

AC/L4

V

WA199-P

W224-P

W223-P

ZOC

WA147-P R1

TERRITORY OF ASHMORE & CARTIER IS
WESTERN AUSTRALIA

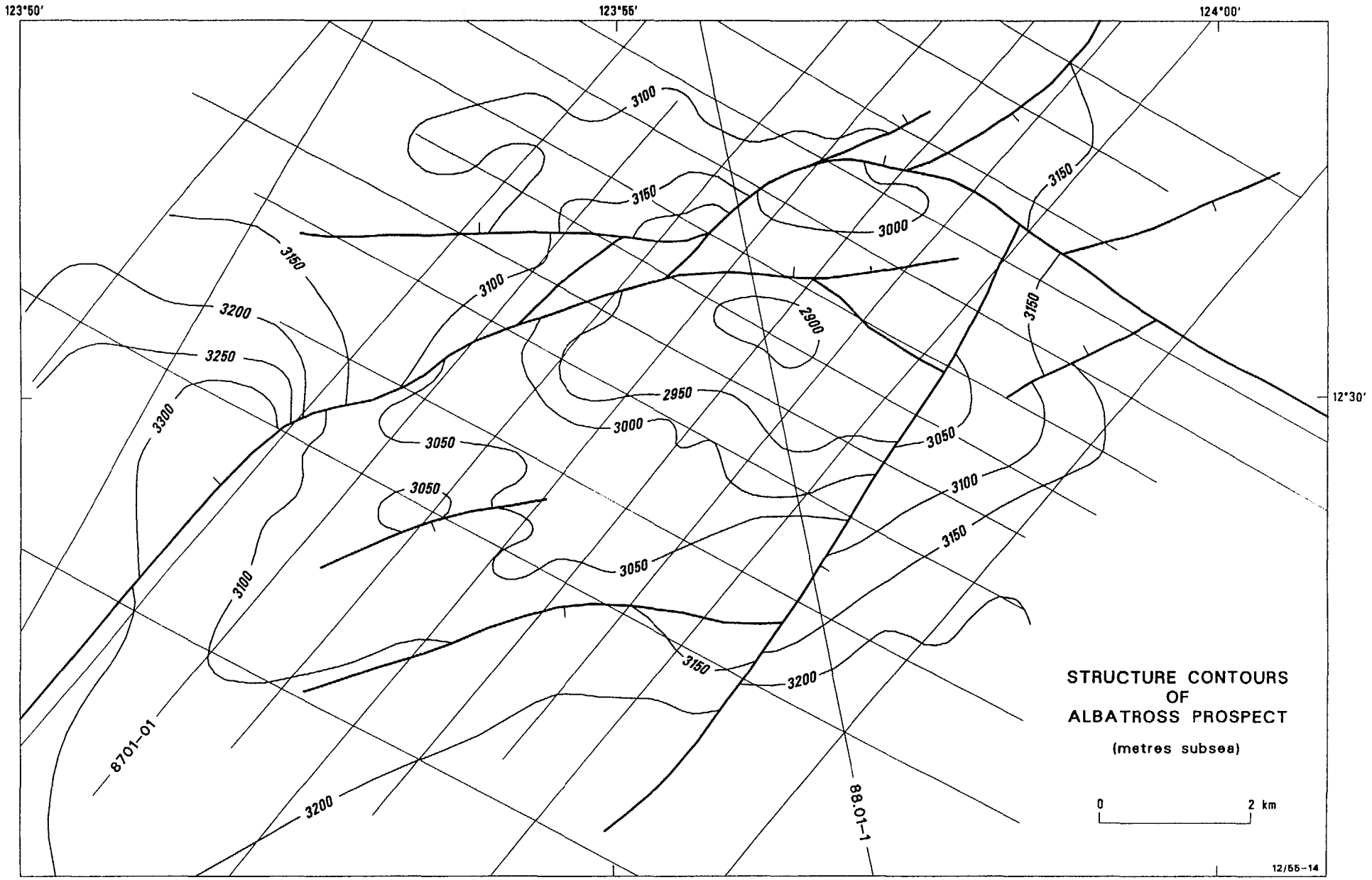
Prospect, leads, drilled structures

Petroleum exploration well

0 50 km

12/85-13

R9100905


123°50'
123°55'
124°00'
12°30'
3100
3150
3000
3150
3150
3100
3200
3250
3300
2900
2950
3000
3050
3050
3050
3100
3150
3100
3050
3150
3200
3200
8701-01
88.01-1
STRUCTURE CONTOURS
OF
ALBATROSS PROSPECT
(metres subsea)
0
2 km
12/55-14

VULCAN SUB-BASIN STRUCTURAL ELEMENTS

123° 124° 125° 126°

11° 12° 13°

INDONESIA

AUSTRALIA

BOUNDARY NOT RESOLVED

ASHMORE PLATFORM

AC/P1 AC/P3 AC/P4 AC/P5 AC/P6 AC/P7 AC/P9 AC/P10 AC/P11 AC/P12 AC/P13

AC/L1 AC/L2 AC/L3

WA199-P WA147-P R1

W223-P W224-P ZOC

'PAQUALIN' AREA

'MAPLE AREA

'PASCAL' AREA

Paqualin Graben

Swan Graben

Puffin Horst

Cleghorn Horst

Paqualin 1

Maple 1

Allaru 1

Pascal 1

Parry 1

4

3,1

2

Puffin

Swan 1

Vulcan 1

Eclipse 1

East Swan 1

Rowan 1

Birch 1

Skua 1

Swift 1

TERRITORY OF ASHMORE & CARTIER IS
WESTERN AUSTRALIA

Prospect, leads, drilled structures

Petroleum exploration well

0 50 km

12/55-15

VULCAN SUB-BASIN/JABIRU TERRACE SEISMIC LINES

123° 124° 125° 126°

11° 12° 13°

INDONESIA

AUSTRALIA

BOUNDARY NOT RESOLVED

TERRITORY OF ASHMORE & CARTIER IS

WESTERN AUSTRALIA

HJ9-109,111 HJ9-114 HJ9-110 HJ9-106 HJ9-127 HJ9-53 HJ9-25 HJ9-02

HV6-877 HV3-307 HV6-201

1720 1320

'NANCAR' AREA

'SOUTH JARRAH' AREA

'PAQUALIN' AREA

'MAPLE' AREA

'PASCAL' AREA

Nancar 1 Voltaire 1 Dillon Shoals 1 Avocet 1A Eider 1 Sahul Shoals 1 North Hibernia 1 Pollard 1 Oliver 1 Nome 1 Turnstone 1 Jabiru 1 Paqualin 1 Brown Gannett 1 Cartier 1 Lucas 1 Pascal 1 Challis 1 Cassini 1 Ibis 1 Osprey 1 Puffin 3,1 4 2 Prion 1 Grebe 1 Skua 1 Champagny 1 Sk2 Swift 1 Delta 1 Keeling 1 Woodbine 1 Bilyara 1 Montara 1 Anderdon 1 Gryphaea 1 Discorbis 1 Kalyptea 1 Asterias 1

AC/P1 AC/P3 AC/P4 AC/P5 AC/P6 AC/P7 AC/P9 AC/P10 AC/P11 AC/P12 AC/P13 AC/L1 AC/L2 AC/L3

W223-P W224-P WA199-P WA147-P R1 ZOC

○ *Petroleum exploration well*

——— *Seismic line*

HJ9-02 *Line number*

(Plates 9 to 22)

0 50 km

12/55-18

JABIRU TERRACE STRUCTURAL FEATURES

123° 124° 125° 126°

11° 12° 13°

INDONESIA

AUSTRALIA

BOUNDARY NOT RESOLVED

North Hibernia 1

Brown Gannett 1

Cartier 1

Lucas 1

Prion 1

Pascal 1

4 3,1 Puffin 2

Grebe 1

Champagny 1

Sahul Shoals 1

Pollard 1

Paqualin 1

Jabiru 1

Challis 1

Cassini 1

Voltaire 1

Lorikeet 1

Dillon Shoals 1

Nancar 1

'NANCAR' AREA

Jarrah 1

Avocet 1A

Eider 1

'SOUTH JARRAH' AREA

Oliver 1

Nome 1

Turnstone 1

Ibis 1

Osprey 1

Skua 1

Sk2

Swift 1

Keeling 1

Woodbine 1

Delta 1

Bilyara 1

Montara 1

Anderdon 1

Gryphaea 1

Discorbis 1

Kalyptea 1

Asterias 1

AC/P1 AC/P2 AC/P3 AC/P4 AC/P5 AC/P6 AC/P7 AC/P9 AC/P10 AC/P11 AC/P12 AC/P13

AC/L1 AC/L2 AC/L3

V

WA199-P

WA147-P R1

W223-P

W224-P

ZOC

TERRITORY OF ASHMORE & CARTIER IS

WESTERN AUSTRALIA

○ *Petroleum exploration well*

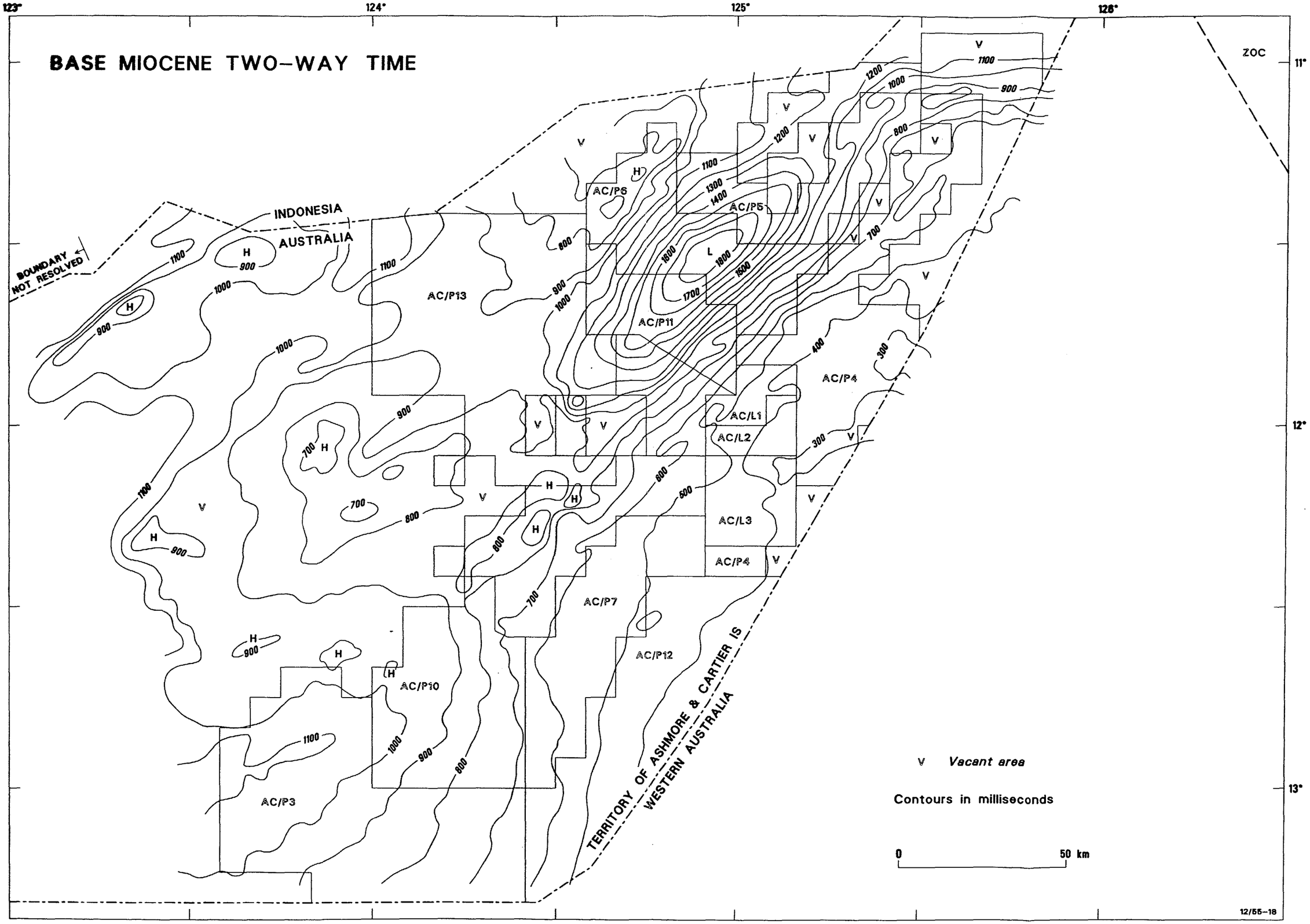
Fault

Prospect, leads, drilled structures

0 50 km

12/55-17

BASE MIOCENE TWO-WAY TIME



(After Patillo & Nicholls, 1990)

INTRA–VALANGINIAN EVENT TWO–WAY TIME

123° 124° 125° 126°

11° 12° 13°

INDONESIA

AUSTRALIA

BOUNDARY NOT RESOLVED

ZOC

ASHMORE PLATFORM

LONDONDERRY HIGH

TERRITORY OF ASHMORE & CARTIER IS
WESTERN AUSTRALIA

1500 2000 2500 3000

Pre–Valanginian sediment

Contours in milliseconds

0 50 km

12/55–19

(After Patillo & Nicholls, 1990)

