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PETROLEUM GEOLCGY OF THE CANNING BASIN

by

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ABSTRACT

Underlying an area of 430 000 km^2 onshore and 165 000 km^2 offshore in Western Australia the Canning Basin contains about 10 000 m of Palaeozoic, Mesozoic, and Cainozoic sedimentary rocks.

The Canning Basin sequence has been divided into 11 informal basin-wide intervals, each of which consists of a group of rock units laid down during roughly the same time span. Each interval contains some marine sediments, and the boundaries between them are typically unconformities or disconformities, so that each interval contains sediments deposited during one or more transgressions or regressions of the sea.

The Fitzroy Graben is the major structure in the basin. Faults separate it from the Leveque and Lennard Shelves to the north, and a faulted hingeline separates it from the Broome Arch to the south. The basin deepens again to the south between the arch and the Lambert and Tabletop Shelves, on the margin of the Pilbara Block. The deeper parts of this irregular synclinal zone form the Kidson Sub-basin and the Willara Sub-basin. The floor of the basin generally deepens offshore towards the edge of the present day continental shelf, where major depocentres are the Bedout and Rowley Sub-basins - north-easterly trending depressions that owe their origin to continental rifting and seafloor spreading.

Oil exploration in the Canning Basin must now be regarded as high risk. Eighty petroleum exploration wells have been drilled, and, even discounting those that have been poorly sited, many structural traps and reservoir sequences have been tested; the most encouraging show to date is a few gallons of oil from Lower Carboniferous sandstone. Offshore, temperatures in the Palaeozoic of the Fitzroy Graben appear to be too high for oil generation to be still continuing, whereas the Mesozoic section has generally not yet reached temperatures adequate for the generation of oil. The best potential onshore rests with the testing of Devonian reef trends, Permian plays in the southeast of the Fitzroy Graben, and Lower Devonian plays where source and seal can be established. Offshore the best potential may be with an unknown and untested Triassic section.

1. INTRODUCTION

1.1 SCOPE OF STUDY

The purpose of the Canning Basin study was to examine the mass of available data from previous geological, geophysical, and drilling surveys, and to synthesise a comprehensive report on the petroleum geology. The available data have accumulated from 102 oil wells (Table 2.6.1), 100 [illegible] surveys (Table 2.5.1), 36 gravity surveys (Table 2.2.1), 16 magnetic surveys (Table 2.3.1), and a number of surface mapping programs by exploration companies, the Bureau of Mineral Resources (BMR), and the Geological survey of Western Australia (GSWA).

To facilitate the regional study of the Canning Basin, the Phanerozoic sedimentary rocks were correlated and then divided into 11 stratigraphic intervals, which are described in detail in Appendices 1-11. The data from 60 seismic surveys were reinterpreted, and the base and thickness of each interval was mapped (Pls. 13-1 to 13-11, 10-1 to 10-11). The environments of deposition of the rocks in each interval are discussed in detail and the structure, geological history, and petroleum potential, are summarised.

1.2 ACKNOWLEDGEMENTS

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1.3 DEFINITION OF THE CANNING BASIN

The Canning Basin covers an onshore area of 430 000 km^2, and an offshore area of 165 000 km^2 to the 200 m bathymetric contour, in Western Australia. It contains a maximum aggregate thickness of about 10 000 m of Palaeozoic, Mesozoic, and Cainozoic sedimentary rocks resting unconformably on a Precambrian basement.

The northeastern margin of the basin is the exposed outcrop of the unconformity between Phanerozoic sediments and Precambrian rocks of the Kimberley Block. Offshore it continues as the subsea outcrop of Jurassic to Lower Cretaceous sediments on Precambrian rocks as far north as latitude 16°S. The margin of the basin, and its junction with the offshore Browse Basin, has been extended arbitrarily westwards along latitude 16°S across the Leveque Platform, Leveque Shelf, and Rowley Sub-basin to the edge of the continental shelf.

The northwestern margin has not been delineated in deeper water as thick sediments continue to the west of the shelf break.

From the shelf break at 18°30'S the southwestern margin trends arbitrarily eastwards to the northern tip of the North Turtle Arch, where it deviates southwards along the crest of the arch. A southerly trending line drawn from the end of the arch to the subsea outcrop of the unconformity between Jurassic to Lower Cretaceous sediments and Precambrian rocks of the Pilbara Block completes the western margin. The southwestern margin continues eastwards from near Turtle Island to the present coastline. From there it extends eastwards and then south-eastwards as the outcrop of the unconformity between Mesozoic or Permian sediments (excluding outliers) and the Precambrian rocks of the Pilbara Block and Paterson Province.

The southern margin with the Officer Basin is arbitrarily selected as the crest of the Warri Arch, which gravity and aeromagnetic interpretation suggest is an anticline within the basement rocks.

The eastern margin is the outcrop of the partly faulted unconformity between predominantly Permian sediments and Precambrian rocks.

1.4 GEOGRAPHICAL SETTING

A large part of the surface expression of the Canning Basin is uninhabitated desert (Fig. 1.4.1). The sparse population is concentrated in the northern and coastal areas and in aboriginal reserves (Pl. 1). The towns of Broome and Derby, with populations over 2000 (Australian Bureau of Statistics ABS, 1975), are the only ports. Fitzroy Crossing, 260 km from the coast on the Fitzroy River, is a small rural centre.

The Great Northern Highway, parts of which are unsealed, runs north along the coast, connecting Broome and Port Hedland, and east along the Fitzroy Valley between Broome, Derby, Fitzroy Crossing, and Halls Creek (northeast of the basin, Pl. 1). Numerous graded station tracks provide access to most of the Fitzroy Valley and to the west coast. South of the Fitzroy River, travel is much more restricted, and access to it is mainly via bulldozed tracks prepared by exploration companies.

The eastern end of the basin is part of the Balwina and Central Australian Aboriginal Reserves. A small aboriginal reserve to the west covers the area around Godfrey Tank. On the west coast the Beagle Bay Aboriginal Reserve occupies the northern end of the Dampier Peninsula.

About three-quarters of the onshore basin forms part of the Great Sandy Desert, which extends northwest to the Fitzroy River. The southeastern part of the basin lies within part of the Gibson Desert. These two areas comprise the Desert Plateau (Fig. 1.4.1) of Guppy, Lindner, Rattigan, & Casey (1958), the Canning Plain of Veevers & Wells (1961), and the Sand Ridge Division of Wright (1964); Jutson (1934) included them in his Sandland or Sandridge Division of the Plateau of Australia. They form the most barren and least inhabited part of the basin, and receive between only 200 and 500 mm of rain (ABS, 1975). East-trending sand dunes and sand plains cover most of the Desert Plateau. The dunes are parallel, often complex sand ridges up to 30 m high, and may be more than 80 km long; interdune areas are between 100 m and 1 km wide (Traves, Casey, & Wells, 1956). Where the sand is absent, ironstone and siliceous rubble form a cover to the underlying rock (Veevers & Wells, 1961). Dissection of the plateau and laterite caps have produced fairly steep cliffs

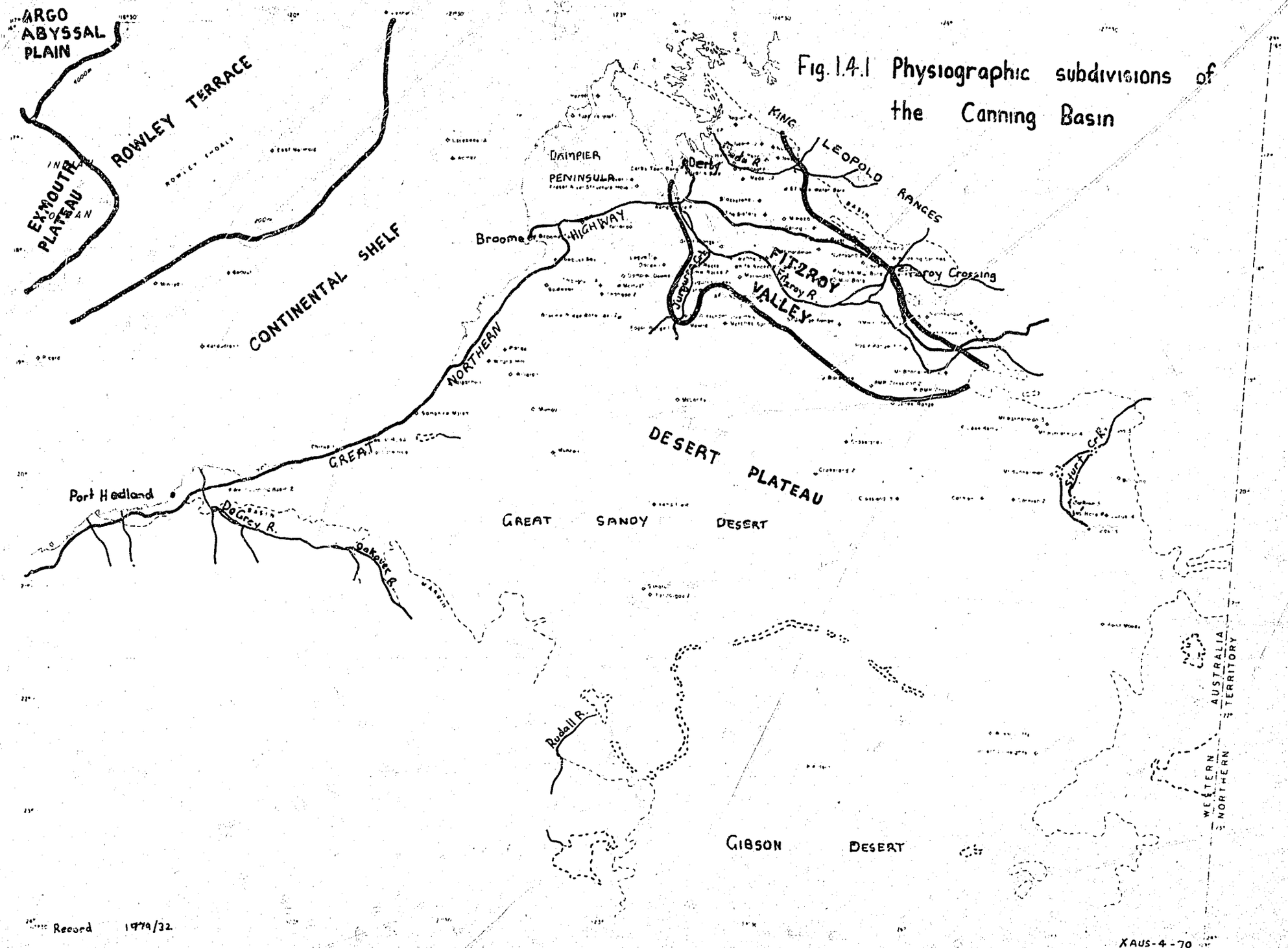


Fig. 1.4.1 Physiographic subdivisions of the Canning Basin

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called breakaways, and isolated mesas, buttes, and small hills above the sand and rubble-strewn plains - e.g., the Edgar Ranges and McLarty Hills (Pl. 1). Others areas of relief such as the Stansmore Range in the east result from faulting.

Drainage in the Desert Plateau is internal. Most of the watercourses are short and dry much of the year, and drain from hills or breakaways directly into the adjacent sand plain. The Rudall River in the southwest merges north into a series of clay pans and salt lakes in its lower reaches (Traves & others, 1956). Sturt Creek, a major stream in the northeast, terminates in Gregory Salt Lake; in the dry season it is reduced to a series of pools (Casey & Wells, 1964). West of Gregory Salt Lake are several isolated dry or salt lakes and clay pans including Lake Jones and Lake McLernon which are not connected to any present watercourse but may have been in the past. Another series of clay pans and salt lakes in the southwestern part of the basin is believed to be the remnant of an old river system (Mulcahy & Betteney, 1972) - the Percival Valley of Veevers & Wells (1961).

The Dampier Peninsula, lying between King Sound and the Indian Ocean, is a northern tongue of the Desert Plateau (Fig. 1.4.1). It is a dune-covered plateau of low relief, which gently rises southward to an elevation of 200 m (Pl. 2); several small mesas and buttes rise above the sand plain in the south. Along the coast the sand dunes give way to outcrops of Mesozoic and Cainozoic rocks and unconsolidated sediments. The north coast is rugged and incised; it is characterised by vertical cliffs and wavecut headlands (Brunnschweiler, 1957). In contrast, the coast south of Chattur Bay in the east and Carnot Bay in the west is generally smooth and unbroken. Tidal mangrove flats have developed at the mouth of many of the bays and along the southern part of the east coast.

The few defined watercourses draining the Dampier Peninsula flow only during the wet season of the quasi-monsoonal climate. The Fraser and Logue Rivers, the most important, drain eastward into King Sound from the central and southern region (Brunnschweiler, 1957). Drainage to the west is more mature than that to the east and has a low gradient.

The Fitzroy Valley (Fig. 1.4.1; Guppy & others, 1956) lies north of the Desert Plateau and east of King Sound. It comprises the lower valley of the Fitzroy and Meda Rivers and their tributaries, and represents the southern part of Jutson's (1934) Fitzroyland or West Kimberley and Wright's (1964) Fitzroy Plains Province. The valley receives between 600 and 700 mm of rain annually (ABS, 1975) in the wet season, and is the most populated part of the Canning Basin. The area rises from sea level in King Sound to 200 m (Pl. 2). It is generally flat except for scattered ridges and small isolated hills. Most of the valley is alluvial plain and sand plain. Short east-trending sand dunes are developed on the sand plains, particularly east of Mount Wynne Creek, north of the Fitzroy River, and along most of the Fitzroy Valley south of the river (Wright, 1964). Sandstone ridges and hills, and isolated outcrops of Fitzroy Lamproite, rise above the surrounding sand plain immediately north and south of the Fitzroy River. South of the river, and mainly east of Jurgurra Creek, lies a dissected plateau reduced to mesas and buttes which rise more than 100 m above the plain. East of these mesas and buttes are a series of prominent sandstone ranges including the St George, Barbwire, and Millyit Ranges (Pl. 1). The coastal area, along the east side of King Sound, is deeply incised and fringed with tidal mangrove flats and swamps which are best developed at the mouths of the Meda and Fitzroy River systems. The tidal flats are several kilometres wide owing to the tidal variations of 10 m in King Sound (Gellatly & Sofoulis, 1973).

The majority of the watercourses in the Fitzroy Valley drain west into King Sound, but a few minor streams have internal drainage and flow directly into sand plains near the base of the hills. The lower reaches of the Fitzroy and Meda River systems become a maze of channels with a wide belt of alluvium where the streams are heavily aggrading. In the upper reaches of the streams, steep banks line well-defined channels that are actively eroding the older alluvium (Thomas, 1958). None of the water courses in the Fitzroy Valley are permanent and even the Fitzroy River contracts to a series of pools in the dry season.

Between the Fitzroy Valley and the King Leopold Range lies a series of northwest-trending ranges which Guppy & others (1958) and Veevers & Wells (1961) call the Limestone Ranges and Wright (1964) refers to as the Fitzroy

Ranges (Fig. 1.4.1). This is the northern part of Jutson's (1934) Fitzroyland, and rises from an elevation of 100 m in the south to nearly 300 m in the north and southeast (Pl. 2). This area, up to 20 km wide (Guppy & others, 1958), stretches from the Van Emmerick Range in the west to north of the Bulka Hills in the east (Pl. 1). Several dissected limestone plateaus and barren, round-topped conglomerate ranges rise above intervening blacksoil plains and low rounded hills. The limestone plateaus, such as the Napier and Geike Ranges, form massive continuous walls of limestone that rise 30-90 m above the surrounding plains. Karst topography is well developed in the limestone, which consequently has a rough surface, though caves are mostly developed on a minor scale. The edges of the limestone plateaus are marked by a pediment surface up to 8 km wide, ending in a steep cliff face (Playford & Lowry, 1966); these pediments dip gently towards the plain. Most of the limestone plateaus are cut by wind or water gaps. In contrast, conglomerate ranges - like the Van Emmerick and Sparke Ranges - are rounded, steeply sloping hills covered by a scree of rounded boulders, pebbles, and cobbles of Precambrian rocks. The plains are underlain by grey to black clay with prominent gilgai (Playford & Lowry, 1966). The gilgai stripes are generally oriented to the east, and have deep cracks in the depressions during the dry season.

Non-perennial streams flow into the tributaries of the Meda and Fitzroy River systems, but dry into permanent pools in the dry season. Some of the stream courses flow partly underground through solution channels. Springs issue from the ranges in several areas but the flow, normally intermittent, seems to depend on annual rainfall (Guppy & others, 1958).

The offshore Canning Basin comprises several morphological areas. The continental shelf is about 200 km wide; to the west it grades into a broad gently inclined marginal terrace, the Rowley Terrace; Fig. 1.4.1, which is difficult to separate from the continental shelf owing to the lack of a clearly recognisable shelf break. Jones (1973) picked the 180 m isobath as the western edge of the shelf. Northwest of the terrace the seafloor gradient steeps dramatically into the Argo Abyssal Plain (Fig. 1.4.1) and in the west it passes into the Exmouth Plateau.

The continental shelf is generally featureless. A scarp, representing an old strandline (Jones, 1973) now in 120 m of water, runs parallel to the present coast. A second scarp, poorly developed and impersistent, lies, east of the first, off the Dampier Peninsula in water 80 m deep. Asymmetric and irregularly spaced sand waves 4-10 m high and up to 20 km apart, and megaripples 1-2 m high and 200 to 300 m apart, disturb the flat shelf surface. The sand waves are restricted to the shelf, but the megaripples are also developed on the Rowley Terrace. Other minor surface irregularities are caused by banks of coarse organic debris and by biohermal structures (Jones, 1971).

The shelf is largely an area of sediment transport and winnowing rather than of deposition. Tidal effects reach to the outer edge of the shelf and much of the shelf is covered by reworked coarse-grained sediments and a thin cover of shelly and oolitic sands. Finer-grained terrigenous sediments are being deposited nearshore. Silt and clay-size carbonate and Globigerina sands accumulating near the outer edge and south and southwest of Rowley Shoals have built a low ridge 20 km wide and up to 45 m high along the shelf edge (Jones, 1971). A shallow trough runs parallel to the ridge on the landward side.

The most prominent features of the Rowley Terrace are the Rowley Shoals, three separate limestone atolls; Mermaid, Clerke, and Imperieuse Reefs (Pl. 1). An unnamed submerged reef 50 km southwest of Imperieuse Reef has a similar alighment and spacing to the three atolls, and previously must have formed part of the same system. The upper flanks of the reefs are steep, but they dip more gently towards the base. The submerged reef rises only 60 to 100 m above the sea floor and is now covered by a minimum of 287 m of water (Pl. 4). Imperieuse Reef, the southernmost atoll, is the only one completely enclosed. Clerke Reef, immediately north of Imperieuse Reef, is bordered on its seaward side by a shallow trench 50 m deep and 5 m across (Jones, 1971). South and east of Rowley Shoals, around the 250 m isobath, an increase in the change in slope may mark an old erosion surface (Jones, 1973). West of Dampier Peninsula, two submerged strandline scarps in water depths of 190 m and 360 m parallel those on the shelf. The deeper scarp has a relief of 120 m and is better developed.

The Exmouth Plateau, west of Rowley Terrace, has been excluded from this study, and the reader is referred to Falvey & Veevers (1974) and Exon & Willcox (1978, in press) for a discussion of the physiography of that area.

1.5 STRUCTURAL SUBDIVISIONS

The Canning Basin has been subdivided into several major structural provinces according to the present-day configuration of the underlying basement. 'Basement' is defined as the floor of Phanerozoic sedimentary rocks, and its shape has been determifned largely by geophysics (seismic and magnetics) supported only locally by drillhole information. Consequently, the reliability of basement contours varies: offshore it is generally low; onshore it is high - especially where seismic and well-control is dense - but low to intermediate toward the sparsely controlled southeastern margin of the basin, where the Panerozoic sequence overlies non-magnetic late Precambrian sedimentary rocks.

Basement contours and structural subdivisions are shown in Plate 15. As shown in this map the major part of the Canning Basin consists of a graben and two sub-basins separated by an arch, all of which are aligned northwest. Offshore, the northeasterly trending Bedout and Rowley Sub-basins are superimposed on this trend. These offshore sub-basins, which owe their origin to Mesozoic rifting and continental drift, are part of a much more extensive wedge of sediments extending along the Northwest Shelf.

The northern shelves form two gently dipping blocks comprising the Leveque Shelf and Lennard Shelf, and the Billiluna Shelf bounded basinward by step-faults and separated by the Bulka Hills inlier. The Leveque and Lennard Shelves are structurally continuous; the Leveque Shelf is the offshore continuation of the Lennard Shelf.

The Fitzroy Graben and adjoining terraces dominate the structure of the Canning Basin. Although the floor of the graben is poorly defined it is thought to be deeper than 10 000 m in at least two localities. The graben can be traced about 150 km offshore, where it may end against a series of north-striking faults (near 121° E) mapped at the base of interval 6 (see Section 1.8). Its strike changes from northwest to west-northwest near the coastline.

Three separate terraces lie on its north side (Pender Terrace, Margaret Terrace, and Betty Terrace), and two lie on its south side (Jurgurra Terrace and Barbwire Terrace); in these areas the depths to basement range from 2000 to 6000 m and 3000 to 7000 m respectively (Pl. 15). The graben seems to have been stable after interval 8 time (see Section 1.8 and isopachs in Plates 10-9 to 10-11).

The South Canning Depression consists of the contiguous Palaeozoic Willara Sub-basin, Kidson Sub-basin, and Wallal Embayment (Pls. 10-1, 10-2, 10-4). According to our mapping, the Wallal Embayment is only partly separated from the Willara Sub-basin, and the seaward extensions of both beneath the Mesozoic Bedout Sub-basin are unclear owing to poor seismic data from pre-Jurassic rocks offshore.

The Broome Arch is a northwesterly trending area of elevated basement rocks between the Fitzroy Graben and the South Canning Depression. The trend of the arch swings to the west-northwest offshore - before it begins its long, gradual plunge to the west. The arch is overlain by about 1000 to 3000 m of sediments.

The southern shelves - Lambert Shelf, Tabletop Shelf, and Ryan Shelf - are mostly broad, poorly known areas of flat-lying to very gently dipping shallow sediments bordering the South Canning Depression and fringing the Pilbara Block and the Amadeus Basin.

The Bedout and Rowley Sub-basins are local depocentres within a much more extensive wedge of Mesozoic sediments extending along the Northwest Shelf. The axes of the basins trend northeast, parallel to the continental margin. They contain over 6000 m of Mesozoic sediments (Pls. 13-5, 13-6).

1.6 GEOLOGICAL AND GEOPHYSICAL CONTROL

Two hundred and forty-two geological control points were used in the study (Pl. 4, Appendix 12). They include all available information from petroleum exploration wells, water wells, measured sections, and seismic shot-holes up to 30 December 1976.

Sixty of the 100 seismic surveys in the Canning Basin have been reinterpreted in the study. They are listed in Table 2.5.1, and the lines are located in Plate 5. Velocity data have been derived from well velocity surveys, sonic logs, and seismic reflection moveouts.

1.7 CORRELATION

Details of each lithological unit identified in the Canning Basin are included in Appendices 1 to 11. The rock unit correlation for this study is summarised in Plates 11-1 to 11-8 and is based on lithology, lateral continuity, order of superposition, seismic tracing, wire-line log correlation, and palaeontological data.

Time correlation charts (Pls. 12-2 to 12-5) relate the rock units based on the ages of their fossils to the geological time scale (Appendices 1 to 11).

1.8 SELECTION OF INTERVALS

The Phanerozoic sequence in the Canning Basin has been divided into sedimentary intervals (Pl. 12-1) to facilitate its description. The division follows the principles outlined by Oriel (in McKee & others, 1959) and already used in the BMR Bulletin on the Sydney Basin (Mayne & others, 1974).

The history of the Canning Basin is one of periods of high sedimentation interspersed with periods of little or no deposition. In the manner proposed by Oriel, the sedimentary intervals represent periods of high sedimentation and their boundaries approximate to periods of little or no deposition. They may be defined by their lithology, time range, or genetically related events. Hence, interval boundaries may be time lines, lithological boundaries, facies boundaries, or basin-wide diachronous breaks in sedimentation.

The best time to attempt to define intervals in a sequence is clearly after the results of an exhaustive study have been examined and the significance of all events appreciated. However, interval boundaries must be chosen early in the study of a basin because they form the basis for 'picking' seismic sections.

The Canning Basin comprises 11 intervals, identified by the numbers 1 - the oldest - to 11 - the youngest. The following discussion outlines the nature both of the intervals selected and of their boundaries. Note that the interval boundaries are not necessarily those that would have been chosen as the most significant at the end of the study.

Interval 1

This is a sequence of Ordovician marine sediments. The base of the interval is not evident in the Fitzroy Graben. Southwest of the graben the base of the interval corresponds to the top of crystalline basement and forms a well-defined persistent seismic horizon. In part of the Kidson Sub-basin the base of the interval is the boundary with Precambrian sediments; although an unconformity, this boundary rarely forms a well-defined seismic horizon away from areas of well control, and has been picked over much of the area from velocity analysis.

Interval 2

This is a Devonian and possibly partly Silurian sequence which evolves from evaporitic marine through continental to marginal marine sediments. On the evidence of a biostratigraphical break, the base of this interval is thought to be a disconformity throughout the Canning Basin south of the Fitzroy Graben, but may be an angular unconformity in the Kidson and Willara Sub-basins. West of the Kidson Sub-basin, it forms a good seismic reflector which is easy to trace, but it is difficult to trace north of the Dummer Range Fault (Pl. 3) except locally near wells in which its position has been established. The interval directly overlies crystalline basement in the northern part of the Lennard Shelf.

Interval 3

The Middle and Upper Devonian carbonate sequences, their correlatives, and the overlying Upper Devonian or Carboniferous regressive clastics constitute interval 3, whose lower boundary is generally taken as a facies boundary at the base of the Devonian carbonate sequence. The boundary is difficult to trace where the carbonate facies is absent - e.g., within the Fitzroy Graben, where an attempt was made to trace it by assuming constant sediment thickness. Away from wells in which its position has been established, it is difficult to trace.

Interval 4

Interval 4 includes Permian and Carboniferous sediments comprising at least three successive regressive sequences. Its base is an unconformity, except in the Fitzroy Graben, where it is apparently conformable on interval 3. The boundary is everywhere marked on the seismic sections by a persistent, strongly reflecting horizon.

Interval 5

Triassic shallow marine and deltaic sediments constitute interval 5, whose lower boundary is presumed to be an hiatus marked by the absence of the palynological zone Tr 1a. This horizon corresponds to a strong reflector near wells in which its position has been established, but it cannot be traced extensively onshore where it is close to the surface. Offshore wells have not penetrated it, so it has not been traced in some areas.

Interval 6

Transgressive and regressive sediments of Jurassic age constitute interval 6, whose base is a regional unconformity that forms a well-defined seismic reflector.

Interval 7

Interval 7 defines an offshore regressive sequence of Jurassic and Cretaceous age that is lithostratigraphically similar to the upper part of interval 6 onshore. Its base is an assumed hiatus in sedimentation inferred from a break in the palynological succession interpreted in offshore wells. It corresponds to a seismic horizon that may be followed close to wells in which its position has been established in nearshore areas, but is difficult to trace farther offshore.

Interval 8

Interval 8, which represents a period of Cretaceous transgressive and regressive cycles, has a lower boundary that was defined and traced in a similar way to that of interval 7.

Interval 9

Upper Cretaceous sediments constitute interval 9, whose base is an apparent break in the palynological succession. An horizon at this level can be traced only with difficulty close to wells in which its position has been established, although it becomes stronger farther offshore.

Interval 10

The base of interval 10, which defines a Lower Tertiary sequence, is an apparent break in the palynological succession.

Interval 11

A series of offshore upper Miocene to Recent carbonates, together with their onshore time correlatives, constitute interval 11, whose base is an apparent break in the palynological succession.

2. PETROLEUM EXPLORATION

2.1 GEOLOGICAL MAPPING

BMR carried out regional geological mapping in the Canning Basin between 1948 and 1952, 1954, 1955, 1957, and 1960. Traves & others (1956), Guppy & others (1958), Veevers & Wells (1961), and Wells, Forman, & Ranford (1964) have described the results of this mapping.

GSWA mapped part of the southern margin of the basin in the late 1950s and early 1960s, and began a long term investigation of the Devonian reef complex of the Lennard Shelf in the early 1960s. BMR and GSWA mapped part of the northern margin of the basin between 1962 and 1971. As a result of this mapping a number of 1:250 000 and 1:253 440 (1 inch = 4 miles) scale maps and explanatory notes were prepared (Fig. 2.1.1).

In 1972, BMR and GSWA started another major phase of geological mapping in the Canning Basin, and continued the detailed work on the Devonian reef complex. Druce & Radke (1973, 1977, in press), Radke (1976), and Nicoll & Druce (in press) have summarised some of the results. BMR and GSWA also started a program of 1:250 000-scale geological mapping of the basin in 1972. The project entailed remapping and continuing this work into the previously unmapped areas (Fig. 2.1.2), and stratigraphic drilling (Yeates & others, 1975b); Towner & others, 1976; Crowe & others, 1978). The fieldwork was completed in 1977.

BMR mapped the offshore part of the basin during a marine survey in 1967 and 1968 (Jones, 1973), and the results are published at 1:1 000 000 scale.

Geological investigations by petroleum exploration companies are summarised in Table 2.1.1. In the last few years interest has grown in the coal and mineral prospects of the Canning Basin, and a number of companies have been involved in the search. Much of this data is not available to BMR and has not been included in this study.

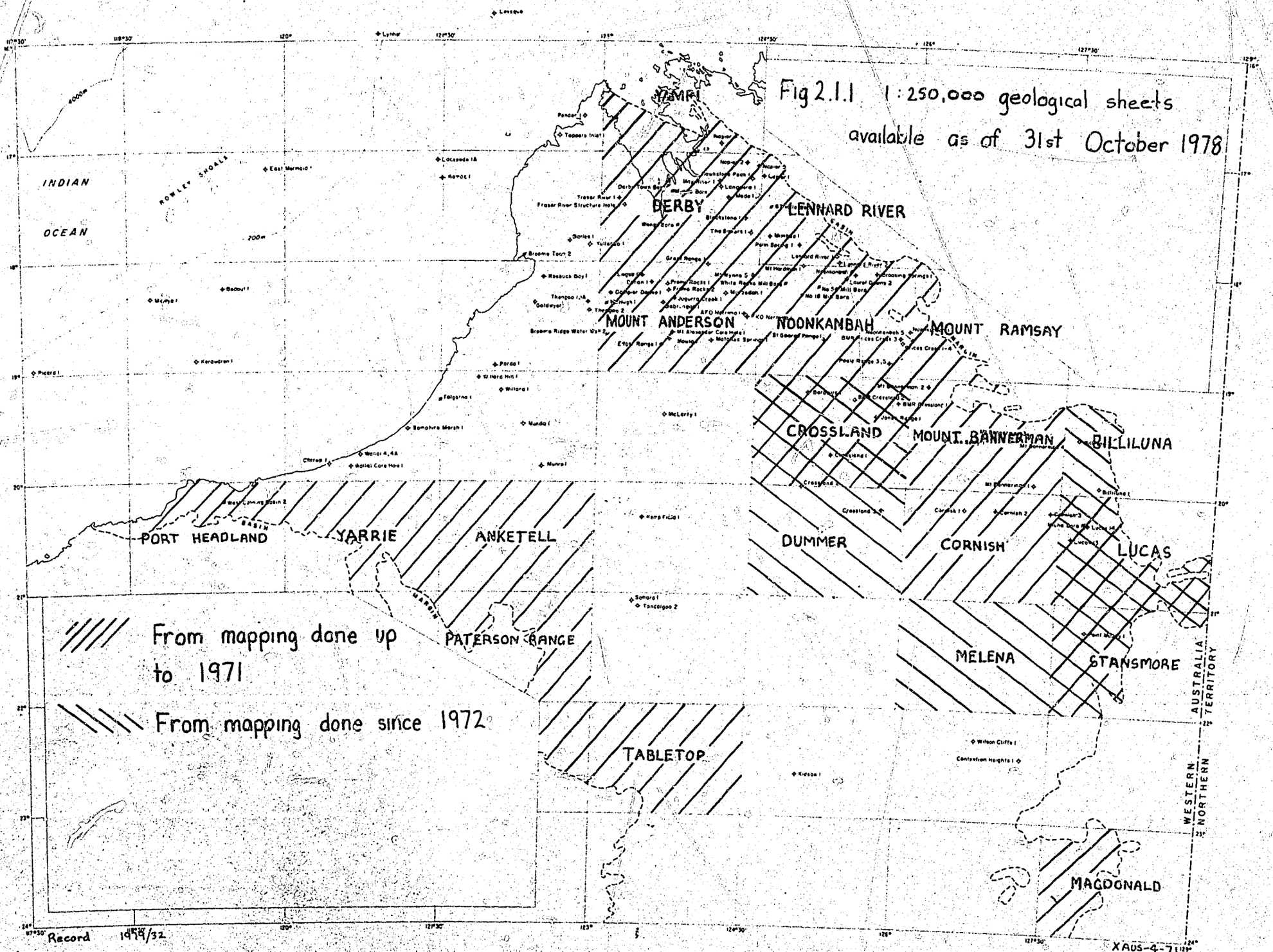

Fig 2.1.1 1:250,000 geological sheets available as of 31st October 1978
WMR
INDIAN OCEAN
ROWLEY SHOALS
DERBY
LENNARD RIVER BASIN
MOUNT ANDERSON
NOONKANBAH
MOUNT RAMSAY
CROSSLAND
MOUNT BANNERMAN
BILLILUNA
PORT HEADLAND
YARRIE
ANKETELL
DUMMER
CORNISH
LUCAS
PATERSON RANGE
MELENA
STANSMORE
TABLETOP
MACDONALD
AUSTRALIA
WESTERN & NORTHERN TERRITORY
From mapping done up to 1971
From mapping done since 1972
Record 1459/32
XAUS-4-71

Table 2.1.1. Geological Investigations in the Canning Basin by Petroleum Exploration Companies

Year	Permit No.	Operator	Reference
1961	PE 30H	WAPET	LOW, 1962
	Over 10 000 sq. miles surveyed		
1962	30H	WAPET	PLAYFORD, 1963
1963	-	WAPET	
	Mapped eastern and south central parts of basin		
	-	Hackathorn Oils	PLAYFORD, 1964
	Mapped extreme eastern part of the basin		
1964	227H	Continental Oil Co. (Aust.)	
	30H	WAPET	
	205H-207H	Alliance Petroleum (Aust.) NL	PLAYFORD, 1965
	151-152H	Geosurveys of Australia	
1965	30H	WAPET	
	227H	Continental Oil Co. (Aust.)	
	151H	Beach Petroleum NL	PLAYFORD, 1966a
	153H	Beach Petroleum NL	
1966	30H	WAPET	
	251H	Gewerkschaft Elwerath	PLAYFORD & LOW, 1967
	Canning-Officer	French Petroleum (Aust.)	
1967	30H	WAPET	
	151-153H	Australian Aquitaine Petroleum	PLAYFORD & LOW, 1968
	259H	French Petroleum (Aust.)	
1968	30H	WAPET	
	205,152,151H	Australian Aquitaine Petroleum	PLAYFORD & LOW, 1969
	213H	BOCAL	
1969	30H	WAPET	
	151-153H	Australian Aquitaine Petroleum	PLAYFORD & COPE, 1970
	106H	Lennard Oil NL	