VACANT AREAS – ASHMORE CARTIER REGION

123° 124° 125° 126°

11° 12° 13°

INDONESIA

AUSTRALIA

BOUNDARY NOT RESOLVED

TERRITORY OF ASHMORE & CARTIER IS

WESTERN AUSTRALIA

North Hibernia 1

Sahul Shoals 1

Pollard 1

Oliver 1

Voltaire 1

Dillon Shoals 1

Nancar 1

'NANCAR' AREA

Avocet 1A

Eider 1

'SOUTH JARRAH' AREA

Nome 1

Turnstone 1

Jabiru 1

Paqualin 1

Challis 1

Cassini 1

Ibis 1

Osprey 1

Brown

Gannett 1

Cartier 1

Lucas 1

Pascal 1

Prion 1

Puffin 4

3,1

2

Grebe 1

Skua 1

Champagny 1

Sk2

Swift 1

Delta 1

Keeling 1

Woodbine 1

Bilyara 1

Montara 1

Anderdon 1

Gryphaea 1

Discorbis 1

Kalyptea 1

Asterias 1

AC/P1

AC/P2

AC/P3

AC/P4

AC/P5

AC/P6

AC/P7

AC/P9

AC/P10

AC/P11

AC/P12

AC/P13

AC/L1

AC/L2

AC/L3

W223–P

W224–P

WA199–P

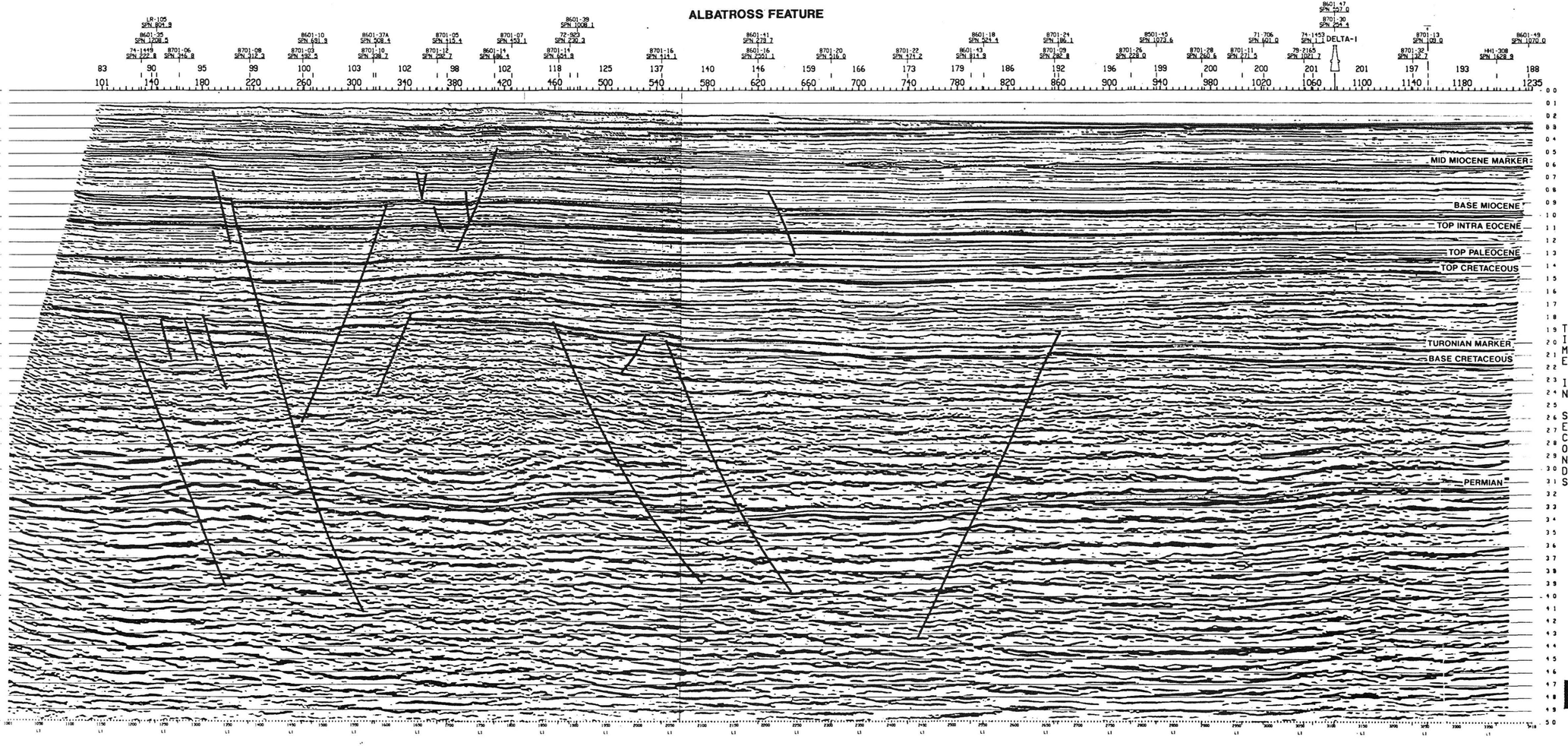
WA147–P R1

ZOC

V

0 50 km

12/55–20



LINE 8801-1
S.P. 101 TO 1235

ELF AQUITAINE EXPLORATION AUSTRALIA
AC/P1 TIMOR SEA
8801 SEISMIC SURVEY

160 DEGREES — DIRECTION SHOT

FILTERED MIGRATION

FIELD DATA

SPREAD DIAGRAM

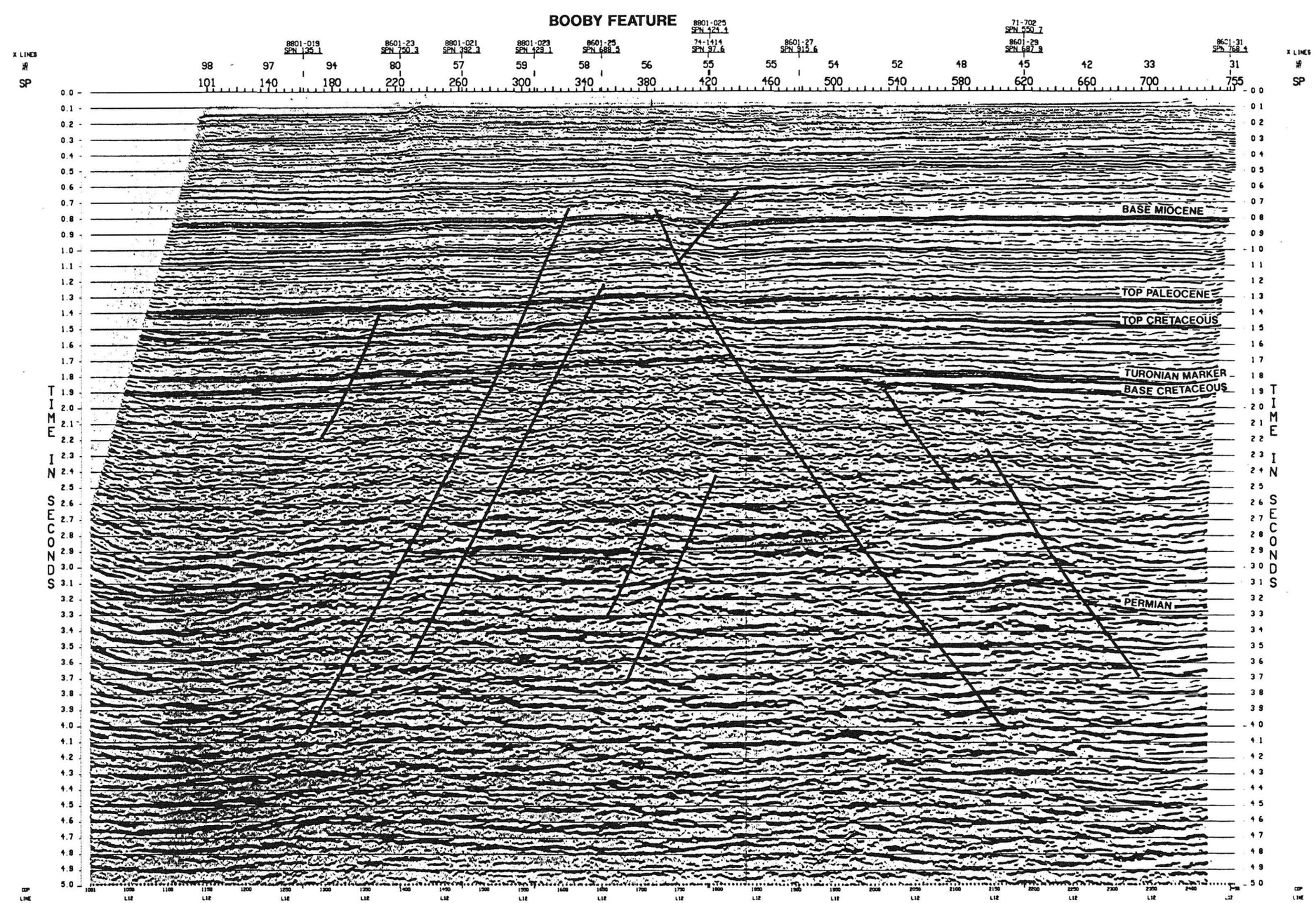
DIGITAL PROCESSING

DISPLAY

INTERPRETATION BY I. LAVERING JULY 1991

2 KM

PLATE 1



LINE 8801-12
S.P. 101 TO 755

ELF AQUITAINE EXPLORATION AUSTRALIA
AC/P1 TIMOR SEA
8801 SEISMIC SURVEY

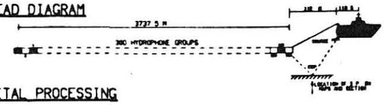
119 DEGREES — DIRECTION SHOT

FILTERED MIGRATION

FIELD DATA

DATA SHOT BY	- HALLIBURTON GEOPHYSICAL SERVICES M.V. PACIFIC TITAN / PARTY 2931
DATE SHOT	- JANUARY, 1988
RECORDING INSTRUMENTS	- TSR
RECORDING FILTERS	- HIGH-CUT FILTER 80 HZ / 72 DB/OCT LOW-CUT FILTER 8 HZ / 12 DB/OCT
RECORDING POLARITY	- A POSITIVE PRESSURE AT THE HYDROPHONE PRODUCES A NEGATIVE NUMBER ON TAPE
DIGITAL TAPE FORMAT	- SEG-D DEMULTIPLEXED
RECORD LENGTH / SAMPLE RATE	- 6.0 SECONDS AT 4 MILLISECOND SAMPLE RATE
ENERGY SOURCE	- AIRGUN VSX SLEEVE
ENERGY PRESSURE / VOLUME	- 1800 PSI / 2190 CU IN
SOURCE DEPTH	- 6 METRES AVERAGE
SHOTPOINT INTERVAL	- 25.0 METRES - 2 POP PER SHOTPOINT
SHOTPOINT ANNOTATION	- SHOTPOINTS ANNOTATED AT CDP POSITION
STREAMER LENGTH	- 3750 METRES 300 GROUPS 12.5 METRE GROUP INTERVAL
STREAMER DEPTH	- 10 METRES AVERAGE
COVERAGE	- 75 FOLD 300 TRACE
PRIMARY NAVIGATION SYSTEM	- SPOT / SAT

SPREAD DIAGRAM



DIGITAL PROCESSING

POLARITY CONVENTION	- THE POLARITY OF THE FIELD RECORDING WAS MAINTAINED THROUGHOUT THE PROCESSING
PROCESSING RECORD LENGTH	- 5.0 SECONDS
PROCESSING SAMPLE PERIOD	- 4 MILLISECONDS
AMPLITUDE RECOVERY(TAR)	- 5.0 DB PER SECOND FROM 0 TO 4.0 SECONDS SPHERICAL DIVERGENCE CORRECTIONS APPLIED
PRE DECONVOLUTION MUTE	- RAMP LENGTH 90 MSECS OFFSET(METRES) 112. 1300. 3850 START TIME(MSECS) -50. 850. 1550
VELOCITY FILTERING (VF)	- USING DIPS OF -6 TO +4 MSEC/TR IN THE SHOT DOMAIN WITH FULL COSINE RAMPING
DESIGNATURE (VF)	- OFFSET DEPENDENT MARINE WAVELET FMAX=125 HZ
SMASH	- TRACE MIX FROM 300 TR/150 FOLD TO 150 TR/75 FOLD
VELOCITY ANALYSIS	- USING 11 DEPTH POINT VELSCAN ANALYSES LOCATED EVERY 2 KM
DEMULTIPLE	- HORIZONTAL CUT-OFF VELOCITY IN NEGATIVE F-K QUADRANT 80000 M/SEC
VELOCITY ANALYSIS	- USING 11 DEPTH POINT VELSCAN ANALYSES LOCATED EVERY 2 KM
NORMAL MOVEOUT CORRECTION	- USING VELOCITIES DERIVED FROM DEMULT VELSCANS
SSD CORRECTIONS	- SHOT & STREAMER STATIC CORRECTIONS 12 MSEC
INSIDE TRACE MUTING	- RAMP LENGTH 90 MSECS OFFSET(M) 112. 408. 1867. 1050 START TIME(MSEC) -50. -50. -50. 50 END TIME(MSEC) 600. 850. 2650. 5000
FIRST BREAK SUPPRESSION	- RAMP LENGTH 90 MSECS OFFSET(METRES) 112. 1300. 3850 START TIME(MSECS) -50. 850. 2650
COMMON DEPTH POINT STACK	- 75 FOLD CDP STACK
TRANSMISSION COMPENSATION DECONVOLUTION (VF)	- TCOMP 2 GATES NOISE 10 PCT SMASH 11 COPS GATE 1 TIME(MSEC) 200 GATE 2 1300
MIGRATION (VF)	- KIRCHHOFF WAVE EQUATION MIGRATION IN F-K DOMAIN WITH DIP LIMIT OF 30 DEGREES, USING ANNOTATED VELOCITIES WITH DIP CORRECTION AND SMOOTHING VELOCITIES CONDITIONED WITH 20 SPACEVELS
TIME VARIANT FILTERING	- FREQUENCY (HZ) TIME (MSEC) 10 - 80 0 10 - 70 800 8 - 60 1500 7 - 55 2000 5 - 50 2500 4 - 40 3000
TIME VARIANT SCALING	- USING 500 MSEC GATES DGCS SCALING. START TIME SURFACE

DISPLAY

HORIZONTAL SCALE	- 20 000 TR/CM 80 000 TR/KM
VERTICAL SCALE	- 10.00 CM/SEC
POLARITY	- NORMAL
TRACE TYPE BIAS	- WIGGLE, 0 PERCENT
DATUM	- SEA LEVEL
DISPLAY UNIT	- 0.692597 CM

DISPLAY GAIN

CDP STACK		
1 SEC 80	2 SEC 80	3 SEC 80
4 SEC 80	5 SEC 80	6 SEC 80

PLOTTED +18DB FROM ABOVE

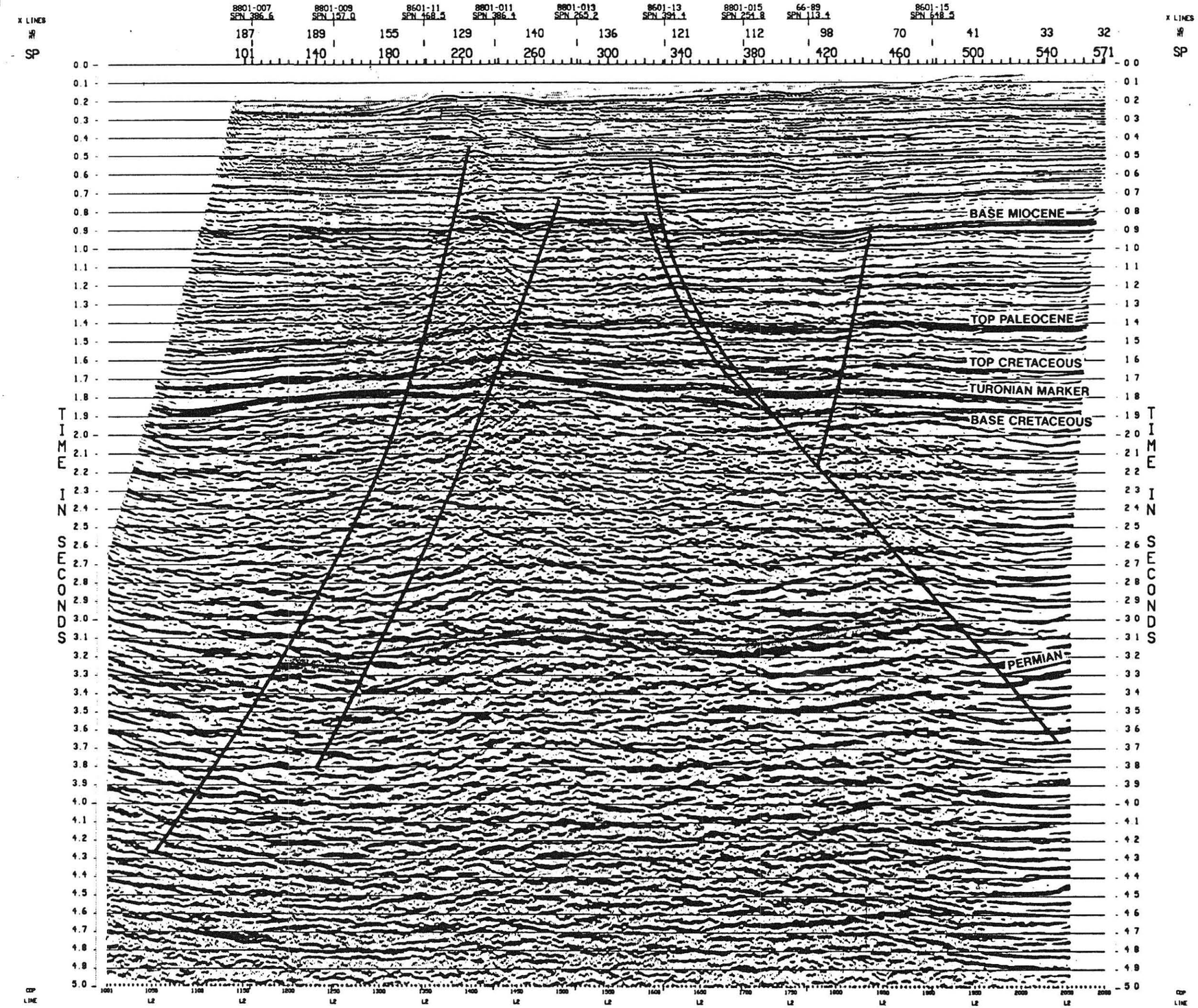
PETROLEUM RESOURCE ASSESSMENT BRANCH

INTERPRETATION BY I. LAVERING JULY 1991

2 KM

PLATE 2

GOOSE FEATURE



LINE 8801-2
S.P. 101 TO 571

ELF AQUITAINE EXPLORATION AUSTRALIA
AC/P1 TIMOR SEA
8801 SEISMIC SURVEY

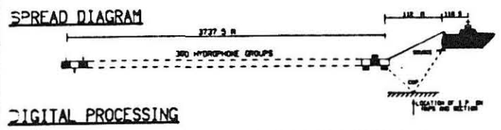
119 DEGREES — DIRECTION SHOT

FILTERED MIGRATION

FIELD DATA

DATA SHOT BY	- HALLIBURTON GEOPHYSICAL SERVICES M V 'PACIFIC TITAN' / PARTY 2931
DATE SHOT	- JANUARY, 1989
RECORDING INSTRUMENTS	- TSR
RECORDING FILTERS	- HIGH-CUT FILTER 90 HZ / 72 DB/OCT LOW-CUT FILTER 8 HZ / 12 DB/OCT
RECORDING POLARITY	- A POSITIVE PRESSURE AT THE HYDROPHONE PRODUCES A NEGATIVE NUMBER ON TAPE
DIGITAL TAPE FORMAT	- SEG-D DEMULTIPLEXED
RECORD LENGTH / SAMPLE RATE	- 6.0 SECONDS AT 4 MILLISECOND SAMPLE RATE
ENERGY SOURCE	- AIRGUN VSX SLEEVE
ENERGY PRESSURE / VOLUME	- 1800 PSI / 2180 CU IN
SOURCE DEPTH	- 6 METRES AVERAGE
SHOTPOINT INTERVAL	- 25.0 METRES 1 POP PER SHOTPOINT
SHOTPOINT ANNOTATION	- SHOTPOINTS ANNOTATED AT CDP POSITION
STREAMER LENGTH	- 3750 METRES 300 GROUPS 12.5 METRE GROUP INTERVAL
STREAMER DEPTH	- 10 METRES AVERAGE
COVERAGE	- 75 FOLD, 300 TRACE
PRIMARY NAVIGATION SYSTEM	- SPOT / SAT