Year	Permit No.	Operator	Reference
1970	EP 17	WAPET	
	EP 31	Australian Aquitaine Petroleum	
	EP 42	WAPET	COPE, 971
	EP 51	Australian Aquitaine Petroleum	
	EP 52	Lennard Oil NL	
1971	EP 32	Australian Aquitaine Petroleum	
	EP 33	Australian Aquitaine Petroleum	
	EP 51	Lennard Oil NL	
	EP 52	Lennard Oil NL	
	EP 17	WAPET	PLAYFORD & LOW, 1972
	EP 42	WAPET	
	EP 58	Associated Australian Oilfields NL	
	EP 59	Associated Australian Oilfields NL	
1972	EP 17	WAPET	
	EP 42	WAPET	
	EP 58	Associated Australian Oilfields NL	LOW, 1973
	EP 59	Associated Australian Oilfields NL	
1973	EP 14,44,67	WAPET	
	EP 32	Australian Aquitaine Petroleum	
	EP 59,70	Associated Australian Resources NL	
	WA 1P	BOCAL	LOW, 1974
	WA 29P	Hematite Petroleum	
	WA 30P	Shell Development (Australia)	
	WA 31P	Amax Petroleum (Australia)	
1974	EP 43	WAPET	
	WA 29P	BOCAL	LOW, 1975
	-	Surface mapping by WAPET	
1975	EP 42	WAPET	CRANK, 1976

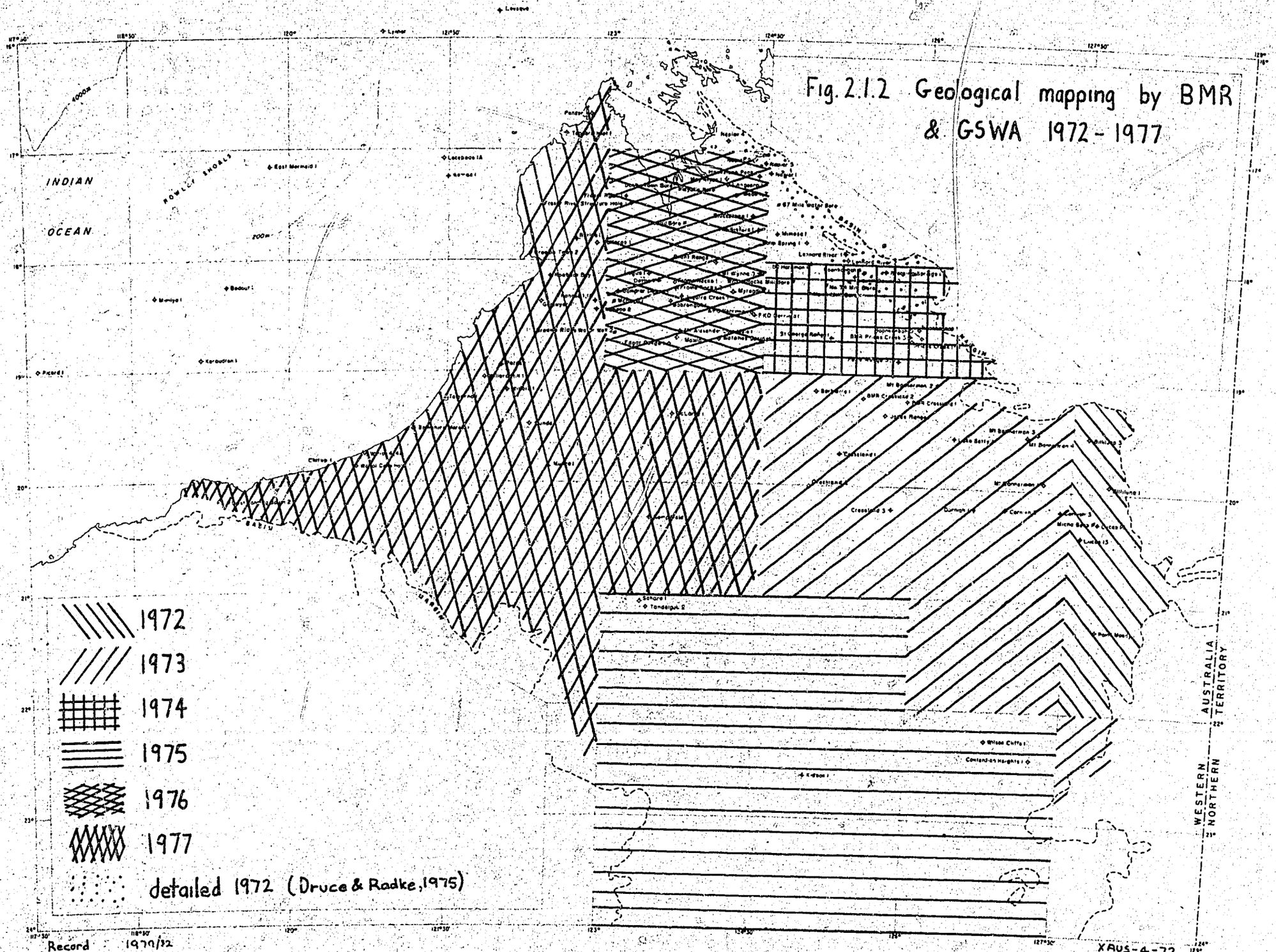


Fig. 2.1.2 Geological mapping by BMR & GSWA 1972 - 1977

2.2 GRAVITY SURVEYS

All gravity surveys in the Canning Basin for which data are available are located in Plate 6 and listed in Table 2.2.1; the data are held in the BMR Gravity Data Bank, in which each survey has a distinguishing number. A composite map of Bouguer anomalies onshore and free-air anomalies offshore, compiled from selected surveys and contoured at 5 mgals on a 4 minute grid, is shown in Plate 7; Bouguer anomalies were calculated using a rock density of 2.2 g/cm^3.

In 1952, BMR made the first gravity survey of the Canning Basin in the Fitzroy Graben (Wiebenga & van der Linden, 1953), where it located a steep gradient over the Fenton Fault (Pl. 3). Subsequent BMR surveys were designed either to provide regional gravity coverage or to assist with the interpretation of subsurface structure. The early surveys were carried out over the northern part of the Canning Basin; although the data were included in the compilation of the regional Bouguer anomaly maps, reports are not available for most surveys.

In 1957, BMR started a program of regional helicopter gravity coverage with a survey along traverses centred in the Kidson Sub-basin. By 1960 the large-scale features of the Bouguer anomaly pattern had been detected and described (Flavelle & Goodspeed, 1962). These data, used in conjunction with the results of airborne magnetic surveys, provided a basis for future seismic exploration. The major features discussed by Flavelle & Goodspeed (1962) were the elongate northwest-trending Bouguer anomaly highs and lows including the 'Fitzroy Trough', 'Broome Swell', 'South Canning Gravity Depression' and 'Anketell Gravity Ridge', other major features they identified include the 'Mount Bannerman Gravity Trough' and 'Stansmore Trough'. They concluded that density variations in Proterozoic sediments in the basement probably contribute to some of the troughs, but that, in the main, Bouguer anomaly lows are due to thick Palaeozoic sediments and Bouguer anomaly highs are due to elevated basement. In addition, they were able to relate many of the steep gravity gradients to known faults, particularly the Pinnacle Fault and Fenton Fault.

TABLE 2.2.1. GRAVITY SURVEYS

BMR survey Number	Survey name	Year	*Reference	PSSA File	Survey type	Configuration
5206	Fitzroy Basin	1952	Wiebenga & van der Linden (1953)		Traverses	Station spacing variable; 400-1600 m
5305	Onslow-Derby (regional)	1953	Dooley (1963)		Road traverses	Station spacing 32 000 m
5308	Kimberley (regional)	1953	*BMR		Road traverse	Station spacing 800 m or 1600 m
5309-10	Poole Range detailed	1953	Everingham (1962)		Traverses	Station spacing 800 m or 1600 m
5406	Halls Creek, Derby, Broome, Kimberley	1954	*BMR		Road traverse	Station spacing 800 m
5407	Grant Range and Myrooda-Lulugui area	1954	*BMR		Road traverse	Station spacing 4800 m
5408	Port Hedland	1954	*BMR		Road traverse	Station spacing 4000 m
5505	Christmas Creek, Derby, Broome, Anna Plains	1955	*BMR		Road traverse	Station spacing 400 m
5606	Billiluna, Anna Plains, Pt Hedland, Pilbara	1956	*BMR		Road traverse	Station spacing 4800 m
5631-33(5630)	Canning Basin	1954-	*WAPET		Grid	Station spacing 16 000 m
5707	Canning Basin	1957	*BMR		Traverse (helicopter)	Station spacing 11 000 m
5941	Barlee gravity survey	1959	WAPET (1964c)	62/1903	Grid	3200 m by 1100 m
6009	Canning and Fitzroy Basins	1960	Flavelle & Goodspeed (1962)		Grid (helicopter)	11 000 m by 11 000 m
6206	Amadeus and South Canning Basins	1962	Lonsdale & Flavelle (1963, 1968)		Grid (helicopter)	11 000 m by 11 000 m
6214	Poole Range	1962	*BMR		Road traverse	Station spacing 800 m and 1600 m
6237	Jurgurra Terrace	1962	WAPET (1962b)	62/1928	Grid	6400 m by 9600 m. Station spacing 200 m
6238	Laurel Downs-Virgin Hills	1962	WAPET (1962b)	62/1928	Along seismic lines	Station spacing 700 m
6239	Napier Downs	1962	Oil Development NL (1962)	62/1931	Grid	3200 m by 2400 m. Station spacing 800 m
6243	Alexander Creek	1962	Hawkstone Oil Co. Ltd (1962)	62/1934	Grid	1600 m by 6400 m. Station spacing 800 m
6366	Lake Betty	1963	WAPET (1963f)	63/1909		
6344	Sahara (regional)	1963	WAPET (1963g)	63/1910	Grid	5000 m by 5000 m
6349	Joanna Springs	1963/64	WAPET (1963e)	63/1908	Grid	4800 m by 4800 m
6437	Stansmore Range	1964	Geosurveys (1964)	64/4807	Grid	4800 m by 4800 m. Station spacing 1600 m along road traverse
6505-06	Canning Basin	1965	*BMR		Grid (helicopter)	11 000 m by 11 000 m
6548	Dampierland (semi-detailed)	1965	WAPET (1965h)	65/4816	Reconnaissance	Station spacing 940 m
6549	Southeast Kidson	1965	WAPET (1965)	65/4814	Grid (helicopter)	4000 m by 4000 m (Station spacing 800 m along road traverse)

BMR survey Number	Survey name	Year	*Reference	PSSA File	Survey type	Configuration
6706	Canning Basin	1967	Whitworth (1970)		Grid (helicopter)	11 000 m by 11 000 m
6739	Jarmura	1967	French Petroleum Co. (1967b)	67/4832	Grid	830 m by 830 m
6740	Noonkanbah	1967	Continental Oil Co. (1967a)	67/4834	Grid	8000 m by 8000 m station spacing 800 m
6742	McLarty	1967	French Petroleum Co. (1967a)	67/11145	Reconnaissance	Station spacing 1000 m
6744	Dakota	1967	Australian Aquitaine Petroleum (1967)	67/11161	Along seismic lines	Station spacing 700 m
6748	Munro Arch	1967	WAPET (1967a)	67/4829	Grid	9700 by 8000 m. Station spacing 800 m
6804	Canning Basin	1968	*BMR		Grid (helicopter)	11 000 m by 11 000 m
6824	NW Shelf	1968	Whitworth (1969a, 1969b)		Marine	Parallel traverses E-W, 16 000 m apart
6837	Ryan	1968	Australian Aquitaine Petroleum (1968b)	68/3026	Along seismic lines	Station spacing 600 m
6911-18	Canning Basin	1969	Derby & Fraser (1969)		Grid (helicopter)	11 000 m by 11 000 m
7044	Stretch Range	1970	Australian Aquitaine (1970)	70/600	Reconnaissance and along seismic lines	Station spacing 700 m
7217	West Coast	1972	*BMR		Marine	Parallel traverses E-W, 60 000 m apart

* Surveys referenced without date do not have accompanying reports, but the data are included in the BMR Gravity Data Bank

Following an amendment to the Petroleum Search Subsidy Act in 1959, a considerable amount of company data became available, and, together with BMR's helicopter gravity results, they now provide both a regional coverage for the onshore area and a local detailed coverage.

In 1968, BMR covered much of the offshore part of the Canning Basin with a ship-borne gravity meter (Whitworth, 1969a, b) during a marine reconnaissance survey of the northwest continental shelf on east-west traverses 1600 m apart. However, this new data was not a timely guide to exploration in the offshore part of the basin because it had already been covered by regional seismic surveys (see Section 2.5). Subsequent BMR marine surveys have completed the reconnaissance coverage.

2.3 MAGNETIC SURVEYS

All magnetic surveys for which data are available are located in Figure 2.3.1 and listed in Table 2.3.1; Plate 8 is a total magnetic intensity contour map compiled from this data. With the exception of one vertical magnetic intensity survey (Gewerkschaft Elwerath Inc., 1966), all surveys have used total magnetic intensity instruments.

BMR made the first airborne magnetic survey in the Canning Basin in 1954 along a narrow strip of the coast and in the general area of the Fitzroy Graben; an interpretation of the survey data indicated that magnetic basement lay at great depth in the central area of the graben, and at relatively shallow depth on the shelf to the north and along the coastal strip (Quilty, 1960). Since this survey exploration companies have extended the reconnaissance coverage over most of the onshore Canning Basin, of which they have surveyed small parts in detail. Not all of these data are available to the public - for example, a survey with a line spacing of 4000 m between the coast and the south Canning Basin survey (WAPET, 1962f) was not subsidised and is therefore unavailable. BMR has obtained most of the available magnetic data offshore (Whitworth, 1969a, b).

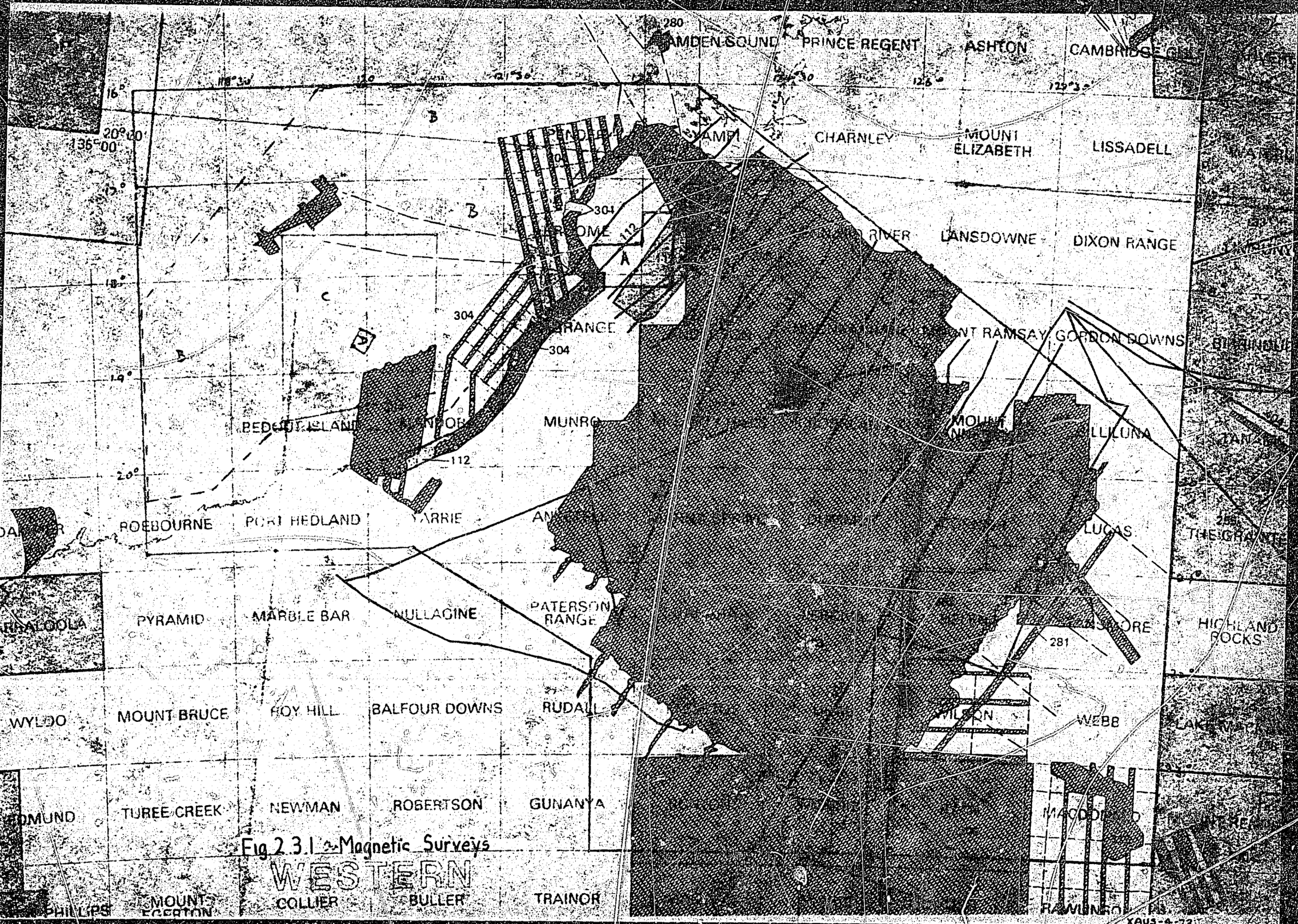


Fig 2.3.1 - Magnetic Surveys

WESTERN

In the main, probably as an attempt to economise, the airborne surveys have had a much wider line spacing than desirable, and as a consequence the level of interpretation which can be applied has been correspondingly limited. Most surveys had a configuration of bands of three lines roughly 2500 m apart; the bands were about 19 000 m apart (WAPET, 1962f). A more useful configuration for the same line length would have been a uniform 5000 m line separation. For recent airborne surveys, exploration companies have recognised the importance of closer line spacing (2000 or 3000 m: Associated Australian Oilfields, 1972b; Australian Aquitaine Petroleum, 1971; WAPET, 1972f) and have also used higher-resolution equipment. The interpretation of offshore data is also severely limited by wide spacing of traverses.

The data have been used to calculate the depth to magnetic basement, and this information has guided more detailed exploration by other geophysical methods. Most interpretation has been based on the infinite dipping tabular body model, and depth estimates available in the various reports listed in Table 2.3.1 probably have error bounds of 20 percent where the model is applicable.

An interpretation of the most extensive onshore airborne magnetic survey in the south Canning Basin (WAPET, 1962f) - indicated two major elongate northwest-trending depressions (the Fitzroy Graben and the Kidson Sub-basin) separated by a shallower zone (the Broome Arch). The northern depression was estimated to be 8000 m deep with steep margins; the southern depression was estimated to be 6000 m deep with gently sloping margins. A belt of strongly magnetic near-surface rocks trending southeast from the Pilbara Block was interpreted as the southern margin of the Kidson Sub-basin and the Canning Basin (Warri Arch, Pl. 18). Some of the depth estimates of this survey have been checked and found to be reasonable. However, in the general area of the Kidson Sub-basin, the anomalies are of low amplitude, and arise from sources of indeterminate slope and linear extent; accordingly these depth estimates are not reliable.

An aeromagnetic survey of the Gibson Desert area (Union Oil Company of California, 1965), adjoining the survey discussed above, better defined the extent of the Warri Arch and noted an association with a linear Bouguer anomaly high described by Lonsdale & Flavelle (1963, 1968). The survey also indicated

a magnetic basement deepening to about 10 000 m to the north of the arch at about latitude 23°, and suggested that the deepening extended into the Amadeus Basin.

Smaller areas fringing on or overlapping the WAPET (1962f) survey were surveyed to delineate individual structures and overall structure. For example, Hackathorn Oils Pty Ltd and Australian Oil Corporation (1963) surveyed the Stansmore Range Fault, which - like other surface faults in the southeastern Canning Basin, showed no strong change of magnetic response across it. Again, WAPET (1966f) - seeking basement highs which might be associated with Devonian reef structures in Kind Sound - postulated that a subsurface west-northwesterly extension of magnetic rocks similar to those of the Oscar Range was a basement high.

More recently detailed areomagnetic surveys of small areas fringing the Canning Basin have been undertaken with the objective of determining detailed basement structure. These surveys include Australian Aquitaine Petroleum (1971), Associated Australian Oilfields (1972b), and WAPET (1972). Two independent interpretations were made of the WAPET (1972) survey, and two significantly different results were obtained for the area of the Lennard Shelf and Margaret Terrace, indicating the inherent ambiguity of the magnetic method.

Offshore, the BMR marine survey (Whitworth, 1969a, b) provides the most extensive magnetic coverage in the area, but the magnetic data was not quantitatively interpreted. Whitworth noted a somewhat similar pattern in the magnetic features to the gravity features and suggested association of the sources. Airborne magnetic surveys of small areas offshore have been interpreted in detail. WAPET (1965g) discussed offshore extensions of the Fitzroy Graben and Broome Arch. WAPET (1969h) reported a northwest-trending extension of magnetic basement in the area of the Rowley Shoals; this interpretation was later challenged by Whitworth (1969a), who considered that there was no evidence for elevated basement.

The lack of knowledge of the magnetic response of the Precambrian rocks in the Pilbara and Kimberley Blocks has hampered the magnetic interpretation of the Canning Basin onshore and offshore. Most surveys have stopped short of the exposed basement rocks, and consequently qualitative attempts to trace magnetic anomaly patterns beneath the sediments of the Canning Basin have been hampered.

TABLE 2.3.1 - AIRBORNE, MARINE, AND GROUND MAGNETIC SURVEYS

Number*	Name of survey	Year	Reference	PSSA File	Altitude (m. above M.S.L.)	Survey configuration	Line direction	Available data		
								Total magnetic intensity		Other
								Contours	Profile	
112	Canning Basin Aeromagnetic Reconnaissance	1954	Quilty (1960)		460	Reconnaissance lines 40 km apart 3 lines 2.5 km apart in bands	NE		**	
253	South Canning Basin	1962	WAPET (1962f, 1966j)	62/1728	600	19 km apart	NNE	**		
281	Stansmore Range	1963	Hackathorn Oil Pty Ltd and Australian Oil Corp. (1963)	63/1700	760	Reconnaissance lines	5 lines NE 9 lines NW	**		
280	Rowley Shoals, Scott Reef, Sahul Banks	1963	Woodside (1964)	63/1709	460	Reconnaissance lines 3 lines 1.6 km apart in bands	Various	**		
309	Gibson Desert	1965	Union Oil Co. of California (1965)	65/4610	760	9.7 km apart	E-W	**		
315	Pollock Hills	1965	Australian Aquitaine Petroleum (1965)	65/4619	800	4 lines 1.5 km apart in bands 18 km apart	N-S	**		
304	Offshore Canning	1965	WAPET (1965g)	65/4614	460	3 lines 2.4 km apart in bands 12.9 km apart	9 bands NNW 4 bands NE	**		
322	King Sound	1966	WAPET (1966f)	66/4623	460	2.4 km spacing	NE	**		
A	Lower Fitzroy	1966	Gewerkschaft Elwerath (1966)	66/11111	ground survey	Along seismic traverses	Various			Vertical magnetic intensity profiles
B	Marine geophysical survey Northwest Shelf	1968	Whitworth (1969a, b)		sea level	Marine reconnaissance; 16-km spacing	E-W	**	**	
364	Walial	1969	WAPET (1969b)	69/3037	300	2 lines 2.4 km apart in bands 8 km apart	NNE	**		
383	Billiluna-Helena	1971	Associated Australian Oilfields (1972b)	71/422	670	3-km spacing	E-W	**		
389	White Hills	1971	Australian Aquitaine Petroleum (1971)	71/508	670	2-km spacing	E-W	**		
395	Lennard Shelf	1972	WAPET (1972f)	72/1019	600	2-km spacing	NE	**		
C	Bedout-Broome Swell	1972	Hematite Petroleum Pty Ltd (1972)	72/2616	sea level	Along seismic traverses	Various		**	
D	Jaubert	1972	Hematite Petroleum Pty Ltd (1973)	73/212	sea level	Along seismic traverses	Various		**	
404	Control Traverses Magnetic Map of Australia	1973	BMR		Various	Traverses at 150, 500, 600, 750 and 1000 m asl	Various		**	

* Number identifies surveysshown n Figure 2.3.1 (after Gerula,1979)
Letter " " additinal to Gerula (1979)

2.4 MAGNETO-TELLURIC SURVEYS

Australian Aquitaine Petroleum (1968a) made an experimental magneto-telluric survey mostly along existing seismic lines in the southeast of the Canning Basin between Point Moody No. 1, Wilson Cliffs No. 1, Kidson No. 1, and Lake Cobb. In a general way the results indicate a westward deepening of an assumed resistive basement away from the Precambrian outcrop and towards the Kidson Sub-basin, where it is about 10 000 m deep near Kidson No. 1. Southwest of Point Moody No. 1, near the western end of seismic line DK 7 (Pl. 6), the results indicate a depth of 10 500 m to basement, while seismic interpretation indicates that the base of Interval 1 lies at 3000-3500 m in this area. Dipping seismic events below base 1 (i.e. the seismic horizon at the base of interval 1) arise from late Precambrian sediments, which may in part account for this discrepancy. The magneto-telluric results seem to show basement depths in excess of that determined by seismic or magnetic interpreta-tion; this may be due to a further section of Proterozoic sediments beneath the late Precambrian sediments.

Depth interpretation of magneto-telluric data in this area is complicated by the presence of very low-resistivity (0.34 ohm-m) ?Proterozoic pyritic shales, encountered in Wilson Cliffs No. 1. Yet the method appears to be useful for determining broad scale features of the Canning Basin, particularly if used in conjunction with seismic data for control.

2.5 SEISMIC SURVEYS

All subsidised and BMR seismic surveys, and some of their more important results, are listed in Table 2.5.1

Seismic exploration of the basin began in 1952 with a BMR survey of the Nerrima Dome area (Vale, Smith, & Garrett, 1953). By 1956 BMR had completed ten seismic surveys in the northern part of the basin; most of them were designed to investigate structure at depth beneath known surface anticlines.

From 1956 onward, almost all seismic surveys in the basin were carried out by private companies. WAPET undertook the first of these, a combined refraction and reflection seismic survey, in the Kimberley Downs area. An important result from these surveys was the discovery of possible reef

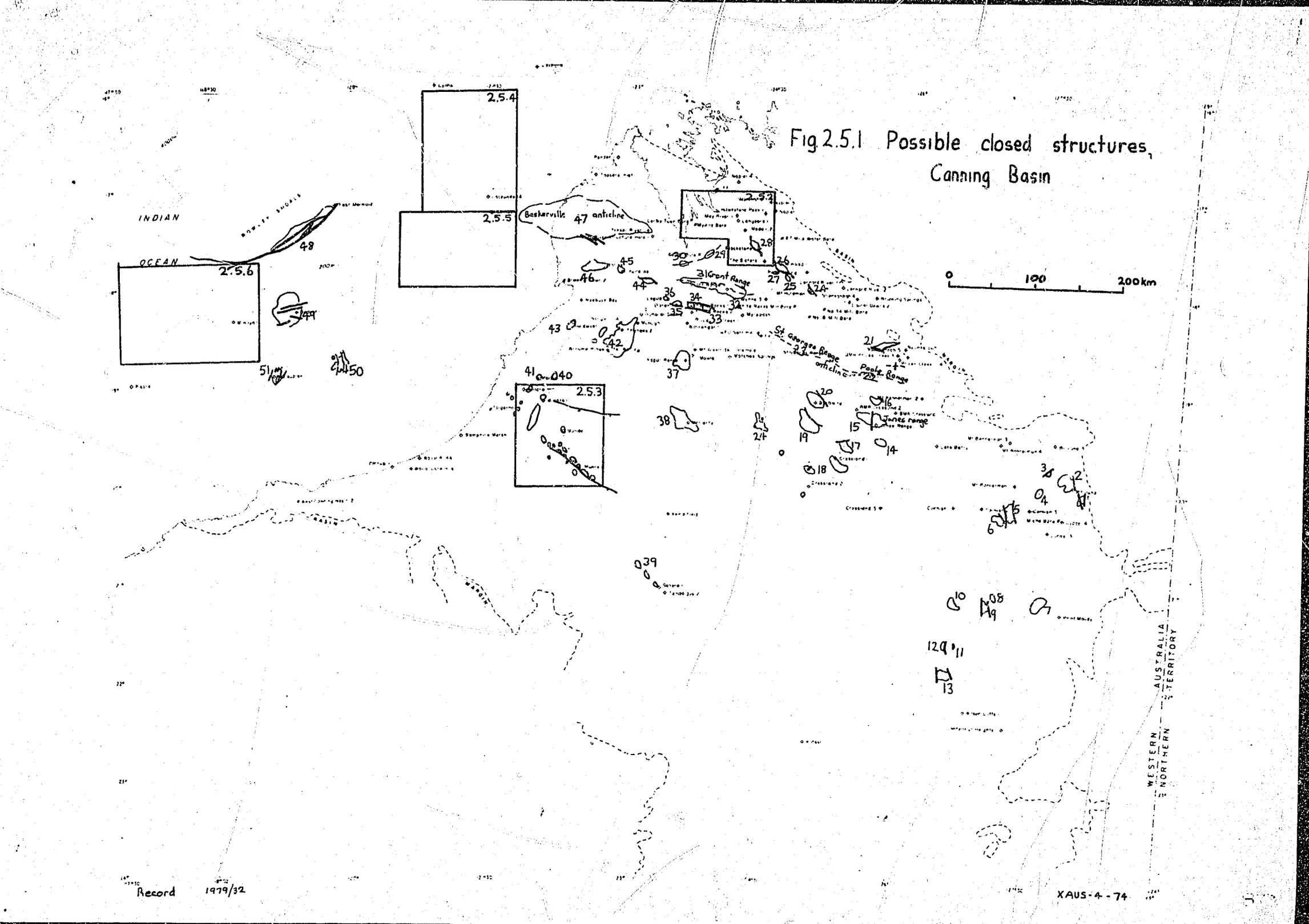
structures at depth in the Lennard Shelf; one of them was subsequently drilled by Meda No. 1. The results of several of these surveys, undertaken between 1956 and 1959, are not available to BMR.

In 1959, the Petroleum Search Subsidy Act was amended and all seismic surveys onshore and most offshore until 1974 were subsidised. Two surveys were carried out in the first three years following this amendment. In 1962, seismic activity began to increase and continued to do so until it reached a peak in 1970, when 17 seismic surveys were undertaken. Seismic exploration has continued at a diminished rate to the present.

Although most of the early surveys were reconnaissance investigations, many subsurface structures were mapped. Subsequent surveys have outlined many more structures; investigated some previously known structures in detail; and downgraded or disproved the existence of others. Figures 2.5.1 to 2.5.6, compiled from structure contour maps in the final reports of seismic surveys listed in Table 2.5.1, show all probable closed seismically defined structures in the basin; these range in area from about 1 to 350 km^2 and have vertical closures estimated at 30 to 1300 m. These structures, however, have been mapped from data and control of different qualities and densities. Statistics for each structure in Figures 2.5.1 to 2.5.6 are listed in Table 2.5.2.

More than 32 000 line-km of both reflection and refraction data was obtained by the end of 1973. More than 75 percent of these seismic surveys were in the northwestern half of the basin, where seismic coverage ranges from detailed to reconnaissance grid. Much of the Kidson Sub-basin, the Fitzroy Graben, and the eastern and southern margins of the basins (Pl. 5) have only a poor seismic coverage.

Data from recent surveys are in general of superior quality compared with those of earlier surveys. Even so, the quality of recent seismic records obtained from some of the areas known to have been associated with poor data appears not to have been enhanced by improvements in data-gathering techniques and increasingly refined data-processing methods. Thick weathering, abrupt topography (e.g., Rowley Shoals area), extensive faulting, and complex structure appear to be some of the many factors responsible for the poor data.