SPREAD DIAGRAM



DIGITAL PROCESSING

POLARITY CONVENTION	- THE POLARITY OF THE FIELD RECORDING WAS MAINTAINED THROUGHOUT THE PROCESSING
PROCESSING RECORD LENGTH	- 5.0 SECONDS
PROCESSING SAMPLE PERIOD	- 4 MILLISECONDS
AMPLITUDE RECOVERY(SAO)	- 5.0 DB PER SECOND FROM 0 TO 4.0 SECONDS SPHERICAL DIVERGENCE CORRECTIONS APPLIED
PRE DECONVOLUTION MUTE	- RAMP LENGTH 50 MSECS OFFSETS(METRES) : 12. 1300. 3850. START TIMES(MSECS) : 50. 850. 1550.
VELOCITY FILTERING (V6)	- USING DIPS OF -6.75/+4 MSEC/TR IN THE SHOT DOMAIN WITH FULL COSINE RAMPING
DESIGNATURE (V6)	- OFFSET DEPENDENT MARINE WAVELET. Fmax=125 HZ
SMASH	- TRACE MIX FROM 300 TR/150 FOLD TO 150 TR/75 FOLD
VELOCITY ANALYSIS	- USING 11 DEPTH POINT VELSCAN ANALYSES LOCATED EVERY 2 KM
DEMULTIPLE	- HORIZONTAL CUT-OFF VELOCITY IN NEGATIVE F-K QUADRANT 8000 M/SEC
VELOCITY ANALYSIS	- USING 11 DEPTH POINT VELSCAN ANALYSES LOCATED EVERY 2 KM
NORMAL MOVEOUT CORRECTION	- USING VELOCITIES DERIVED FROM DEMULT VELSCANS
SSD CORRECTIONS	- SHOT & STREAMER STATIC CORRECTIONS 12 MSEC
INSIDE-TRACE MUTING	RAMP LENGTH 50 MSECS OFFSETS(M) : 112. 409. 1047. 1650 START TIMES(MSEC) : 50. 30. 50. 50 END TIMES(MSEC) : 600. 850. 2450. 5000
FIRST BREAK SUPPRESSION	- RAMP LENGTH 50 MSECS OFFSETS(METRES) : 12. 1300. 3850 START TIMES(MSECS) : -50. 850. 2450
COMMON DEPTH POINT STACK	- 75 FOLD CDP STACK
TRANSMISSION COMPENSATION DECONVOLUTION (V3)	- TCOMP 2 GATES NOISE 10 PCT SMASH 11 CDPS TAU MIN 30 MSECS TAU MAX 130 MSECS
MIGRATION (V7)	- KIRCHHOFF WAVE EQUATION MIGRATION IN F-K DOMAIN WITH DIP LIMIT OF 30 DEGREES USING ANNOTATED VELOCITIES WITH DIP CORRECTION AND SMOOTHING
TIME VARIANT FILTERING	- VELOCITIES CONDITIONED WITH 28 SPACEVELS FREQUENCY (HZ) — TIME (MSEC) 12 - 80 — 0 10 - 70 — 800 8 - 60 — 1500 5 - 55 — 2000 5 - 50 — 2500 5 - 40 — 3000
TIME VARIANT SCALING	- USING 500 MSEC GATES DGCS SCALING. START TIME SURFACE

DISPLAY

HORIZONTAL SCALE	25 000 TR/CM 80 000 TR/KM
VERTICAL SCALE	10.00 CM/SEC
POLARITY	NORMAL
TRACE TYPE BIAS	WIGGLE & PERCENT
DATUM	SEA LEVEL
DISPLAY UNIT	C 692597 CM

DISPLAY GAIN

CDP	1SMS
1MSEC 0.0	6dB/OCT 50 100.0

PLOTTED -1000 FROM ABOVE

PETROLEUM RESOURCE ASSESSMENT BRANCH

INTERPRETATION BY I.LAVERING JULY 1991

2 KM

PLATE 3

PSLA 83/36

LINE VS-01
S.P. 1 TO 2612

VULCAN SHOALS
SCIENTIFIC SURVEY
ASHMORE-CARTIER 1983 NON-EXCLUSIVE

FINAL STACK

FIELD DATA

SPREAD DIAGRAM

DIGITAL PROCESSING

DISPLAY

GEOPHYSICAL SERVICE INTERNATIONAL
A DIVISION OF TEXAS INSTRUMENTS LTD

SW

NE

Key to seismic horizons: ① Base Miocene ② Top Eocene ③ Top Cretaceous ④ Breakup Unconformity

INTERPRETATION BY I. LAVERING JULY 1991

PLATE 4

PSLA 83/36

LINE VS-07
S.P. 1 TO 2466

VULCAN SHOALS
SCIENTIFIC SURVEY
ASHMORE-CARTIER 1983 NON-EXCLUSIVE

FINAL STACK

FIELD DATA

SPREAD DIAGRAM

DIGITAL PROCESSING

SURVEY

GEOPHYSICAL SERVICE INTERNATIONAL
A DIVISION OF TEXAS INSTRUMENTS LTD

SW

NE

Channels

Channel system

Key to seismic horizons: ① Base Miocene ② Top Eocene ③ Top Cretaceous ④ Breakup Unconformity

INTERPRETATION BY I. LAVERING JULY 1991

PLATE 5

PSLA 83/36

LINE VS-08
S.P. 1 TO 1844

VULCAN SHOALS
SCIENTIFIC SURVEY
ASHMORE-CARTIER 1983 NON-EXCLUSIVE

FINAL STACK

FIELD DATA

SPREAD DIAGRAM

DIGITAL PROCESSING

DISPLAY

GEOPHYSICAL SERVICE INTERNATIONAL
A DIVISION OF TEXAS INSTRUMENTS LTD.

SW

NE

Key to seismic horizons: ① Base Miocene ② Top Eocene ③ Top Cretaceous ④ Breakup Unconformity

PETROLEUM RESOURCE ASSESSMENT BRANCH

INTERPRETATION BY I. LAVERING JULY 1991

PLATE 6

PSLA 83/36

LINE VS-10A

S.P. 1 TO 1739

VULCAN SHOALS
SCIENTIFIC SURVEY
ASHMORE-CARTIER 1983 NON-EXCLUSIVE

FINAL STACK

FIELD DATA

SPREAD DIAGRAM

DIGITAL PROCESSING

DISPLAY

GEOPHYSICAL SERVICE INTERNATIONAL
A DIVISION OF TEXAS INSTRUMENTS LTD.

PROCESSING CHECKED BY

PRION 1

GREBE 1

NW

SE

Key to seismic horizons: ① Base Miocene ② Top Eocene ③ Top Cretaceous ④ Breakup Unconformity

PETROLEUM RESOURCE ASSESSMENT BRANCH

INTERPRETATION BY I. LAVERING JULY 1991

PLATE 7

LINE VS-11

S.P. 1 TO 1221

VULCAN SHOALS SCIENTIFIC SURVEY ASHMORE-CARTIER 1983 NON-EXCLUSIVE

104 DEGREES → ← DIRECTION SHOT

MIGRATION

FIELD DATA

DATA SHOT BY	- G S I PARTY 2931 M V EUGENE MCDERMOTT II
DATE SHOT	- OCTOBER-NOVEMBER 1983
RECORDING INSTRUMENTS	- DUAL DFS V
RECORDING FILTERS	- HIGH-CUT FILTER AND SLOPE 90 HZ @ 72 DB/OCTAVE LOW-CUT FILTER AND SLOPE 8 HZ @ 18 DB/OCTAVE
RECORDING POLARITY	- A POSITIVE PRESSURE AT THE HYDROPHONE PRODUCES A POSITIVE NUMBER ON TAPE AND AN UPWARD DEFLECTION ON THE FIELD MONITOR RECORD
DIGITAL TAPE FORMAT	- SEG B 1600 BPI PHASE ENCODED
RECORD LENGTH / SAMPLE RATE	- 6 0 SECONDS AT 4 MILLISECOND SAMPLE RATE
ENERGY SOURCE	- 4075 CU IN AIRGUN ARRAY OPERATING AT 2000 PSI
GUN DELAY	- 51 2 MILLISECONDS
SOURCE DEPTH	- 6 METRES AVERAGE
SOURCE TO ANTENNA DISTANCE	- 62 METRES
SHOTPOINT ANNOTATION	- SHOTPOINTS ANNOTATED AT SOURCE POSITION
STREAMER LENGTH	- 2880 METRES 192 GROUPS 15 METRE GROUP INTERVAL
STREAMER TYPE	- G S I MULTIPLEXOR STREAMER
STREAMER DEPTH	- 12 METRES AVERAGE
HYDROPHONES	- 80 PER GROUP
COVERAGE	- 48 FOLD 192 TRACE
NAVIGATION SYSTEM	- SATNAV/SONAR

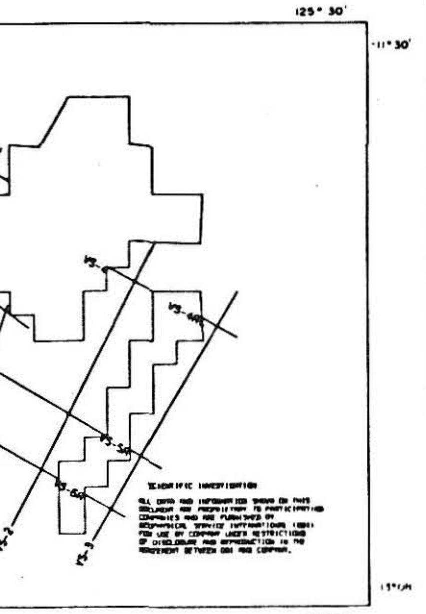
SPREAD DIAGRAM

2865 M

192 GEOPHONE GROUPS

DIGITAL PROCESSING

POLARITY CONVENTION	- THE POLARITY OF THE FIELD RECORDING WAS REVERSED THROUGHOUT THE PROCESSING AND DISPLAY
PROCESSING RECORD LENGTH	- 5 0 SECONDS
PROCESSING SAMPLE PERIOD	- 4 MILLISECONDS
STATIC CORRECTIONS	- SHOT AND STREAMER STATIC 12 MSEC AVERAGE AIRGUN DELAY 51 2 MSEC
AMPLITUDE RECOVERY(TAR)	- 7 0 DB PER SECOND FROM 0 TO 3 0 SECONDS SPHERICAL DIVERGENCE CORRECTIONS APPLIED
TRACE EDIT AND REVERSAL PRE DECONVOLUTION MUTE	- TR 192 AT 0 SEC. TR 135 AT 1SEC TR 1 AT 2 4SEC RAMP LENGTH 96 MSECS
VELOCITY FILTERING	- CUTS -2 5KM/SEC . +4 5KM/SEC
DESIGNATURE	- INDIVIDUAL SHOT STATISTICAL WAVELET ESTIMATE
EQUALISATION	- 1500 MSEC GATE . START TR 1 2000 MSEC START TR 192 2500 MSEC
COMMON DEPTH POINT GATHER	- 4 X 48 FOLD. 7 5 METRE CDP INTERVAL
VELOCITY ANALYSIS	- USING 9 DEPTH POINT VELSCAN ANALYSES LOCATED EVERY 3 KILOMETRES
NORMAL MOVEOUT CORRECTION	- USING ANNOTATED VELOCITIES
FIRST BREAK MUTING	- TR 1 AT 0 SEC. TR 12 AT 1 1SEC TR 48 AT 2 5SEC RAMP LENGTH 96 MSECS
COMMON DEPTH POINT STACK	- 48 FOLD CDP STACK
DECONVOLUTION	- GAP . 90 PERCENT TWO-WAY WATER TIME (ZW) 3 FILTERS . LENGTH - 30 PERCENT ZW DESIGN GATE WB - 300 - WB - 4300
MIGRATION	- KIRCHHOFF WAVE EQUATION MIGRATION IN FK DOMAIN NARROW ANGLE .USING DIP CORRECTED AND SMOOTHED VELOCITIES
TIME VARIANT FILTERING	- PASSBAND (HZ) TIME (MSEC) 15 - 90 1000 15 - 70 2000 12 - 55 3500 12 - 50 5000
TIME VARIANT SCALING	- USING 2 X 300.3 X 500.800 2 X 1000 MSEC GATES REGULAR SCALERS.START TIME WB
DECIMATION IN DISPLAY	



DISPLAY

HORIZONTAL SCALE	
VERTICAL SCALE	10.000000 CM / SEC
POLARITY	NORMAL
TRACE TYPE BIAS	0 0 PERCENT
DATUM	SEA LEVEL
DISPLAY UNIT	

DISPLAY GAIN

04 JAN 1984
01 27 01

PARTY 6867

GEOPHYSICAL SERVICE INTERNATIONAL

(A DIVISION OF TEXAS INSTRUMENTS LTD)

PROCESSING CHECKED BY - A Young

Key to seismic horizons: ① Base Miocene ② Top Eocene ③ Top Cretaceous ④ Breakup Unconformity

PETROLEUM RESOURCE ASSESSMENT BRANCH

INTERPRETATION BY I. LAVERING JULY 1991

PLATE 8

PSLA 87-21.

TRACK HV6-201
CDPS 1488-2456

BHP PETROLEUM AUSTRALIA
VULCAN E3D SURVEY

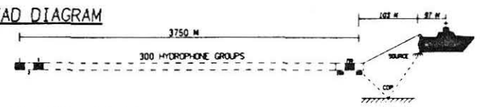
SOUTH-EAST

FILTERED 3D MIGRATION

FIELD DATA

DATA SHOT BY	- G S I PARTY 2993 M V MAGNIFICENT CREEK
DATE SHOT	- DECEMBER 1987 - JANUARY 1988
RECORDING INSTRUMENTS	- DFDS480-TITAN
PRE-DIGITIZATION MIXING	- TRACE MIX 5 1 TRACES 1-108 3 TRACES 109-204 1 1 TRACES 205-300
RECORDING FILTERS	- HIGH-CUT FILTER AND SLOPE 180 HZ @ 72 DB/OCTAVE LOW-CUT FILTER AND SLOPE 8 HZ @ 18 DB/OCTAVE
RECORDING POLARITY	- A POSITIVE PRESSURE AT THE HYDROPHONE PRODUCES A NEGATIVE NUMBER ON TAPE
DIGITAL TAPE FORMAT	- SEG D 6250 BPI
RECORD LENGTH / SAMPLE RATE	- 6 0 SECONDS AT 2 MILLISECOND SAMPLE RATE
ENERGY SOURCE	- 2180 CU IN VSX SLEEVE AIRGUN ARRAY OPERATING AT 1900 PSI
GUN DELAY	- 51 2 MILLISECONDS
SOURCE DEPTH	- 6 METRES AVERAGE
SOURCE TO ANTENNA DISTANCE	- 96 79 METRES
SHOTPOINT INTERVAL	- 25 00 METRES
STREAMER LENGTH	- 3750 METRES 300 GROUPS 12 50 M GROUP INTERVAL
STREAMER TYPE	- DIGITAL FIBRE OPTIC
STREAMER DEPTH	- 10 METRES AVERAGE
COVERAGE	- 75 FOLD 300 TRACE
PRIMARY NAVIGATION SYSTEM	- SPOT
BACKUP NAVIGATION SYSTEM	- G P S