Record 1979/32

XAUS-4-74

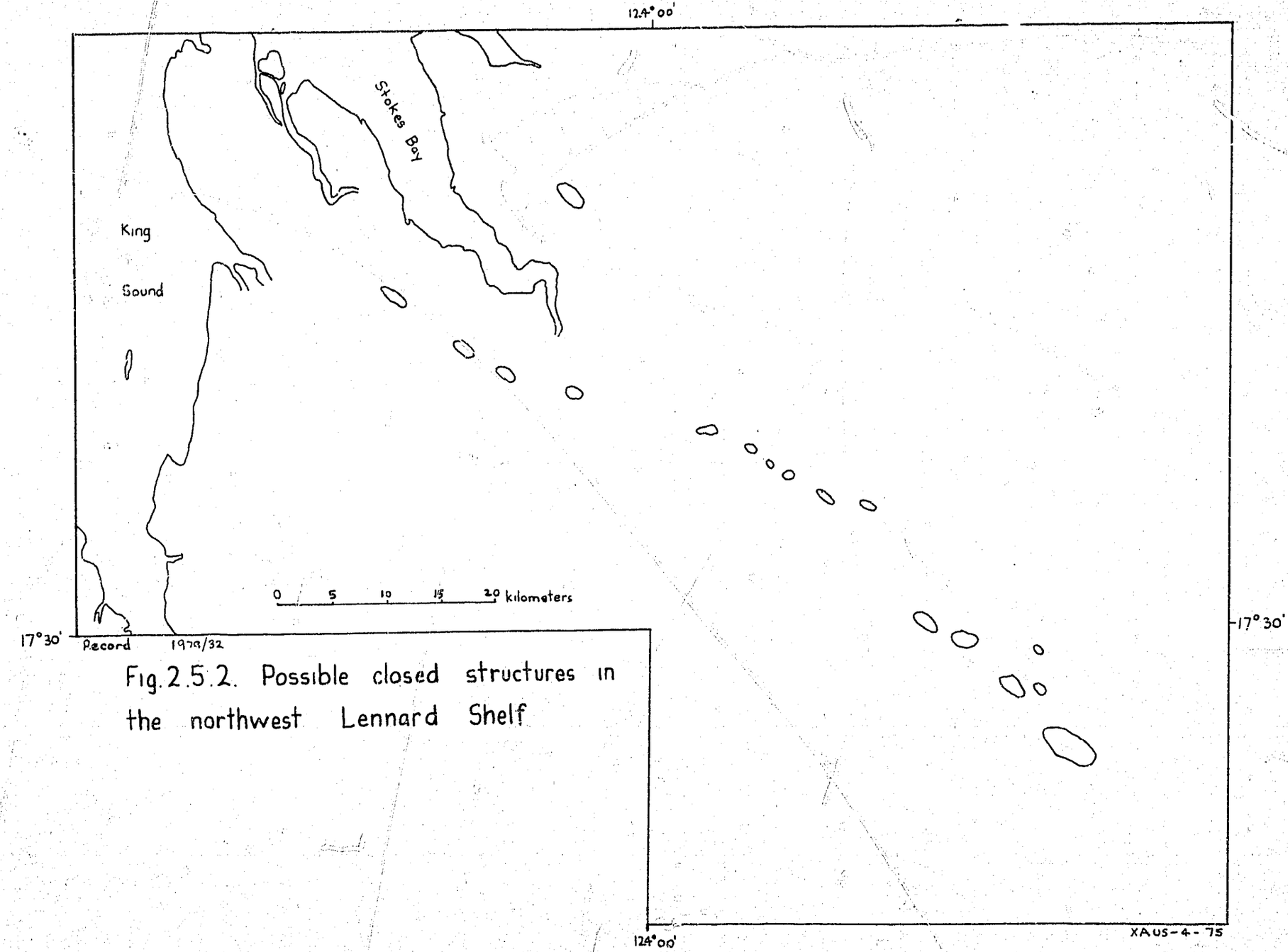
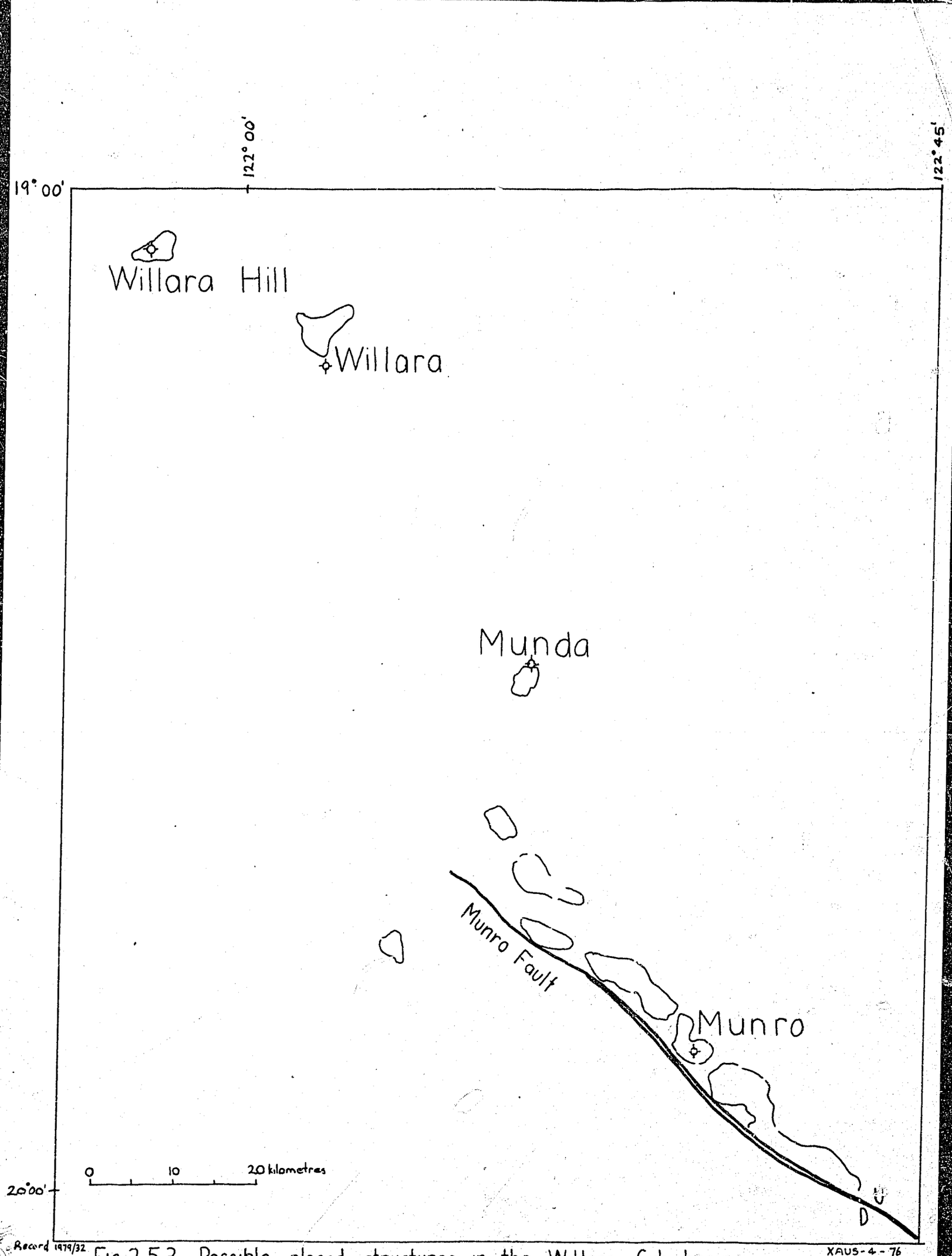


Fig. 2.5.2. Possible closed structures in the northwest Lennard Shelf



Record 1979/32 Fig 2.5.3 Possible closed structures in the Willara Sub-basin XAUS-4-76

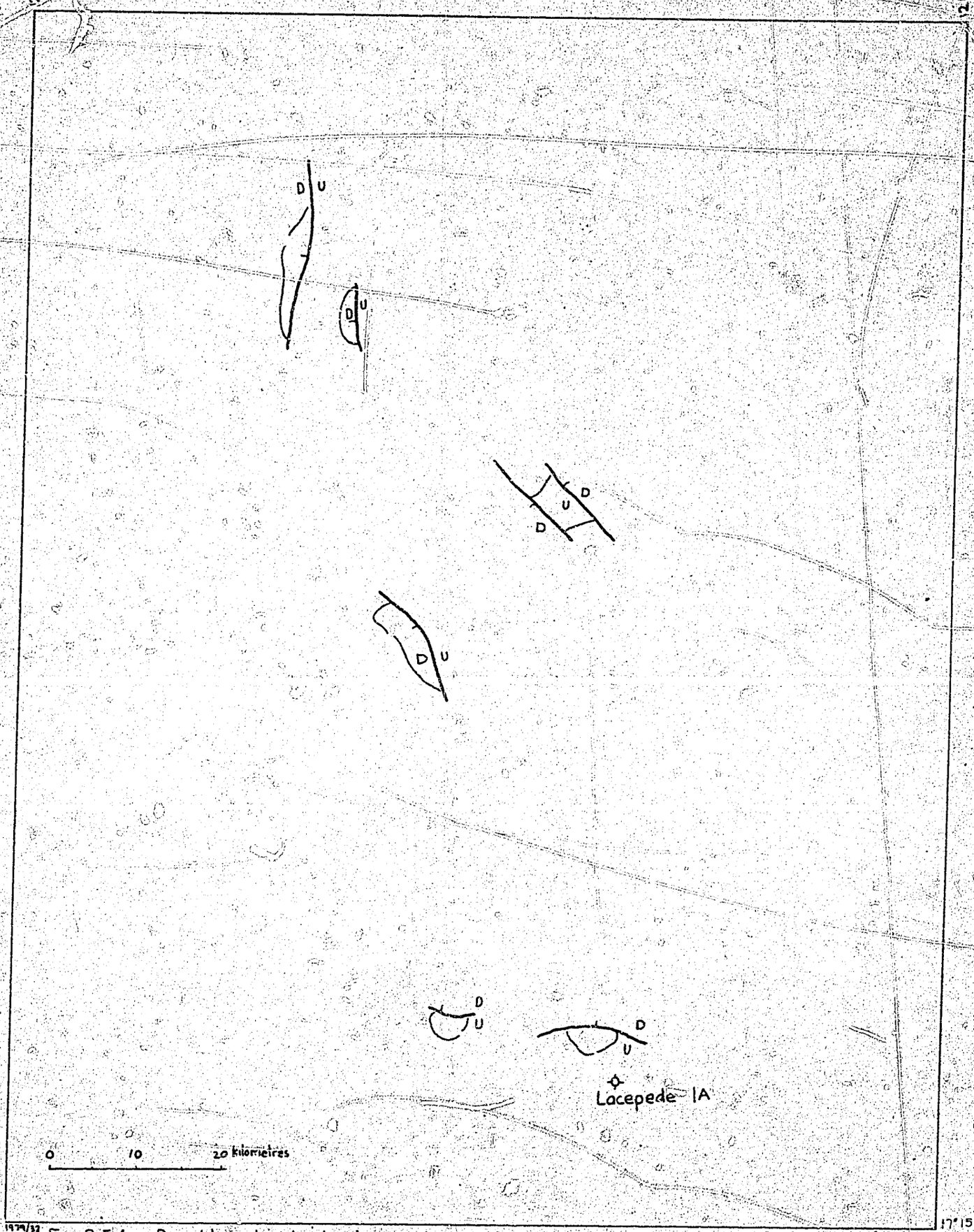


Fig. 2.5.4 Possible closed structures north of Lacepede No.1A

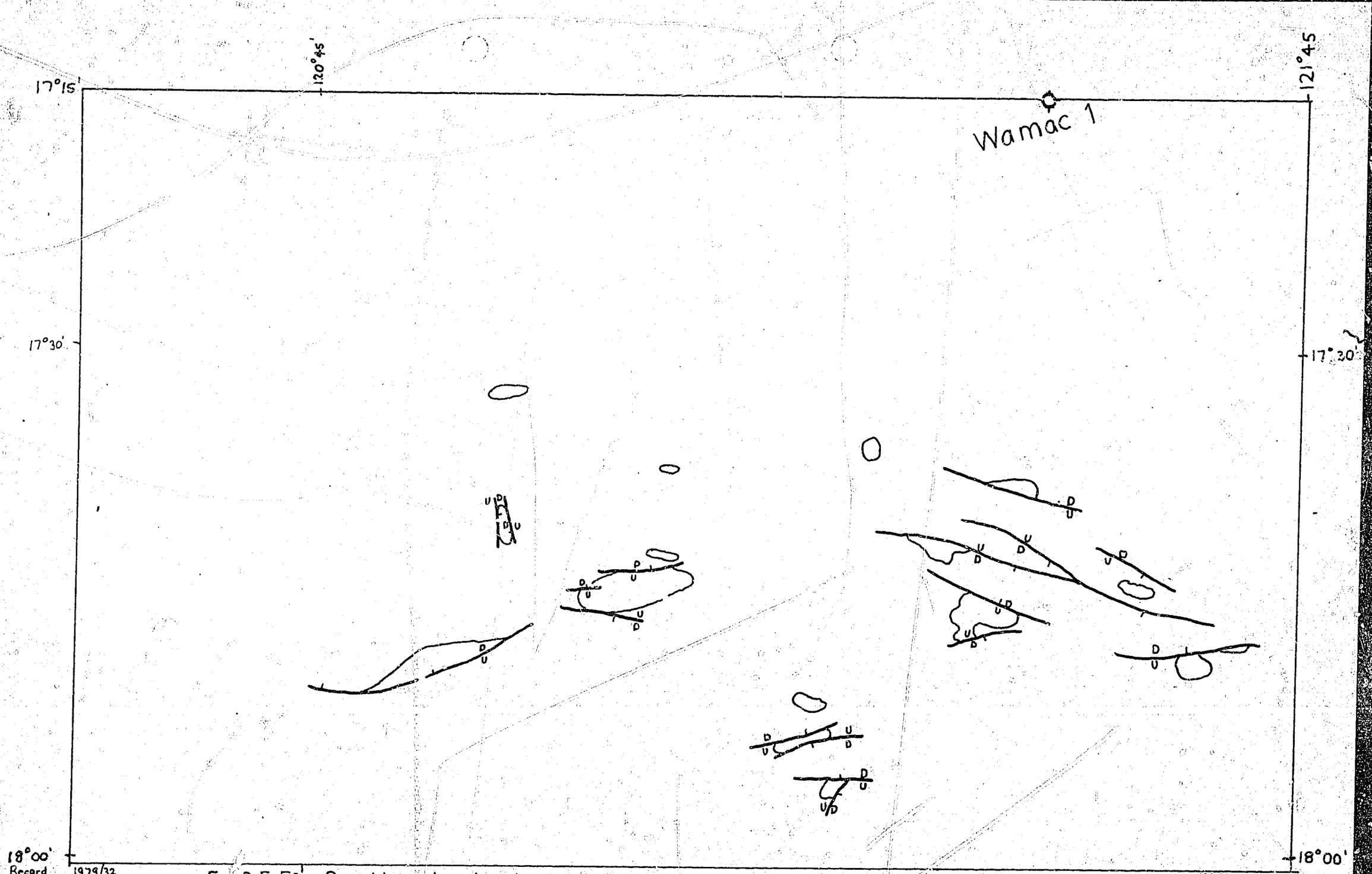


Fig. 2.5.5 Possible closed structures south of Wamac No.1

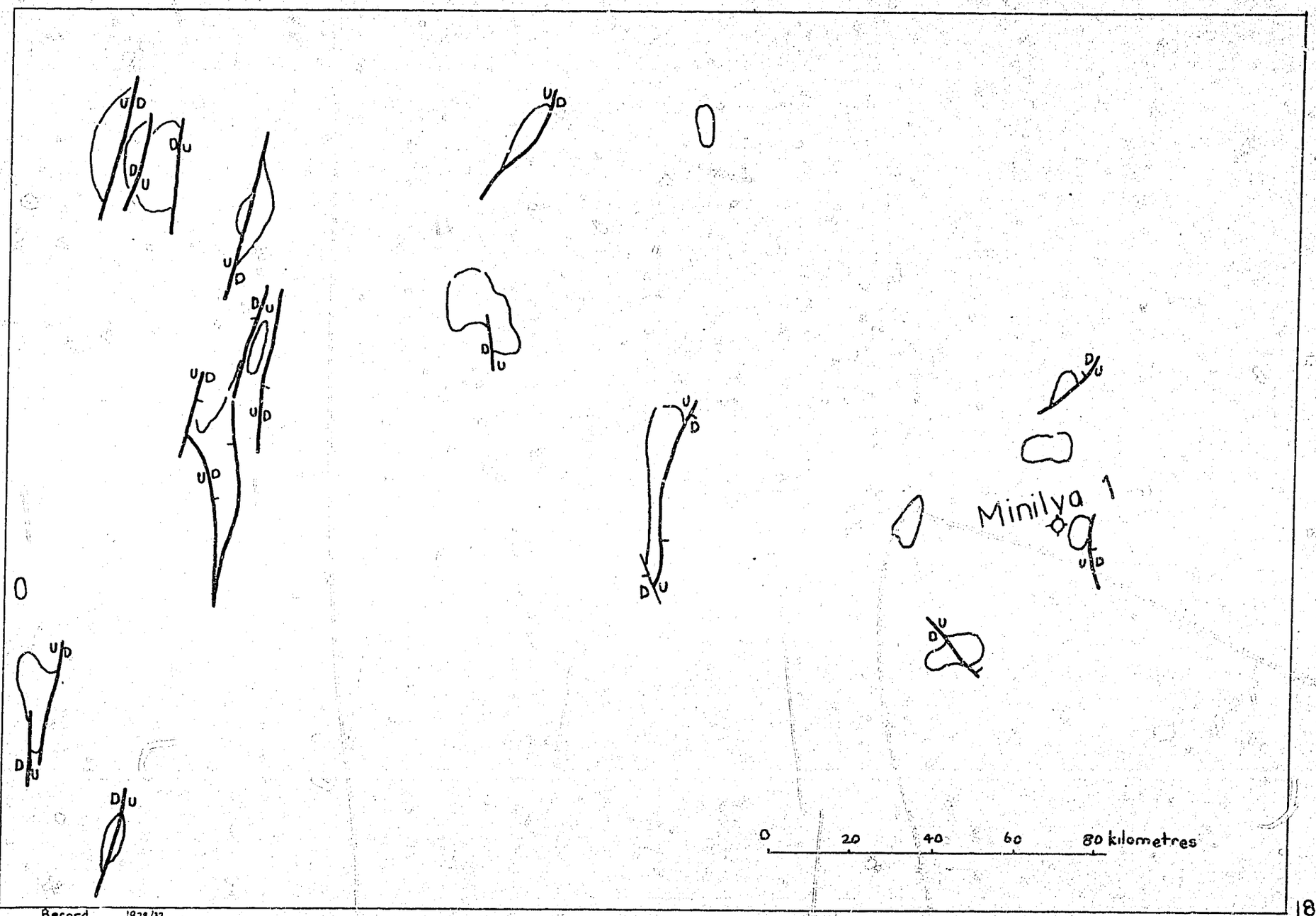


Fig. 2.5.6 Possible closed structures near Minilya No. 1

A generalised seismic data quality map based on an examination of the seismic record sections from lines located in Plate 5 is shown in Appendix 13. In areas of good data, the reflections can be everywhere traced with reasonable assurance and are recognisable by character. In areas of fair quality, events can be traced with reasonable assurance only on continuous record sections. In areas of poor-quality data, both character correlation and the tracing of reflections are difficult.

Velocity data are available from well velocity surveys, sonic logs, and seismic reflection moveout. Velocities derived from well surveys represent direct vertical velocities from various points at depth to the surface, and are the most accurate information for calculating depths from seismic travel times. Information derived from sonic logs, when used in conjunction with other velocity data, can be used for reliable time-to-depth conversion.

Most velocity data for the Canning Basin, however, have been determined from seismic reflection moveout (NMO), of which the main objective has been to calculate correction times in order to obtain the best possible stacked records. The accuracy of these NMO velocities depends on the quality of the seismic data, and their values are usually lower than velocities derived from well surveys (Steel, Jr., 1941).

In the offshore Canning Basin, non-confidential data from seismic surveys and petroleum exploration wells have provided more than 2000 NMO velocity profiles and four velocity profiles derived from well surveys. Some discrepancies have been observed between NMO velocities determined along seismic lines parallel to the strike and those along lines in the direction of dip. However, most of the anomalous velocities appear to be associated with poor seismic data. It has been necessary, therefore to select the more reliable NMO velocity profiles.

In areas of similar water depth and sedimentary thickness, the velocity changes little, and a single time-depth relation may be used. The offshore area of the basin may be divided into six velocity provinces, for which one velocity function may be applied (Appendix 13). Missties along the boundaries between velocity provinces were removed by smoothing the contours.

Twenty-eight velocity profilies derived from well surveys and sonic logs (Appendix 13) and about 1000 NMO velocity profiles are available for the onshore area of the basin. The irregular distribution and the different qualities of the NMO velocities together with the diverse and sometimes large lateral velocity variations required the selective use of individual velocity information to convert time to depth. In many large areas where velocity information is not available, the velocities from the nearest well had to be used to calculate depths. In the McLarty, Joanna Springs, and most of the Sahara surveys, depth estimates were made using velocities from Edgar Range No. 1, McLarty No. 1, Kemp Field No. 1, and Sahara No. 1 (Appendix 13). Depth values at places between any two velocity control points were calculated using linearly interpolated velocities, except in the Helena, Wilson, and most of the Ryan surveys where depth estimates were made using velocity data from Wilson Cliffs No. 1.

TABLE 2.5.1 BMR AND SUBSIDISED SEISMIC SURVEYS IN THE CANNING BASIN
* Seismic surveys from which data have been re-interpreted

No.	Name of survey	Date	Results	Reference
1	Nerrima Dome	1952	Structure at depth of 2100 m bears no relation to surface anticline; major unconformity at 600 m	Vale & others (1953)
2	Poole Range-Prices Creek area	1953	Thick section of sediment south of Pinnacle Fault	Smith (1955)
3	Deep Well Anticline, Myroodah (reflection)	1954	Reflections from a depth of 7300 m	Williams (1955)
4	Poole Range-Christmas Creek area (reflection)	1954	Thick sediment and a structure beneath Poole Range Anticline	Williams (1956)
5	Broome area (preliminary investigation)	1954	Anticline at depth; thick sediments (in the order of 3800 m)	Vale & Williams (1955)
6	Christmas Creek area (refraction)	1955	A refractor (velocity 4600 m/s) at about 2100 m unconformable with the overlying refractor is probably base 4.	Smith (1957)
7	West of Langeys Crossing (reflection)	1955	Thick sediments (up to 6000 m)	Vale & Smith (1956)
8	Fenton Fault	1955	Fenton Fault at Barns Flow is a normal fault	Vale & Smith (1959)
9	Near La Grange (reflection)	1955	Sediment thickness ranges from about 1300 m to 2400 m	Smith (1960)
10	Broome (reflection)	1954-55	Thick folded sediments (up to 3000 m)	Smith (1961)
11	Blue Hills-Logue	1959-60	Four pre-Permian anticlines and a possible salt structure	WAPET (1962a, g)
12	Dampier Fault (reflection)	1959-60	Five areas of interest with several probable closed structures	WAPET (1962e)
13	The Sisters	1962	Anticline in the Sisters area is cut by a near-surface fault*	Mines Administration (1962)

No.	Name of survey	Date	Result	Reference
14	Hawkstone Peak	1962	Hawkstone Peak structure defined	WAPET (1962d)
15	*Laurel Downs	1962	Gogo Anticline outlined; area has complex structure	WAPET (1962c)
16	Goorda-Logue	1963	Inconclusive	WAPET (1963a)
17	*Gogo	1963	N dip at N side of Gogo Anticline confirmed	WAPET (1963b)
18	*Sahara	1963-64	At least 3000 m of sediment likely	WAPET (1963d)
19	Balgo-Lake Betty	1963	Coverage and data insufficient to determine closure of Balgo and Lake Betty Anticlines	WAPET (1963c)
20	*Parda	1964	Parda structure, and a sub-basin containing about 3000 m of sediment separated from the Broome Arch by a fault	WAPET (1964a)
21	Northwest Sheif (marine)	1964	Gently NW-dipping reflector	BOCAL (1964)
22	*St Georges Range	1964	Closed structure 1500 m beneath St Georges Range Anticline; area of closure mapped as 57 by 32 km	Continental Oil Co. of Australia Ltd (1964)
23	*Montebello-Mermaid (marine)	1965	Offshore Canning Basin extends NW across continental shelf	BOCAL (1965)
24	*Poole Range	1965	Closure mapped about 4900 m beneath Poole Range Anticline	Continental Oil Co. of Australia Ltd (1965a)
25	*Crossland	1965	Despite poor data, several anticlines delineated	Continental Oil Co. of Australia Ltd (1965c)

No.	Name of survey	Date	Result	Reference
26	*West Lennard	1965	Several inferred reef structures in the Kimberley Downs area	WAPET (1965b)
27	*Southeast Kidson	1965	About 4500 m thickness of sedimentary rocks	WAPET (1965a)
28	Broome Swell	1965	Area has complex structure	Continental Oil Co. of Australia Ltd (1965b)
29	*Barbwire Range	1965	A number of faulted anticlines	Continental Oil Co. of Australia Ltd (1965d)
30	Mowla	1965	Several possible closed structures	WAPET (1965c)
31	Marrin (Vibroseis)	1966	Regional dip is to W	WAPET (1966a)
32	Willara Hill	1966	Two anticlinal structures opening to W; definition of Willara Hill Structure improved	WAPET (1966b)
33	*Betty (detail)	1966	Permian structure with closure of about 100 m mapped beneath Lake Betty Anticline	WAPET (1966i)
34	*Dampierland	1966	Pender Terrace separated from the Fitzroy Graben by a fault; Tapper Ridge discovered	WAPET (1966c)
35	*West Meda	1966	Detailed evaluation of previously indicated reef structures failed to substantiate them	WAPET (1966d)
36	*Lower Fitzroy	1966	Barlee Anticline and another close structure E of it indicated	Gewerkschaft Elwerath (1966)
37	*Roebuck	1966	Five possible structures; further investigation recommended	WAPET (1966e)
38	Nita-Willara	1966	Previously mapped structures further investigated	WAPET (in confidence)

No.	Name of survey	Date	Result	Reference
39	*McLarty	1967	Two small anticlines mapped, and recommended for drilling	French Petroleum Co. (Aust.) Pty Ltd (1967a)
40	*Dakota	1967	Four structures mapped	Australian Aquitaine Petroleum Pty Ltd (1967)
41	*Wallal (marine)	1967	Wallal Embayment has estimated sedimentary thickness of 4000 m	WAPET (1967b)
42	*Baskerville	1968	Despite poor data, 3 probable closed structures mapped	WAPET (1968b)
43	*Lennard	1968	Probable reef structures at depth	WAPET (1968a)
44	*Offshore Canning-Seringapatam (marine)	1968	Section thickens to NW: probable closed structures beneath Clerke and Imperious reefs	BOCAL (1968)
45	*Ryan	1968	Thick section west of Stansmore 1:250 000 Sheet area may be E extension of Fitzroy Graben	Australian Aquitaine Petroleum Pty Ltd (1968b)
46	Northwest Shelf	1968	Base Tertiary horizon mapped	Whitworth (1969a, b)
47	Napier (refraction)	1968	A continuous refractor with velocity of 5500 m/s to 6000 m/s mapped in Upper Devonian, and tied to Hawkstone Peak No. 1	Westralian Oil Ltd (1968)
48	*Legendre-Marie (marine)	1969	Several faulted anticlines	BOCAL (1969)
49	*Bedout (marine)	1969	Fitzroy Graben shallows to W	WAPET (1969a)
50	*Contention Heights (refraction)	1969	E margin of Kidson Sub-basin delineated; several structural trends outlined	Australian Aquitaine Petroleum Pty Ltd (1969a)
51	Matches Springs	1969	Edgar Range Anticline persists at depth	Total Exploration Australia (1969)

No.	Name of survey	Date	Result	Reference
52	*Adele-Scott (marine)	1969	Several structural anomalies W of Fitzroy Graben	BOCAL (1969b)
53	Baron Range	1969	E limit of Ordovician sediments and 2 anticlines mapped	Australian Aquitaine Petroleum Pty Ltd (1969b)
54	*Munro Arch	1969	No confirmation of gravity-indicated Munro Arch; Admiral Bay fault extends to E, contrary to previously suggested trend	WAPET (1969c)
55	*Alexander	1969	Too poor for reliable mapping	Lennard Oil NL (1969)
56	*Munro R-1	1969	Structures in Willara Sub-basin further investigated; Anketell Ridge detected	WAPET (1969e)
57	*Jurgurra Terrace	1969	Five structures mapped; 2 recommended for drilling	WAPET (1969d)
58	*Canning (marine)	1970	About 1000 to 6000 m sedimentary section	WAPET (1970a)
59	*King Sound (marine)	1970	W extension of Lennard Shelf defined	WAPET (1970b)
60	*Tyral-Evals (marine)	1970	Regional dip is to W	BOCAL (1970a)
61	Alexander II	1970	Poor data, but several structures may be worthwhile drilling; depth to basement ranges from about 600 to 2600 m	Lennard Oil NL (1970)
62	*Helena	1970	Fault separates a basement high from the Fitzroy Graben in N	WAPET (1970d)
63	*Tabletop	1970	Tabletop Shelf outlined at S margin of Kidson Sub-basin	WAPET (1970c)

No.	Name of survey	Date	Result	Reference
64	*Stretch Range	1970	Large anticline partly outlined; unconformity at about 2000 m	Australian Aquitaine Petroleum Pty Ltd (1970)
65	*Crossland	1970	Dummer Range Fault mapped between Barbwire Terrace and Broome Arch	WAPET (1970f)
66	*Gogo Trig	1970	Four culminations of the Gogo Anticline	WAPET (1970g)
67	*Lake Betty	1970	Area has complex faulted structure	WAPET (1970e)
68	*Laurel	1970	Section thickens markedly to S	WAPET (1970h)
69	*Oscar	1970	Inconclusive over Oscar Ridge, but 7 possible closed structures indicated	WAPET (1970i)
70	*Anketell	1970	An anticlinal trend mapped on poor data	WAPET (1970n)
71	*Broome-Samphire	1970	Broad structure with estimated closure of 60 m mapped in Broome Arch	WAPET (1970k)
72	*Pender	1970	Lennard Shelf extends offshore	WAPET (1970j)
73	*Trimouille-Dillon	1970-71	Previously indicated structures investigated and evaluated	BOCAL (1970b)
74	*Munro Detail	1971	Munro Fault and several structures further delineated	WAPET (1970m)
75	*Lake Auld	1971	Previously magnetic and gravity-indicated fault at S margin of Kidson Sub-basin confirmed	WAPET (1970l)
76	*Crossland Platform	1971	Several structures mapped and recommended for further investigation	WAPET (1971a)
77	*North Broome	1971	Several small faulted anticlines mapped	WAPET (1971b)

No.	Name of survey	Date	Result	Reference
78	*Poulton	1971	A few structures beneath suspected base Permian	WAPET (1971c)
79	*Munro D-2	1971	Structures in Munro area investigated in detail; drill site recommended	WAPET (1971d)
80	*North Broome D-2	1972	Previously outlined structure investigated and recommended for drilling	WAPET (1972a)
81	Monte Bello-Turtle	1972	Additional reconnaissance coverage in parts of the basin	BOCAL (1972a)
82	*East Canning	1972	Seven closed structures, some only poorly controlled, and Jones Range structure mapped	WAPET (1972b)
83	*Lennard Shelf	1972	Four closed structures, some fault-controlled	WAPET (1972c)
84	*Dampier Downs-Collins	1972	Poor data; several structures partly delineated	WAPET (1972d)
85	*Bedout-Broome Swell (marine)	1972	Two block-faulted structures mapped in Bedout area	Hematite Petroleum Pty Ltd (1972)
86	*Hickey Hills	1972	Sedimentary section thickens to N into the Kidson Sub-basin; possible pre-Ordovician salt structure indicated	Australian Aquitaine Petroleum Pty Ltd (1972)
87	Narringla (marine)	1972	Several Palaeozoic structures near S margin of offshore extension of the Fitzroy Graben	BOCAL (1972b)
88	*Liveringa Ridge	1972	Five anticlinal axes mapped; some worth further investigation	WAPET (1972e)
89	Steamboat-Spit (marine)	1973	A few deep-water structures in Mesozoic ssction	BOCAL (1972c)

No.	Name of survey	Date	Result	Reference
90	Mermaid-Cartier (marine)	1973	Extensively faulted zone with probable closed structures	BOCAL (1973a)
91	*Thornton	1973	Several closed structures mapped at N margin of graben and along E extension of Broome Arch	Associated Australian Oilfields NL (1972a)
92	Jaubert	1973	Faulted anticline delineated	Hematite Petroleum Pty Ltd (1973)
93	Sahara II	1973	Anticlinal trend with probably 3 culminations mapped	WAPET (1973a)
94	Crossland III	1973	Semi-detail coverage on previously indicated structures	WAPET (1973g)
95	Collins II	1973	Poor data; improved control on previously indicated structures	WAPET (1973b)
96	Jones Range-Halls Range	1973	Confirmed closure over Jones Range structure	WAPET (1973c)
97	Barbwire II	1973	Three anticlines partly delineated	WAPET (1973d)
98	Doran	1973	Poor data; detailed Doran structure	WAPET (1973e)
99	Liveringa II	1973	Two previously indicated structures further investigated	WAPET (1973f)
100	Bedout North (marine)	1974	Small structures mapped on N flank of Bedout structure	BOCAL (1974a)

TABLE 2.5.2. POSSIBLE CLOSED STRUCTURES

Structure No.	Datum (m)	Depth (m)	Approx. vert. closure (m)	Approx. hor. closure (km^2)	Strat. level of closure	Type of structure	Age	Data quality	Test well	Remarks
1	300	2600	200	20	Interval 3	Fault-controlled closure	Pre-interval 4	Fair	None	Mapped closure based on one line only.
2	300	1650	600	100	Interval 3	Fault-controlled closure	Pre-interval 4	Fair	None	"
3	300	1425	350	20	Interval 3	Faulted anticline	Pre-interval 4	Fair	None	"
4	300	5700	250	30	Interval 3	Anticline	Pre-interval 4	Poor	None	"
5	300	2700	350	100	Interval 3	Fault-controlled closure	Post-interval 4	Fair	None	"
6	300	4650	600	50	Interval 3	Anticline	Post-interval 4	Poor	None	"
7	400	3000	400	150	Probably interval 3	Anticline	Post-interval 4	Good	None	"
8	300	3500	50	20	Probably interval 3	Anticline	Post-interval 4	Fair	None	"
9	300	1500	100	50	Near base 2	Faulted anticline	?Post-interval 4	Fair	None	"
10	300	600	70	75	Base 4	Anticline	?Post-interval 4	Good	None	"
11	300	1000	20	10	Interval 4	Anticline	?Post-interval 4	Fair	None	"
12	300	1050	75	25	Interval 4	Faulted anticline	?Post-interval 4	Fair	None	"
13	300	1150	150	100	Base 3	Anticline	?Pre-interval 4	Fai	None	Closure may also occur within interval 4.
14	200	5700	230	50	Interval 3	Anticline	Post-interval 4	Fair	None	Closure based on one line.
15	200	4380	1340	450	Interval 3	Faulted anticlines	?Post-interval 4	Poor to fair	Jones Range 1	Adequate seismic coverage
16	200	4150	230	75	?Interval 3	Anticline	?Post-interval 4	Poor	None	Adequate coverage but data poor.
17	200	1750	230	100	Interval 3	Anticline	Pre-interval 4	Fair	None	Horizontal closure uncertain.
18	200	1200	60	35	Base 2	Anticline	Pre-interval 4	Good	None	Probably associated with salt structure.
19	200	500	400	350	Interval 2	Fault-controlled closure	Pre-interval 4	Poor	None	Insufficient control; poorly defined.
20	200	900	300	175	Interval 1	Anticline	?	Poor to non-existent	Barbwire 1	Closure doubtful.
21	200	2600	900	130	?Interval 1	Fault-controlled closure	?Pre-interval 4	Fair to good	None	Extent of closure uncertain.
22	-	Exposed at the surface	Unknown		Interval 4	Anticline	Post-interval 4		Poole Range 1	Closure has not been outlined.
23	-	Exposed at surface	Unknown	-	Interval 4	Anticline	Post-interval 4		St George Range 1	Total closure has not been determined.
24	200	1200	50	75	Interval 2	Anticline	Pre-interval 4	Good	None	Probably associated with salt structure.
25	Sea level	1220	50	50	Near the top of interval 3	Fault-controlled closure	Pre-interval 4	Poor to fair	Mt Hardman 1	Closure also occurs at a depth of 4000 m
26	Sea level	4000	680	100	Interval 3	Faulted anticline	Pre-interval 4	Fair to good	Mimosa 1	More seismic needed to establish extent of closure.
27	Sea level	1600	200	50	Near top of interval 3	Faulted anticline	Pre-interval 4	Poor to fair	None	Closures also occur at deeper level.

TABLE 2.5.2. POSSIBLE CLOSED STRUCTURES

Structure No.	Datum (m)	Depth (m)	Approx. vert. closure (m)	Approx. hor. closure (km^2)	Strat. level of closure	Type of structure	Age	Data quality	Test well	Remarks
28	Sea level	1800	?00	125	Interval 2	Faulted anticline	Pre-interval 3	Fair	Blackstone 1	
29	Sea level	2000	200	75	Interval 4	Anticline	Post-interval 4	Fair	None	Closure based on one line only.
30	Sea level	2500	100	40	Interval 4	Anticline	Post-interval 4	Fair	None	"
31	Sea level	1700	?350	120	Interval 4	Anticline closed to W	Post-interval 4	Poor	None	Eastern extent of closure yet to be defined.
32	-	Exposed at the surface	Unknown		Interval 4	Anticline	Post-interval 4	Poor	Grant Range 1	Closure has not been determined; appears to adjoin structure 31.
33	Sea level	450	500	Unknown	?Interval 2	Probable salt anticline/dome	Pre-interval 4	Fair	None	Closure based on one line only; probably related to structure 34.
34	Sea level	120	550	10	Interval 2	Salt anticline/dome	Pre-interval 4	Poor	Frome Rocks 1	More seismic required to map total closure.
35	Sea level	670	500	50	Interval 3	Anticline	Pre-interval 4	Fair	Doran 1	Area of closure uncertain.
36	Sea level	1100	80	300	Interval 4	Anticline	Post-interval 4	Fair	Logue 1	Adequate seismic coverage.
37	150	500	150	120	Interval 2	Anticline	?Pre-interval 4	Poor	Edgar Range 1	Insufficient seismic coverage.
38	150	1300	200	500	Interval 2	Anticline	?Pre-interval 4	Poor to fair	McLarty 1	
39	244	1200	less than 25	40	Interval 2	Anticlines	Pre-interval 4	Fair to good	Sahara 1 was drilled near the structure	Closures based on only one seismic line.
40	Sea level	1275	25	30	Interval 2	Anticline	Pre-interval 4	Fair to good	None	"
41	Sea level	1100	80	3	At the top of interval 1	Anticline	?Pre-interval 2	Fair	Parda 1	
42	Sea level	500	140	800	Interval 2	Broad anticline	Pre-interval 4	Fair to good	Thangoo 1, 1A, 2	Low relief anticline consisting of several pinnacles.
43	Sea level	800	200	400	At top of interval 1	Anticline	?Pre-interval 4	Fair	Goldwyer 1	Closure based on one line only.
44	Sea level	2500	700	80	Base 4	Fault-controlled closure	Post-interval 4	Poor	None	Closure not yet established.
45	Sea level	750	150	30	Interval 3	Faulted anticline	Pre-interval 6	Poor to fair	Yulleroo 1	Adequate seismic coverage.
46	Sea level	700	750	300	Interval 3	Large anticline	Pre-interval 6	Fair to good	Barlee 1	Closure adequately mapped.
47	Sea level	700	800	7500	Base 4	Large anticline	Pre-interval 6	Poor to fair	None	Closure based on 3 widely spaced seismic lines.
48	Sea level	5000	200	120	Base 6	Fault-controlled closure	?	Fair to good	East Mermaid 1 was drilled near the structure	Complex faulted structure.
49	Sea level	2900	400	450	Base 6	?Faulted anticline	?Pre-interval 6	Poor to fair	Bedout 1	Pre-interval 6 structure which remained prominent for most of the Mesozoic.
50	Sea level	2300	100	175	Probably within interval 5	Fault-controlled closure	?Pre-interval 6	Fair to good	None	Vertical closure may be less than estimated.
51	Sea level	4500	500	75	Probably within interval 4	Fault-controlled closures	Pre-interval 6	Poor to fair	Kerandren 1	Closure may also occur in interval 5

TABLE 2.5.2. POSSIBLE CLOSED STRUCTURES

Structure No.	Datum (m)	Depth (m)	Approx. vert. closure (m)	Approx. hor. closure (km^2)	Strat. level of closure	Type of structure	Age	Data quality	Test well	Remarks
Fig. 2.5.2.	Sea level	Average 2600	30	1 to 3	Interval 3	Structures	Interval 3	Fair to good	Meda 1, Langoora 1, Blackstone 1	Small closures probably associated with Upper Devonian reefs.
Fig. 2.5.3.	Sea level	1500 to 2500	30 to 200	1 to 30	Interval 2	Anticlines	Post-interval 4	Good	Munda 1, Munro 1, Willara 1, Willara Hill 1	Probably associated with salt diapirism.
Fig. 2.5.4.	Sea level	1500 to 2500		1 to 18	Interval 6	Fault anticlines	Post-interval 6	Fair to good	Lacepede 1, Wamac 1	Mostly fault-controlled closures.
Fig. 2.5.5.	Sea level	800 to 2000	50	2 to 50	Base 6	Faulted anticlines	Post-interval 6	Generally good	None	Small closures. Despite good data and adequate seismic coverage, control for individual closure insufficient.
Fig. 2.5.6.	Sea level	150 to 3500	Up to 200	3 to 75	? Base 5	Faulted anticlines	?Post-interval 5	Poor to fair	Minilya 1	Most of closures based on only one seismic line.

2.6 DRILLING

Between 1922 and 1974, 13 petroleum exploration companies drilled 80 wells. BMR drilled an additional 23 stratigraphic holes, mostly less than 300 m deep but four were over 500 m deep (Table 2.6.1). Much of the drilling was concentrated in the Fitzroy Graben. Supplementary shallow stratigraphic data is provided by numerous water-bores, of which most were drilled by landholders. No economic hydrocarbons were encountered and a dry-hole analysis is included in Chapter 8 (see Table 8.2).

Attention was first focussed on the Canning Basin in 1919, when Mr Harry Price reported an oil scum in a water-bore being sunk in the Prices Creek area (north Fitzroy Graben, Pl. 1). Mr T. Blatchford, a geologist with the Western Australian Mines Department, confirmed the presence of oil. Bore samples yielded up to 0.026 percent mineral oil. Mineral oil was also detected in a seepage in the same area.

The Freney Kimberley Oil Company Ltd was formed, and embarked on a four-well drilling program in the Prices Creek area in 1922-23. Prices Creek Nos 1, 2, and 3, shallow wells drilled in the lower Ordovician Emanual Formation (interval 1), all recorded oil shows. Prices Creek No. 4 was drilled south of a fault separating it from the other three wells and penetrated 122 m of Grant Formation (interval 4). The well encountered water but no oil. Further drill sites were picked using geological information.

Mount Wynne No. 1 was sited on the Mount Wynne Anticline and commenced drilling in 1922. Bitumen and asphalt recovered from cores was analysed as a true petroleum of the soft asphaltum type. Unable to deepen Mount Wynne No. 1, No. 2 was drilled nearby but abandoned at 19 m owing to drilling difficulties. Mount Wynne No. 3 spudded in 1923 and reached total depth of 657 m in 1925; globules of oil and bitumen were reported from several Permian sandstone horizons.

The Poole Range Anticline was tested between 1926 and 1933. Poole Range No. 2, a shallow pilot hole, encountered water but no hydrocarbons. However, Poole Range No. 3, a deeper test, recovered oil mixed with paraffin and asphalt; it was abandoned in 1930 owing to cementing failures that allowed

water to stand within 50 m of the surface. Poole Range No. 5 spudded 3 km east-northeast of the other wells in 1932. While it was being drilled the Freney Kimberley Oil Company Ltd went into voluntary liquidation and reformed as the Freney Kimberley Oil Company NL (FKO). The new company abandoned the well at a total depth of 995 m in the Grant Formation.

In 1937 the Commonwealth Government Oil Advisory Committee, appointed in 1936, recommended that the Fitzroy River area (Fitzroy Graben) be further tested. FKO started drilling Nerrima No. 1 in 1939 with a Government rig. Operations were suspended in 1942 at 1302 m, because of the war, without reaching the Devonian target. Work resumed in 1949, but was abandoned the next year without deepening the well.

West Australian Petroleum Pty Ltd (WAPET) was formed in the early 1950s and acquired most of the onshore basin under tenement. WAPET's first well, Grant Range No. 1, was to have been a deep Devonian test in the centre of the graben, but it was abandoned at 3936 m in the Carboniferous Anderson Formation (interval 3) after encountering only minor shows. Grant Range No. 1 was the first deep test in the basin (the deepest until 1965) and the first exploration well to drill through the Permian. WAPET drilled two follow-up dry holes, Fraser River Structure Hole and Fraser River No. 1, in 1955.

In 1954, Associated Australian Oilfields NL and FKO combined to form Associated Freney Oilfields NL (AFO), which drilled three anticlinal test wells in the Fitzroy Graben in 1955 to 1957. Two of these, Nerrima No. 1 and Sisters No. 1, recorded minor oil shows in the Permian (Table 2.6.1); formation tests in Nerrima No. 1 recovered only water and mud. The abandonment of Sisters No. 1 in 1957 marked the end of AFO's drilling operations in the basin.

Between 1955 and 1956 BMR drilled three stratigraphic wells - two within the Fitzroy Graben - to provide additional information in critical areas. Jurgurra Creek No. 1, located on the Jurgurra Terrace (Pl. 15), was the first well drilled south of the Fenton Fault (Pl. 1).

WAPET extended their operations south of the Fitzroy Graben in 1956 and drilled the first two wells on the Broome Arch (Pl. 15): Dampier Downs No. 1 and Roebuck No. 1 reached total depth in Ordovician limestone, erroneously interpreted as Devonian at the time, without encountering hydrocarbons. WAPET

spudded a stratigraphic hole, Wallal Core Hole, farther south near the coast in the south Canning Basin in 1957. BMR drilled two stratigraphic holes in the same area in 1958.

Most petroleum exploration wells drilled in the basin after 1957 were subsidised under the Petroleum Search Subsidy Acts. WAPET drilled the first subsidised well in the basin, Samphire Marsh No. 1, south of the Willara Sub-basin (Pl. 15) in 1958; intervals 2 and 3 were absent and the well reached basement without encountering hydrocarbons. WAPET further tested the Broome Arch in 1958, when it drilled Mount Alexander Core Hole and Goldwyer No. 1. Goldwyer No. 1 encountered oil shows from the Willara Formation and oil stain in the Goldwyer Formation (interval 1). Thangoo No. 1, drilled on the Broome Arch in 1959, encountered oil shows in both Permian and Ordovician sediments; WAPET abandoned it in Ordovician limestone when the hole collapsed, and sited Thangoo No. 1A nearby. Thangoo No. 1A encountered oil shows throughout the Ordovician section, but not in the Permian; nevertheless, WAPET considered the results from Thangoo No. 1A downgraded the Ordovician in the southern part of the Canning Basin, and no further tests were done on the Broome Arch until 1965.

WAPET drilled Meda No. 1 in the Fitzroy Graben in 1958. The well was the first of many to test a predicted Devonian reef play, and encountered shows more encouraging than any before or since. Several gallons of crude oil and salt water were recovered from sandstone in the Lower Carboniferous Laurel Formation (interval 3), but further testing proved the occurrence was not commercial. Oil stain and weak gas flows were also recorded in the underlying reef complex.

In 1959, WAPET drilled Meda No. 2 in the Fitzroy Graben, and Frome Rocks No. 1 on the Jurgurra Terrace. Meda No. 2, an unsubsidised test drilled close to Meda No. 1, was disappointing as formation tests recovered only gas-cut mud. Frome Rocks No. 1 reached total depth in salt without reaching its Ordovician objective. The salt was unexpected and the structure is now known to be a diapir - the only one drilled in the basin (Fig. 3.1.1). Frome Rocks No. 2 encountered dead oil shows, but did not penetrate the salt.

WAPET drilled 10 wells in various parts of the basin between 1960 and 1965. Although most wells were sited on seismically defined structures, few had any hydrocarbon shows. The Devonian reef complex was the principle target in the Fitzroy Graben, and potential reservoirs in the Permian and Ordovician were the principle targets on the Broome Arch. Sahara No. 1 was drilled in the Kidson Sub-basin (Pl. 15) and Willara No. 1, to the west, encountered thick Ordovician marine sediments below the Carribuddy Formation.

In the latter part of 1965, drilling started in the eastern part of the Fitzroy Graben. Continental Oil Company of Australia Ltd drillled St George Range No. 1 on the St George Anticline on a farmout from WAPET, and Australian Aquitaine Petroleum Pty Ltd (AAP) drilled Point Moody No. 1 on the Point Moody Anticline; neither well recorded significant shows. WAPET spudded Kidson No. 1 in the untested southeastern part of the basin to evaluate the southern Kidson Sub-basin.

In 1967 WAPET further tested the Devonian reef complex play with two wells - May River No. 1 and Blackstone No. 1 - both of which encountered minor hydrocarbon shows in interval 3. Blackstone No. 1, deepened to 3052 m as a stratigraphic test after encountering hard and dense Devonian limestone, encountered Ordovician rocks that previously had been proved only in the Prices Creek area of the Fitzroy Graben. In the same year Gewerkschaft-Elwerath drilled a dry hole, Yulleroo No. 1, in the southern part of the Graben on a farmout from WAPET. The well encountered minor gas shows, and was abandoned in interval 3 at 4575 m - the deepest in the basin.

Total Exploration Australian Pty Ltd embarked on a five-well program in 1968 to test seismically determined structures on and near the Broome Arch. All wells, except Mowla No. 1, bottomed deep in the Ordovician. The results were generally disappointing.

AAP drilled their second hole in the eastern Canning Basin in 1968. Wilson Cliffs No. 1 tested the northeastern edge of the Kidson Sub-basin without encountering significant hydrocarbon shows. It was the only well to intersect Proterozoic sediments above crystalling basement.

WAPET drilled three shallow wells in 1968. Doran No. 1 tested one of a series of en-echelon domes on the Jurgurra Terrace. Willara Hill No. 1 and Chirup No. 1 were spudded along the south coast. None of the wells encountered significant hydrocarbons.

Lennard Oil NL started a four-well program to test the Devonian reef complex in the northern part of the Fitzroy Graben in 1969. Only minor shows were recorded. Target reservoirs in the first three wells were flushed with fresh water, and reservoirs in the fourth were tight.

In 1970, BOC of Australia Ltd (BOCAL) acting as operator for a consortium consisting of Shell Development Pty Ltd, Woodside Oil NL, and BOCAL drilled the first offshore well, Lacepede No. 1A, which tested an anticline in the Fitzroy Graben. Although it encountered only traces of gas, it confirmed the presence of thick Jurassic and Cretaceous sediments offshore. BOCAL drilled Bedout No. 1, offshore in the Bedout Sub-basin, the following year.

WAPET put down four wells in the eastern Canning Basin in 1971: Crossland Nos 1, 2, and 3 were drilled as coreholes to obtain stratigraphic information on the pre-Permian of the Barbwire Terrace and the Broome Arch; and Lake Betty No. 1, in the graben, failed to encounter its Pillara Formation (interval 3) target, which was faulted out. Also in 1971, WAPET drilled Munda No. 1 to test a salt pillow structure south of the Broome Arch; the well encountered no oil shows, but confirmed the salt core. WAPET drilled Tappers Inlet No. 1 in 1971 and Pender No. 1 in 1972 near the north coast: the Devonian carbonate target at Tappers Inlet No. 1 was tight; and the target horizon at Pender No. 1 was flushed.

WAPET drilled seven other wells in 1972 and 1973 to evaluate structural or stratigraphic traps in various parts of the basin. No significant oil or gas shows were reported. In the same period, BMR completed 13 shallow stratigraphic holes in the northeastern Canning Basin and five shallow holes in the northern part of the Fitzroy Graben as part of a geological mapping project.

AAP's third well, Contention Heights No. 1, tested the eastern edge of the Kidson Sub-basin in 1973, and encountered only minor traces of gas.

In 1973, Hematite Petroleum Pty Ltd drilled Keraudren No. 1, on a farmout from BOCAL, to test the Triassic of the central part of the Bedout Sub-basin. In the same year Amax Petroleum Inc. put down Wamac No. 1 also on a farmout from BOCAL, to test the Palaeozoic in the graben near Lacepede No. 1A. Both wells were dry. Shell Development Pty Ltd drilled East Mermaid No. 1, again on a farmout from BOCAL, to a depth of 4068 m in the Rowley Sub-basin, but again significant hydrocarbons were not discovered.

In 1974, BOCAL drilled Minilya No. 1, an unsubsidised offshore test of a positive feature in the Bedout Sub-basin, without detecting significant hydrocarbons. WAPET drilled Jones Range No. 1, an unsubsidised well, in the graben; its Devonian carbonate target proved to be absent and the well was abandoned at 2540 m.

No wells were drilled in the basin in 1975 or 1976.

TABLE 2.6.1 EXPLORATION DRILLING

Legend:
* denotes subsidised well
target interval underlined
O = Oil, related indicators in brackets (F = fluorescence, S = stain)
G = Gas, carbon base in brackets (C_1, C_2, C_3, C_4)
S = Solid, related indicators in brackets (A - asphalt, B = bitumen)

Year	Name of well	Company	Station number (Appendix 12)	Sheet area	Total depth (m)	Intervals penetrated	HYDROCARBONS Intervals 11-7	6	5	4	3	2	1	Comments	Status
1922	Prices Creek 1	Freney Kimberley Oil Co. Ltd	124	Noonkanbah	307	1							0	Emanual Fm - traces of mineral oils, richest sample .01% petrol; petrol odour	Abandoned
1922	Prices Creek 2	Freney Kimberley Oil Co. Ltd	124	Noonkanbah	104	1							0	Emanual Fm - traces of mineral oil	Abandoned
1922-3	Mt Wynne 1	Freney Kimberley Oil Co. Ltd	74	Mt Anderson	273	4				S(A,B)				Grant Fm - asphalt and bitumen analysed as 86% petrolene, 13% asphaltene	Abandoned
1923	Prices Creek 3	Freney Kimberley Oil Co. Ltd	124	Noonkanbah	247	1							0	Emanual Fm - traces of oil, petrol odour over most of formation - probably mineral oil	Abandoned
1923	Prices Creek 4	Freney Kimberley Oil Co. Ltd	124	Noonkanbah	135	4, 3 Target not reached									Abandoned
1923	Mt Wynne 2	Freney Kimberley Oil Co. Ltd		Mt Anderson	18	4									Abandoned
1923-5	Mt Wynne 3	Freney Kimberley Oil Co. Ltd	74	Mt Anderson	657	11, 4				O, S(B)				Grant Fm C - globules of oil. Bitumen	Abandoned
1926-7	Poole Range 2	Freney Kimberley Oil Co. Ltd		Noonkanbah	320	4									Abandoned
1927-30	Poole Range 3	Freney Kimberley Oil	121	Noonkanbah	995	4				O, G				Grant Fm - brown oil on surface of artesian water had mixed paraffin and asphalt base. Analysed as 75% lubricating oil, 4.3% kerosene, rest asphalt and wax. Gas shows with minor quantities of light oil	Abandoned
1932-3	Poole Range 5	Freney Kimberley Oil Co. Ltd/Freny Kimberley Oil Co NL	121	Noonkanbah	471	4									Abandoned
1939-42/ 49-50	Nerrima 1	Freney Kimberley Oil Co. Ltd	69	Mt Anderson	1302	11, 4 Target not reached				G				Poole Fm - slight gas shows	Suspended/ abandoned
1954-55	Grant Range 1	West Australian Petroleum Pty Ltd.	62	Mt Anderson	3936	11, 4, 3				G, S(A,B)			G, S(A,B)	Grant Fm B) - bituminous material Grant Fm A) Anderson Fm) - fetid gas odour, fluorescence. Solid bituminous material. Trace of asphalt	Abandoned

Year	Name of well	Company	Station number (Appendix 12)	Sheet area	Total depth (m)	Intervals penetrated	HYDROCARBONS							Comments	Status
							Intervals								
							11-7	6	5	4	3	2	1		
1955	Nerrima 1	Associated Freney Oilfields NL	68	Mt Anderson	2765	4, 3				O, S(A)	S(B)			Grant Fm C - dead oil stain. DST 4, 5 recovered water. Asphalt Grant Fm B - dead oil stain. DST 2, 3 recovered water and mud Grant Fm A - core 7 asphalt. DST 1 recovered water Anderson Fm - traces of bitumen	Abandoned
1955	Jurgurra Creek 1	Bureau of Mineral Resources	32	Mt Anderson	512	11, 4									Abandoned
1955	Fraser River Structure Hole 1	West Australian Petroleum Pty Ltd	13	Derby	367	11, 6									Abandoned
1955-56	Laurel Downs 2	Bureau of Mineral Resources	100	Noonkanbah	1219	11, 4, 3									Abandoned
1955-56	Myrcodah 1	Associated Freney Oilfields NL	65	Mt Anderson	1829	4									Abandoned
1955-56	Fraser River 1	West Australian Petroleum Pty Ltd	12	Derby	3094	11, 6, 4, 3 Target not reached									Water well
1956	Prices Creek 3	Bureau of Mineral Resources	123	Noonkanbah	212	1, B									Abandoned
1956	Dampier Downs 1	West Australian Petroleum Pty Ltd	25	Mt Anderson	923	11, 6, 4, 1									Abandoned
1956	Roebuck Bay 1	West Australian Petroleum Pty Ltd	19	La Grange	1219	11, 8, 6, 4, 2, 1									Abandoned
1956-57	Sisters 1	Associated Freney Oilfields NL	59	Derby	2996	4, 3				O(S)				Clanmeyer Sltst - core 12 spot of live oil	Abandoned
1957	Wallal Core Hole 1	West Australian Petroleum Pty Ltd	235	Mandora	309	11, 8, 6									Water well
1958	Wallal 4	Bureau of Mineral Resources	234	Mandora	430	11, 8, 6									Abandoned
1958	Wallal 4A	Bureau of Mineral Resources	234	Mandora	678	11, 8, 6, 5, 4, B									Water well
1958	Samphire Marsh 1	West Australian Petroleum Pty Ltd	233	Mandora	2031	11, 8, 6, 4, 1, B Devonian target not intersected									Water well
1958	Meda 1*	West Australian Petroleum Pty Ltd	46	Derby	2685	11, 5, 4, 3, B				O, G(C_1)				Laurel Fm - recovered a few gallons of paraffin-based crude oil, oil stain and fluorescence in side-wall core. Weak gas flow Napier Fm - Gas in drilling mud. DST 2 had weak natural gas flow, recovered 100 MCF/day mainly methane gas. DST 3-5 recovered mud Pillara Fm - Brown oil stain. Gas in drilling mud. DST 6 recovered gas-cut water and mud	Abandoned

Year	Name of well	Company	Station number (Appendix 12)	Sheet area	Total depth (m)	Intervals penetrated	HYDROCARBONS Intervals 11-7	6	5	4	3	2	1	Comments	Status
1958	Goldwyer 1	West Australian Petroleum Pty Ltd	20	La Grange	1439	11, 8, 6, 4, 1, B					O(S, F)			Goldwyer Fm - oil staining and fluorescence. DST 1 dry Willara Fm - free oil in vugs core 11; small globules of oil and fluorescence core 13. DST 3 dry. DST 4-9 recovered salt water	Abandoned
1958	Mt Alexander Core Hole 1	West Australian Petroleum Pty Ltd	30	Mt Anderson	62	6									Abandoned
1959	Meda 2	West Australian Petroleum Pty Ltd	46	Derby	2325	11, 5, 4, 3					O(S), G			Laurel Fm - bleeding globules of brown oil; stain Nullara Lst - traces of gas with salt water, DST 3 recovered gas-cut mud and salt water. DST 4 recovered gas-cut mud and salt water	Abandoned
1959	Thangoo 1*	West Australian Petroleum Pty Ltd	21	La Grange	1059	11, 8, 6, 4, 1					O(S)		O(S)	Grant Fm C - oil stain, water flushed Goldwyer Fm - oil globules in dolomite vugs Willara Fm - oil stain and fluorescence	Abandoned
1959	Frome Rocks 1*	West Australian Petroleum Pty Ltd	34	Mt Anderson	1220	11, 6, 3, 2 Ordovician target not reached									Abandoned
1959	Frome Rocks 2*	West Australian Petroleum Pty Ltd	33	Mt Anderson	2287	11, 6, 4, 3 Ordovician target not reached					O(S,F)			Laurel Fm - dead brown oil stain Lulu'gui Fm - yellow fluorescence and cut	Abandoned
1959-60	Thangoo 1A*	West Australian Petroleum Pty Ltd	21	La Grange	1655	11, 8, 6, 4, 1 B							O(S)	Goldwyer Fm - live brown oil and viscous oil residue in dolomite veins Willara Fm - oil traces	Abandoned
1960	Barlee 1*	West Australian Petroleum Pty Ltd	16	Broome	2471	11, 8, 6, 3 Targets not reached					$G(C_1)$, S(B)			Anderson Fm - methane gas. Bitumen	Abandoned
1962	Babrongan 1*	West Australian Petroleum Pty Ltd	51	Mt Anderson	2469	11, 6, 4, 3 Devonian target not not reached					$G(C_1)$ S(B)			Grant Fm B - methane gas in lignitic shale from gas detector. Babrongan Beds - bitumen in dolomite.	Abandoned
1962	Hawkstone Peak 1*	West Australian Petroleum Pty Ltd	53	Derby	1188	11, 4, 3, 2, B								Fresh water flushed	Abandoned
1962	Brooking Springs 1	West Australian Petroleum Pty Ltd	95	Noonkanbah	161	3									Abandoned
1962	Langoora 1*	West Australian Petroleum Pty Ltd	45	Derby	1615	11, 5, 4, 3, B									Abandoned
1963	Tandalgoo 2	West Australian Petroleum Pty Ltd	214	Sahara	152	11, 8, 6, 4									Abandoned
1963	Tandalgoo 3	West Australian Petroleum Pty Ltd		Sahara	125	11, 8, 6, 4									Abandoned

Year	Name of well	Company	Station number (Appendix 12)	Sheet area	Total depth (m)	Intervals penetrated	HYDROCARBONS							Comments	Status
							Intervals								
							11–7	6	5	4	3	2	1		
1965	Sahara 1*	West Australian Petroleum Pty Ltd	215	Sahara	2120	11, 8, 6, 4, 3, 2									Abandoned
1965	Parda 1*	West Australian Petroleum Pty Ltd	229	La Grange	1907	8, 6, 4, 2, 1, B							O(S)	Goldwyer Fm – oil staining and fluorescence	Abandoned
1965	Willara 1*	West Australian Petroleum Pty Ltd	227	Munro	3903	11, 8, 6, 4, 2, 1				O(F), $G(C_1C_2C_3)$			$G(C_1)$	Grant Fm A – oil fluorescence. Methane gas 10 000 ppm, ethane gas 1000 ppm, propane gas 80 ppm. DST 1 recovered water Willara Fm – methane gas 2000 ppm	Abandoned
1965-6	St George Range 1*	Continental Oil Co. of Australia Ltd	108	Noonkanbah	4437	4, 3				G, S(B)	O(S), G, S(B)			Grant Fm C – bituminous shale. Cut and fluorescence and minor gas readings Anderson Fm – gas shows followed by salt water in fractured sandstone. Bituminous shale good cut and fluorescence. Laurel Fm – faint spotty oil stain. Gas show tested 102 MCF/day	Abandoned
1965-6	Point Moody 1*	Australian Aquitaine Petroleum Pty Ltd	189	Stansmore	2441	11, 4, 3				$G(C_1,C_2)$				Grant Fm C – gas not measured. DST 3 recovered salt water Grant Fm A – methane gas 1%, ethane gas 2%	Abandoned
1965-6	Kidson 1*	West Australian Petroleum Pty Ltd	204	Ural	4431	11, 8, 6, 4, 3, 2, 1									Abandoned
1967	May River 1*	West Australian Petroleum Pty Ltd	44	Derby	1678	11, 5, 4, 3, B					O(S), G			Laurel Fm – hydrocarbon staining, gas show	Abandoned
1967	Blackstone 1*	West Australian Petroleum Pty Ltd	58	Derby	3050	11, 5, 4, 3, 2, 1					O(S), $G(C_1,C_2)$ S(A,B)			Laurel Fm – minor shows methane and ethane gas. DST 1 recovered gas-cut mud Yellow Drum Sst – Bitumen traces in core 6 Nullara Lst – oily stain. Core 8 asphalt infill fractures	Abandoned
1967	Yulleroo 1*	Gewerkschaft Elverath Inc.	15	Broome	4572	11, 8, 6, 4, 3					G			Anderson Fm – DST 8 gas 12 MCF/day. DST 5 gas 48 MCF/day	Abandoned
1968	McLarty 1*	Total Exploration Australia	218	McLarty Hills	2591	11, 6, 4, 2, 1							O(F), S(B)	Goldwyer Fm – fluorescence, bituminous shale Willara Fm – pinpoint fluorescence, bituminous material	Abandoned
1968	Edgar Range 1*	Total Exploration Australia	26	Mt Anderson	1968	6, 4, 2, 1, B							O, G	Nita Fm – core 3 bled live oil and salt water. DST 1 recovered mud Goldwyer Fm – fluorescence Nambeet Fm – gas bubbles in vertical fractures. DST 2 tested dry	Abandoned
1968	Kemp Field 1*	Total Exploration Australia	216	Joanna Spring	1181	11, 6, 4, 3, 2					O(F)			Mellingerie Lst – core 2, 3 pinpoint yellow fluorescence. DST 1 recovered mud	Abandoned

Year	Name of well	Company	Station number (Appendix 12)	Sheet area	Total depth (m)	Intervals penetrated	HYDROCARBONS Intervals 11-7	6	5	4	3	2	1	Comments	Status
1968	Wilson Cliffs 1*	Australian Aquitaine Petroleum Pty Ltd	195	Wilson	3722	11, 6, 4, 3, 2, 1, B							G($C_1C_2C_3$), S(B)	'Middle Fm' - gas bubbles on core surface; methane through propane Nambeet Fm - yellow fluorescence, possible bitumen, rare methane gas	Abandoned
1968	Doran 1*	West Australian Petroleum Pty Ltd	35	Mt Anderson	763	11, 6, 4, 3 Devonian target not reached				S(B)				Grant Fm A - bituminous residue	Water well
1968	Willara Hill 1*	West Australian Petroleum Pty Ltd	228	Munro	858	11, 8, 6, 4									Abandoned
1968	Chirup 1	West Australian Petroleum Pty Ltd	236	Mandora	763	11, 8, 6, 4									Abandoned
1969	Matches Springs 1*	Total Exploration Australia	67	Mt Anderson	2835	11, 6, 4, 3, 2, 1 Lower Ordovician target not reached							O(F)	Nita Fm - cutting showed weak fluorescence. Tested dry	Abandoned
1969	Mowla 1*	Total Exploration Australia	29	Mt Anderson	762	11, 6, 4, 3 Target not reached				S(B)				Grant Fm A - traces of bituminous material	Abandoned
1969	Napier 1*	Lennard Oil NL	52	Lennard	1801	3, 2, B					S(B)			Poulton Fm - pyrobitumen	Abandoned
1969	Napier 2*	Lennard Oil NL	47	Derby	1607	11, 3, 2, B				S(B)	G(C_1)			Nullara Fm - traces of bitumen Poulton Fm - small amounts of methane gas	Abandoned
1970	Napier 4*	Lennard Oil NL	43	Yampi	965	4, 3, 2, B									Abandoned
1970	Napier 5*	Lennard Oil NL	48	Derby	1657	3, 2, B				G(C_1)	G(C_1)			Nullara Fm - methane gas show Poulton Fm - minor methane gas	Abandoned
1970	Lacepede 1A*	BOC of Australia Ltd	3	Offshore E51/5	2287	11, 9, 8, 7, 6, 3	G(C_1)			G(C_1C_2)				Jurassic - methane gas up to 600 ppm, no fluorescence Anderson Fm - methane gas 2000 ppm, ethane gas 15 ppm	Abandoned
1971	Bedout 1*	BOC of Australia Ltd	239	Offshore E52/12	3073	11, 10, 9, 8, 7, 6, 5									Abandoned
1971	Tappers Inlet 1*	West Australian Petroleum Pty Ltd	5	Pender	2856	10, 8, 6, 4, 3, 2, 1, B				O			O, G($C_1C_2C_3$)	Pillara Fm - oil bleeding from core slice 4 Gap Creek Fm - oil bleeding from core slice 1, 2, 3; fluorescence in other core slices. Methane, ethane, and propane gases	Abandoned
1971	Crossland 1*	West Australian Petroleum Pty Ltd	155	Crossland	913	11, 6, 4, 3									Abandoned
1971	Crossland 2*	West Australian Petroleum Pty Ltd	156	Dummer	914	11, 6, 4, 2									Abandoned
1971	Crossland 3*	West Australian Petroleum Pty Ltd	157	Dummer	915	11, 4, 3									Abandoned
1971	Lake Betty 1*	West Australian Petroleum Pty Ltd	154	Mt Bannerman	3146	4, 3, 2 Ordovician target not reached				G(C_1C_2)				Yellow Drum Sst - methane and ethane gas show. DST 1 recovered 37 m gas-cut mud	Abandoned

Year	Name of well	Company	Station number (Appendix 12)	Sheet area	Total depth (m)	Intervals penetrated	HYDROCARBONS Intervals 11-7	6	5	4	3	2	1	Comments	Status
1971	Munda 1*	West Australian Petroleum Pty Ltd	219	Munro	1067	8, 6, 4, 2									Abandoned
1972	Pender 1*	West Australian Petroleum Pty Ltd	8	Pender	912	10, 8, 6, 4, B Target not present									Abandoned
1972	Palm Spring 1*	West Australian Petroleum Pty Ltd	80	Lennard River	1067	11, 4, 3									Abandoned
1972	Barbwire 1*	West Australian Petroleum Pty Ltd	111	Crossland	1071	6, 4, 3, 2, 1									Abandoned
1972	Munro 1*	West Australian Petroleum Pty Ltd	220	Munro	2116	8, 6, 4, 2, 1, B							O(F)	Willara Fm - fluorescence and cut	Abandoned
1972	Logue 1*	West Australian Petroleum Pty Ltd	36	Mt Anderson	2699	11, 6, 4, 3			O(S), $G(C_1C_2)$					Grant Fm A - side-wall core 15 brown oil stain calculated 86% water-saturated. Methane gas 63 ppm, trace ethane	Abandoned
1972	Billiluna 1	Bureau of Mineral Resources	172	Billiluna	123	4									Abandoned
1972	Lennard River 1	Bureau of Mineral Resources	89	Lennard River	63	3									Abandoned
1972	Lennard River 2	Bureau of Mineral Resources	92	Lennard River	69	4, 3									Abandoned
1972	Noonkanbah 1	Bureau of Mineral Resources	127	Noonkanbah	155	3									Abandoned
1972	Noonkanbah 4	Bureau of Mineral Resources	99	Noonkanbah	69	3									Abandoned
1972	Noonkanbah 5	Bureau of Mineral Resources	125	Noonkanbah	69	3									Abandoned
1973	Thangoo 2*	West Australian Petroleum Pty Ltd	22	La Grange	1472	11, 8, 6, 4, 1, B			O(F)				O(F)	Grant Fm A - side-wall cores 13-16 have fluorescence and cut calculated 76% water-saturated. Willara Fm - cores 1, 2, 3, have fluorescence and cut	Abandoned
1973	Mimosa 1*	West Australian Petroleum Pty Ltd	60	Lennard River	4177	11, 5, 4, 3 Middle Devonian target not reached			O(S) $G(C_1C_2C_3C_4)$ S(A)					Gogo Fm Equiv - oil stain, fluorescence and cut; gas: methane through butane. DST 2 recovered gas-cut mud with small oil film. Core 1 has bituminous odour, fluorescence and cut. Asphaltic residue.	Abandoned
1973	Mt Hardman 1*	West Australian Petroleum Pty Ltd	79	Noonkanbah	3360	4, 3			O(S) $G(C_1C_2C_3C_4)$					Laurel Fm - oil stain; cut and fluorescence; gas: methane through butane	Abandoned
1973	Contention Heights 1*	Australian Aquitaine Petroleum Pty Ltd	196	Wilson	1791	11, 6, 4, 3, 2, 1							$G(C_1)$	Goldwyer Fm) Middle Fm)- traces of methane Nambeet Fm) gas 0.1%	Abandoned
1973	East Mermaid 1	Shell Development Pty Ltd	1	Offshore E50/8	4068	11, 10, 9, 8, 7, 6	G	G						Cretaceous - gas less than 600 ppm Jurassic - methane gas less than 100 ppm	Abandoned

Year	Name of well	Company	Station number (Appendix 12)	Sheet area	Total depth (m)	Intervals penetrated	HYDROCARBONS Intervals 11-7	6	5	4	3	2	1	Comments	Status
1973	Wamac 1*	Amax Petroleum (BOC)	2	Offshore E51/5	2764	11, 9, 8, 7, 6, 3					$G(C_1C_2)$			Anderson Fm? - methane gas 800 ppm ethane gas 35 ppm	Abandoned
1973	Keraudren 1*	Hematite Petroleum Pty Ltd	238	Offshore E50/12	3844	11, 10, 9, 8, 7, 6, 5		$G(C_1)$	$G(C_1)$					Jurassic - methane gas 600 ppm Triassic - methane gas 1100 ppm	Abandoned
1973	Billiluna 3	Bureau of Mineral Resources	170	Billiluna	151	3									Abandoned
1973	Cornish 1	Bureau of Mineral Resources	162	Cornish	164	11, 4									Abandoned
1973	Cornish 2	Bureau of Mineral Resources	163	Cornish	227	11, 5									Abandoned
1973	Cornish 3	Bureau of Mineral Resources	174	Cornish	99	11, 4									Abandoned
1973	Crossland 1	Bureau of Mineral Resources	145	Crossland	262	11, 4									Abandoned
1973	Crossland 2	Bureau of Mineral Resources	115	Crossland	139	4									Abandoned
1973	Lucas 13	Bureau of Mineral Resources	178	Lucas	189	5									Abandoned
1973	Lucas 14	Bureau of Mineral Resources	176	Lucas	102	4									Abandoned
1973	Mt Bannerman 1	Bureau of Mineral Resources	165	Mt Bannerman	203	11, 4									Abandoned
1973	Mt Bannerman 2	Bureau of Mineral Resources	144	Mt Bannerman	139	11, 4									Abandoned
1973	Mt Bannerman 3	Bureau of Mineral Resources	167	Mt Bannerman	94	11, 4									Abandoned
1973	Mt Bannerman 4	Bureau of Mineral Resources	166	Mt Bannerman	151	11, 4									Abandoned
1974	Minilya 1	BOC of Australia Ltd	240	Offshore E50/12	2400										Abandoned
1974	Jones Range 1	West Australian Petroleum Pty Ltd	118	Crossland	2509	6, 4, 3			$G(C_1)$		O(F), S(B)			Grant Fm A - methane gas 80 ppm - Fresh water flushed Anderson Fm - minor fluorescence and traces of bitumen Laurel Fm - traces of bituminous stain	Abandoned

Three wells drilled by BOCAL outside the Canning Basin have also been referred to in this study; they are Leveque No. 1 ($15^{o}45'12"S$, $122^{o}00'18"E$) and Lynher No. 1 ($15^{o}56'25"S$, $121^{o}04'59"E$) in the southern Browse Basin, and Picard No. 1 ($18^{o}58'00"S$, $117^{o}37'21"E$) in the Carnarvon Basin.