SPREAD DIAGRAM



DIGITAL PROCESSING

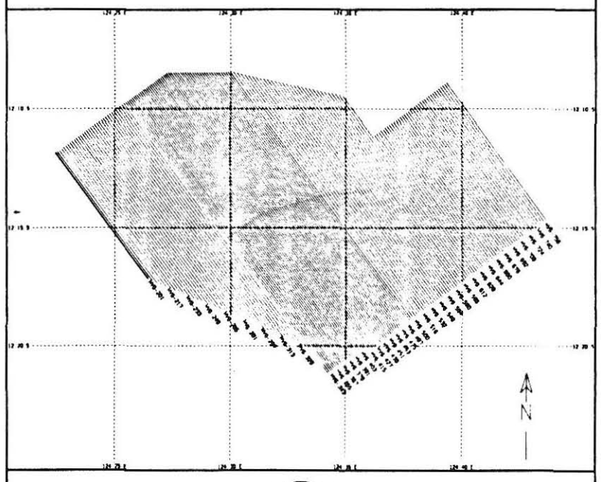
POLARITY CONVENTION	- THE POLARITY OF THE FIELD RECORDING WAS MAINTAINED THROUGHOUT THE PROCESSING AND DISPLAY
PROCESSING RECORD LENGTH	- 5 0 SECONDS
RESAMPLE	- MINIMUM PHASE RESAMPLE FROM 2 TO 4 MSEC
STATIC CORRECTIONS	- AIRGUN DELAY 51 2 MSEC
AMPLITUDE RECOVERY(TAR)	- 5 0 DB PER SECOND FROM 0 TO 4 0 SECONDS SPHERICAL DIVERGENCE CORRECTIONS APPLIED
PRE DECONVOLUTION MUTE	- RAMP LENGTH 96 MSECS OFFSETS(METRES) 250 500 3850 START TIMES(MSECS) 0 500 2600
VELOCITY FILTERING (V6)	- SPC DOMAIN FULL COSINE RAMPS -4 50 / -2 25 MSEC/TRACE
DESIGNATURE (V6)	- USING THREE OFFSET DEPENDENT WAVELETS FMAX=125
SWASH	- TRACE MIX FROM 300 TR/75 FOLD TO 150 TR/75 FOLD
VELOCITY FILTERING (V6)	- CRP DOMAIN FULL COSINE RAMPS -9 0 / -4 50 MSEC/TRACE
VELOCITY ANALYSIS	- USING 21 DEPTH POINT VELSCAN ANALYSIS LOCATED EVERY 750 METRES ON SELECTED VELOCITY LINES
DEMULTIPLE	- HORIZONTAL CUT-OFF VELOCITY IN NEGATIVE F-K QUADRANT 80000 METRES/SECONDS PCTMAX 15
PRE STACK SCALING	- GATE LENGTHS 1000 2000 MSECS
NORMAL MOVEOUT CORRECTION	- INTERPRETED VELOCITIES ANNOTATED
SSD CORRECTIONS	- SHOT & STREAMER STATIC CORRECTIONS 11 MSECS
INSIDE-TRACE MUTING	- RAMP LENGTH 96 MSECS OFFSETS(METRES) 100 900 920 1100 1900 1920 END TIMES(MSECS) 1400 1850 1850 2000 2800 6000 START TIMES(MSECS) 6000 6000 4000 3900 3400 6001
LOCATION CORRECTIONS	- TO MOVE EACH TRACE TO THE CENTRE OF DENSITY
FIRST BREAK SUPPRESSION	- RAMP LENGTH 96 MSECS OFFSETS(CM)/START TIMES 250/0 500/425 3850/2350
COMMON DEPTH POINT STACK	- 75 FOLD CDP STACK
LOCATION CORRECTIONS	- TO MOVE EACH TRACE TO THE REGULAR(GEOM) LOCATION
INTELLIGENT INTERPOLATOR	- USING SPACE AND TIME VARIANT DIP GUIDE
MIGRATION	- FINITE DIFFERENCE MIGRATION 45 DEGREE ALGORITHM 40 MSEC TIMESTEP
DIPCON	- FX DOMAIN 30 DEGREE DIP CONTROL
TIME VARIANT FILTERING	- FREQUENCY(HZ) TIME(MS) FREQUENCY(HZ) TIME(MS) 12 - 70 0 8 - 40 2700 10 - 50 1000 6 - 30 3400 10 - 50 2000
TIME VARIANT SCALING	- USING 250 250 AND 500 MSECS GATES REGULAR SCALERS START TIME WB + 100 MSECS
DECIMATION	- ALTERNATE CDPS

DISPLAY

HORIZONTAL SCALE	- 250 000 M /CM
VERTICAL SCALE	- 9 524 CM/SEC
POLARITY	- NORMAL
TRACE TYPE BIAS	- WIVAR 5 PERCENT
DATUM	- SEA LEVEL
DISPLAY UNIT	- 0 692597 CM

DISPLAY GAIN

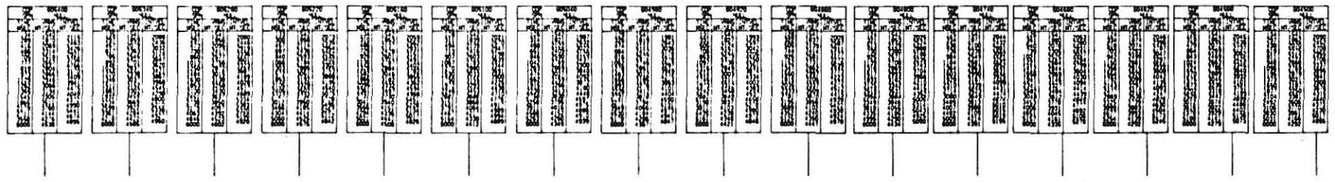
INPUT	
CDP GAIN DB	ALL TIME MSEC
-81 0	0



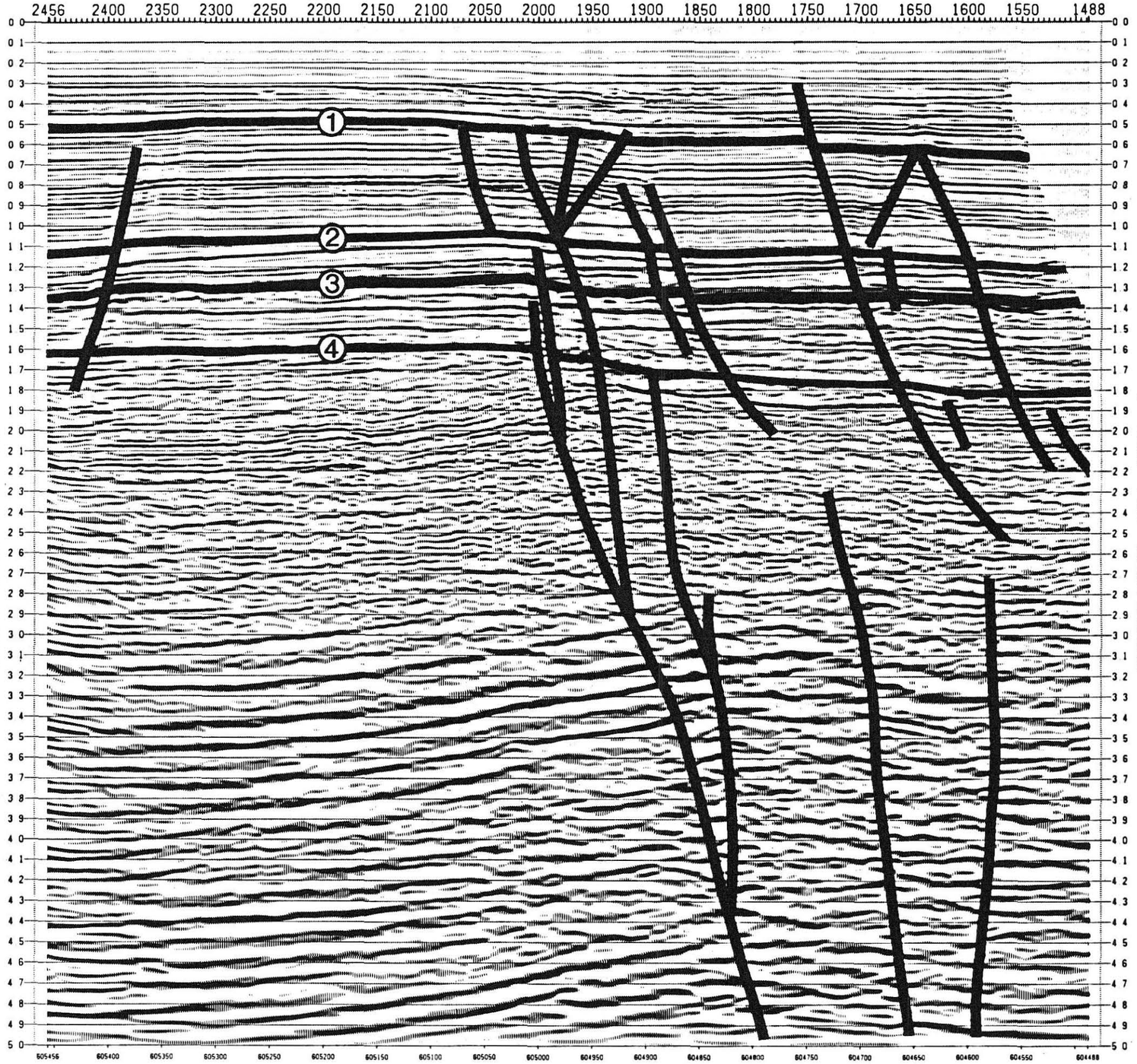
15 AUG 1988 PARTY 6860

GEOPHYSICAL SERVICE INC
A HALLIBURTON COMPANY

PROCESSING CHECKED BY -



NW SE



Key to seismic horizons:
① Base Miocene
② Top Palaeocene
③ Top Cretaceous
④ Base Cretaceous

PETROLEUM RESOURCE ASSESSMENT BRANCH

INTERPRETATION BY I. LAVERING JULY 1991

PLATE 9

FILTERED 3D MIGRATION
TRACK HV6-201
CDPS 1488-2456
BHP PETROLEUM AUSTRALIA
VULCAN E3D SURVEY

FILTERED 3D MIGRATION
TRACK HV6-201
CDPS 1488-2456
BHP PETROLEUM AUSTRALIA
VULCAN E3D SURVEY

70 08 20 86-03 58 80 90 15AUG88 10 59 41 100 VSN 015486 110 AMMDSPB3DMIG-201 120 TVF7157J 0008 130 FRAME 002 OF 002 140 150 160 170 08 20 86-03 58 180 190 15AUG8

SW

PAQUALIN FEATURE

NE

ICH 37/21

CROSS TRACK CDP 1320
TRACKS801-1161

BHP PETROLEUM AUSTRALIA
ROSELLA/P11 E3D SURVEY

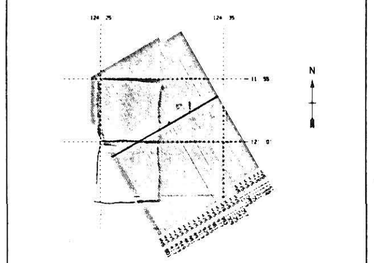
FILTERED 3D MIGRATION

FIELD DATA

SPREAD DIAGRAM

DIGITAL PROCESSING

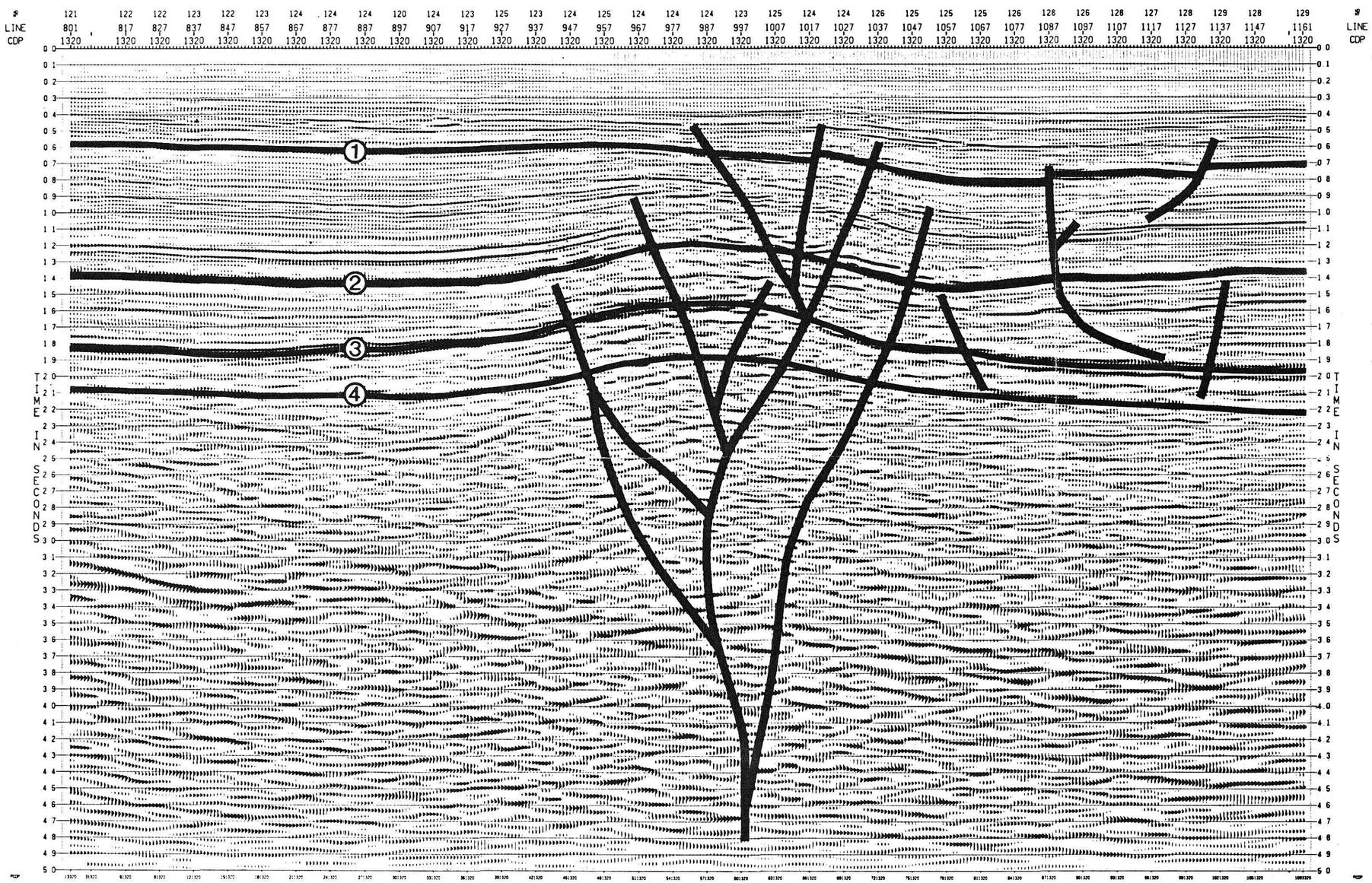
DISPLAY



08 JUL 1988 — PARTY 6860

GEOPHYSICAL SERVICE INC

PROCESSING CHECKED BY



Key to seismic horizons: ① Base Miocene ② Top Palaeocene ③ Top Cretaceous ④ Base Cretaceous

VSN 023922 AMTDSPBCROSS1040 TVF5499J 0049 FRAME 001 OF 002 08JUL88 11 04 13 VSN 023922 AMTDSPBCROSS1040 TVF5499J 0049 FRAME 002 OF 002 08JUL88 11 04 13

PETROLEUM RESOURCE ASSESSMENT BRANCH

INTERPRETATION BY I. LAVERING JULY 1991

PLATE 10

PSLA 87/21

CROSS TRACK CDP 1720
TRACKS801-1161

BHP PETROLEUM AUSTRALIA
ROSELLA/P11 E3D SURVEY

FILTERED 3D MIGRATION

FIELD DATA

DATA SHOT BY	: G.S.I. PARTY 2893 M.V MAGNIFICENT CREEK
DATE SHOT	: OCTOBER - NOVEMBER 1987
RECORDING INSTRUMENTS	: DFS/SERCEL/TITAN
PRE DIGITIZATION MIXING	: TRACE MIX 1 - 6 TRACES 1-108 7 - 12 TRACES 109-204 13 - 18 TRACES 205-300
RECORDING FILTERS	: HIGH CUT 0 PHASE AND SLOPE 180 HZ @ 72 DB OCTAVE LOW CUT FILTER AND SLOPE 8 HZ @ 18 DB OCTAVE
RECORDING POLARITY	: A POSITIVE PRESSURE AT HYDROPHONE PRODUCES A POSITIVE NUMBER ON TAPE
DIGITAL TAPE FORMAT	: SEG Y SEG D
RECORD LENGTH / SAMPLE RATE	: 6.0 SECONDS AT 2 MILLISECOND SAMPLE RATE
ENERGY SOURCE	: 2160 CU. IN. 18 SLEEVE AIRGUN ARRAY OPERATING AT 1800 PSI
GUN DELAY	: 51.2 MILLISECONDS
SOURCE DEPTH	: 6 METRES AVERAGE
SOURCE TO ANTENNA DISTANCE	: 38.9 METRES
SHOTPOINT INTERVAL	: 25.00 METRES
STREAMER LENGTH	: 3150 METRES 300 GROUPS 12.50 M GROUP INTERVAL
STREAMER TYPE	: DIGICON SOLID STATE
STREAMER DEPTH	: 7.5 METRES AVERAGE
COVERAGE	: 75 FOLD 300 TRACE
PRIMARY NAVIGATION SYSTEM	: SPOT
BACKUP NAVIGATION SYSTEM	: D.P.S