3. GEOPHYSICAL INTERPRETATION

3.1 SEISMIC

Fifty-seven petroleum exploration wells provided the subsurface control for the tracing of the bases of the 11 Phanerozoic sedimentary intervals (see Section 1.8) on seismic-record sections (Pl. 5). Seismic velocities were used to convert the depths of the bases into two-way travel times, and the bases were then plotted onto the seismic-record section. The interval bases were then traced from the wells. When direct control was not available, interval velocities and such geological features as angular unconformity, salt anticlines, and possible reef structures were used to predict the identity of horizons.

The seismic interpretations of intervals in each of the major structural divisions onshore (Section 1.5, Pl. 15) and in the offshore part of the basin are discussed below.

3.1.1 Willara Sub-basin

In Munro No. 1, base 1 (i.e. the seismic horizon at the base of interval 1) is at the interface between sedimentary and crystalline rocks, from which a strong seismic reflection has been recorded. The southward-thinning interval 1 (Pl. 10-1) is downfaulted to the south across the Munro Fault (Pl. 13-1; WAPET, 1970 m), which appears to have been active before and after the deposition of interval 2 sediments. The weakening of the seismic reflection associated with base 1 to the southeast may indicate a change in basement lithology.

A strong and continuous reflection represents base 2 except along the southern margin of the sub-basin, where interval 2 thins out before it reaches the basin margin. Many small anticlines (about 3 km across) have a core of interval 2 material with an estimated interval velocity of 4000 m/s, similar to the velocity of the salt sequence in Willara No. 1. These structures were interpreted as salt anticlines (Fig. 3.1.1). As many of them are near the

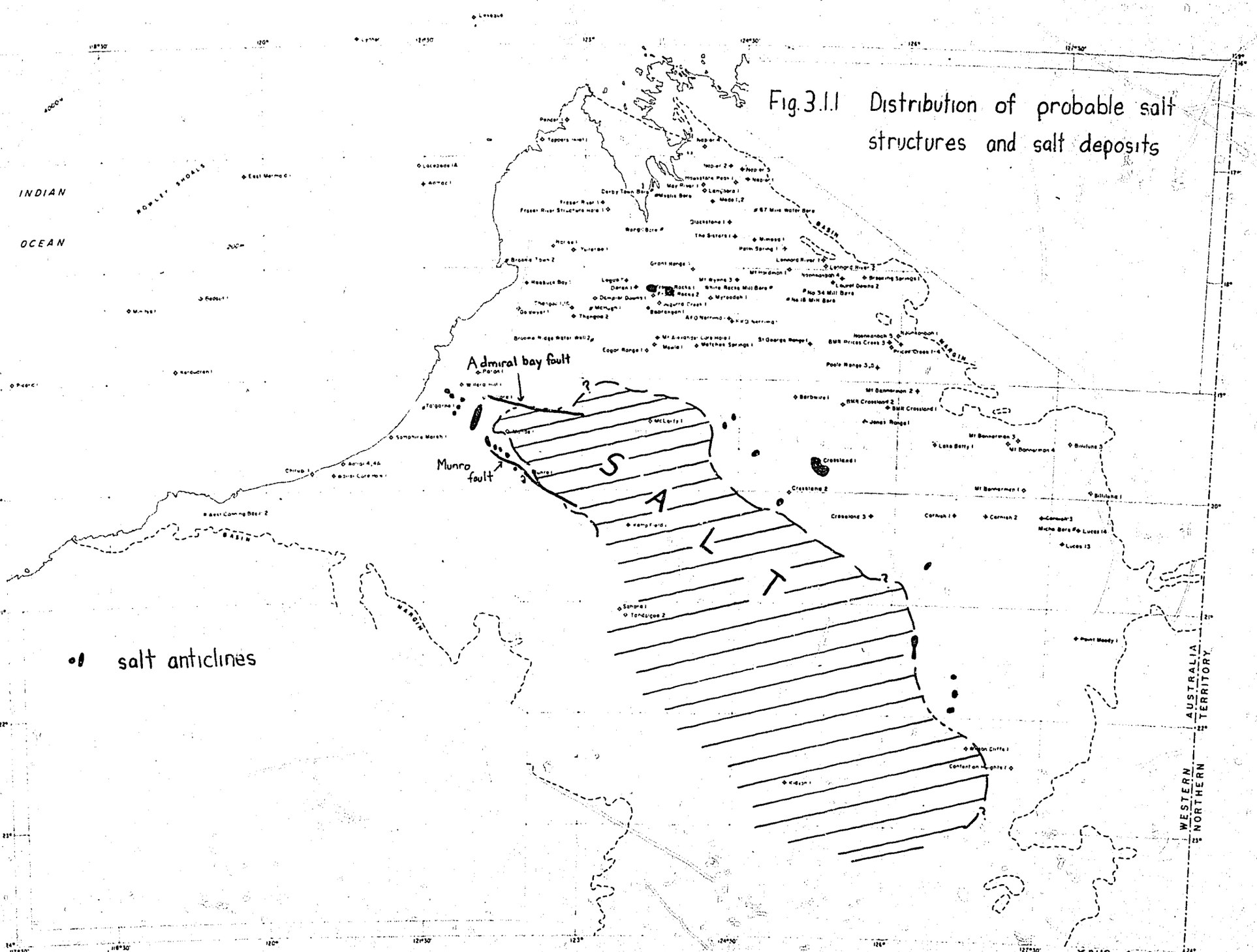


Fig. 3.1.1 Distribution of probable salt structures and salt deposits

Record 1979/32

TABLE 3.1.1.1. WELL CONTROL AND SEISMIC EVENTS

Base	Well control	Remarks
1	Munro No. 1, Samphire Marsh No. 1	Strong seismic reflection weakens south and south-eastward
2	Munro No. 1, Willara No. 1	Strong and continuous reflection
3	-	Absent
4	Munda No. 1, Munro No. 1, Samphire Marsh No. 1, Willara No. 1	Moderately strong reflection with angular unconformity
5.	-	Absent
6	Munda No. 1, Munro No. 1, Samphire Marsh No. 1, Willara No. 1	Very shallow, indicates unconformity
7,8,9, 10,11	-	Unknown or absent

Munro Fault, the salt migration may be due to renewed movement along the fault, which also displaced base 2. In the area of salt diapirism, the upper part of interval 2 and all of interval 4 have been folded.

Base 4, characteristically an angular unconformity, was traced without difficulty, even though a strong reflection from the top of the lowest member of the Grant Formation (interval 4) commonly locally masks the moderately strong reflection from it.

The generally shallow base 6 marks the boundary between the folded interval 4 and the flat-lying interval 6, showing that the salt anticlines had been emplaced, probably in the Late Triassic, before interval 6 sediments were deposited.

To the south, the seismic-record quality deteriorates as the sedimentary section thins.

3.1.2 Kidson Sub-basin

TABLE 3.1.2.1. WELL CONTROL AND SEISMIC EVENTS

Base	Well control	Remarks
1	Wilson Cliffs No. 1	Moderately strong reflection in the west to non-existent over the centre and eastern margin
2	Kidson No. 1, McLarty No. 1, Wilson Cliffs No. 1	Strong to moderately strong reflection except in the Wilson and most of the Ryan 1:250 000 Sheet areas
3	Kidson No. 1, Kemp Field No. 1, Sahara No. 1, Wilson Cliffs No. 1	Weak to moderately strong reflection within a limited extent
4	As for base 3	Moderately strong to strong reflection
5	-	Absent
6	Kidson No. 2, Sahara No. 1	Traced only within a radius of about 75 km from Kidson No. 1
7,8,9, 10,11	-	Absent

As with the Willara Sub-basin, the reflection from base 1 in the Kidson Sub-basin weakens before it eventually disappears to the southeast: this weakening is probably associated with the transition of the rocks beneath interval 1 from crystalline to sedimentary. From the Kidson Sub-basin, base 1 shallows gradually to the north. The boundary separating the sub-basin from the Broome Arch is uncertain.

A continuous strong reflection from the interface between the Tandalgoo Red Beds and the Carribuddy Formation of interval 2 persists over a large area and was used effectively as a marker horizon in correlating data on discontinuous seismic-record sections. Although wells drilled in the Kidson Sub-basin have penetrated thick salt sequences in interval 2, there is no evidence of salt structures within the sub-basin except in the southeastern corner of the Morris 1:250 000 Sheet area, where a salt anticline probably occurs in ?Proterozoic sediment unconformable beneath interval 1.

Except in the area near Kidson No. 1, base 3 was identified using an intra-interval 2 reflection as a marker horizon.

Base 4 is generally associated with a moderately strong to strong reflection and is typically along an angular unconformity at the margin of the sub-basin. Where direct well control was lacking and data could not readily be correlated, it was picked at a level that indicated an angular unconformity.

Southward, the sediments thin and extend beyond 24°S, into the Officer Basin.

3.1.3 Broome Arch

Refraction seismic profile 69-RC2 (Pl. 5) was used to correlate data from Wilson Cliffs No. 1 (in the Kidson Sub-basin) to the Helena 1:250 000 Sheet area where only rough depths to interval boundaries could be determined. The generally weak and discontinuous reflections have resulted in the difficulty of tracing base 1 in this area. Base 2 is a moderately strong reflector below a stronger reflector which probably marks the top of the Carribuddy Formation. Several small anticlinal features may be reef structures in interval 3 (Drew & Evans, 1975), but most of them appear to be velocity anomalies generated at or near the surface. Base 4 was traced along the shallowest reflection indicating local angular unconformities (Pl. 14, section A-A^1).

TABLE 3.1.3.1. WELL CONTROL AND SEISMIC EVENTS

Base	Well control	Remarks
1	Goldwyer No. 1, Thangoo Nos. 1A and 2, Edgar Range No. 1	Moderately strong reflection in the west to non-existent in the east
2	Edgar Range No. 1	Weak to moderately strong reflection
3	Mowla No. 1	Weak to non-existent reflection
4	Goldwyer No. 1, Thangoo Nos. 1A and 2A, Dampier Down No. 1, Edgar Range No. 1, Crossland No. 2, Roebuck Bay No. 1	Moderately strong to strong reflection associated with angular unconformity
5	-	Absent
6	As for base 4	Generally weak reflection at shallow depth
7,8,9, 10,11	-	Unknown or absent

In the Crossland and Dummer 1:250 000 Sheet areas the three most prominent reflections have been interpreted as an horizon in interval 1, base 2, and base 4. A reflection associated with a velocity change from about

3200 m/s to 4900 m/s, similar to that recorded at the base of the Carribuddy Formation in Barbwire No. 1 (Barbwire Terrace), probably represents base 2. Base 4 is characterised by an angular unconformity.

Probable salt anticlines in the Broome Arch are evident in the Dummer, Crossland, McLarty Hills, and Helena 1:250 000 Sheet areas (Fig. 3.1.1.), and features attributed to collapse structures, probably as a result of salt leaching, are evident in the Mount Anderson and the northern part of the McLarty Hills 1:250 000 Sheet areas. Data below base 4 in the Mount Anderson Sheet area are generally poor, and the levels of base 1, base 2, and base 3 were obtained largely from phantom tracing. Within the Broome Arch, interval 3 is evident only in Mowla No. 1, but no seismic reflection appears to be associated with its base.

In La Grange Sheet area, the reflection from the top of the Willara Formation (interval 1) is prominent. Base 2 was traced from Parda No. 1 and Willara No. 1 (in the Willara Sub-basin) on a moderately strong seismic event which shallows rather rapidly to the north before being truncated by base 4 (Pl. 14, section D-D^1).

Onshore and offshore seismic events were difficult to correlate owing to the lack of direct ties and the generally poor data along the coast. Only regional trends are apparent, and the Mesozoic sediments thicken markedly to the northwest as the Palaeozoic rocks gradually become thinner (Pl. 14, section F-F^1).

The Broome Arch is separated from the Willara Sub-basin by the Admiral Bay Fault (Pl. 15), which has been interpreted from geophysical data and was active probably from the early Palaeozoic to the Early Permian.

3.1.4 Jurgurra Terrace

Only bases 4 and 6, both indicating angular unconformities, were traced successfully in the Jurgurra Terrace. The absence of any discernible reflection below base 4 east of Shallow Well (Pl. 1) is probably due to the presence of a thick high-velocity carbonate section at the top of interval 3. Elsewhere on the terrace, reflections from below base 4 indicate that the pre-Permian

TABLE 3.1.4.1. WELL CONTROL AND SEISMIC EVENTS

Base	Well control	Remarks
1	-	Unknown
2	Matches Springs No. 1	Traced only a short distance from the well on a very weak reflection
3	Matches Springs No. 1	No reflection
4	Matches Springs No. 1, Babrongan No. 1, Logue No. 1, Doran No. 1, Frome Rocks Nos. 1 and 2	Generally associated with moderately strong reflection showing angular unconformity
5	-	Absent
6	As for base 4	Shallow; associated with a weak to moderately strong reflection, which in places indicates angular unconformity
7,8,9, 10,11	-	Either absent or shallow

rocks are faulted and folded into a number of anticlines and synclines. Of these, an anticline bounded both to the north and south sides by faults lies (line K, Pl. 5) about 20 km east of Frome Rocks No. 1. Proximity and similarity of shape to the structure drilled by Frome Rocks No. 1 suggest that the two structures have a similar origin (Fig. 3.1.1.).

The Fenton Fault (Pl. 15) marks the northern boundary of the Jurgurra Terrace. In Mount Arthur and Mount James it displaces the base of Permian sediments to the north (Casey, 1958a; Wiebenga & Van der Linden, 1953) by about 1600 m. The fault extends to the west, to within 2 km north of Frome Rocks No. 1 and Doran No. 1 and probably to about 6.5 km north of Logue No. 1, with a decreasing magnitude of displacement. Farther to the west, several faults cut base 4, but the identity of the Fenton Fault is difficult to ascertain.

To the south the Jurgurra Terrace is separated from the Broome Arch by the pre-Permian Dampier Fault (Veevers & Wells, 1961), which displaces the pre-Permian rocks to the north by about 1000 m (Pl. 14, section C-C^1) near Mount Bullen (Pl. 1). Available seismic data are too poor to exactly locate the eastern extension of the Dampier Fault. East of Matches Springs No. 1, the area between the Fenton Fault and the Dampier Fault narrows, and the basement rises eastward to a depth of less than 2000 m. This shallow basement separates the Jurgurra Terrace from the Barbwire Terrace in the southeast.

3.1.5. Barbwire Terrace

The Barbwire Terrace is separated from the Broome Arch by the Dummer Range Fault (WAPET, 1970 f) which - like the Dampier Fault - is a pre-Permian fault displacing base 2 by as much as 2000 m (Fig. 6.2.2.2; Pl. 14, section B-B^1).

In the Crossland No. 1 area, base 2 was traced on a reflection across which the calculated interval velocity increases by the same order as that measured at the base of the Carribuddy Formation (from 3200 m/s to 4900 m/s) in Barbwire No. 1. Base 3 was traced on a moderately strong reflection near to a level at which there is a change in interval velocity similar to that measured at the top of the Tandalgoo Red Beds (from 5000 m/s to 3000 m/s) in Barbwire No. 1; this reflection, however, fades out about 7 km north of Crossland No. 1, probably as a result of a change in lithology.

Pre-Permian sediments generally dip to the north, except near Crossland No. 1 immediately north of the Dummer Range Fault, where rocks of interval 3 and the upper part of interval 2 dip to the south at about 15° against the fault (Fig. 6.2.2.2). Here, base 2 is almost flatlying, and a pillow-like structure in interval 2 is probably a salt anticline.

TABLE 3.1.5.1. WELL CONTROL AND SEISMIC EVENTS

Base	Well control	Remarks
1	-	Unknown
2	Barbwire No. 1	Data within 20 km of Barbwire No. 1 are too poor for a direct tie to the well
3	Barbwire No. 1	As for base 2
4	Barbwire No. 1, Crossland Nos. 1 and 3	Strong reflection within 50 km of Crossland No. 1 weakens northward and southeastward; angular unconformity
5	-	Absent
6	As for base 4	Very shallow; no discernible reflection
7,8,9, 10,11	-	Absent or unknown

A strong seismic event indicating an angular unconformity represents base 4. Reflection from base 4 weakens as it dips to the north. Many faults cut the terrace, but only a few of them intersect base 4: the one displacing base 4 with the largest throw is probably the southeastern extension of the Fenton Fault. In the Cornish and eastern part of the Dummer 1:250 000 Sheet area, the Dummer Range Fault and the Fenton Fault cannot be mapped with certainty owing to poor seismic data, but the two fault systems appear to converge into a single fault zone at the southeastern limit of the Barbwire Terrace.

3.1.6 Fitzroy Graben

TABLE 3.1.6.1. WELL CONTROL AND SEISMIC EVENTS

Base	Well control	Remarks
1	-	Unknown
2	-	Unknown
3	Lake Betty No. 1	No associated seismic reflection
4	Point Moody No. 1, Jones Range No. 1, St George Range No. 1, Nerrima No. 1, Grant Range No. 1, Fraser River No. 1, Yulleroo No. 1, Barlee No. 1, Lake Betty No. 1	Weak to moderately strong reflection; angular unconformity in Lake Betty area
5	-	Moderately strong reflection
6	Fraser River No. 1, Yulleroo No. 1, Barlee No. 1	Only in the western part of the graben; moderately-strong to strong reflection; angular unconformity
7,8,9, 10,11	-	Absent or unknown

The most prominent seismic event in the Broome and Derby 1:250 000 Sheet areas is the reflection from an unconformity between the almost flat-lying sediments of interval 6 and the folded older rocks (Pl. 14, section D-D[1]). Of the many anticlines below this unconformity, the Baskerville and the Barlee

Anticlines are the largest; the Baskerville Anticline extends east from about 40 km offshore to Fraser River No. 1 (Pl. 13-4). The thick Permo-Carboniferous sediments intersected in Fraser River No. 1, and probably the Devonian sediments too, thin to the north away from the axis of the Baskerville Anticline (Fig. 3.1.2); this suggests that the anticline developed in a depocentre, probably in the Late Triassic.

A continuous and moderately strong conformable reflection representing base 5 persists from the Lennard Shelf to the Fitzroy Graben. In the deeper part of the graben, base 4 is also conformable and is a weak to moderately strong reflection. Seismic data in the Grant Range area are poor and no direct tie to Grant Range No. 1 has been established.

In the northeastern corner of the Crossland 1:250 000 Sheet area, seismic data are generally poor. Farther east, in the western part of the Mount Bannerman Sheet area, near Lake Betty, the seismic data indicate an angular unconformity at base 4, although the continuity of seismic events is badly affected by severe faulting in this area.

In the Stansmore and Cornish Sheet areas, three seismic surveys have provided only a sparse coverage. Subsurface control (Point Moody No. 1) is available only for base 4, which was traced on a weak to moderately strong reflection. Here, base 1 was taken at the lowest strong but continuous reflection, for which the maximum depth is estimated to be 8 km (Pl. 13-1). At the northern end of seismic line 68-R1 and the eastern end of line 68-R2 (Pl. 5), this reflection shallows rapidly to the east, suggesting that the basement rises steeply toward the edge of the basin; on line 68-R1, the dip is about 22° to the west.

Many of the faults in the Stansmore and Cornish areas, as indicated on the structure contour map for base 4 (Pl. 13-4), have been mapped at the surface (Yeates & others, 1975b). One of these is the Stansmore Fault, which intersects seismic line 72-D in the Cornish Sheet area and line 72-SR2 in the Stansmore Sheet area. This fault was taken as the line separating the central graben from the Betty Terrace to the north.

3.1.7 Betty Terrace

The absence of well control, and the sparse seismic coverage, have left the Betty Terrace as one of the least-explored areas in the Canning Basin. Base

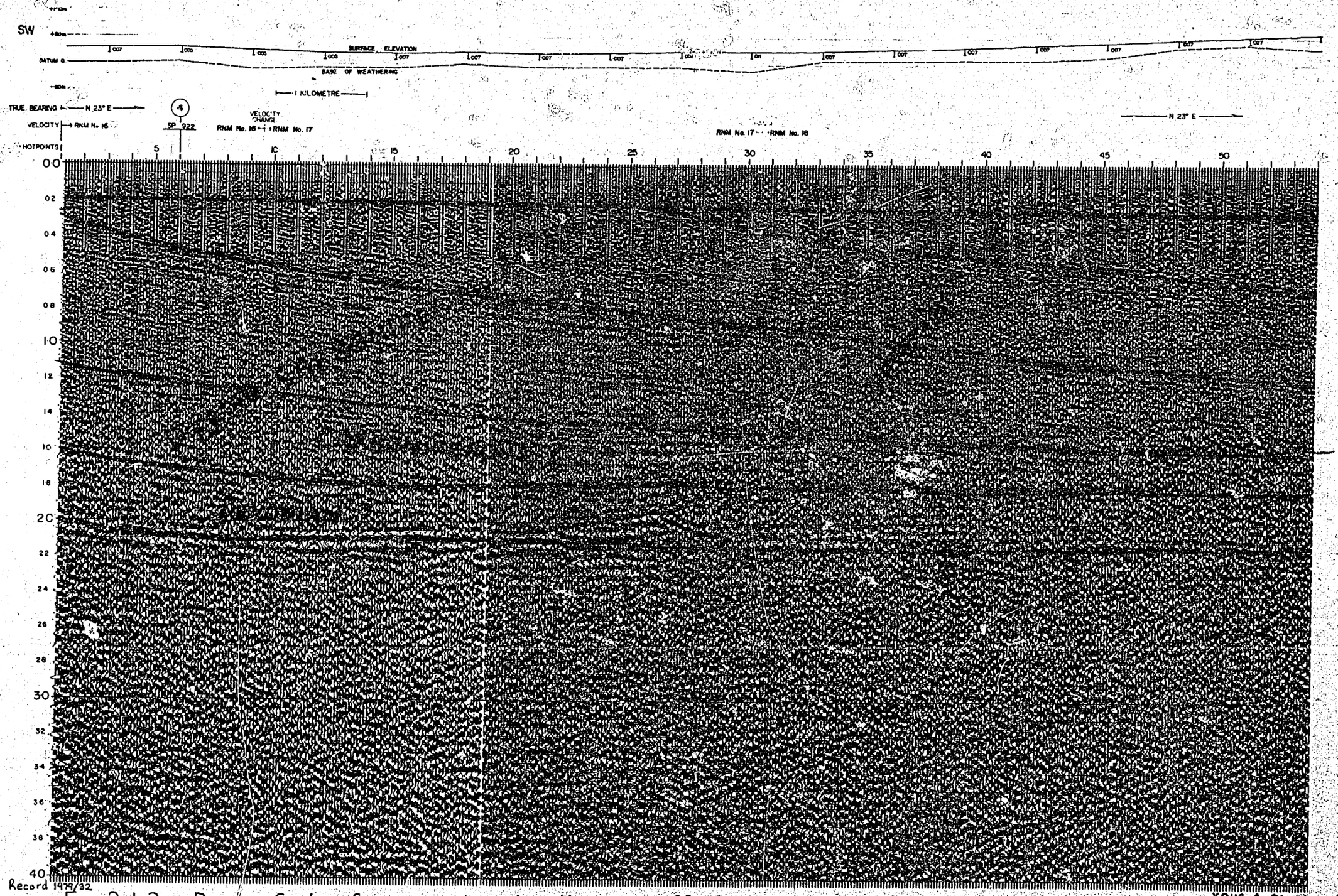


Fig. 3.1.2 Permo-Carboniferous sediments thinning off Baskerville anticline, along line 70-T

4 was traced from the Helena sheet area on a generally discontinuous, though in places strong, seismic event.

In the Billiluna sheet area, the depth to base 1 was estimated from the depth to the lowest, in places strong, primary reflection. North of Mount Mueller, at the northern end of line 72-B (Pl. 5), a possible low-angle fault separates a thick sequence of sediment in the south from an area devoid of seismic reflections, which is probably underlain by crystalline basement; the southward dip of this possible fault is about 20°. Instead of being faulted, though, the attitude of the basement may be similar to that in the Stansmore 1:250 000 Sheet area (section 3.1.6) - i.e., steeply inclined.

3.1.8 Margaret Terrace

TABLE 3.1.8.1 WELL CONTROL AND SEISMIC EVENTS

Base	Well control	Remarks
1	-	Moderately strong discontinuous reflection
2	Blackstone No. 1	Moderately strong reflection, weakens to the southeast
3	Blackstone No. 1	Strong reflection over the Blackstone structure; diminishes southeastward
4	Blackstone No. 1, Sisters No. 1, Mimosa No. 1, Palm Springs No. 1, Mt Hardman No. 1	Moderate to strong reflection; some angular unconformity
5	Blackstone No. 1, Mimosa No. 1	Moderately strong and continuous reflection
6,7,8,9, 10,11	-	Absent

Similar to the terraces adjoining the southern margin of the graben, the Margaret Terrace contains a thick (about 4 km) interval 3 mainly of Late Devonian age. To the south, the terrace is separated from the graben by the Pinnacle Fault System (Pl. 15).

The shallow-lying base 5 was traced only to the west of Mimosa No. 1 (Pl. 13-5), on a continuous, generally moderately strong event. In the shallow part of the terrace, base 4 represents an unconformity at the top of a high-velocity Upper Devonian carbonate sequence from which a strong reflection has been recorded.

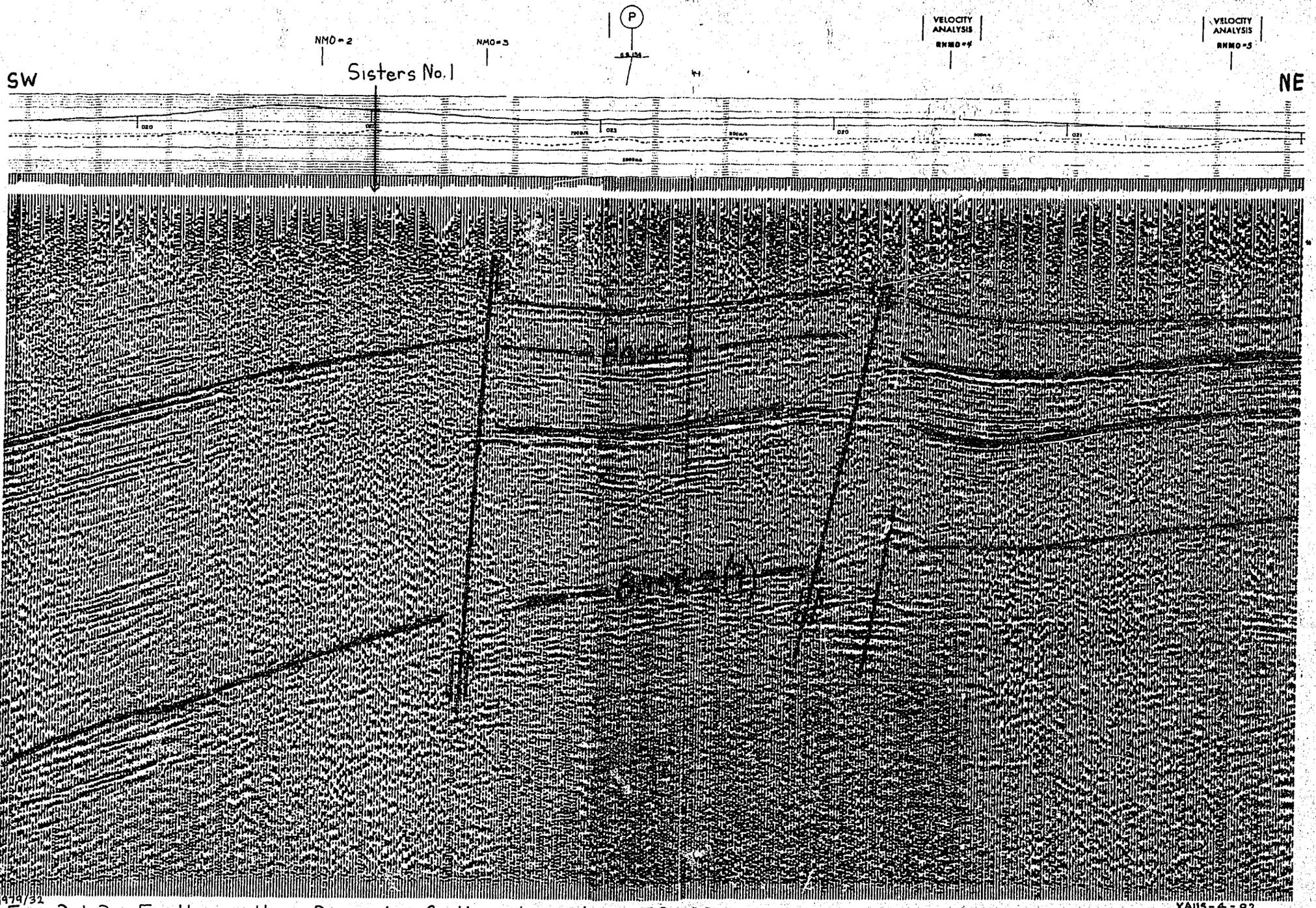
In the area near Blina (Pl. 1) and Mimosa No. 1, an angular unconformity also occurs in interval 3, between rocks of Frasnian and Famennian age. This unconformity coincides with base 3 in Blackstone No. 1, which was drilled on a pre-Upper Devonian homoclinal structure. In the deeper part of the terrace, base 3 was traced on a weak reflection which fades out farther to the southeast.

From Blackstone No. 1, base 2 was traced on a moderately-strong reflection corresponding to a change in interval velocity (from 4100 m/s to 4700 m/s) as measured at the base of the Poulton Formation in the well.

The depth to crystalline basement in the Blackstone structure was estimated from magnetic data. This estimate was used to establish the depth to base 1, which was then traced over a small part of the terrace on a generally discontinuous reflection. Base 1 dips to the southeast and data quality deteriorates in this direction.

To the north, the Margaret Terrace is bounded by the Markham Fault (Pl. 13-1), which appears to be either a low-angle (about 23°) normal fault or the expression of a steeply dipping basement similar to that in the Stansmore and Billiluna Sheet areas.

Sisters No. 1 was drilled on a Late Triassic anticline immediately south of a fault in the Pinnacle Fault System. At depth, the fault is normal - pre-Permian sediments to the south are on the downthrow side - but at and above base 4 it is reverse (Fig. 3.1.3).



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Fig. 3.1.3 Faults in the Pinnacle fault system, line 70-AF

3.1.9 Lennard Shelf

TABLE 3.1.9.1 WELL CONTROL AND SEISMIC EVENTS

Base	Well control	Remarks
1	Tappers Inlet No. 1	No reflection
2	Meda No. 1, Langoora No. 1, Tappers Inlet No. 1	Weak to non-existent reflection
3	Meda No. 1, Langoora No. 1, May River No. 1, Hawkestone Peak No. 1, Tappers Inlet No. 1	Generally weak reflection
4	As for base 3	Moderately strong to strong reflection
5	As for base 3	Moderately strong reflection
6	Tappers Inlet No. 1	Moderately strong reflection
7	-	Absent
8	Tappers Inlet No. 1	Weak to non-existent reflection
9	-	Absent
10	Tappers Inlet No. 1	Very shallow, no reflection

The Lennard Shelf has only a comparatively thin veneer of sediment where interval 1 and interval 2 are either very thin or absent. It is separated from the graben by the Beagle Bay Fault (Pl. 13-1) and from the Margaret Terrace partly by the Markham Fault.

The area between May River No. 1 and Meda No. 1 is covered by seismic surveys in greater detail than any other part of the Canning Basin. Data from a few important seismic lines have been selected for interpretation.

In a large part of the shelf, base 2 and base 3 also represent the top of the Precambrian basement. As in the Margaret Terrace, the most prominent reflection in the Lennard Shelf is at the top of the Upper Devonian carbonate of interval 3. A number of small structures within the interval may be reefs. WAPET drilled Meda No. 1 through one of them and confirmed it as a reef. An

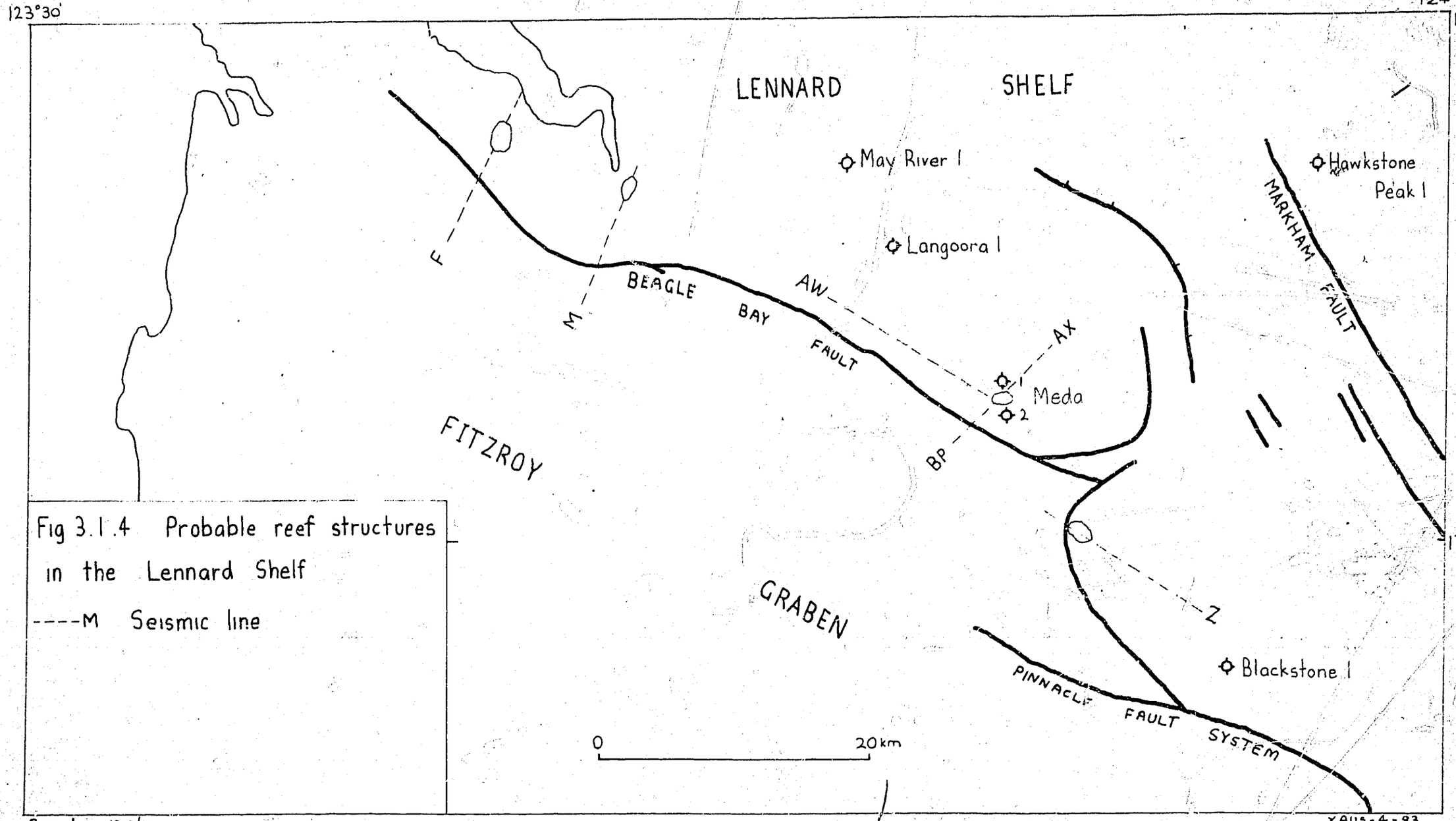


Fig 3.1.4 Probable reef structures in the Lennard Shelf

----M Seismic line

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analysis of the seismic records indicates that the frequency of recorded seismic signals increases over the Meda structure; this is consistent with the high-frequency anomalies usually associated with reefs (Fitton & Long, 1967; Lyons & Dobrin, 1971). Several seismic records indicate frequency increases over other structures on the Lennard Shelf; these have been interpreted as probable Upper Devonian reefs (Fig. 3.1.4).

3.1.10 Offshore

TABLE 3.1.10.1 WELL CONTROL AND SEISMIC EVENTS

Base	Well control	Remarks
1,2,3,4	-	Unknown
5	Bedout No. 1	Identity of reflection uncertain
6	Lacepede No. 1A, Wamac No. 1, Lynher No. 1, Bedout No. 1, Keraudren No. 1	Moderately strong to strong event; unconformity in some areas
7	As for base 6	Moderately strong event in Lacepede 1A-Lynher 1 area, to weak and discontinuous event, in Bedout Sub-basin
8	As for base 6	Generally moderately strong event
9	As for base 6	Weak event except in the north-west of Bedout Sub-basin
10	Lynher No. 1, Bedout No. 1, Keraudren No. 1	Moderately strong and continuous event where present
11	As for base 6	Weak at shallow depths, but moderately strong event in the deeper part of the basin; unconformity in some areas

Although Lacepede No. 1A and Wamac No. 1 intersected Palaeozoic rocks, subsurface control for horizons below base 5 in the offshore Canning Basin is absent. In the Lacepede No. 1 area, pre-interval 6 rocks are severely folded into several synclines and anticlines resembling those in the onshore Fitzroy Graben. These fold trends have been mapped and are included in Plate 13-4. The Fitzroy Graben appears to extend at least 100 km offshore beneath the Mesozoic sediment.

Well control for base 5 in the offshore area is limited to Bedout No. 1, where about 110 m of interval 5 sediments are present. Immediately south and east of Bedout No. 1, interval 5 thickens markedly. Here, base 5 is both an angular unconformity and a moderately strong seismic event. Interval 5 appears to be completely eroded over some parts of the Bedout high, and the correlation of base 5 to the north of this structure is uncertain. A circular structure, probably an igneous intrusion, at the western end of line 68-183, about 140 km north of Port Hedland (Pl. 13-5), may be of Late Triassic age.

Except in the area west of the Bedout high, where it is cut by a number of faults, base 6 coincides with a continuous and strong seismic reflection. In the Lacepede No. 1 A area, this horizon is a well-defined event indicating an angular unconformity between the almost flat-lying sediment of interval 6 and the folded older rocks, mainly of Palaeozoic age. In the deeper part of the Bedout Sub-basin where interval 5 is thick, base 6 is conformable.

Except in areas near Lacepede No. 1A and Bedout No. 1, base 7 was traced on an event which is mostly discontinuous and weak, especially in the area where the depth to base 7 is less than 600 m.

Base 8 and base 9 coincide with generally moderately strong reflections. At the northern end of line 71-640 (about 130 km west of Imperieuse Reef), base 9 is an unconformity separating rocks of interval 9 from the underlying block-faulted interval 6. About 60 km northwest of Mermaid Reef, a broad feature about 25 km wide resembling a channel or a sedimentary wedge occurs within interval 9.

Base 10 coincides with a generally continuous reflection which becomes very prominent in the deeper area. Base 11 coincides with a reasonably strong reflection in the deeper parts of the basin, especially where interval 11 onlaps a prograding sequence of interval 10. In the area near Lacepede No. 1A and Keraudren No. 1, base 11 is shallow and in places difficult to trace.

3.2 MAGNETIC

The interpretation presented here is intended as a supplement to earlier interpretations made on individual surveys - not as a replacement. However, as more geological and geophysical information is available for the Canning Basin now than when the earlier surveys were done it is possible to draw wider conclusions for the area than was previously possible. In order to make this interpretation, the detailed maps at their original scale were studied in conjunction with surface geological maps, structure contour maps, and Bouguer anomaly contours. The interpretation discusses the main features of the magnetic field and the magnetic susceptibility data, and outlines the gross tectonic elements of the Canning Basin as seen in the magnetic basement, both onshore and offshore. A discussion of the composition of the magnetic basement is included in Section 4.2. A simplified 100-nT-interval total magnetic intensity contour map for the Canning Basin is shown in Plate 8 (BMR, 1976).

3.2.1 Qualitative interpretation

Onshore the contours of total magnetic intensity show a pattern of linear anomalies mainly oriented west-northwest subparallel to the main structural trends of the Canning Basin. The amplitudes of most of these anomalies are less than 250 nT, but some are up to 500 nT in the Fitzroy Graben in the Cornish Sheet area, and in the Runton Sheet area adjacent to the Rudall Metamorphics.

Within the Fitzroy Graben the magnetic pattern is fairly flat except for the strong anomaly in the Cornish Sheet area and a 250-nT circular anomaly in the Derby Sheet area. To the north on the Margaret Terrace and Lennard Shelf, the magnetic pattern is a complex of small circular and linear anomalies often truncated near boundaries of the structural subdivisions; the generalised trend of these anomalies is northwest (Pl. 8).

The magnetic pattern in the Jurgurra Terrace, Barbwire Terrace, and Broome Arch includes both circular and linear anomalies; circular anomalies predominate in the northwest, and narrow northwest-trending linear anomalies predominate in the southeast of the Broome Arch.

The magnetic field in the Kidson Sub-basin is mainly fairly flat, but has broad anomalies of 250-nT amplitude in the south near the Tabletop Shelf, and in the northwest. One broad linear anomaly of 250-nT amplitude about 30 km wide extends into the Willara Sub-basin; it appears to be similar to two other anomalies in the west of the Kidson Sub-basin.

On the Ryan Shelf, Tabletop Shelf, and Lambert Shelf, the magnetic pattern includes small circular and narrow linear anomalies due to relatively shallow sources.

Magnetic coverage is not available for a strip 100 km wide inland from the coast. Offshore, magnetic coverage is provided by marine surveys on east-west lines 16 km apart. The contours from this widely spaced data mainly show a pattern of linear anomalies of amplitude up to 1000 nT, but usually less than 500 nT. The most striking feature is a group of 500-1000 nT linear anomalies of east-west to north-south trend in the Broome Arch. The northernmost anomaly trends east (Plate 8), but the magnetic charts show that elements of it trend northwest.

In the west of the Bedout Sub-basin, the magnetic anomalies are less than 50 nT in amplitude; although trend directions are difficult to determine, the main trend is northeast. In the offshore part of the Leveque Arch, some of the anomalies trend north-south and others east-west.

3.2.2 Discussion of basement magnetic susceptibility data

As an aid to the magnetic interpretation, tests of magnetic susceptibility were made on the very few basement rocks available from wells. These, and similar tests made for the Lennard Shelf aeromagnetic survey (WAPET, 1972f), comprise all the available data for the Canning Basin (Table 3.2.2.1). These data are summarised and compared with other published values of susceptibility for similar rock types to those tested in the Canning Basin, in Table 3.2.2.2.

The number of samples of basement rocks is inadequate to give a clear indication of the common susceptibility contrasts in the area, but we can make tentative conclusions.

Mafic igneous rocks are the most magnetic of those tested, but their susceptibility values are on the whole somewhat lower than published averages for similar rock types (Grant & West, 1965). Nearly all values lie in the range

TABLE 3.2.2.1
MAGNETIC SUSCEPTIBILITY MEASUREMENTS

	Locality	Station No. (Appendix 12)	Depth below sea level (m)	Lithology	No. of samples tested	Susceptibility cgs x 10^6 Min.	Max.	Mean
** BMR measurements	Wamac No. 1	2	2555-2560	Dolerite, shale	1			132
			2590-2595	Dolerite, shale	1			88
			2735-2784	Dolerite	4	156	180	165
	Tappers Inlet No. 1	5	*2834	Metabasalt	1			15
	Pender No. 1	8	* 887	Schist	1			4
	Fraser River No. 1	12	2759-2761	Shale	1			4
			*3012	Gabbro	1			390
			*3030	Gabbro	1			305
	Barlee No. 1	16	2218-2221	Limonite-stained quartz sand	1			428
			2221-2224	Quartz sand, shale	1			132
			2276-2279	Dolerite	1			104
			2283-2285	Quartz sand, shale	1			64
			2361-2364	Shale	1			52
			2364-2373	Dolerite	3	324	580	429
	Goldwyer No. 1	20	1346-1356	Granite	1			75
	Thangoo No. 1A	21	*1476	Biotite phyllite	1			40
	Thangoo No. 2	22	*1279	Gneiss	1			4
	Meda No. 1	46	*2637	Dolomitised schist	1			4
	Hawkstone Peak No. 1	53	*1136	Quartzite	1			<4
	Wilson Cliffs No. 1	195	*3277	Black shale	1			20
	Munro No. 1	220	*2056	Granite	2	305	420	362
	Parda No. 1	229	1772-1798	Gneiss	4	4	20	8
	Samphire Marsh No. 1	233	2009-2024	Granite	3	8	16	10
	Wallal No. 4A	234	574-667	Gneiss	4	8	24	17
	Bedout No. 1	239	3016-3044	Basalt	5	144	400	251
*** WAPET, 1972 f	Fraser River No. 1	12	2947	Gabbro	?			1600
	Napier No. 4	43	760	Quartzite	?			<5
	May River No. 1	44	not stated	Schist	?			65
	Langcora No. 1	45	1550	Schist	?			<5
	Napier No. 2	47	1415	Schist	?			<5
	Napier No. 5	48	1501	Gneiss	?			<5
	Napier No. 1	52	1624	Gneiss	?			<5

* Core Sample.

** Magnetic susceptibility measurements by BMR were made with a BISON 3101 or BISON 3101A susceptibility meter, and for all crushed samples and cores were corrected for air space. Accuracy of method used + 20%.

*** Magnetic susceptibility measurements by Compagnie Generale de Geophysique (CGG) (1973) were made with a Scintrex SM-4 susceptibility meter.

TABLE 3.2.2.2
MAGNETIC SUSCEPTIBILITY OF BASEMENT ROCKS, CANNING BASIN

Rock type	No. of samples tested	Percent having volume susceptibility (cgs)							
		$k<10^{-4}$		$10^{-4}<k<10^{-3}$		$10^{-3}<k<4\times10^{-3}$		$k>4\times10^{-3}$	
Mafic extrusive	5	(5)	-	(29)	100	(47)	-	(19)	-
Mafic intrusive	11	(24)	9	(27)	91	(28)	-	(21)	-
Granite	6	(60)	33	(23)	67	(16)	-	(1)	-
Gneiss, schist, quartzite, slate	17	(71)	100	(22)	-	(7)	-	(0)	-
Unmetamorphosed sediments	7	(73)	71	(19)	29	(4)	-	(4)	-

Values in parenthesis are percentages derived for similar rock types (Grant & West, 1965, p. 366)

TABLE 3.2.2.3
TENTATIVE MAGNETIC SUSCEPTIBILITY CONTRASTS

Lithology	Background	Susceptibility contrast (cgs units x 10^{-6})
?Permian mafic igneous	Palaeozoic sediments	400
Basement metamorphics (gneiss, schist, shale, quartzite)	Palaeozoic sediments	60
Granite	Basement metamorphics	400
Granite	Palaeozoic sediments	400
Basement mafic igneous	Basement metamorphics and Palaeozoic sediments	not known (probably 5000)

An interpretation of the magnetic anomalies in the Canning Basin indicates that susceptibility contrasts are often considerably higher than those tabulated above. For example the source of the 500-nT anomaly in the northern Cornish Sheet area has an estimated susceptibility of 5500 x 10^{-6} cgs, similar to that published for dolerite, but is an order of magnitude greater than measured values for the area. Thus the magnetic susceptibility data available for basement rocks in the Canning Basin is far from complete. An interpretation of the magnetic anomalies indicates that susceptibilities of basement rocks do not exceed 6000 x 10^{-6} cgs.

3.2.3 Depth of magnetic basement

Depth to magnetic basement for the Canning Basin was compiled from the more reliable depth estimates and is shown in Plate 15. This shows less detail than the unpublished maps compiled individually from data from the various magnetic surveys in the area; in places, these may show intrabasement structures wrongly interpreted to indicate basement topography. The map is incomplete because magnetic data are not available for the whole area, and because some of the data are not suitable for quantitative interpretation owing to either technical surveying problems in the early work or the lack of suitable anomalies (as in the Fitzroy Graben and Kidson Sub-basin).

Original flight charts were used for depth interpretation of the WAPET (1962f) surveys; for other surveys, profiles were redrawn from contour maps of total magnetic intensity. In the main, and where applicable, the depth interpretation methods for the steeply dipping tabular body model were used (Peters, 1949; Gay, 1963). Quantitative interpretation methods applicable to fault-step anomalies were used (Grant & West, 1965; Martin, 1965) where the geophysics or surface mapping indicated that such models would be appropriate; these models unfortunately give results liable to large errors. In a few places methods applicable to plug or stock like bodies were used.

Onshore

Most information is available for the relatively shallow shelf areas around the basin and in the Broome Arch, where the depths to basement are contoured (Pl. 15). In the deeper parts of the basin, only a few isolated depths

have been estimated. Broadly speaking, the form of the magnetic basement is similar to that established by seismic interpretation, but magnetically interpreted faults do not necessarily coincide with seismically determined faults, and estimates of the depth to magnetic basement often exceed the seismically interpreted depth to base 1. The depth discrepancy indicates that non-magnetic sediments probably separate magnetic crystalline basement from base 1; this is discussed further in Section 4.2. The discrepancy in the location of faults indicates that changes in the composition of the magnetic basement do not necessarily coincide with faults in the overlying sedimentary section. Offshore, the depth estimates appear to fall into two groups: one deep, attributed to a crystalline basement probably of Precambrian age; the other shallower, attributed to volcanics in the Palaeozoic section, possibly similar to those in Bedout No. 1 and Wamac No. 1.

Along the length of the Fitzroy Graben, there are only three anomalies for which depth estimates are believed to be reliable, and these indicate a shallowing from 15 000 m near Grant Range No. 1 to 6000 m in the Cornish Sheet area. There are no anomalies near the southeastern end of the graben to provide a reliable depth estimate, but the depth to magnetic basement is 15 000 m to the north near Micha Bore. Offshore, the estimated depth to magnetic basement is in the range 1200-3500 m, within the seismically indicated Canning Basin sequence; these are believed to be due to Palaeozoic volcanics. Farther off-shore the depth to magnetic basement is estimated to be 9000-13 000 m; it may be a continuation of the crystalline basement at a similar depth range onshore.

In the Kidson Sub-basin, the depth to magnetic basement is 10 000 m in the west near Sahara No. 1 and shallows to 6000 m to the east.

Near Kemp Field No. 1 the depth to magnetic basement is 11 000 m, 7000 m deeper than the seismically determined depth to base 1.

Anomaly 1 (Plate 7) is a zone of Bouguer anomaly high which lies within the Broome Arch, Jurgurra Terrace, and Barbwire Terrace; culminations of the high lie over basement highs. This anomaly is due to the topography of relatively shallow Precambrian basement rocks.

Anomaly 2 is a zone of Bouguer anomaly high which lies within the Lennard Shelf, Pender Terrace, and Margaret Terrace. It appears to be continuous with a zone of Bouguer anomaly highs which swing north-northeast fringing the Kimberley Basin in the Mount Ramsay Sheet area. Culminations of the high with north-northeast trend lie over mafic intrusives of the early

Lamboo Complex (Plumb & Derrick, 1973), of the Halls Creek Mobile Zone. Anomaly 2 in the Canning Basin, then, is probably mainly due to similar high-density rocks in the Precambrian basement, rather than to topography of the basement.

Anomaly 3 is a zone of Bouguer anomaly high which lies within the Lambert Shelf and Tabletop Shelf. This feature, named the 'Anketell Regional Gravity Ridge' by Flavelle & Goodspeed (1962), has culminations which lie over the Rudall Metamorphic Complex of the Pilbara Block. The Bouguer anomaly high is attributed to density contrasts within the Precambrian basement rocks. Similar rocks probably extend in the subsurface to the southeast beneath the Warri Arch, and towards the Musgrave Block. Seismic and magnetic interpretations indicate that the arch is an area of elevated crystalline basement overlain by ?Precambrian sediments beneath the flat lying Palaeozoic sediments.

The three zones of Bouguer anomaly highs described above extend offshore and are evident in the free-air anomalies. Anomaly 3 is arcuate around the Pilbara Block; anomaly 2 extends into the offshore part of the Fitzroy Graben; and anomaly 1 lies within the offshore part of the Broome Arch.

Onshore between the highs, Bouguer anomaly lows lie over the areas of deepest Palaeozoic sediments, particularly the Kidson Sub-basin and Fitzroy Graben. These lows are in part due to low-density Palaeozoic sediments, but the prominent low in the Fitzroy Graben is mainly due to low-density rocks beneath the Palaeozoic sediments.

3.3 GRAVITY

BMR regional helicopter gravity surveys with an 11 000 m grid have covered the Canning Basin. Exploration companies have also surveyed parts of the basin. A gravity map (Plate 7) is contoured at 5 mGal intervals, based on a four-minute sampling grid. The contours onshore are for Bouguer anomalies computed with a density of 2.2 g/cm^3. The contours offshore are for free-air anomalies, and accordingly show influence of the water depth.

Specific gravity measurements for dry core samples, or density logs, are available in well completion reports on most wells drilled under the Petroleum Search Subsidy Acts. This information would be useful for assessing regional density changes, necessary for interpretation by stripping (Hammer, 1963).

The interpretation presented here is mainly qualitative and is intended as a supplement to the interpretations made from earlier surveys (Flavelle & Goodspeed, 1962; Lonsdale & Flavelle, 1963, 1968).

3.3.1 Qualitative interpretation

The high-amplitude anomalies in the Canning Basin trend west-northwest, parallel to the major structural features in the area - for example, the Fenton Fault and Pinnacle Fault. Many of the gravity anomalies are in some way related to the structural features in the Palaeozoic and Mesozoic sediments in the basin, though some are clearly due to lateral density contrasts within the Precambrian crystalline basement.

Onshore, the Bouguer anomalies show a general increase from -40 mGal in the southeast of the Canning Basin to zero and above near the coast. The pattern is dominated by three broad linear zones of west-northwest-trending Bouguer anomaly highs which parallel the main structural trends in the area.

3.3.2 Reefs and salt structures

Yungul (1961) discussed gravity prospecting for reefs, and concluded that isolated reefs often show recognisable positive gravity anomalies of the order of 0.5 mGal; the amplitude and shape of the anomaly depend largely on what has happened after the reef was covered. Theoretical anomalies were calculated for models of reef structures believed to be typical for the Lennard Shelf (Section 3.1.9). An example model with estimated rock densities included a lateral density change across the reef, and a vertical density increase above the reef owing to the compaction of the overlying sediments (Lyons & Dobrin, 1971). The net Bouguer anomaly over the reef was + 0.9 mGal of which the effect of compaction alone was 0.17 mGal for a reef 150 m thick - the minimum thickness expected. The gravity method may have an application in the exploration for buried reef structures in the area, but their identification would probably depend on recognition of a low amplitude gravity anomaly over a considerable strike extent.

The density of gravity stations in the Lennard Shelf is too low to allow conclusive identification of reef-type anomalies. However, a Bouguer anomaly high of 5 mGal close to the axis of seismically interpreted reef

structures (Fig. 3.1.4) may be an indication of the presence of high-density carbonate rocks.

Seismic interpretation indicates the presence of salt structures around the Kidson Sub-basin and Willara Sub-basin. Measurements on drill-core indicate that salt in the Carribuddy Formation has a density of 2.3 g/cm^3, and that enclosing sediments are of higher densities (2.4-2.6 g/cm^3). The anomaly should theoretically show the edge of the salt, and the salt pillows or larger salt structures should produce negative anomalies of 1-5 mGal, possibly with local central high anomalies within the lows (Grant & West, 1965). However, the Bouguer anomaly data in the Kidson Sub-basin are from stations too far apart to detect small-scale features associated with salt.

4. PRECAMBRIAN BASEMENT

4.1 PRECAMBRIAN ROCK TYPES SURROUNDING AND BENEATH THE CANNING BASIN

The Canning Basin succession includes Palaeozoic, Mesozoic, and Cainozoic sediments resting unconformably on Precambrian basement rocks. Basement rocks crop out in the Halls Creek Province and Victoria River Basin in the north, in the Granites-Tanami Block, Arunta Block, and Amadeus Basin in the east, and in the Pilbara Block and Paterson Province to the south of the Canning Basin. They include igneous and metamorphic rocks and unmetamorphosed sediments (Pl. 17); in particular, the Victoria River Basin, Granites-Tanami Block, and Amadeus Basin contain thick sequences of unmetamorphosed late Precambrian sedimentary rocks. Similar rocks extend beneath the Canning Basin. For example, Temple (1970) equated quartzite in Napier No. 4 on the Lennard Shelf with the King Leopold Beds, and Watt & Temple (1971) equated gneiss in Napier No. 5 with the Lamboo Complex of the Halls Creek Province. Table 4.1.1 compiled from well completion reports, summarises the lithologies that have been recorded. They include granite, basalt, dolerite, gabbro, schist, phyllite, gneiss, quartzite, and shale. However as only 19 onshore wells (and none offshore) have penetrated basement its lithology over large areas is unknown and can only be inferred from geophysical interpretation.

TABLE 4.1.1. PRECAMBRIAN BASEMENT ROCKS PENETRATED BY DRILLHOLES

Well name	Station Number	Depth to basement bsl (m)	Total depth bsl (m)	*Rocks penetrated
Leveque No. 1	-	886		Gabbro
Tappers Inlet No. 1	5	2813	2834	Metabasalt
Pender No. 1	8	880	888	Mica schist
Goldwyer No. 1	20	1339	1357	Granite
Thangoo No. 1A	21	1382	1482	Biotite phyllite
Thangoo No. 2	22	1245	1279	Chlorite-muscovite gneiss
Edgar Range No. 1	26	1780	1832	Quartz-mica schist
Napier No. 4	43	851	874	Quartzite
May River No. 1	44	1622	1658	Oligoclase-epidote-actinolite schist
Langoora No. 1	45	1573		Quartz-chlorite-biotite, calc. schist
Meda No. 1	46	2609	2655	Quartz-chlorite schist
Napier No. 2	47	1502	1521	Mica schist
Napier No. 5	48	1575	1583	Granite gneiss
Napier No. 1	52	1699	1727	Granite gneiss
Hawkestone Peak No. 1	53	1123	1136	Quartzite
67 Mile Bore	56	712	860	Granite
BMR Prices Creek No. 1	123	22	53	Biotite schist
Wilson Cliffs No. 1	195	3058	3277	Silty shale, siltstone, sandstone
Munro No. 1	220	2046	2056	Granite
Parda No. 1	229	1670	1800	Chlorite gneiss
Samphire Marsh No. 1	233	2066	2022	Microcline-plagioclase-hornblende-quartz granite
Wallal Nos. 4 & 4A	234	688	688	Biotite-quartz-oligoclase gneiss
WCB2	237	20	52	Siltstone, shale

* Description summarised from composite well logs, well completion report, or WAPET section

4.2 GEOPHYSICAL INTERPRETATION OF BASEMENT LITHOLOGIES

Magnetic, gravity, and seismic data were interpreted to help determine the nature of the basement and to determine the thickness of the unmetamorphosed Precambrian sedimentary rocks. Likely areas of granite, mafic igneous rocks, banded iron formations, metamorphic rocks, and unmetamorphosed sediments were distinguished and are outlined in Plate 9.

Broadly speaking, the various types of outcropping basement rocks are characterised by recognisable patterns on the total magnetic intensity and Bouguer anomaly maps (Table 4.3.2). Some of these patterns can be traced beneath the Canning Basin and can be used in conjunction with seismic and drilling data to interpret the type of basement. In the deeper parts of the basin, where basement has not be drilled, the interpretation is less reliable. This qualitative interpretation was assisted where possible by quantitative gravity modelling and estimates of magnetic susceptibility and depth to magnetic basement.

Two main types of basement are distinguished in Plate 9: one is made up predominantly of igneous and metamorphic rocks; the other is made up mainly of Precambrian sedimentary rocks overlying igneous and metamorphic rocks. Distinguishing the type of basement is more difficult offshore than offshore, because offshore there is no well control and the magnetic and gravity coverage is comparatively sparse.

Igneous and metamorphic basement. The gravity pattern and depth to magnetic basement calculations suggest that the igneous and metamorphic rocks of the Granites-Tanami Block and the Arunta Block connect in a northerly trending belt at shallow depth beneath the Canning Basin in the Cornish, Helena, and Wilson 1:250 000 Sheet areas (Pl. 9).

A belt of dense high-grade metamorphic rocks, in part interlayered with thick linear mafic rocks, and granite of the Paterson Province, probably extends into the subsurface northwest across the Tabletop, Rudall, Paterson Range, Anketell, Yarrie, and Mandora Sheet areas, and southeast beneath the Warri Arch. The western limit is uncertain; the pattern of gravity and magnetic anomalies terminates near Bedout No. 1. The rocks in this belt may in part be similar to those in the Rudall Metamorphic Complex and possibly the Musgrave-Mann complex. An arcuate belt of probable banded iron formations, metasediments, mafic rocks, and granite - an extension of the Pilbara Block - occurs to the southwest in the Roebourne and Bedout Island Sheet areas.

The metamorphic rocks and granite of the Halls Creek Province can be traced into the subsurface of the Mount Bannerman, Mount Ramsay, Noonkanbah, Lennard River, Derby, and Yampi Sheet areas.

Basement beneath the central part of the onshore Canning Basin probably consists of metamorphic rocks with interlayered linear steeply dipping mafic igneous rocks, and two broad linear belts of granite in the Lagrange, Munro, Anketell, and Joanna Spring Sheet areas. The pattern is not sufficiently definitive to allow correlation with basement rocks in the surrounding terrain, but they are roughly on trend with the Arunta Complex and Olia Gneiss in the margins of the Amadeus Basin.

The magnetic and gravity anomaly patterns are not well defined offshore, and the magnetic pattern is disturbed in many places by near-surface source anomalies from within the Palaeozoic or Mesozoic section. The west-northwest-trending gravity and magnetic anomaly patterns terminate near the

200-m bathymetric contour. Leveque No. 1, to the north of the area of study, encountered gabbro beneath the sediments of the Canning Basin.

Sedimentary basement. The tentative thickness of the Precambrian sedimentary rocks, determined from an interpretation of the magnetic and seismic data, is shown in Figure 4.2.1.

In the south of seismic line 72/HH 1 (Pl. 5), in the Morris Sheet area, reflections are present up to 2500 m below the base of interval 1. They dip northwards into the Kidson Sub-basin somewhat less steeply than those at the base of interval 1, and fade out in the north. The sequence below the base of interval 1 is folded independently of the rocks beneath, indicating decollement, and there is evidence of salt intrusion in the anticlines. The diapiric formation may be a correlative of the Bitter Springs Formation of the Amadeus Basin, and may also be the diapiric formation in the Woolnough Hills Diapir (Van de Graaff, 1974; Preiss, 1976). Therefore these basement rocks are thought to be of late Precambrian (Adelaidean) age. A thick southwesterly dipping sequence of Precambrian sedimentary rocks is interpreted beneath the sediments of the Canning Basin on lines 70-A, 70-Z, and, 69E, offshore, about 25 km northwest of Chirup No. 1.

Aeromagnetic interpretation reveals a northerly trending area of elevated magnetic basement in the east of the Ryan Sheet area, where Precambrian sedimentary rocks crop out. Interpretation of seismic events on line 68/R6 to the west of the high in the Ryan Sheet area, and on lines 67/DK1 and 67/DK4 to the east of the high in the Wilson Sheet area (Pl. 5), and magnetic depth estimates, show that crystalline igneous and metamorphic rocks probably lie at shallow depth beneath the late Precambrian sediments on the crest and that the late Precambrian sediments thicken to the east and west of the high.

Magnetic basement lies as much as 7000 m below the Canning Basin sediments in the McLarty, Munro, and Joanna Springs Sheet areas, and about 4000 m below the Canning Basin sediments in the Sahara Sheet area (Fig. 4.2.1). These non-magnetic rocks are probably sedimentary, but there is insufficient data available to determine their full thickness range and extent beneath the central part of the Kidson Sub-basin.