SPREAD DIAGRAM

DIGITAL PROCESSING

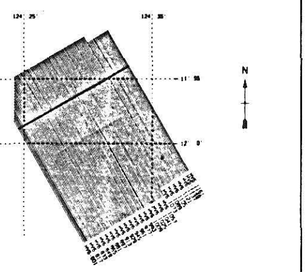
POLARITY CONVENTION	: THE POLARITY OF THE FIELD RECORDING HAS BEEN MAINTAINED THROUGHOUT PROCESSING AND DISPLAY
PROCESSING RECORD LENGTH	: 6.0 SECONDS
RESAMPLE	: MINIMUM PHASE RESAMPLE FROM 2 TO 4 MSEC
STATIC CORRECTIONS	: 12 MSEC
AMPLITUDE RECOVERY(ATTAR)	: 6.0 DB PER SECOND FROM 3.0 TO 4.0 SECONDS
PRE DECONVOLUTION MUTE	: SPHERICAL DIVERGENCE CORRECTIONS APPLIED RAMP LENGTH 88 MSECS OFFSETS(METRES) 250 600 3850 START TIMES(MSECS) 0 500 2600
VELOCITY FILTERING (VS)	: CMP DOMAIN FULL OFFSET RAMPS 0.0 - 6.50 - 9.25 MSEC/TRACE
DESIGNATURE (VS)	: USING THREE OFFSET DEPENDENT WAVELETS, FMAX=125 HZ
SMASH	: TRACE MIX FROM 300 TRACE FOLD TO 150 TRACE FOLD
VELOCITY FILTERING (VS)	: CMP DOMAIN FULL OFFSET RAMPS 0.0 - 6.50 MSEC/TRACE
VELOCITY ANALYSIS	: USING 31 DEPTH POINT JELSEN ANALYSIS LOCATED EVERY 50 METRES ON SELECTED VELOCITY LINES
DEMULTIPLE	: HORIZONTAL CUT OFF VELOCITY NEGATIVE FIX
PRE STACK SCALING	: QUADRATIC BOOST METRES SECONDS - BETMAN 78 GATE LENGTH 1000 MSECS OFFSETS(METRES) 250 600 3850 START TIMES(MSECS) 8000 4000 3950 3400 8001
NORMAL MOVEOUT CORRECTION	: INTERPRETED VELOCITIES ANNOTATED
SSD CORRECTIONS	: SHOT & STREAMER STATIC CORRECTIONS 12 MSECS
INSIDE TRACE MUTING	: RAMP LENGTH 88 MSECS OFFSETS(METRES) 100 1300 1301 1400 2200 2201 CMP TIMES(MSECS) 1400 1900 1902 2200 2800 8201 START TIMES(MSECS) 8000 4000 3950 3400 8001
LOCATION CORRECTIONS	: TO MOVE EACH TRACE TO THE CENTRE OF DENSITY
FIRST BREAK SUPPRESSION	: RAMP 88 MSECS OFFSETS(METRES) 250/6 600/425 3850/2350
COMMON DEPTH POINT STACK	: 75 FOLD CDP STACK
LOCATION CORRECTIONS	: TO MOVE EACH TRACE TO THE REGULAR (GEOM) LOCATION
INTELLIGENT INTERPOLATOR	: USING SPACE AND TIME VARIANT DIP GUIDE
MIGRATION	: FINITE DIFFERENCE MIGRATION 45 DEGREE ALGORITHM 48 MSEC TIMESTEP
TIME VARIANT FILTERING	: FREQUENCY(HZ) TIME(MS) FREQUENCY(HZ) TIME(MS) 12 78 6 2700 10 60 3800 90 3400 8 40 4000
TIME VARIANT SCALING	: USING THE 250 AND 600 MSECS GATES REGULAR SCALERS START TIME 48 - 100 MSECS
DECIMATION	: EVEN CDPS DISPLAYS

DISPLAY

HORIZONTAL SCALE	: 250.000 M /CM
VERTICAL SCALE	: 1.524 CM/SEC
POLARITY	: NORMAL
TRACE TYPE BIAS	: WIGGLE & PERCENT
GAIN	: 1.0
DISPLAY UNIT	: 0.5322189 CM

DISPLAY GAIN

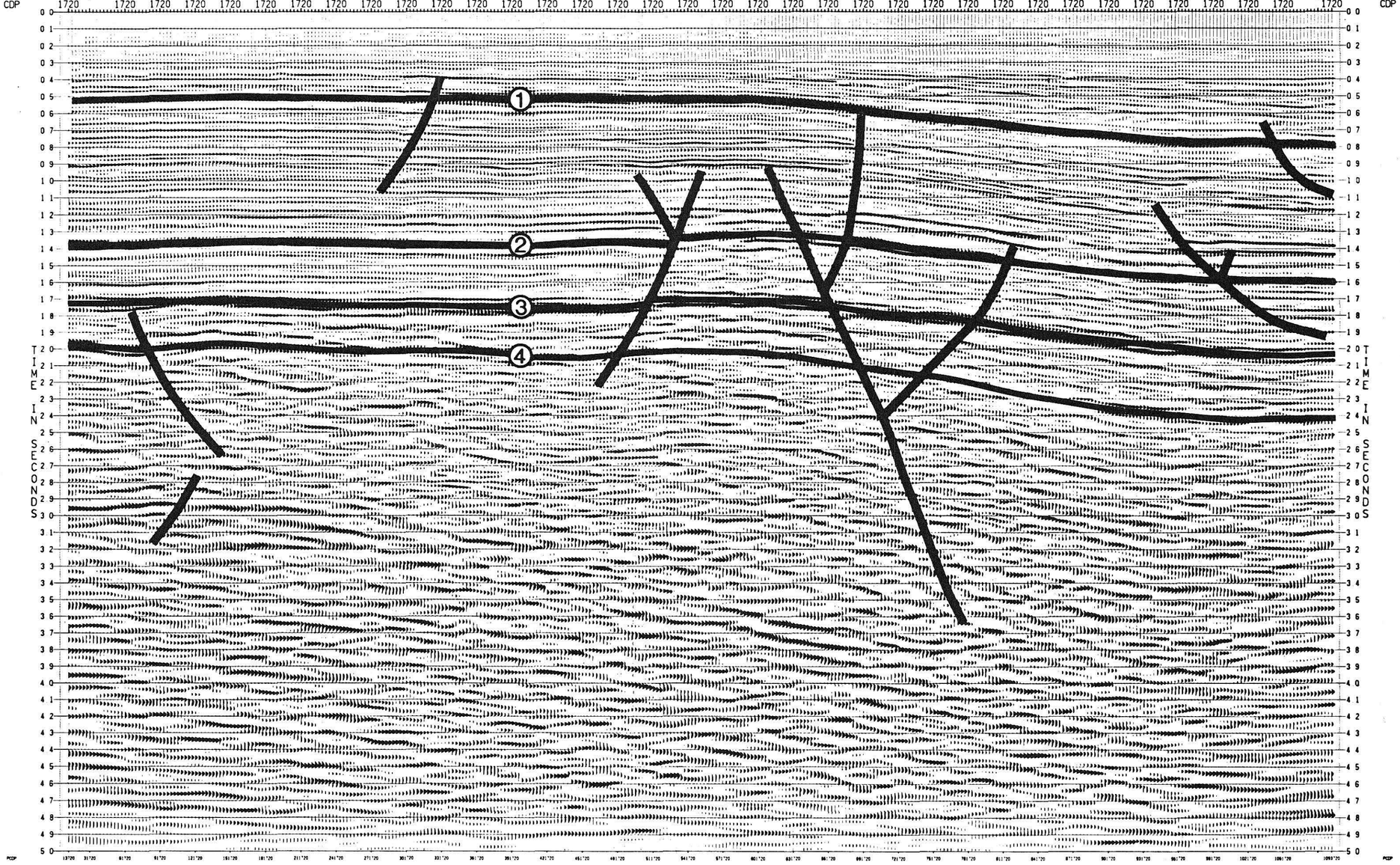
DEV	
25	45
35	55



08 JUL 1988 PARTY 6860

GEOPHYSICAL SERVICE INC
A HALLIBURTON COMPANY

PROCESSING CHECKED BY



Key to seismic horizons: ① Base Miocene ② Top Palaeocene ③ Top Cretaceous ④ Base Cretaceous

VSN 021255 AMTDSPBCROSS1720 TVF5499J 0007 FRAME 001 OF 002 08JUL88 16 44 51 VSN 021255 AMTDSPBCROSS1720 TVF5499J 0007 FRAME 002 OF 002 08JUL88 16 44 5

PETROLEUM RESOURCE ASSESSMENT BRANCH

INTERPRETATION BY I. LAVERING JULY 1991

PLATE 11

PS619 87/51

TRACK HV6-877
CDPS 240-2264

BHP PETROLEUM AUSTRALIA
ROSELLA/P11 E3D SURVEY

SOUTH EAST

FILTERED 3D STACK

FIELD DATA

DATA SHOT BY	: G.S.I. (V) PARTY 2693 M.V. MAGNIFICENT CREEK
DATE SHOT	: OCTOBER - NOVEMBER 1987
RECORDING INSTRUMENTS	: GEOSERO/TITAN
PRE-DIGITIZATION MIXING	: TRACE MIX : 1:1 TRACES 1-108 1:2 TRACES 109-204 1:1 TRACES 205-300
RECORDING FILTERS	: HIGH-CUT FILTER AND SLOPE : 180 HZ @ 72 DB/OCTAVE LOW-CUT FILTER AND SLOPE : 8 HZ @ 18 DB/OCTAVE
RECORDING POLARITY	: AN INCREASE IN PRESSURE ON THE HYDROPHONE PRODUCES A NEGATIVE NUMBER ON TAPE
DIGITAL TAPE FORMAT	: SEG D 8058 BPI
RECORD LENGTH / SAMPLE RATE	: 6.0 SECONDS AT 2 MILLISECOND SAMPLE RATE
ENERGY SOURCE	: 2160 CU. IN. VSI SLEEVE AIRGUN ARRAY
GUN DELAY	: 97.7 MILLISECONDS
SOURCE DEPTH	: 6.5 METRES AVERAGE
SOURCE TO ANTENNA DISTANCE	: 36.78 METRES
SHOTPOINT INTERVAL	: 25.00 METRES
NUMBER OF STREAMERS	: 6 AT 100 METRES, 300 GROUPS 12.50 M GROUP INTERVAL
STREAMER TYPE	: DIGITAL FIBRE OPTIC
STREAMER DEPTH	: 10 METRES AVERAGE
COVERAGE	: 75 FOLD 300 TRACE
PRIMARY NAVIGATION SYSTEM	: SPOT
BACKUP NAVIGATION SYSTEM	: G.P.S.

SPREAD DIAGRAM

DIGITAL PROCESSING

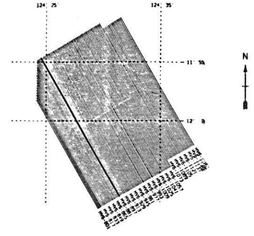
POLARITY CONVENTION	: THE POLARITY OF THE FIELD RECORDING HAS BEEN MAINTAINED THROUGHOUT THE PROCESSING AND DISPLAY
PROCESSING RECORD LENGTH	: 5.0 SECONDS
RESAMPLE	: MINIMUM PHASE RESAMPLE FROM 2 TO 4 MSEC
STATIC CORRECTIONS	: AIRGUN DELAY : -52.2 MSEC
AMPLITUDE RECOVERY(TAR)	: 5.0 DB PER SECOND FROM 3.0 TO 4.0 SECONDS
PRE DECONVOLUTION MUTE	: SHOT & STREAMER STATIC CORRECTIONS APPLIED RAMP LENGTH : 96 MSECS OFFSET(METRES) : 250 600 3850 START TIME(MSECS) : 0 600 2800
VELOCITY FILTERING (VXE)	: SPC DOMAIN PASS/REJECT TIME RAMPS : 6.50 / 7.25 MSEC/TRACE DESIGNATURE (VXE) : PASS/REJECT DEPENDENT VELOCITIES LOCATED EVERY 750 M'S ON SELECTED VELOCITY LINES
SMASH	: TRACE MIX FROM 300 TR/6 FOLD TO 150 TR/75 FOLD
VELOCITY FILTERING (VXE)	: CMP DOMAIN FULL COSINE RAMPS : 9.0 / 9.4 SE MSEC/TRACE PASS/REJECT VELOCITIES LOCATED EVERY 750 M'S ON SELECTED VELOCITY LINES
VELOCITY ANALYSIS	: HORIZONTAL CUT OFF VELOCITY IN MEMORY : 2500 MAXIMUM BOOST METRES/SECOND : PLTAU 1%
DEMULTIPLE	: GATE LENGTHS : 1500, 2000 MSECS GATE START TIMES : 1800, 2000 MSECS
PRE STACK SCALING	: INTERPOLATED VELOCITIES : KNOTS AT 1849/2500
NORMAL MOVEOUT CORRECTION	: SHOT & STREAMER STATIC CORRECTIONS : 12 MSECS
SSD CORRECTIONS	: RAMP LENGTH : 96 MSECS
INSIDE TRACE MUTING	: OFFSET(METRES) : 100 1300 1391 1400 2200 2201 START TIMES(MSECS) : 1600 1800 1988 2000 2800 4001
LOCATION CORRECTIONS	: TO MOVE EACH TRACE TO THE CENTRE OF GRAVITY
FIRST BREAK SUPPRESSION	: RAMP LENGTH : 96 MSECS OFFSET(M)/START TIMES : 250/0 500/425 3850/2350
COMMON DEPTH POINT STACK	: 75 FOLD 300 TRACE
LOCATION CORRECTIONS	: TO MOVE EACH TRACE TO THE REQUIRED LOCATION
TIME VARIANT FILTERING	: FREQUENCY(HZ) TIME(MS) : FREQUENCY(HZ) TIME(MS) 12 0 8 4700 10 500 6 4800 8 1000 4 5000
TIME VARIANT SCALING	: USING 250, 2500 AND 5000 MSECS GATES
DECIMATION	: REGULAR SCALERS START TIME : 48 TO 100 MSECS : EVEN CDPS DISPLAYS

DISPLAY

HORIZONTAL SCALE	: 250.000 M /CM
VERTICAL SCALE	: 5.524 CM/SEC
POLARITY	: NORMAL
TRACE TYPE BIAS	: VIVAR & PERCENT
DATUM	: SEA LEVEL
DISPLAY UNIT	: 0.625535 CM

DISPLAY GAIN

DB	MIN	MAX
0	0%	0%
6	0%	0%



22 JUN 1988 PARTY 6860

GEOPHYSICAL SERVICE INC
A HALLIBURTON COMPANY

PROCESSING CHECKED BY :

NW SE

CDP 2264 2200 2150 2100 2050 2000 1950 1900 1850 1800 1750 1700 1650 1600 1550 1500 1450 1400 1350 1300 1250 1200 1150 1100 1050 1000 950 900 850 800 750 700 650 600 550 500 450 400 350 300 240 CDP

TIME IN SECONDS

Key to seismic horizons: ① Base Miocene ② Top Palaeocene ③ Top Cretaceous ④ Base Cretaceous

PETROLEUM RESOURCE ASSESSMENT BRANCH

INTERPRETATION BY I. LAVERING JULY 1991

PLATE 12

FILTERED 3D STACK
TRACK HV6-877
CDPS 240-2264
BHP PETROLEUM AUSTRALIA
ROSELLA/P11 E3D SURVEY

22JUN88 22 50 54 006661 AMTZZRBROSEL0877 TVF6299J 0008 FRAME 002 OF 003
22JUN88 22 50 54 SN 006661 AMTZZRBROSEL0877 TVF6299J 0008 FRAME 003 OF 003

PSLA 87/21

BHP Petroleum

PERMIT : AC/P-2 SURVEY : HV3

LINE : HV3-307

SHOT POINTS : 692 - 1071

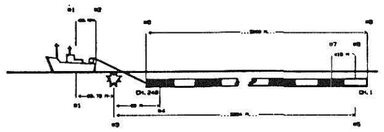
FINAL STACK

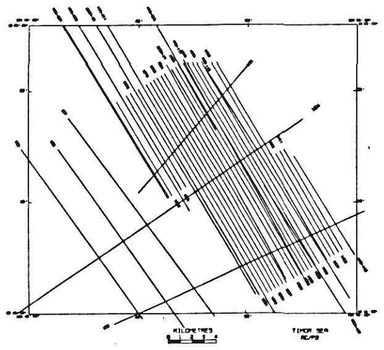
RECORDING PARAMETERS

RECORDED BY : GEOPHYSICAL SERVICE INC.
VESSEL : M/V MAGNIFICENT OCEAN
INSTRUMENTS : FCS III
SAMPLE RATE : 2 MS.
SHOTPOINT INTERVAL : 30 M.
GROUPS : 240
GROUP INTERVAL : 15 M.
AIRGUN PRESSURE : 1800 PSI.
SOURCE : AIRGUN - VSX SLEEVE
GUN DEPTH : 7 M.
NEAR OFFSET : 90 M.

DATE RECORDED : 23RD APRIL, 1988
STREAMER : MULTIPLEX : 240 CHANNEL
STREAMER LENGTH : 3000 M.
TAPE FORMAT : SEG D 8058 B.P.I.
RECORD LENGTH : 6 SEC.
FILTER : HI - 108 HZ 72 DB.
LO - 8 HZ 18 DB.
FOLD : 60
ARRAY VOLUME : 2268 CU. IN.
AVE. STREAMER DEPTH : 10 M.
FAR OFFSET : 3604M.