A broad arcuate Bouguer anomaly low which extends from east of the Halls Creek Province into the Fitzroy Graben in the Billiluna, Mount Bannerman, Crossland, Noonkanbah, and Mount Anderson Sheet areas may be due to a thick

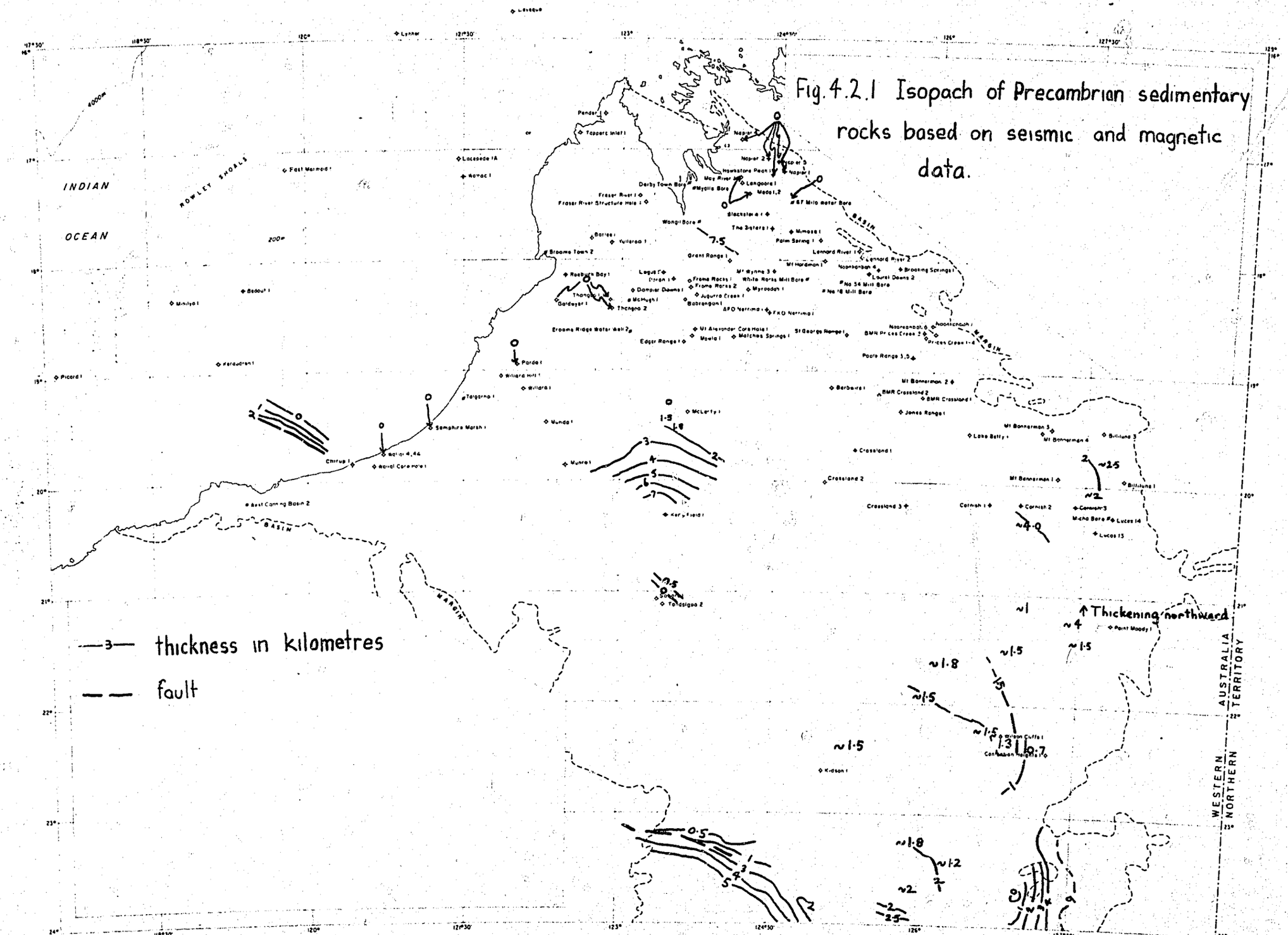


Fig. 4.2.1 Isopach of Precambrian sedimentary rocks based on seismic and magnetic data.

Record 1979/32

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87%

section of relatively low-density unmetamorphosed sediments on an unknown but possibly granitic basement. They may consist of late Precambrian sediments, similar to those in the adjacent Birrindudu and Victoria River Basins. An alternative explanation is that the gravity pattern may be caused by the thick Palaeozoic sediments within the graben or by density contrasts within the crust and mantle.

Precambrian sediments may also occur in the Noonkanbah Sheet area in a circular zone which extends off the main Bouguer anomaly low, and in the Cornish, Lucas, and Helena Sheet areas. However, in these two zones, the presence of the sediments is postulated mainly from magnetic data.

Depth to basement. To date, the depth to basement in the Canning Basin has been delineated by magnetic interpretation, in the most part by WAPET (1962f), onshore, and Whitworth (1969a), offshore. We have combined the information from wells and seismic interpretation, and have made additional estimates of depth to magnetic basement to provide a more detailed map (Pl. 15) than previously available.

The structure contours should be regarded as form lines where they are based only on the estimated depth to magnetic basement and where the seismic data was inadequate to pick the base of the Phanerozoic sediments. The offshore interpretation is based on seismic data that cannot be reliably interpreted, and in E51/1 Sheet area in the Rowley Sub-basin the interpretation is based on three estimates of depth to magnetic basement.

The onshore interpretation of the Fitzroy Graben, the Kidson Sub-basin, and the Warri Arch is based mainly on magnetic data, and the depths shown may be excessive because non-magnetic Precambrian sediments occur in these areas.

The deepest parts of the basin lie onshore in the Fitzroy Graben and the Willara and Kidson Sub-basins, and offshore in the Fitzroy Graben and the Bedout and Rowley Sub-basins. In the Fitzroy Graben, basement is at a depth of over 6000 m over most of its length, and reaches 10 000 m in at least three areas; west of Wamac No. 1, in the Derby Sheet area, and in the Noonkanbah Sheet area. The magnetic interpretation in E51/1 Sheet area suggests a fourth depression, at 13 000 m depth, possibly in an offshore extension of the Fitzroy Graben beneath the Rowley Sub-basin.

5. STRATIGRAPHY AND DEPOSITIONAL ENVIRONMENTS

5.1 INTERVAL 1

Introduction

Interval 1 includes the Nambeet, 'Middle', Willara, and Goldwyer Formations, the Roebuck Dolomite, and the Nita Formation of Early and middle Ordovician age and their correlatives throughout the Canning Basin. The interval rests unconformably on the Precambrian crystalline and sedimentary basement rocks (Pl. 17) and is overlain unconformably by Devonian and younger sedimentary rocks (Fig. 5.1.1).

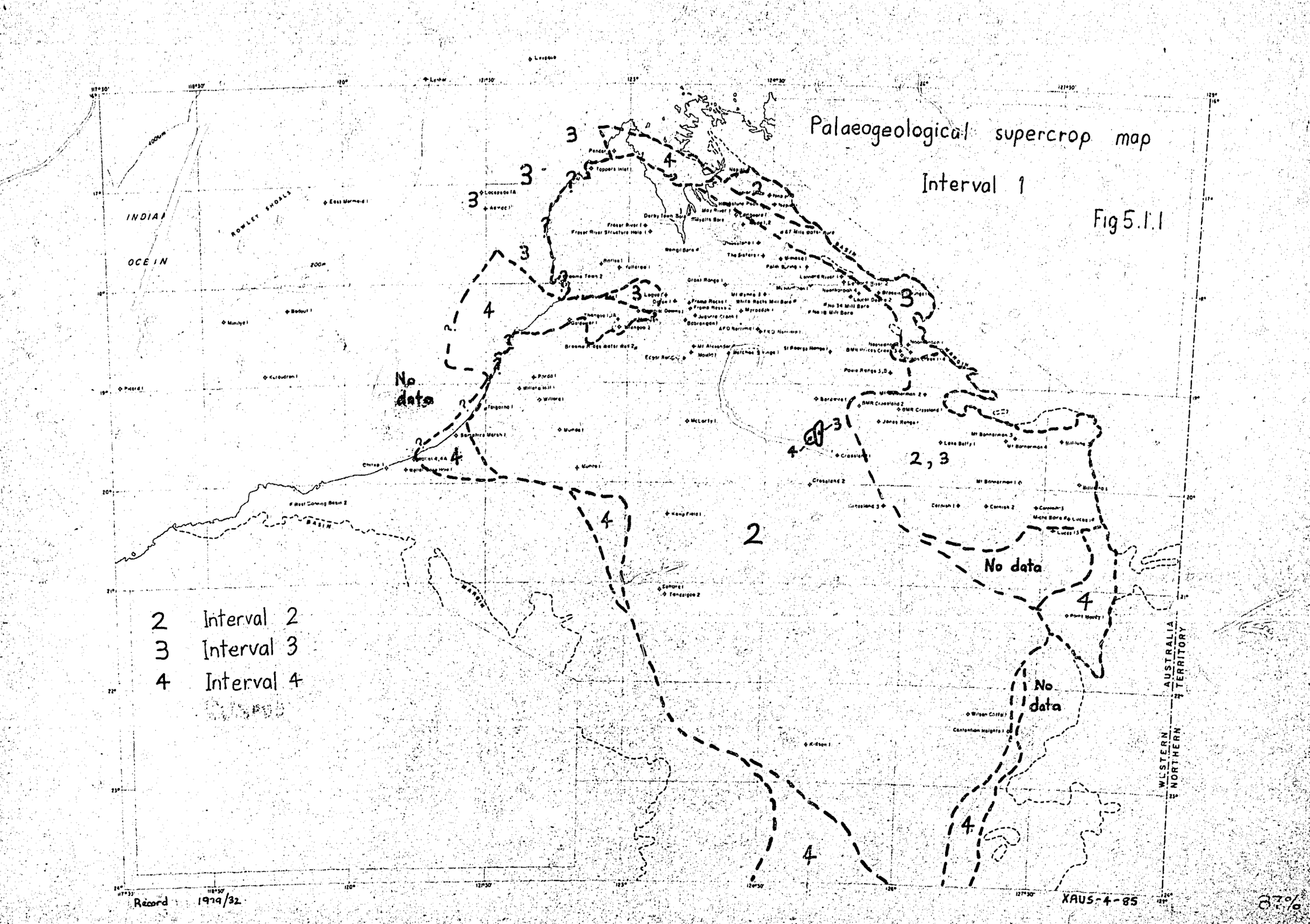
Details of lithology, contacts, correlation, and age of each formation are discussed in Appendix 1 and illustrated in Figures 5.1.2, 5.1.4, and 5.1.5 and Plates 10-1, 12-1, 13-1, and 13-2.

Thickness

The interval is widespread and probably occurs in all structural subdivisions of the basin (Pls. 10-1, 12-2); the thickest accumulations occur in the Willara (over 2400 m) and Kidson (over 3000 m) Sub-basins and the Fitzroy Graben (over 2600 m). At least some of the differential subsidence that must have occurred is a result of faulting. There is little data on the thickness of the interval over large areas of the Kidson Sub-basin and the Fitzroy Graben, especially in their deeper parts, and offshore, so maximum preserved thickness probably exceeds 3000 m. Upper Ordovician rocks may also have been deposited in the basin but are not now known to be preserved.

Lithology

The complex of palaeotectonic events that controlled deposition, and erosion of the top of the interval, make it difficult to present any more than broad generalisations concerning major lithological trends. The interval comprises chiefly marine fine-grained clastic sedimentary rocks and carbonates (Figs. 5.1.2, 5.1.4, 5.1.5; Pl. 10-1). Clastic material (mainly shale) is more common in the depocentres, and limestone and dolomite predominate over the



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Broome Arch. Sandstone is more common towards the east, suggesting a source along the present eastern margin.

Depositional environments

Palaeomagnetic data (Embleton, 1973; Smith, Briden, & Drewry, 1973) place the Canning Basin near the palaeoequator in a warm and humid climate during the Ordovician (McTavish & Legg, 1976). An abundant and varied fauna (Appendix 1) indicates that the sediments were probably laid down in a shallow sea on a wide shelf. Irwin (1965) has suggested that the slope in an epeiric sea is less than 2 cm/km and that the shallowness of the water is sufficient to generally eliminate circulation. A single depositional facies and its related environment of deposition may extend up to hundreds of miles in width. Depositional facies usually develop parallel to the shoreline and migrate laterally with time in response to minor fluctuations in sea level, change of slope, or change in rate of deposition. Because of the diachronous nature of these sediments (Pl. 13.2) any meaningful discussion of depositional environment requires it be related to time. For this study the biostratigraphic zones established by McTavish & Levv (1976) (Fig. 5.1.2) are used for time control.

Transgression

Interval 1 commenced with a marine transgression to the east* that deposited siliceous and dolomitic sandstone - the basal Nambeet and Emanuel Formations - in the structurally lower parts of the basin (Pl. 15). The presence of sandstone of Tremadocian age at the base of the Nambeet Formation in Samphire Marsh No. 1 indicates that the sea had reached the present coastal area by the earliest Ordovician. The transgression is best illustrated in the South Canning Depression (see Section 1.5), where the base of the Nambeet Formation becomes progressively younger to the east. As the sea moved eastward, the sandstone in the west became increasingly calcareous and finer-grained and grades

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* Veevers & McElhinny (1976) have suggested that the transgression resulted from plate divergence that opened up the Tethyan sea between Australia and an unknown continent in the Early Ordovician.

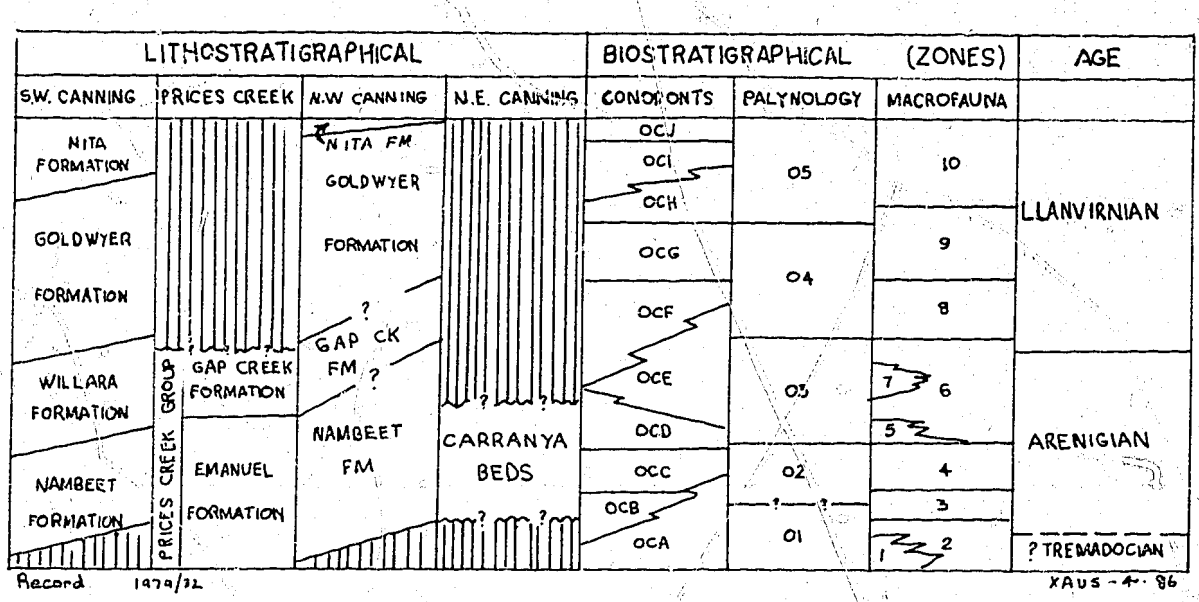


Fig 5.1.2 Biostratigraphical Zones, Interval 1

After McTavish & Legg (1976)

upward into interbedded shale and limestone. There is little offshore data. No data is available from the Fitzroy Graben area, and of the wells sited on the surrounding terraces and shelves that penetrated into the Ordovician only two reached its base. The Emanuel Formation, known from outcrop and wells at Prices Creek, is predominantly sandstone grading upward into interbedded sandstone and limestone; it is similar in lithology and therefore probably similar in depositional history to the basal Ordovician south of the Broome Arch. The basal sandstone in BMR Prices Creek No. 3 is undated, but outcropping limestone and shale stratigraphically above it is of earliest Arenigian age. This suggests that the transgressive sandstone in this area was deposited at about the same time or perhaps a little earlier than similar sandstone to the south of the arch.

The area transgressed and the type of sediment deposited during the early transgression were strongly influenced by topography, which in turn reflects the relative resistance to erosion of the various basement lithologies (Pl. 9) as well as the tectonic history.

The sea probably inundated first the present offshore part of the Canning Basin in the Tremodocian and then spread east in two long tongues. One tongue of the sea extended along the Fitzroy Graben, the other extended across the subsiding Willara Sub-basin. Early in the Arenigian (Fig. 5.1.3) the sea was approaching and may even have reached the eastern edge of the Canning Basin. Emergent landmasses of substantial relief - the Kimberley and Pilbara Blocks - existed north of the graben and south of the Willara and Kidson Sub-basins, and another occurred in the east. Most of the Broome Arch was emergent at this time although the sea probably crossed it to the north of McLarty No. 1.

The basal rocks - Nambeet and Emanuel Formations - are coarse to fine-grained sandstone with glauconitic laminae, commonly well sorted, with sedimentary structures such as cross-bedding, scour-and-fill, and vertical and horizontal burrows, suggesting deposition in an intertidal environment with a limited fauna. The conglomerate and siliceous and ferruginous sediments at the base of this sequence are probably remnants of soil and alluvium reworked by the transgressing sea. Overlying these sediments are the early Arenigian sediments, mainly fine-grained clastics with minor limestone and an abundant marine fauna in the Willara Sub-basin and interbedded clastics and abundantly fossiliferous limestone at Prices Creek (Fig. 5.1.4), which were probably deposited in sea deeper than the intertidal range. Farther east subsidence and sedimentation

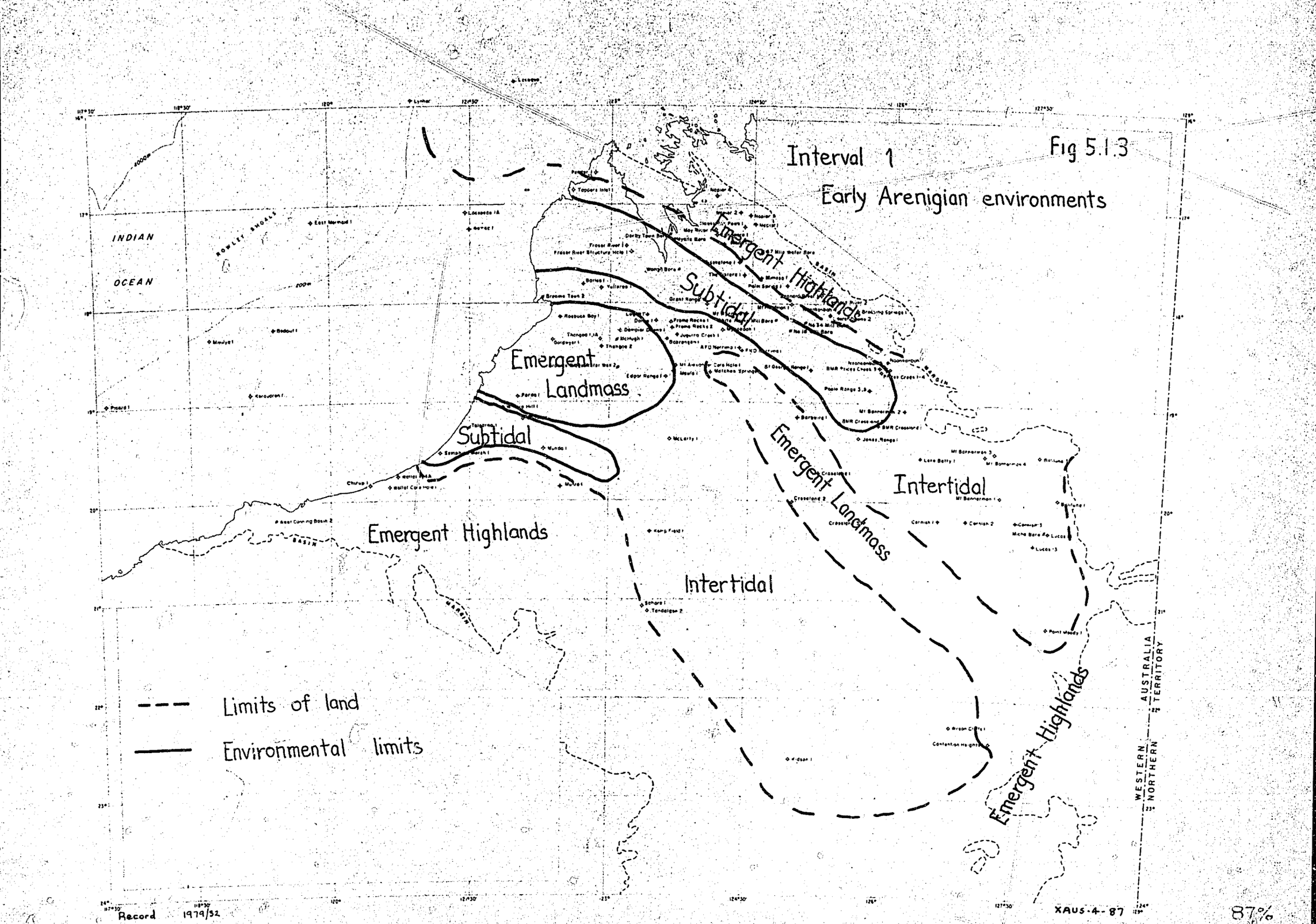
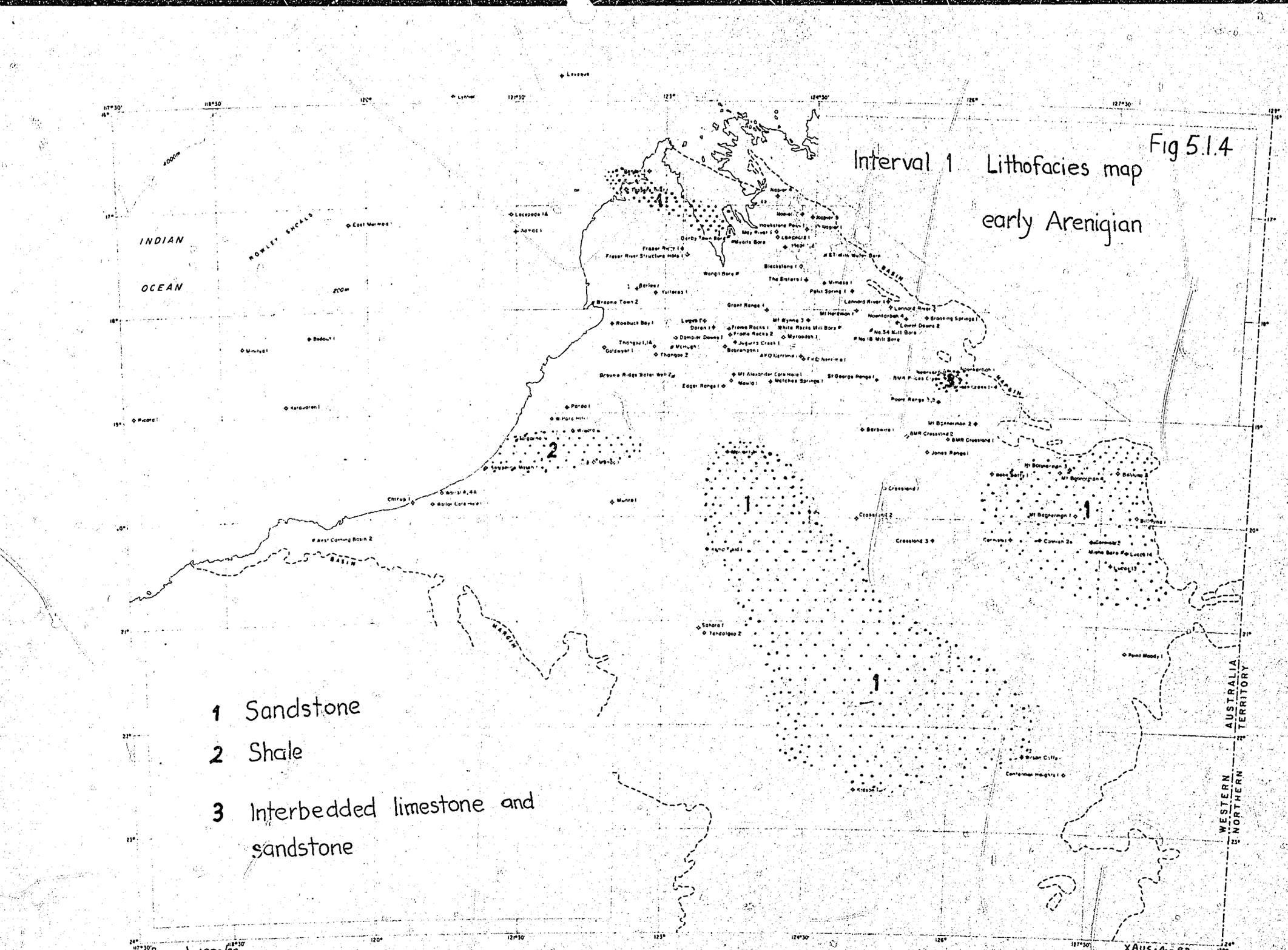

Interval 1
Fig 5.1.3
Early Arenigian environments
INDIAN
OCEAN
Emergent Highlands
Subtidal
Emergent Landmass
Subtidal
Emergent Landmass
Intertidal
Emergent Highlands
Intertidal
Emergent Highlands
Limits of land
Environmental limits
WESTERN AUSTRALIA
NORTHERN TERRITORY
Record 1979/52
XAUS-4-87

Fig 5.1.4

Interval 1 Lithofacies map

early Arenigian



1 Sandstone

2 Shale

3 Interbedded limestone and sandstone

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87%

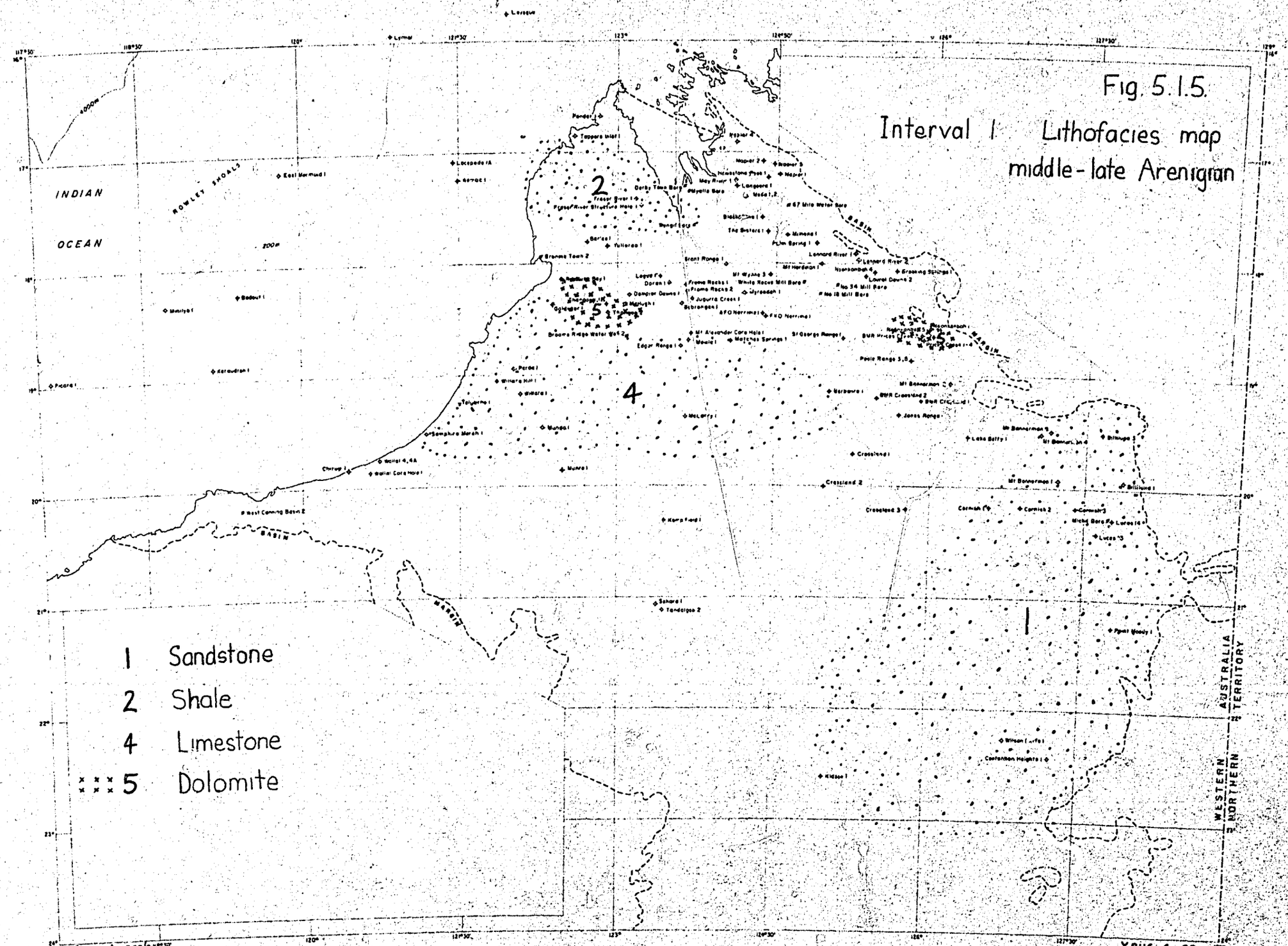
rates were probably in equilibrium as intertidal sedimentation continued throughout most of the Early Ordovician.

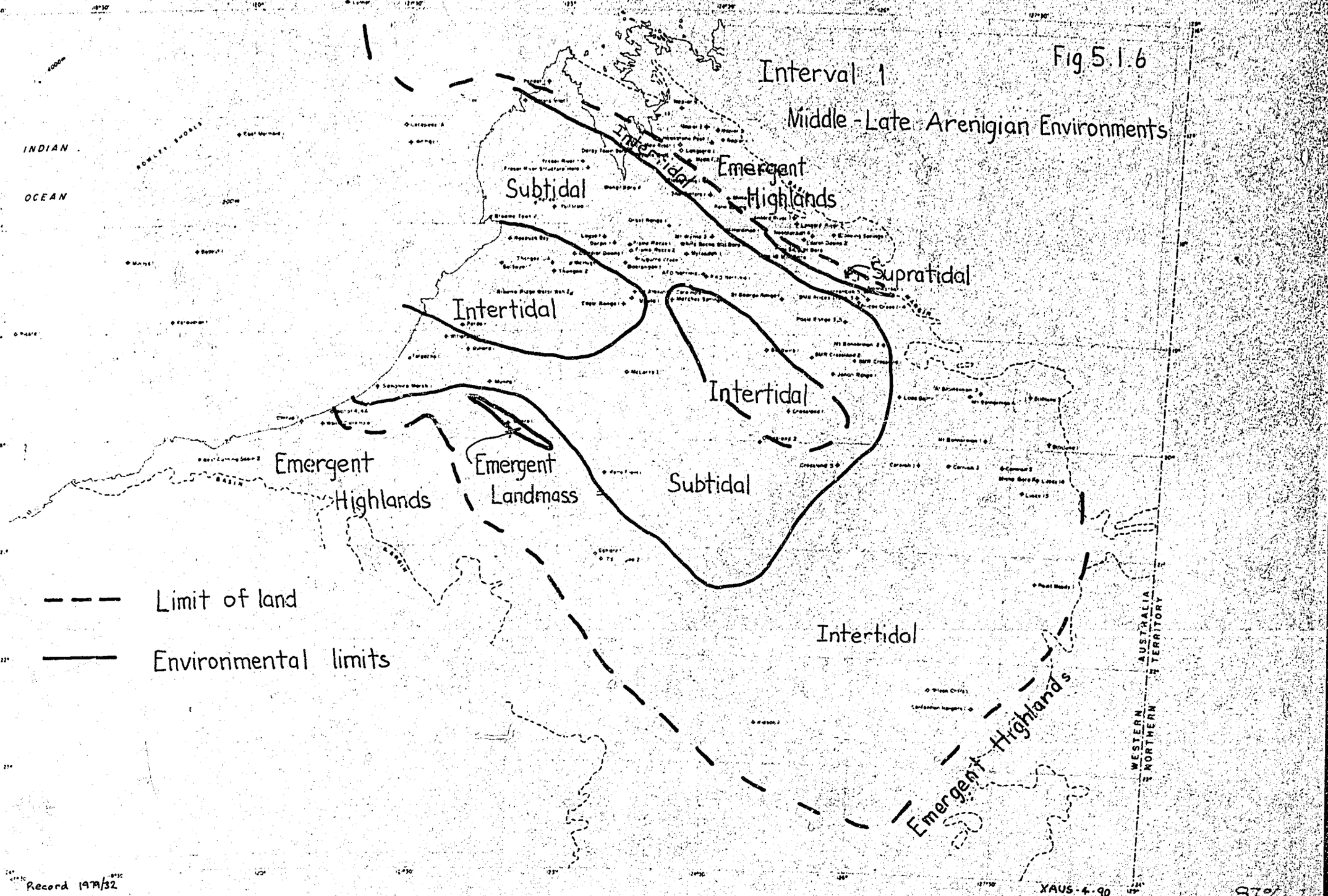
The main source for the coarse clastics was the eastern landmass (Fig. 5.1.3) which probably had substantial differential uplift to supply such a large volume of material. The finer-grained clastic sediments, probably the result of deep chemical weathering in a humid equatorial climate (McTavish & Legg, 1976), were most likely derived mainly from the emergent metamorphic and igneous highlands of the Pilbara and Kimberley Blocks.