328.5 DEGREES





PROCESSED BY : DIGITAL EXPLORATION LTD.

DIGICON, BRISBANE

B.H.P. : [illegible]

DIGICON - GEO: : MR. G. KOO
SUPERVISOR : MR. G. ARMSTRONG

Q.C. : Q. Koo

DATE : 15 TH JANUARY 1988

PROCESSING SEQUENCE

(1) TRANSCRIPTION :
SEG-D FIELD TAPE FORMAT TO DIGICON INTERNAL FORMAT
DATA LENGTH..... 5 SEC.
SAMPLE RATE..... 2 MSEC.
FIELD REELS PROCESSED. FT 867447-867448

(2) RESAMPLE :
FROM 2MS. TO 4MS.. MINIMUM PHASE ANTI-ALIAS FILTER
BUTTERWORTH LOW PASS 8/8-98/72

(3) VELOCITY FILTER :
SHOT DOMAIN VELOCITY FILTERING
2-D RECURSIVE BUTTERWORTH DIP FILTER
PASS RANGE : +/-3.75 MS/TRACE
(+/- 4000 M/SEC .24DB/OCTAVE TAPERS)

(4) 2:1 ADJACENT TRACE TRACE SUM :
WITH PARTIAL MOVEOUT COMPENSATION TO ARRAY CENTRES

(5) STATIC CORRECTIONS :
AIRGUN TIMING DELAY .... -51.2 MS.
SOURCE CORRECTION ..... +3.5 MS.
STREAMER CORRECTION ..... +8.2 MS.
TOTAL STATIC = ... -39.50 MS.

(6) SPHERICAL DIVERGENCE CORRECTION :

TIME	0	1000	2000	3000	4000	5000
VELOCITY	1500	1500	2550	2600	3000	4000

(7) GAIN CORRECTION :
EXPONENTIAL + +7.5 DB FROM 0 MS. TO 5000 MS.

(8) WAVELET DECONVOLUTION :
OFFSET DEPENDENT DEFLAT
NO. OF OPERATERS PER SHOT = 3
DETERMINISTIC COMPENSATION FOR INSTRUMENT RESPONSE
AND SOURCE/STREAMER GHOSTS
DESIGN WINDOW NEAR : 0.48 TO 3.8 SEC.
FAR : 2.5 TO 3.5 SEC.
OUTPUT : ZERO PHASE

(9) VELOCITY FILTER :
RECEIVER DOMAIN VELOCITY FILTERING
2-D RECURSIVE BUTTERWORTH DIP FILTER
PASS RANGE : +/-7.5 MS/TRACE
(+/- 4000 M/SEC .24DB/OCTAVE TAPERS)

(10) C.D.P. GATHER :
MAXIMUM FOLD : 60

(11) VELOCITY ANALYSIS :
DIGICONS' VELFAN ROUTINE AT 750 M. INTERVALS.
ANALYSIS OVER 21 ALTERNATE CDPS & 11 VELOCITY FUNCTIONS
VELOCITY INTERPRETATION BY B.H.P. PETROLEUM

(12) MULTIPLE SUPPRESSION :
REMOVAL OF ONE FK QUADRANT USING 2-D RECURSIVE BUTTERWORTH
FILTERING TECHNIQUE (QUAD).
TIME : 0. 5000.
% OF PRIMARY VEL : 80. 90.

(13) N.M.O. CORRECTION :
USING B.H.P. PETROLEUM SUPPLIED VELOCITY FIELD.

(14) PRE-STACK MUTES :
: OUTER TRACE MUTE SP'S 892-832,984-1071.

OFFSET (M.)	300	510	1940	3054	3851	3604
TIME (MS.)	0	500	1200	1600	2200	2500

: OUTER TRACE MUTE SP'S 853-963.

OFFSET (M.)	300	510	1546	3839	3604
TIME (MS.)	0	500	1000	2250	2500

: INNER TRACE MUTE

OFFSET (M.)	100	700	1000	1300	1400
TIME (MS.)	1000	1600	2500	3200	5000

(15) COMMON DEPTH POINT STACK :
ARRAY/MUP FOLD : 60

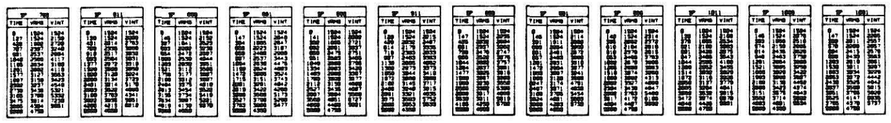
(16) BANDPASS FILTER :

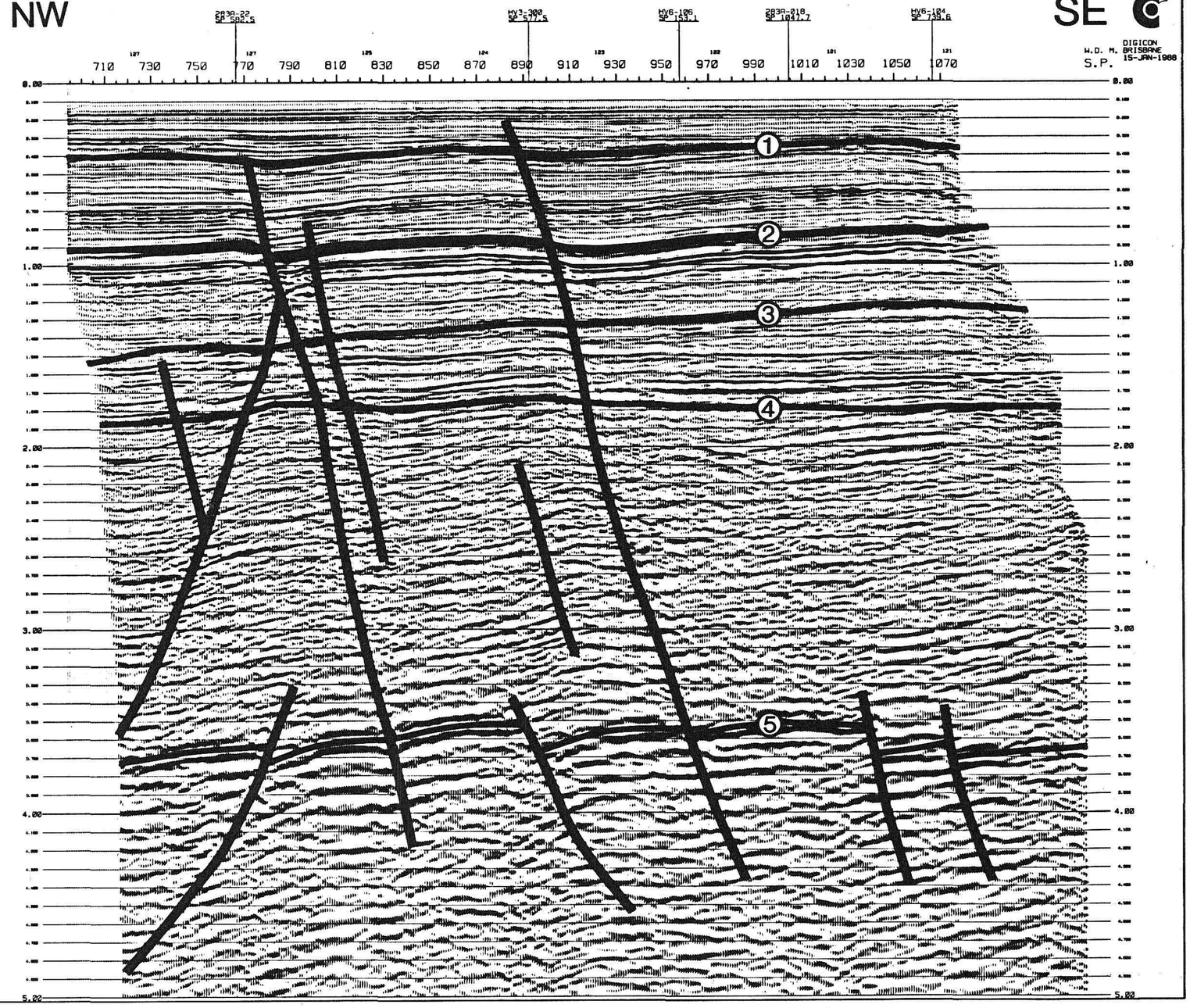
TIME (SECS.)	PASSBAND/SLOPE (DB/OCTAVE.)
0.00	12/24 - 78/72 HZ
1.00	18/24 - 58/72 HZ
2.00	18/24 - 58/72 HZ
2.70	8/24 - 48/64 HZ
3.40	5/24 - 38/48 HZ

(17) TRACE EQUALISATION :
A) 50 TO 950 (MS.) - 1 GATE
100 TO 350 (MS.) - 1 GATE
250 TO 650 (MS.) - 1 GATE
B) 500 TO 4000 (MS.) - MULTI-GATES.
LENGTH = 1000 MS.
WITH 50% OVERLAP
C) 3500 TO 5000 (MS.) - 1 GATE

(18) ADJACENT TRACE SUM :
2:1 VERTICAL STACK. EQUIVALENT TRACE WEIGHTS

(19) DISPLAY :
HORIZONTAL SCALE : 21.106 C.P.I. (1:25.000)
VERTICAL SCALE : 3.75 INCH/SEC.
DATUM : MEAN SEA LEVEL
SHOTPOINTS ANNOTATED AT SOURCE LOCATION
FIELD POLARITY MAINTAINED THROUGHOUT PROCESSING
DISPLAY POLARITY : REVERSE DISPLAY GAIN : 0.05





Key to seismic horizons:
① Base Miocene
② Top Palaeocene
③ Top Cretaceous
④ Base Cretaceous
⑤ Top Permian

PETROLEUM RESOURCE ASSESSMENT BRANCH

INTERPRETATION BY I. LAVERING JULY 1991

PLATE 13

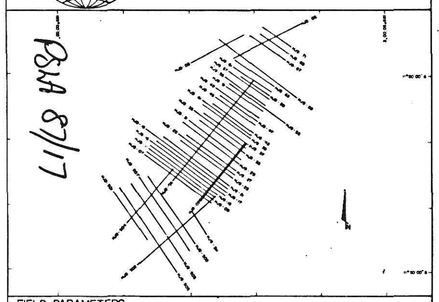
GEOLOGICAL SURVEY

LINE HJ9 – 02
SHOTPOINTS 101 – 1038
CLIENT BHP PETROLEUM.
AREA TIMOR SEA. AC/P4.

FILTERED STACK

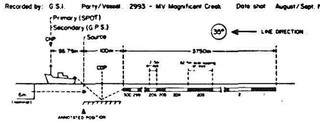
HORIZONTAL SCALE: 1: 25,000 DATUM: Mean Sea Level.
VERTICAL SCALE: 375 mm/sec DATE: March 1988

HORIZON SEISMIC AUSTRALIA PTY. LTD.
Perth Processing Centre, W.A.



FIELD PARAMETERS

Recorded by: G.S.I. Party/Vessel: 2993 – MV Magnificent Creek. Date shot: August/Sept. 1987.



SEISMIC SOURCE

Type:	VSX sleeve.
Number:	4 airguns
Capacity:	2280 cu in
Pressure:	1900 PSI
Shot interval:	25m
Array dimensions:	length 15.95m width 25m.

RECEIVERS

Number of groups:	300
Channels 1 - 204:	3 groups running out in cable giving 62.5m overlapping arrays, recording single 12.5m groups.
Channels 205 - 300:	
Number per 12.5m group:	32

RECORDING SYSTEM

Type:	TITAN 1000	Low cut filter:	8 Hz
Gain:	6 dB	Slope:	18 dB/octave.
Format:	SEG D.	High cut filter:	480 Hz
Record length:	6 secs.	Slope:	72 dB/octave.
Sample interval:	2 ms.	S.O.D. to T_0 delay:	5x 2.

Record polarity: increase in pressure recorded as negative numbers on tape (SEG normal)

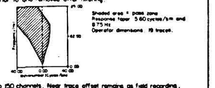
PROCESSING SEQUENCE

Processing record length: 5 secs. Sample rate: 4 msecs.

① TRANSCRIPTION INCLUDING AMPLITUDE COMPENSATION: 8 dB/sec to 4 secs.

② RESAMPLE: to 4 ms.

③ F-K FILTER: free form design filter 200ms scalars applied to data prior to and removed after filtering.



④ ALTERNATE TRACE DECIMATION: to 150 channels. Near trace offset remains as field recording.

⑤ INSTRUMENT DEPHASE: using model pulse.

⑥ SIGNATURE DECONVOLUTION: data derived wavelet, traces 1-102, 103 - 150 separate wavelets.
design window: near traces 500 - 4000 ms.
for trace 2500 - 4500 ms.
output zero phased, shaped to 8 - 70 Hz
12 36 dB/octave butterworth filter.

⑦ PREDICTIVE DECONVOLUTION BEFORE STACK: Operator length: 260 ms.
Predictive gap: 24 ms
Design window: near traces 300 - 4500 for trace 2500 - 5000
Application window: near trace 0 - 5000 for trace 2300 - 5000

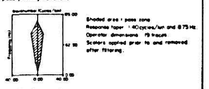
⑧ EDIT AND CDP GATHER: 150 channel, 75 fold.

⑨ DATUM CORRECTION: -5x 2 ms S.O.D. to T_0 delay, + time for gun and cable depth.

⑩ BRUTE STACK

⑪ VELOCITY ANALYSIS: using 20 CDP 'Omnivels' located at approx. 2km intervals, geologically dependent

⑫ MULTIPLE ATTENUATION: using annotated F-K fans applied to data NMO corrected with 1st pass primary function.



⑬ VELOCITY ANALYSIS: using 20 CDP 'Omnivels' located at approx. 1 km intervals, geologically dependent

⑭ NMO CORRECTION: using 2nd pass primary function.

⑮ MUTE: specified time followed by 28 ms taper.

outer trace	Offset (m):	227, 653	2503, 3828	
	Time (ms):	200, 1000	1700, 2600	
inner trace	Offset (m):	103	450	700
	Time (ms):	100 - 5000	1700 - 5000	2700 - 5000

⑯ PRE-STACK EQUALISATION: using fixed windows of 3500 & 1500 ms.

⑰ CDP STACK:

⑱ BANDPASS FILTER: filters include cosine squared tapers

Apparent time (ms)	Frequency (cycles (Hz))
0	10 - 15 - 70 - 80
600	5 - 10 - 60 - 70
1300	3 - 10 - 50 - 60
2200	3 - 8 - 40 - 50
2700	3 - 6 - 30 - 40

⑲ POST-STACK EQUALISATION: using fixed windows of 3x250, 2x500, 2x1000, 1250 ms.

⑳ WATER REPLACEMENT STATICS: using replacement velocity of 2130 m/sec.

㉑ TRACE MIXING: using 1:2:1 running mix.

DISPLAY PARAMETERS

Intersections taken from map based on SPOT.

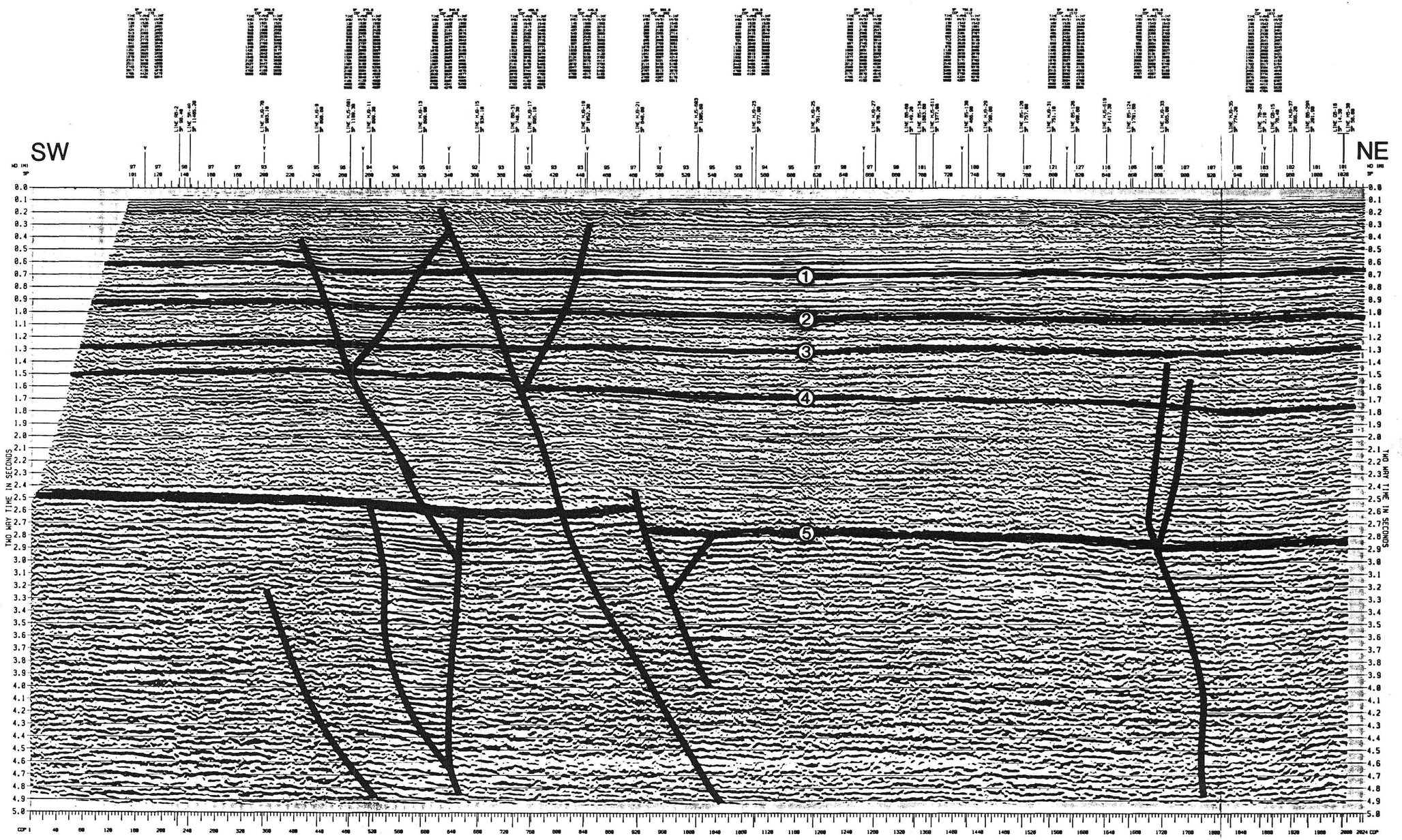
Display polarity: increase in pressure = negative numbers on tape = plotted white. (SEG normal)
DISPLAY VA/W GAIN 650FX. BIAS 0% black. INTENSITY: 2.

M. Stanley

FILTERED
STACK
1:25000

LINE HJ9-2
SP 101 - 103
38.5°

SW NE



Key to seismic horizons:
① Base Miocene
② Top Palaeocene
③ Top Cretaceous
④ Base Cretaceous
⑤ Top Permian

PETROLEUM RESOURCE ASSESSMENT BRANCH

INTERPRETATION BY I. LAVERING JULY 1991

PLATE 14

RSLA 87/17

LINE HJ9 - 53

SHOTPOINTS 101 - 976

CLIENT BHP PETROLEUM.

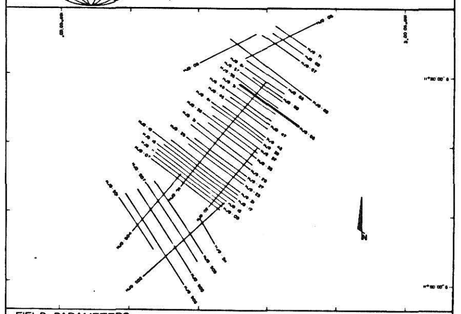
AREA TIMOR SEA. AC/P4.

FILTERED STACK

HORIZONTAL SCALE: 1:25 000 DATUM: Mean Sea Level.

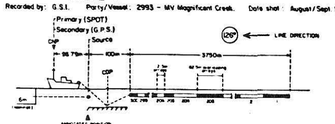
VERTICAL SCALE: 3.75 inch/sec DATE: March 1988

SEISMIC AUSTRALIA PTY. LTD.
Perth Processing Centre, W.A.



FIELD PARAMETERS

Recorded by: G.S.I. Party/Vessel: 2993 - M/V Magnificent Creek. Date shot: August/Sept 1987.



SEISMIC SOURCE

Type	VSX sleeve.
Number:	4 strings
Capacity:	2880 cu in.
Pressure:	1800 PSI
Shot interval:	25m
Array dimensions	length 13.95m width 25m.

RECEIVERS

Number of groups	300
Channels 1 - 204:	6 groups running mix in cable giving 6.25m overlapping arrays.
Channels 205 - 300	recording single 12.5m groups.
Number per 12.5m group	32

RECORDING SYSTEM

Type	TITAN 1000	Low cut filter:	8 Hz
Gain	IFP.	Slope:	18 dB/octave.
Format:	SEG D	High cut filter:	180 Hz.
Record length:	6 secs	Slope:	72 dB/octave.
Sample interval:	2 ms.	S.O.D. to T_0 delay:	5f.2.

Record polarity: increase in pressure recorded as negative numbers on tape (SEG normal)

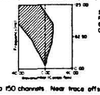
PROCESSING SEQUENCE

Processing record length 5 secs. Sample rate 4 msecs.

(1) TRANSCRIPTION INCLUDING AMPLITUDE COMPENSATION: 6 dB/sec to 4 secs

(2) RESAMPLE: to 4ms.

(3) F-K FILTER: free form design filter 200ms sections applied to data prior to and removed after filtering.



(4) ALTERNATE TRACE DECIMATION: to 150 channels. Near trace offset remains as field recording.

(5) INSTRUMENT DEPHASE: using model pulse.

(6) SIGNATURE DECONVOLUTION: data derived wavelet, traces 1-102, 103 - 150 separate wavelets. design window near trace 500 - 4000 ms. far trace 2500 - 4500 ms. output zero phase, shaped to 8 - 70 Hz. 36 dB/octave butterworth filter.

(7) PREDICTIVE DECONVOLUTION BEFORE STACK: Operator length: 260 ms. Predictive gap: 24 ms. Design window: near trace 300 - 4500 far trace 2500 - 5200 Application window: near trace 0 - 5000 far trace 2300 - 5000

(8) EDIT AND CDP GATHER 150 channel, 75 fold.

(9) DATUM CORRECTION -5t 2 ms S.O.D. to T_0 delay, + time for gun and cable depth.

(10) BRUTE STACK:

(11) VELOCITY ANALYSIS: using 20 CDP 'Omnivels' located at approx. 2km intervals, geologically dependant.

(12) MULTIPLE ATTENUATION: using conventional F-K filter applied to data NMO corrected with 1st pass primary function.

(13) VELOCITY ANALYSIS: using 20 CDP 'Omnivels' located at approx. 1 km intervals, geologically dependant

(14) NMO CORRECTION: using 2nd. pass primary function.

(15) MUTE: type: fast time followed by 25 ms taper.

outer trace	Offset (m)	227 , 653 , 2503 , 3828		
	Time (ms)	200 , 1000 , 1700 , 2600		
inner trace	Offset (m)	100	450	700
	Time (ms)	1100 - 5000	1700 - 5000	2700 - 5000

(16) PRE-STACK EQUALISATION: using fixed windows of 3500 & 1500 ms.

(17) CDP STACK:

(18) BANDPASS FILTER: filters include cosine squared tapers

Application time (ms)	Frequency limits (Hz)
0	10 , 15 - 70 , 80
600	5 , 10 - 60 , 70
1300	3 , 10 - 50 , 60
2200	4 , 8 - 40 , 50
2700	3 , 6 - 30 , 40

(19) POST-STACK EQUALISATION: using fixed windows of 3 x 250, 2 x 500, 2 x 1000, 1250 ms.

(20) WATER REPLACEMENT STATICS: using replacement velocity of 2130 m/sec.

(21) TRACE MIXING: using 1 2 1 running mix.

DISPLAY PARAMETERS

Intersections taken from map based on SPOT.

Display polarity increase in pressure = negative numbers on tape = plotted white. (SEG normal)

DISPLAY VA/W. GAIN 650FX. BIAS 0% black. INTENSITY: 2.

FILTERED
STACK
1:25000

LINE HJ9-53
SP 101 - 976
→ 126°

NW

SE

TWO WAY TIME IN SECONDS

CDP

Key to seismic horizons:

① Base Miocene
② Top Palaeocene
③ Top Cretaceous
④ Base Cretaceous
⑤ Top Permian

PETROLEUM RESOURCE ASSESSMENT BRANCH

INTERPRETATION BY I. LAVERING JULY 1991

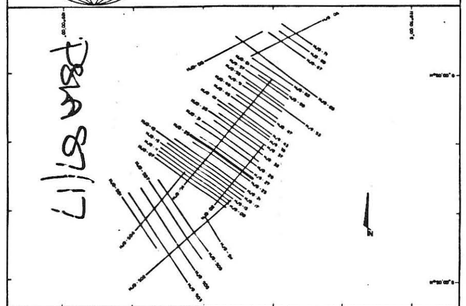
PLATE 15

LINE	HJ9 – 25
SHOTPOINTS	101 – 974
CLIENT	BHP PETROLEUM.
AREA	TIMOR SEA. AC/P4.

FILTERED STACK

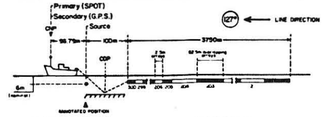
HORIZONTAL SCALE: 1 : 25000 DATUM : Mean Sea Level.
VERTICAL SCALE: 375 Inch/sec DATE : March 1988

SEISMIC AUSTRALIA PTY. LTD.
Perth Processing Centre, W.A.



FIELD PARAMETERS

Recorded by: G.S.I. Party/Vessel: 2993 – MV Magnificent Creek. Date shot : August/Sept 1987.



SEISMIC SOURCE

Type	VSX sleeve.
Number :	4 strings.
Capacity :	2950 cu.in.
Pressure :	1800 PSI.
Shot interval :	25m.
Array dimensions :	length 131.95m. width 25m.

RECEIVERS

Number of groups :	300.
Channels 1 - 204 :	3 groups running ews in cable giving 62.5m overlapping arrays.
Channels 205 - 300 :	recording single 12.5m groups.
Number per 12.5m group :	32.

RECORDING SYSTEM

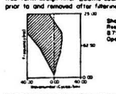
Type	TITAN 1000.	Low cut filter :	6 Hz
Gain:	IFP	Slope :	18 dB/octave.
Format:	SEG D.	High cut filter :	180 Hz.
Record length :	6 secs	Slope :	72 dB/octave.
Sample interval :	2 ms.	S.O.D. to T_0 delay :	9.2.

Record polarity: Increase in pressure recorded as negative numbers on tape (SEG normal)

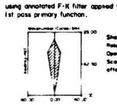
PROCESSING SEQUENCE

Processing record length: 5 secs. Sample rate : 4 msecs.

1. TRANSCRIPTION INCLUDING AMPLITUDE COMPENSATION: 8 dB/sec to 4 secs.
2. RESAMPLE : to 4ms.
3. F-K FILTER: free-form design filter 200ms scalars applied to data prior to and removed after filtering.



4. ALTERNATE TRACE DECIMATION : to 150 channels. Near trace offset remains as field recording.
5. INSTRUMENT DEPHASE : using model pulse.
6. SIGNATURE DECONVOLUTION : data derived wavelet, traces 1 - 102 , 103 - 150 separate wavelets.
   design window near trace 500 - 4000 ms
   far trace 2500 - 4000 ms.
   output zero phase, shaped to 8 - 70Hz
   12 36 dB/octave butterworth filter.
7. PREDICTIVE DECONVOLUTION BEFORE STACK Operator length: 260 ms.
   Pre-whitening 24 ms.
   Design window near trace 300 - 4500 far trace 2500 - 5000
   Application window near trace 0 - 5000 far trace 2300 - 5000
8. EDIT AND CDP GATHER : 150 channel, 75 fold.
9. DATUM CORRECTION : -5.2 ms S.O.D. to T_0 decay, +1/ms for gun and cable depth.
10. BRUTE STACK :
11. VELOCITY ANALYSIS : using 20 CDP 'Omnivels' located at approx. 2km intervals, geologically dependent
12. MULTIPLE ATTENUATION : using annotated F-K filter applied to data NMO corrected with 1st pass primary function.



13. VELOCITY ANALYSIS using 20 CDP 'Omnivels' located at approx. 1 km intervals, geologically dependent
14. RESIDUAL CORRECTION using 2nd pass primary function.
15. MUTE specified time followed by 28 ms taper

outer trace	Offset (m):	227 , 653 , 2503 , 3828			
	Time (ms)	200 , 1000 , 1700 , 2600			
inner trace	Offset (m)	63	450		700
	Time (ms) :	1100 - 5000	1700 - 5000	2700 - 5000	

16. PRE-STACK EQUALISATION: using fixed windows of 3500 & 1500 ms.
17. CDP STACK
18. BANDPASS FILTER :

Application time (ms)	Frequency (Hz)
0	10 , 15 - 70 , 80
600	5 , 10 - 50 , 70
1300	5 , 10 - 50 , 60
2200	4 , 8 - 40 , 50
2700	3 , 6 - 30 , 40

19. POST-STACK EQUALISATION: using fixed windows of 3 x 250 , 2 x 500 , 2 x 1000 , 1250 ms.
20. WATER REPLACEMENT STATICS: using replacement velocity of 2130 m/sec.
21. TRACE MIXING : using 1:2:1 running rms.

DISPLAY PARAMETERS

Intersections taken from map based on SPOT

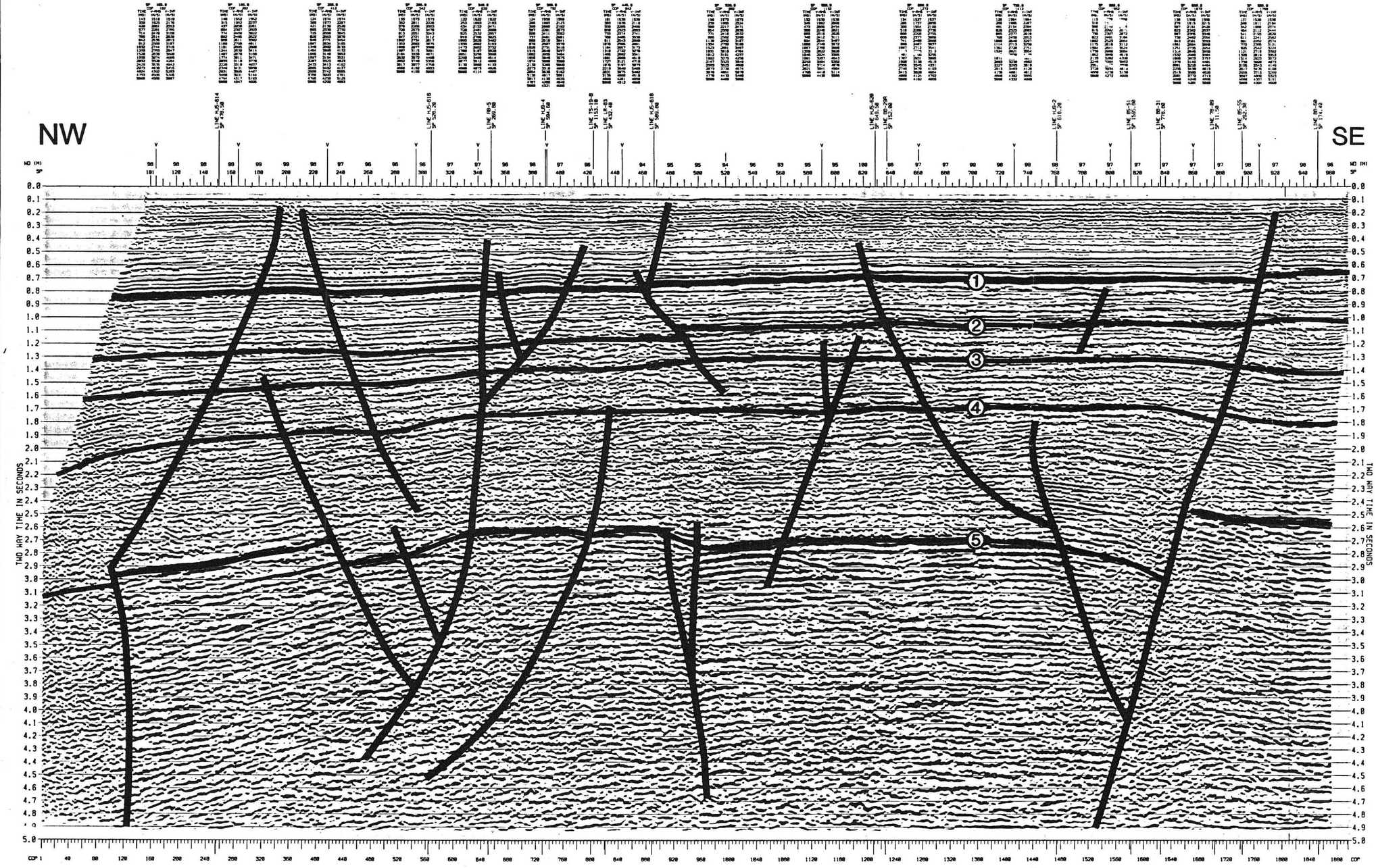
Display polarity : increase in pressure = negative numbers on tape = plotted white (SEG normal)
DISPLAY : VAR/VE. GAIN: 650 FX. BIAS 0% black. INTENSITY : 2.

M. Stanley

FILTERED
STACK
1:25000

LINE HJ
SP 101
CDP 974

NW SE



Key to seismic horizons:

① Base Miocene
② Top Palaeocene
③ Top Cretaceous
④ Base Cretaceous
⑤ Top Permian

PETROLEUM RESOURCE ASSESSMENT BRANCH

INTERPRETATION BY I. LAVERING JULY 1991

PLATE 16

PCLA 87/7

BHP Petroleum

PERMIT : PEP/P-4 SURVEY : HJ9

LINE : HJ9-127

SHOT POINTS : 101 - 1626

MIGRATION

RECORDING PARAMETERS

PROCESSING SEQUENCE

PROCESSED BY : DIGITAL EXPLORATION LTD.

DIGICON DATAPRO

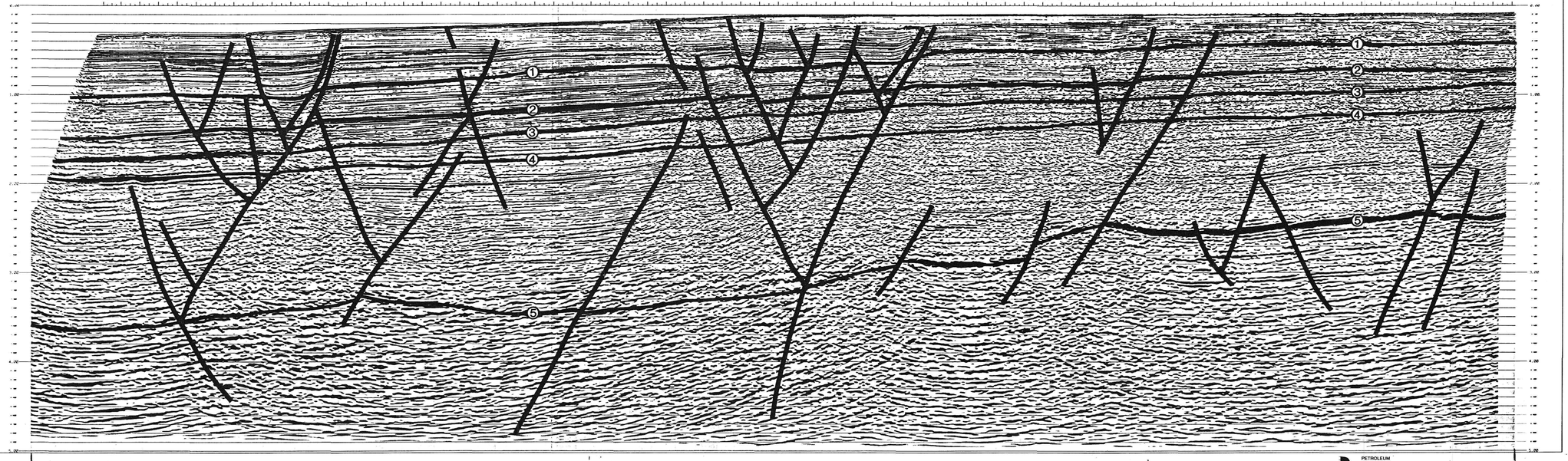
B.H.P. : MR. G. MILLIP

DIGICON : MR. G. KOO
SUPERVISOR : MR. D. ARMSTRONG

G.C. :

DATE : 28 TH JULY, 1988

NNW SSE



Key to seismic horizons: ① Base Miocene ④ Base Cretaceous
② Top Palaeocene ⑤ Top Permian
③ Top Cretaceous

PETROLEUM RESOURCE ASSESSMENT BRANCH

INTERPRETATION BY I. LAVERING JULY 1991

PLATE 17

PCA 87/17

BHP Petroleum

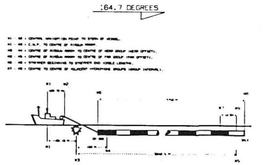
PERMIT : AC/P-4 SURVEY : HJ9

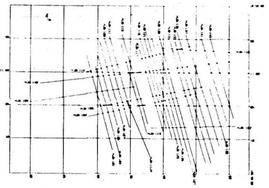
LINE : HJ9-109

SHOT POINTS : 101 - 1124

MIGRATION

RECORDING PARAMETERS





PROCESSED BY : DIGITAL EXPLORATION LTD.
DIGICON, BRISBANE

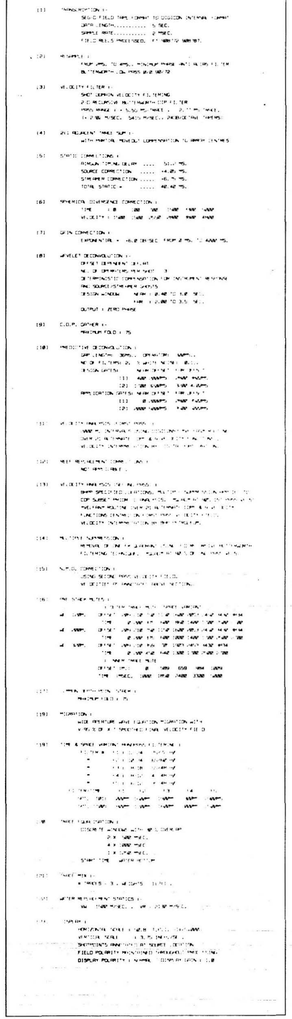
B.H.P. : MR. G. MCWILLIAM

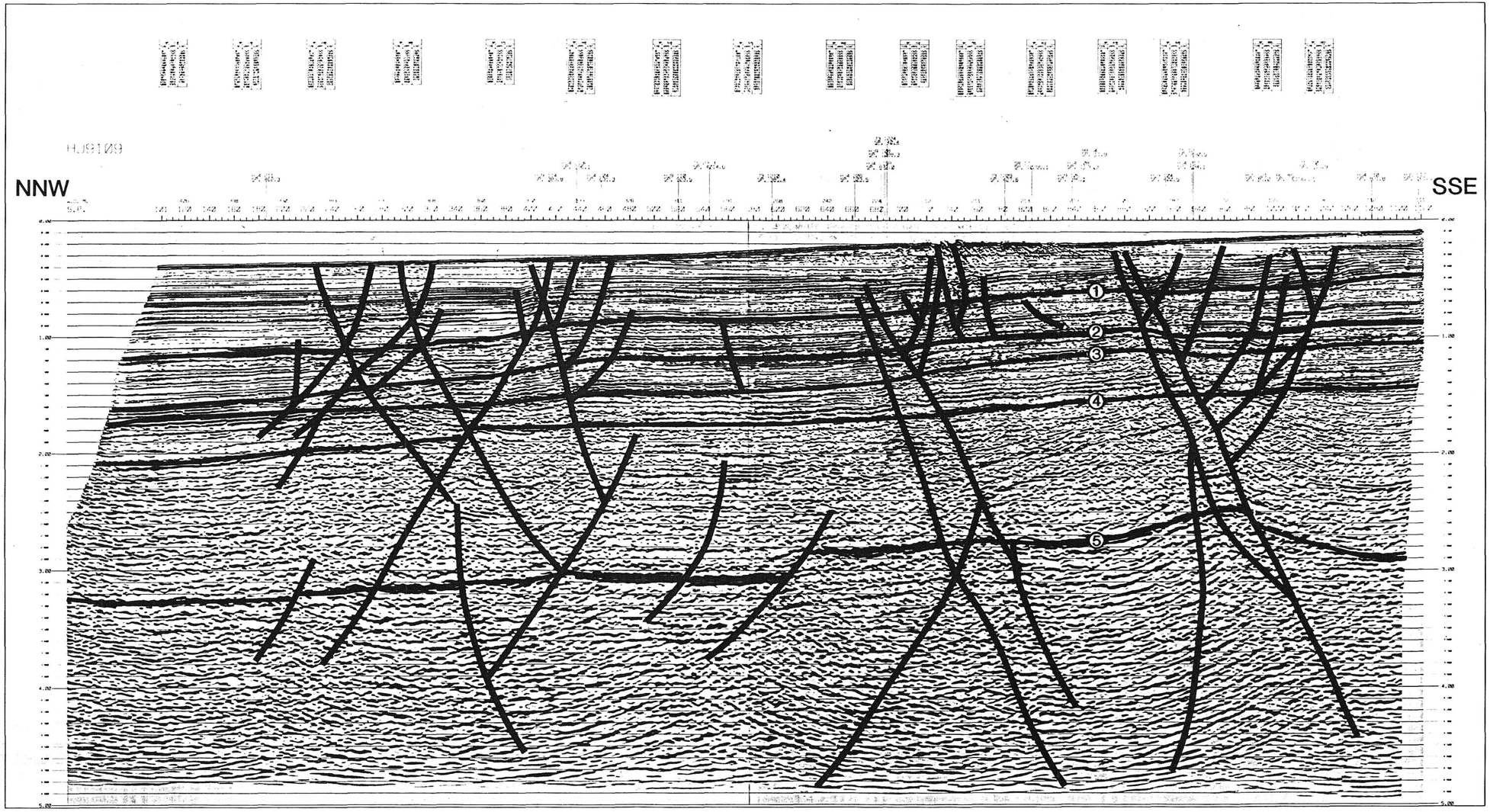
DIGICON - GEO. SUPERVISOR : MR. G. KOO
MR. G. ARMSTRONG

Q.C. :

DATE : 27 TH JULY, 1988

PROCESSING SEQUENCE





Key to seismic horizons:
① Base Miocene
② Top Palaeocene
③ Top Cretaceous
④ Base Cretaceous
⑤ Top Permian

PETROLEUM RESOURCE ASSESSMENT BRANCH

INTERPRETATION BY I. LAVERING JULY 1991

PLATE 18

PSLA 87/17

BHP Petroleum

PERMIT : AC/P-4 SURVEY : HJ9

LINE : HJ9-111

SHOT POINTS : 905 - 20

MIGRATION

RECORDING PARAMETERS

344.8 DEGREES

PROCESSED BY : DIGITAL EXPLORATION LTD.
DIGICON, BRISBANE

B.H.P. : MR. G. MEILLERE

DIGICON - G.O. : MR. S. ADD
SUPERVISION : MR. G. FREEKING

G.C. :

DATE : 26 TH JULY, 1988

PROCESSING SEQUENCE

NNW SSE

Key to seismic horizons:
① Base Miocene
② Top Palaeocene
③ Top Cretaceous
④ Base Cretaceous
⑤ Top Permian

PETROLEUM RESOURCE ASSESSMENT BRANCH

INTERPRETATION BY I. LAVERING JULY 1991

PLATE 19

PSLA 87/7

BHP Petroleum

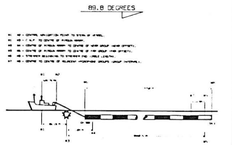
PERMIT : AC/P 4 SURVEY : HJ9

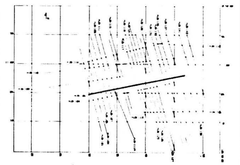
LINE : HJ9-106

SHOT POINTS : 101 - 1350

MIGRATION

RECORDING PARAMETERS





PROCESSED BY : DIGITAL EXPLORATION LTD.
DIGICON, BRISBANE

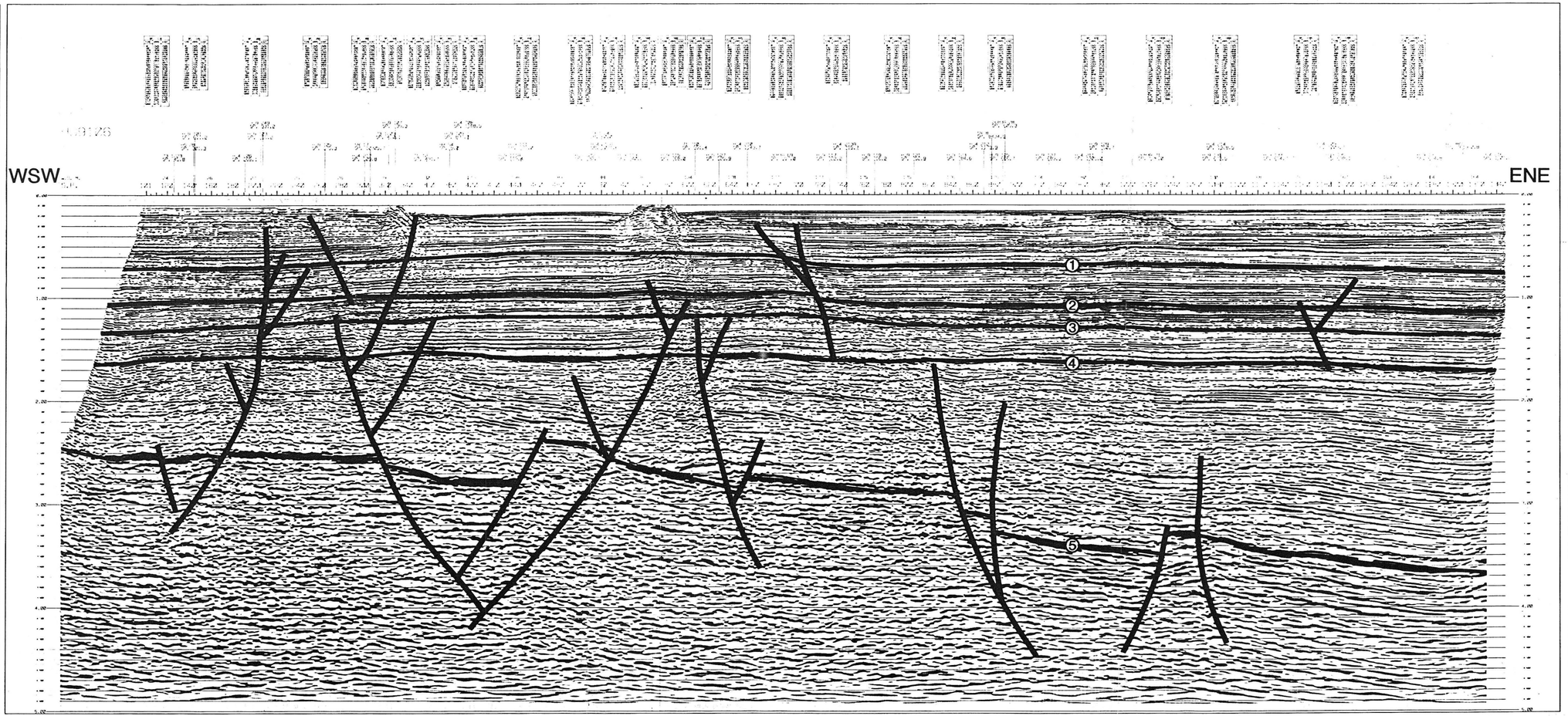
M.H.P. : MR. G. MEHLERT

DIGICON
FIELD : MR. G. KIDD
SUPERVISOR : MR. G. HAMMOND

Q.C. :

DATE : 20 NO JULY, 1988

PROCESSING SEQUENCE



Key to seismic horizons:
① Base Miocene
② Top Palaeocene
③ Top Cretaceous
④ Base Cretaceous
⑤ Top Permian

PETROLEUM RESOURCE ASSESSMENT BRANCH

INTERPRETATION BY I. LAVERING JULY 1991

PLATE 20

PSLA 87/17

BHP Petroleum

PERMIT : PEP-4 SURVEY : HJ9

LINE : HJ9-110

SHOT POINTS : 101 - 2338

MIGRATION

RECORDING PARAMETERS

PROCESSED BY : DIGITAL EXPLORATION LTD.
DIGICON, BRISBANE

PROCESSING SEQUENCE

HJ9110

WSW

ENE

Key to seismic horizons:
① Base Miocene
② Top Palaeocene
③ Top Cretaceous
④ Base Cretaceous
⑤ Top Permian

PETROLEUM RESOURCE ASSESSMENT BRANCH

INTERPRETATION BY I. LAVERING JULY 1991

PLATE 21

PSCA 87/17

BHP Petroleum

PERMIT : AC/P-4 SURVEY : HJ9

LINE : HJ9-114

SHOT POINTS : 101 - 1298

FINAL STACK

RECORDING PARAMETERS

75.1 DEGREES

PROCESSED BY : DIGITAL EXPLORATION LTD.
DIGICON, BRISBANE

B.H.P. : MR. G. MCWILLIAM

DIGICON - P.D. SUPERVISOR : MR. G. ROD
MR. G. ARMSTRONG

Q.C. :

DATE : 27 TH JULY, 1988

PROCESSING SEQUENCE

HJ9114

WSW ENE

S.P. 121 375 1298

Key to seismic horizons:
① Base Miocene
② Top Palaeocene
③ Top Cretaceous
④ Base Cretaceous
⑤ Top Permian

PETROLEUM RESOURCE ASSESSMENT BRANCH

INTERPRETATION BY I. LAVERING JULY 1991

PLATE 22