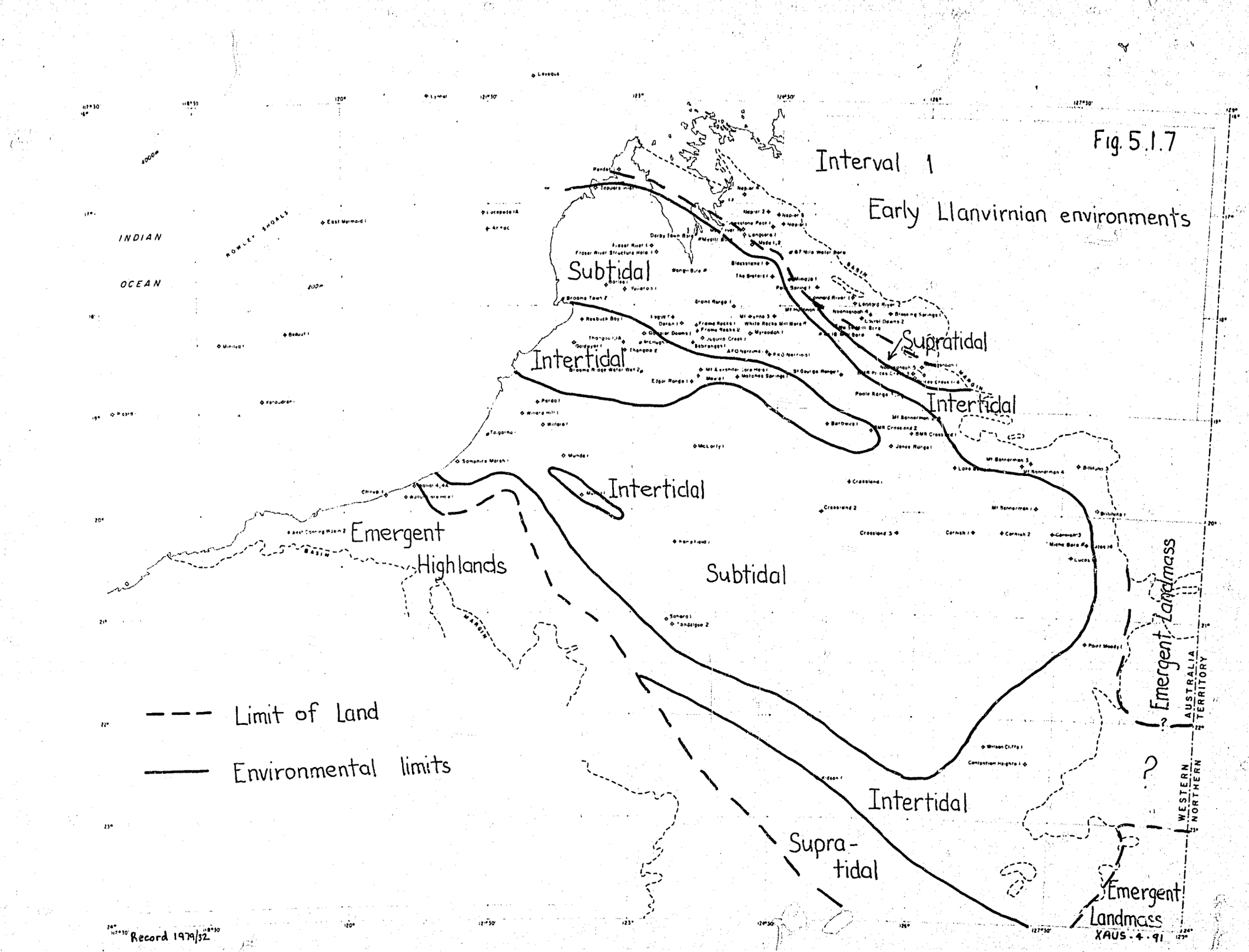
Inundation of the Broome Arch was completed by the middle of the Arenigian and the carbonates of the Willara and Gap Creek Formations (Fig. 5.1.6) were deposited in a shallow epeiric sea in the west. The carbonates are bioturbated, interbedded with dark shale, and contain fauna suggestive of a subtidal environment. At the same time intertidal sediments were deposited over the Broome Arch and to the north, south, and east. Sandstone derived from the eastern highlands was deposited in the east. Dolomite and bioclastic limestone, desiccation cracks, bioturbation, and ripple marks indicate an intertidal environment over the western Broome Arch and possibly part of the eastern Broome Arch. Caverns in the area of the Thangoo wells indicate that parts of the arch may have even been emergent and exposed to subaerial erosion (McTavish & Legg, 1976) in the late Arenigian.

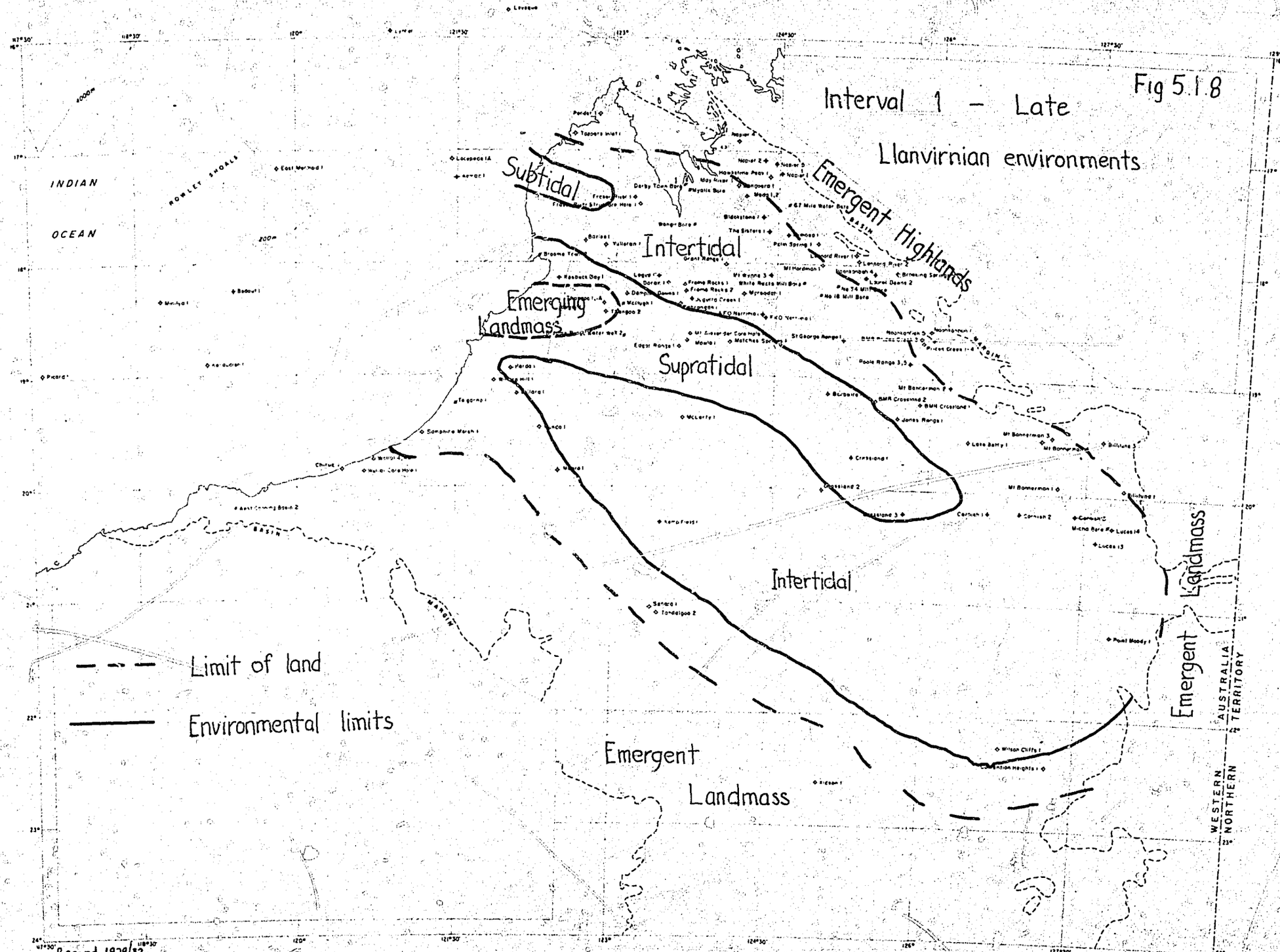
The dolomite and sandstone of the Gap Creek Formation in the Prices Creek area were deposited in the intertidal and eventually supratidal zones in the middle and late Arenigian (Fig. 5.1.6). Shallower waters and the presence of interbedded siliceous sandstone imply movement along the fault north of the Prices Creek area (Broad, 1973). The Munro Fault was also active south of the Willara Sub-basin. The upthrown side of the fault (as indicated by Munro No. 1) remained an emergent landmass, a narrow island surrounded by a shallow epeiric sea.

In the early Llanvirnian the area of subtidal sedimentation had expanded (Fig. 5.1.7) and the landmass on the upthrown side of the Munro Fault was submerged. Shale and carbonate of the Goldwyer Formation were deposited in a shallow epeiric sea that extended into the eastern Kidson Sub-basin and probably across the now subdued eastern land mass into the Amadeus Basin. The deepest part of the Kidson Sub-basin had apparently shifted north by the Llanvirnian. The southern part shallowed and supratidal to intertidal sediments were deposited there (Fig. 5.1.7), as indicated by the presence of gypsum crystals, anhydrite veins, and mudcracks in Kidson No. 1 (Laporte, 1969).


Fig. 5.1.5.
Interval 1 Lithofacies map
middle-late Arenigian
INDIAN
OCEAN
ROWLEY SHOALS
200m
BASIN
MARGIN
WESTERN AUSTRALIA
NORTHERN TERRITORY
1 Sandstone
2 Shale
4 Limestone
5 Dolomite
Record 1979/52
XAUS-4-89
87%


Fig 5.1.6
Interval 1
Middle - Late Arenigian Environments
INDIAN
OCEAN
Subtidal
Intertidal
Emergent
Highlands
Supratidal
Intertidal
Intertidal
Emergent
Highlands
Emergent
Landmass
Subtidal
Intertidal
Emergent Highlands
Limit of land
Environmental limits
WESTERN AUSTRALIA
NORTHERN TERRITORY
Record 1978/32
XAUS-4-90
87%


Fig. 5.1.7
Interval 1
Early Llanvirnian environments
INDIAN
OCEAN
ROWLEY SHOALS
Subtidal
Supratidal
Intertidal
Intertidal
Intertidal
Emergent
Highlands
Subtidal
Emergent Landmass
AUSTRALIA
TERRITORY
WESTERN
NORTHERN
Intertidal
Supra-
tidal
Emergent
Landmass
Limit of Land
Environmental limits
Record 1979/32
XAUS-4-91



Record 1979/32

XAUS-4-92

Rocks of Llanvirnian age are absent from the northeastern Canning Basin and the Prices Creek area, and if deposited they must have been removed by subsequent erosion. Lenses of dolomite, coquina, and sedimentary structures in wells on the Broome Arch suggest that deposition continued in shallow water, probably fluctuating between the subtidal and intertidal zones, and for brief periods the arch may have been emergent. Cyclic deposits of shale and limestone in Blackstone No. 1 suggest periodic subsidence due to faulting in the northern part of the basin during the Llanvirnian.

Regression

The sediments of the Nita Formation grading upwards from shale to limestone to dolomite and dolomitic limestone, and finally into anhydritic carbonate and shale clearly record a change in the environment of deposition from subtidal through intertidal to supratidal (Fig. 5.1.8) as the sea regressed northward to the Fitzroy Graben in the late Llanvirnian (middle Ordovician). Subsidence ceased in the Kidson and Willara Sub-basins, but continued along the northern part of the Fitzroy Graben which continued to receive sediment into the Llandeilian (late middle Ordovician). This suggests that the sea regressed westward, along the Fitzroy Graben, and possibly entirely out of the Canning Basin. The final stages of the regression may have continued into the Late Ordovician, but no sediments of this age are known to be preserved.

Increasing amounts of anhydrite near the top of interval 1 imply a climatic change from humid to semi-arid.

5.2 INTERVAL 2

Introduction

Interval 2 contains sediments deposited in the Lower and Middle Devonian. Three units, the basal Carribuddy Formation, the overlying Tandalgoo Red Beds, and the laterally equivalent Poulton Formation, constitute the bulk of the interval, which also includes an unnamed Lower Devonian dolomite in Roebuck Bay No. 1 and thick units of uncertain lithology interpreted from seismic data to be present deep beneath the Fitzroy Graben. The interval disconformably and unconformably overlies Interval 1 (Fig. 3.12.1) and is conformably and discon-

formably overlain by younger units. The stratigraphy of the units within the interval is summarised in Appendix 2.

Thickness

The interval is confined to the subsurface, apart from some outcrops of undated but possibly correlative coarse-grained clastic sediments overlying the Precambrian in the northwestern margin of the basin. Tracing of the interval on seismic sections between well control has been hindered by the absence of strong reflections to mark its boundaries. The interval is preserved throughout much of the basin (Pl. 10-2), although its extent across and to the north of the Fitzroy Graben is uncertain. The interval was truncated by erosion near the Broome Arch before interval 4 was deposited, and its upper part (the Tandalgoo Red Beds) is absent from the Willara Sub-basin, probably also as a result of pre-interval 4 erosion. The Poulton Formation was deposited in palaeotopographically low areas north of the Fitzroy Graben.

A complete section is preserved in the Kidson Sub-basin where the interval is 3600 m thick. It thins away from this depocentre, a depositional effect accentuated by later erosion, but may attain thicknesses in excess of 2000 m again in poorly known areas of the Fitzroy Graben (Pl. 10-2). The relative thicknesses of the component formations of the interval are shown in the lithological correlation diagrams (Pl. 11A-H).

Lithology

In the better-known area in the southern part of the Canning Basin the interval consists of red-brown and green anhydritic dolomite, dolomitic shale, crystalline brown sandy halite, thin limestone, and red claystone of the Carribuddy Formation, overlain by sandstone - ranging from fine-grained to pebbly - of the Tandalgoo Red Beds. This sandstone ranges from highly permeable and clean to tight with a clay matrix. Red and brown pigments are common and in part the component sand grains are frosted and well-rounded.

The halite beds may continue beneath the Fitzroy Graben onshore and offshore, but only red clastics, ranging from clay to conglomerate, occur to the north.

Depositional environments

The time between the middle or Late Ordovician regression at the close of interval 1 and the Middle Devonian transgression at the beginning of interval 3 may be broken into:

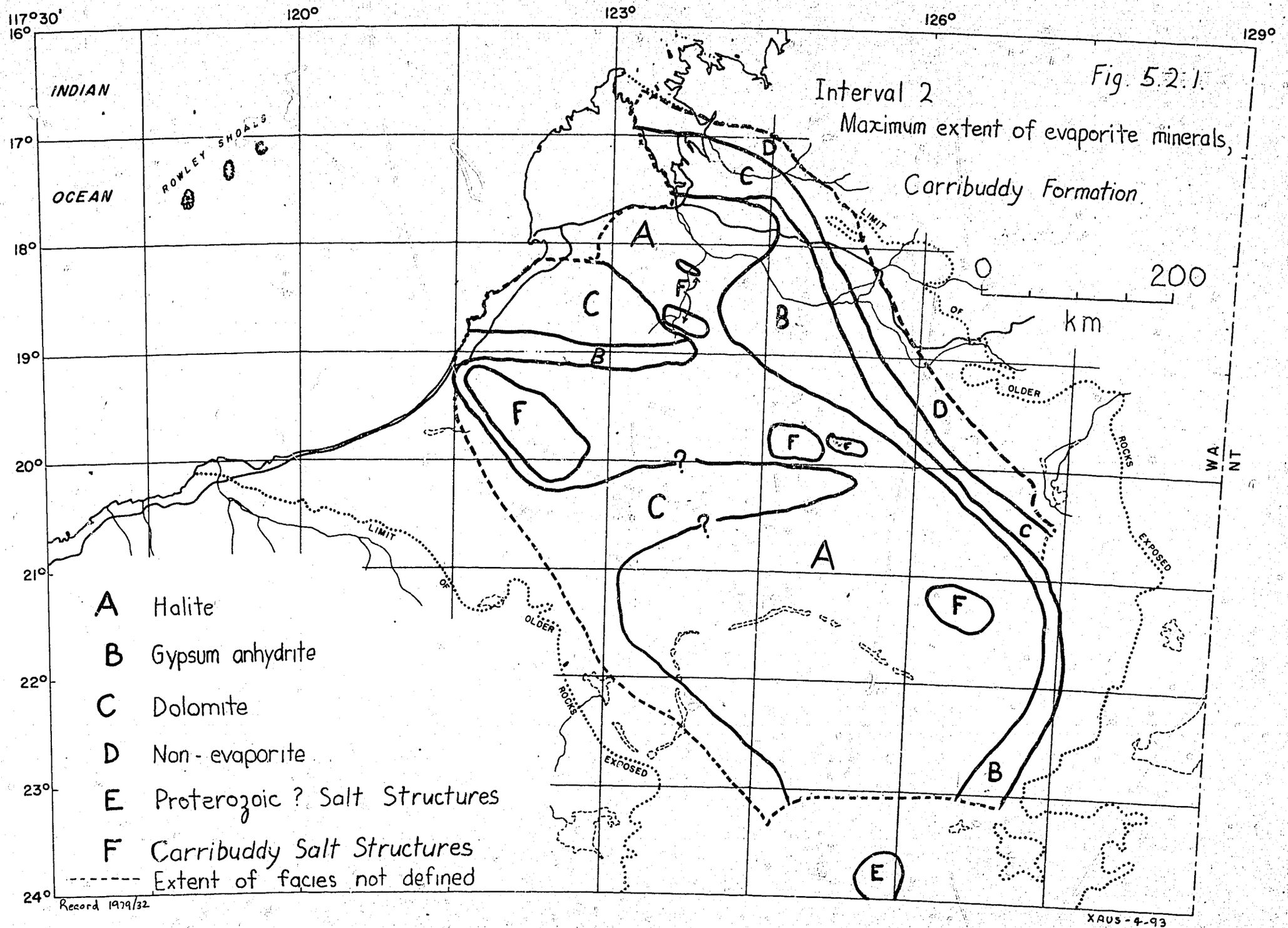
(1) Transgression and deposition of widespread evaporites, probably in the Early Devonian; and

(2) Regression and deposition of continental red beds, probably mainly in the Middle Devonian.

Deposition of evaporites

Glover (1973) has described three sedimentary facies that make up much of the Carribuddy Formation; these are the grey dolomitic facies, the red dolomitic facies, and the halite facies. These are all interbedded in the thickest section so far penetrated (Kidson No. 1), but the maximum extent of each of the evaporitic minerals within the formation, and its correlatives, shows an interesting distribution (Fig. 5.2.1). Halite is localised in the centre of the basin, and there is a progression outwards through gypsum or anhydrite to dolomite, and then to a belt of sediments in the north of the basin that contain no evaporitic minerals. This distribution is generalised and does not represent a single time plane. It is also incomplete because the sequence has been eroded in the west and the sampling is very broad. However the only evaporitic minerals identified to date are halite, dolomite, anhydrite, and barite (Glover 1973, and pers. comm.). The apparent absence of other salts, taken together with the low initial bromine content of the halite, suggests that a brine of sufficient concentration for their precipitation was not formed.

Staining of the fine-grained dolomites by hematite, the growth of authigenic silica, and the post-depositional solution of halite and its re-precipitation with an incresed bromine content - probably derived from surrounding clay minerals (Glover, 1973) - are consistent with diagenesis by lower-salinity groundwater. This type of diagenesis must have recurred sporadically during deposition of the unit, because the effects are evident low down in the sequence and cannot be related to proximity to the overlying Tandalgoo Red Beds, which are a good aquifer.


Fig. 5.2.1.
Interval 2
Maximum extent of evaporite minerals,
Carribuddy Formation
117°30'
120°
123°
126°
129°
16°
17°
18°
19°
20°
21°
22°
23°
24°
INDIAN
OCEAN
ROWLEY SHOALS
0
200
km
WA
NT
LIMIT OF OLDER ROCKS EXPOSED
A Halite
B Gypsum anhydrite
C Dolomite
D Non - evaporite
E Proterozoic ? Salt Structures
F Carribuddy Salt Structures
------ Extent of facies not defined
Record 1979/32
XAUS-4-93

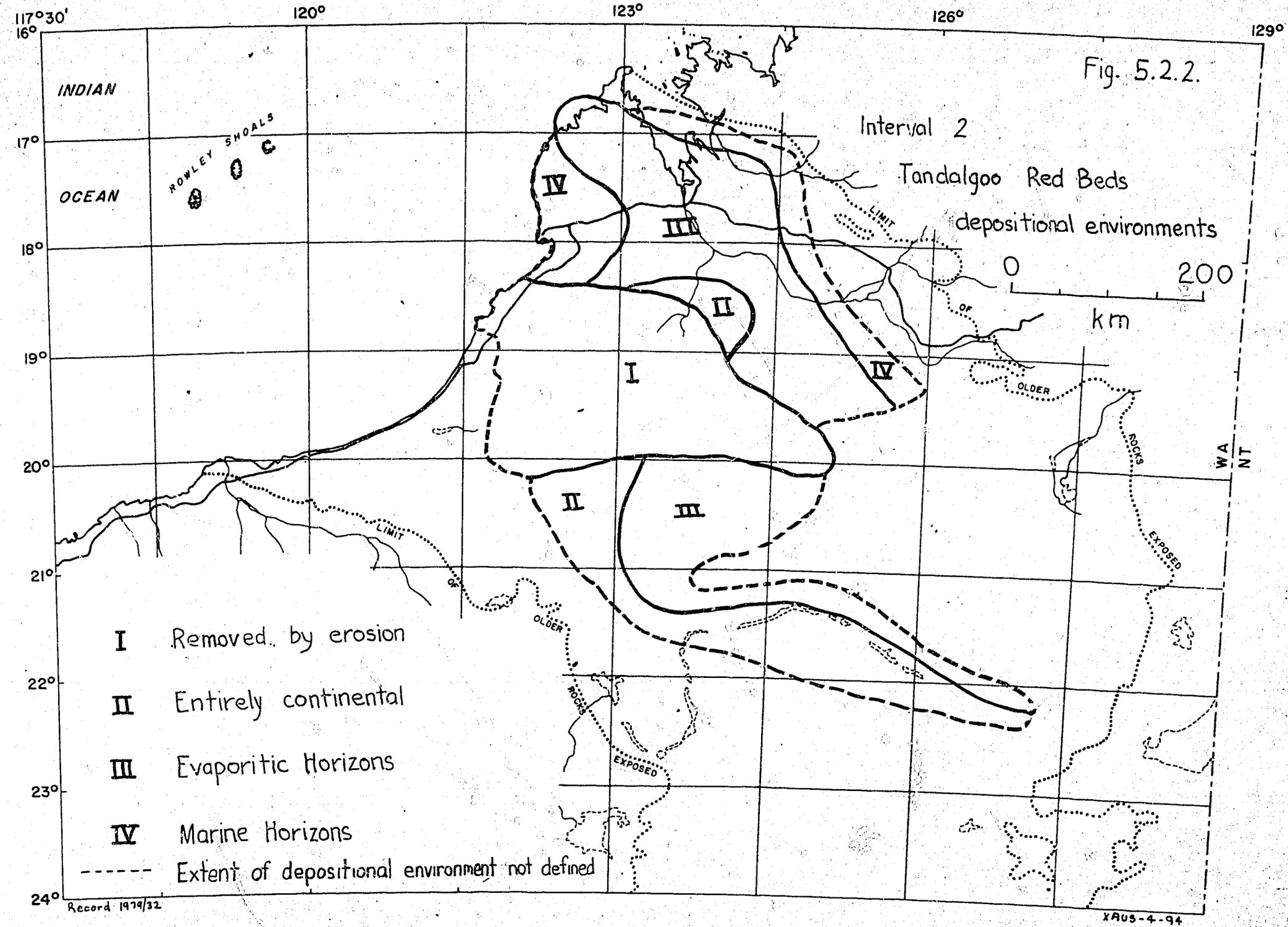
The grey dolomitic facies (Glover, 1973) contains mud curls and is cross laminated, and both the grey and the red dolomitic facies contain stromatolites. Marine organisms have been recorded from the Carribuddy Formation, although biological remains are very rare (Appendix 2).

The paucity of data and the shortage of suitable depositional models in recent sediments renders the interpretation of the depositional environments of the complex of lithologies in this part of the interval difficult. The interpretation must take into account the following constraints: (1) the great volume of the evaporites; (2) the long hiatus preceding deposition; (3) the rapid establishment of a zoned evaporite mineral distribution; (4) the geochemistry of the evaporites; (5) the primary sedimentary structures indicating subaqueous accumulation; (6) biological evidence for a marine origin for part of the sequence; and (7) diagenetic features indicating periodic emergence during deposition of the evaporites.

Hsu (1971) & Friedman (1971) have reviewed the various models proposed for the origin of large evaporite deposits. The main models are: (1) the shallow barred basin with a standing body of recharging brine; (2) the deep barred basin with a standing body of recharging brine; (3) the evaporation of a large brine-soaked sabkha; and (4) the dessication of a deep isolated marine basin.

The validity of the first two models has been questioned (Hsu, 1971) since their suggested recent analogues, the Gulf of Kara Bogaz and the Red Sea respectively, have been found to have other origins. The third model implies post-depositional increase in evaporative grade of pore waters in a supratidal environment, whereas there is evidence that the Canning Basin evaporites underwent diagenetic alteration by lower-salinity groundwater and that evaporative conditions existed at the time of sedimentation. However with a little modification the model could well explain a proportion of the evaporite mineral accumulation.

The model of a deep-water dessicating basin was proposed by Hsu (1971) to explain the occurrence of Messinean evaporites in the Mediterranean, where halite and other evaporites are intimately inter-bedded with pelagic sediments. In the Canning Basin shallower water sediments are interbedded, but with appropriate modification this model would satisfy the required constraints. The deflating pediment of the pre-Carribuddy stage was rapidly invaded by a sea with restricted circulation. There followed successive periods of evaporation,


117°30'
120°
123°
126°
129°
16°
17°
18°
19°
20°
21°
22°
23°
24°
INDIAN
OCEAN
ROWLEY SHOALS
Fig. 5.2.2.
Interval 2
Tandalgoo Red Beds
depositional environments
0
200
km
LIMIT
OF
OLDER
ROCKS
EXPOSED
WA
NT
I Removed by erosion
II Entirely continental
III Evaporitic Horizons
IV Marine Horizons
Extent of depositional environment not defined
Record 1979/32
XAUS-4-94

precipitation, and recharge, with the concentrated brine being diluted by local runoff at the margins of the basin. Evaporation laid bare the margins of the basin where sabkha supratidal flats developed with pore-water reactions from local runoff that served to produce some of the diagenetic modifications noted by Glover (1973).

Postevaporative red bed phase

Throughout their deposition, the chemical sediments of the evaporating basin were flanked by correlative clastic sediments which are preserved only in the north of the basin. With the final withdrawal of the evaporative seas this marginal clastic environment migrated across the basin to form extensive sand deposits. In the thickest preserved sections (Kidson No. 1) these sediments seem to have accumulated largely as wind dunes (Fig. 5.2.2), but elsewhere fluvial channel fills are inferred from wire-line log profiles, suggesting the presence of interbedded wadi deposits. Although detailed work needs to be done on the Tandalgoo Red Beds and their correlatives they were probably deposited in an arid desert. Northwards the thinning sequence shows greater lithological variation, and in its upper parts it contains both anhydrite and dolomite, and this belt passes northward into a sequence which contains fossiliferous marine sedimentary rocks in its upper part (Napier Range area).

The Tandalgoo Red beds are correlated with part of the Mereenie Sandstone of the Amadeus Basin (Wells & others, 1970).

5.3 INTERVAL 3

Introduction

Interval 3 comprises Middle Devonian to Lower Carboniferous sediments of the Lennard River Group and its correlatives, and the Fairfield Group and the Anderson Formation. The interval is conformable and disconformable on interval 2 and is overlain unconformably by interval 4. The stratigraphy of the component stratigraphic units is summarised in Appendix 3. Relations and time correlation of rock units in the northern part of the basin are illustrated in Figure 5.3.1a, b and thickness and lithology of the interval are summarised in Plate 10-3.

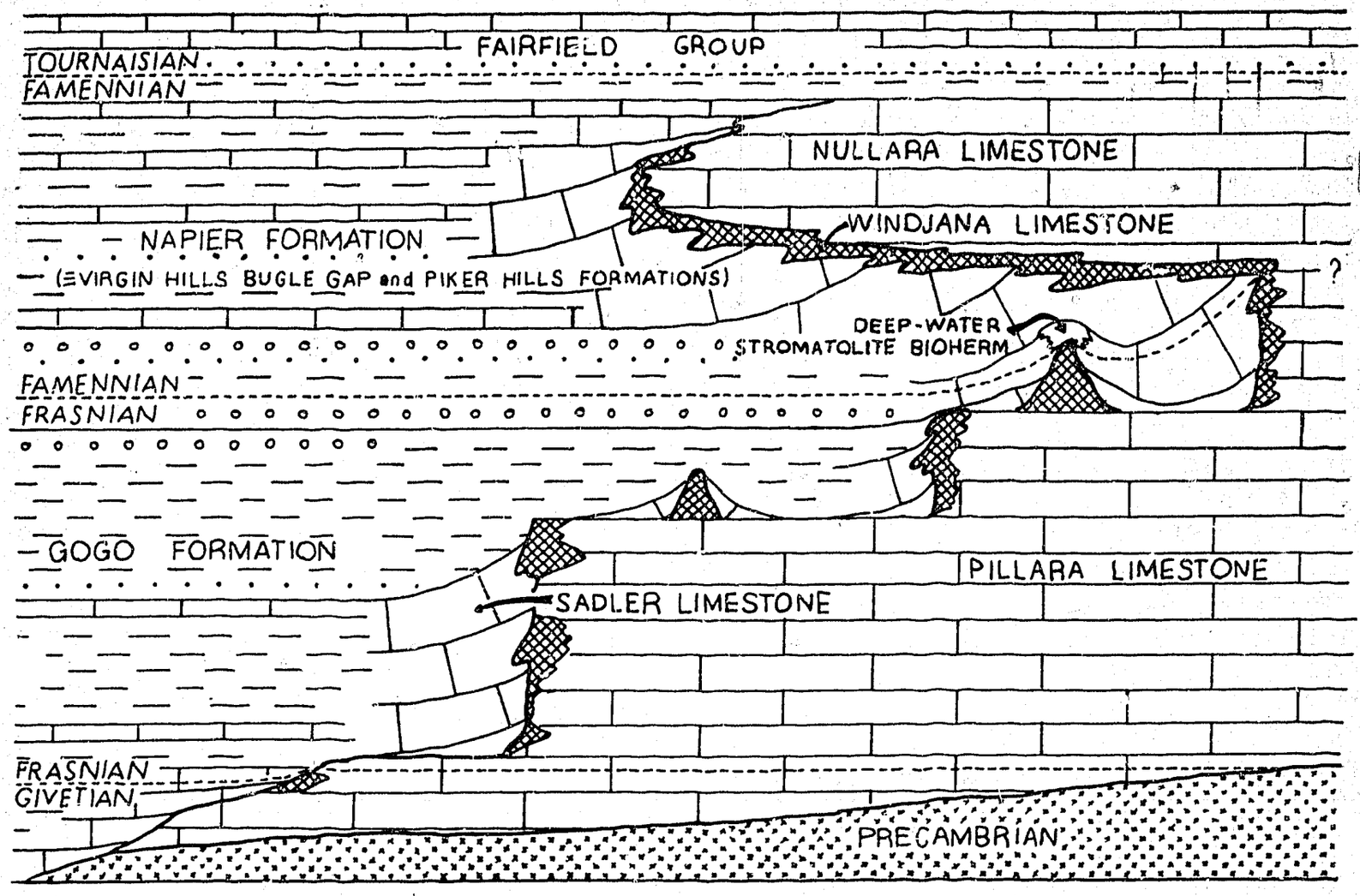
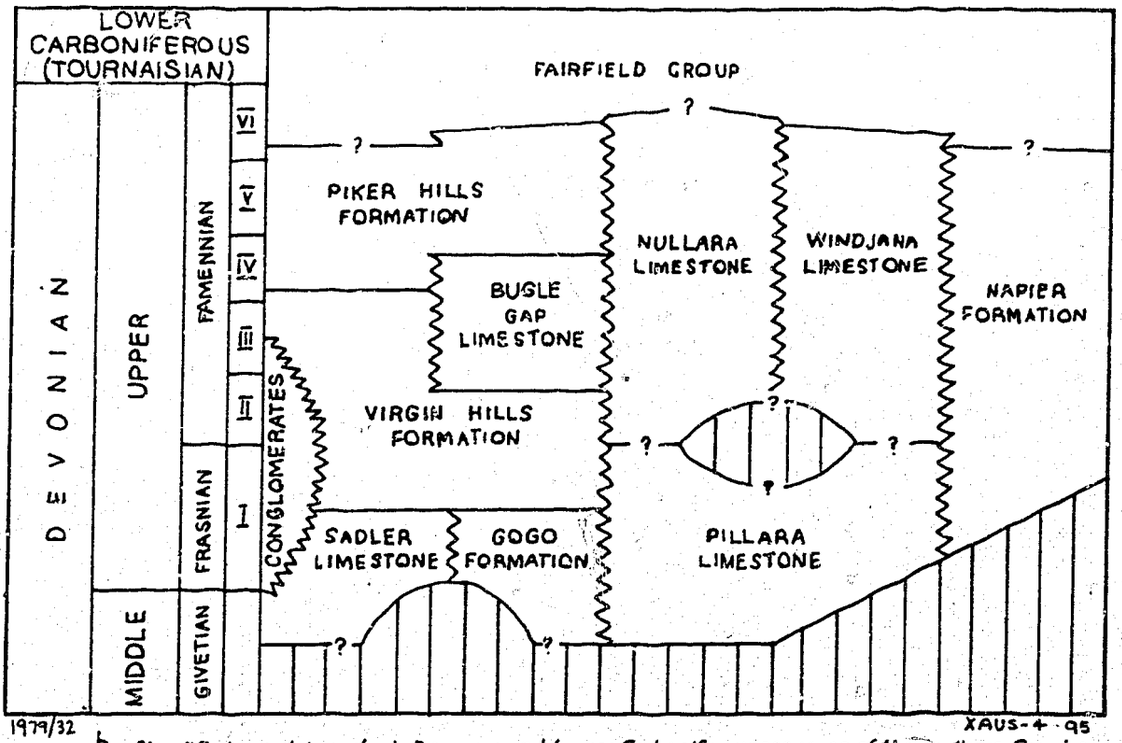


Fig. 5.3.1 a. *Diagrammatic section illustrating relationships of stratigraphic units in the reef complexes (slightly modified after Playford, 1976)*



Record 1979/32 XAUS-4-95

b. *Simplified correlation chart, Devonian and Lower Carboniferous sequence of the northern Canning Basin (slightly modified after Playford, 1976)*

Thickness

The original extent and thickness of the interval is incompletely known because part is missing owing to Carboniferous erosion in the Willara Sub-basin and on the Broome Arch, but it may have been deposited over much of the area of the Canning Basin. Carboniferous erosion has removed part of the interval from all areas south of the Fitzroy Graben (Pl. 10-3). The upper part of the interval, the Fairfield Group and the Anderson Formation, occurs only in the Fitzroy Graben and on the Lennard Shelf.

The interval is over 2000 m thick in the Fitzroy Graben, but is rarely over 1000 m thick on the terraces and shelves bordering the graben.

Lithology

The lithology of the interval is summarised in Plates 10-3 and 11-1 to 8. The sediments of the Lennard River Group include: conglomerate with a red-brown sandstone matrix; fining-upward sandstone units intercalated with limestone; and a variety of shallow-marine carbonate sediments, including grey and white stromatoporoid and algal biostromes, calcarenite, recrystallised dolomite, and, particularly in the Kidson Sub-basin, laminated dolomite with traces of gypsum. These shallow-marine carbonates acted as the sources for a number of carbonate slope deposits composed of calcareous breccia and conglomerate with steep depositional dips intercalated with both coarse and fine-grained terrigenous clastic sediments. Basinal sediments are mostly fine-grained and interbedded with laterally continuous coarser-grained units of calcarenite and sandstone.

There is a marked structural control of facies, particularly in the Lennard River Group, in which carbonate bodies formed only on the shelves and terraces adjacent to the Fitzroy Graben. Logan & Semeniuk (1976) have described many fabrics and structures within these carbonates that may reflect a complex post-depositional history of solution and load metamorphism.

The overlying Fairfield Group is composed of detrital limestone, dark grey shale, siltstone, and fine-grained to conglomeratic sandstone. The proportion of sandstone in the group ranges from over 30 percent in Napier No. 4 to under 5 percent in Napier No. 5 and reflects complex local facies variation. This group has been described in detail by Druce & Radke (in press).

Depositional environments

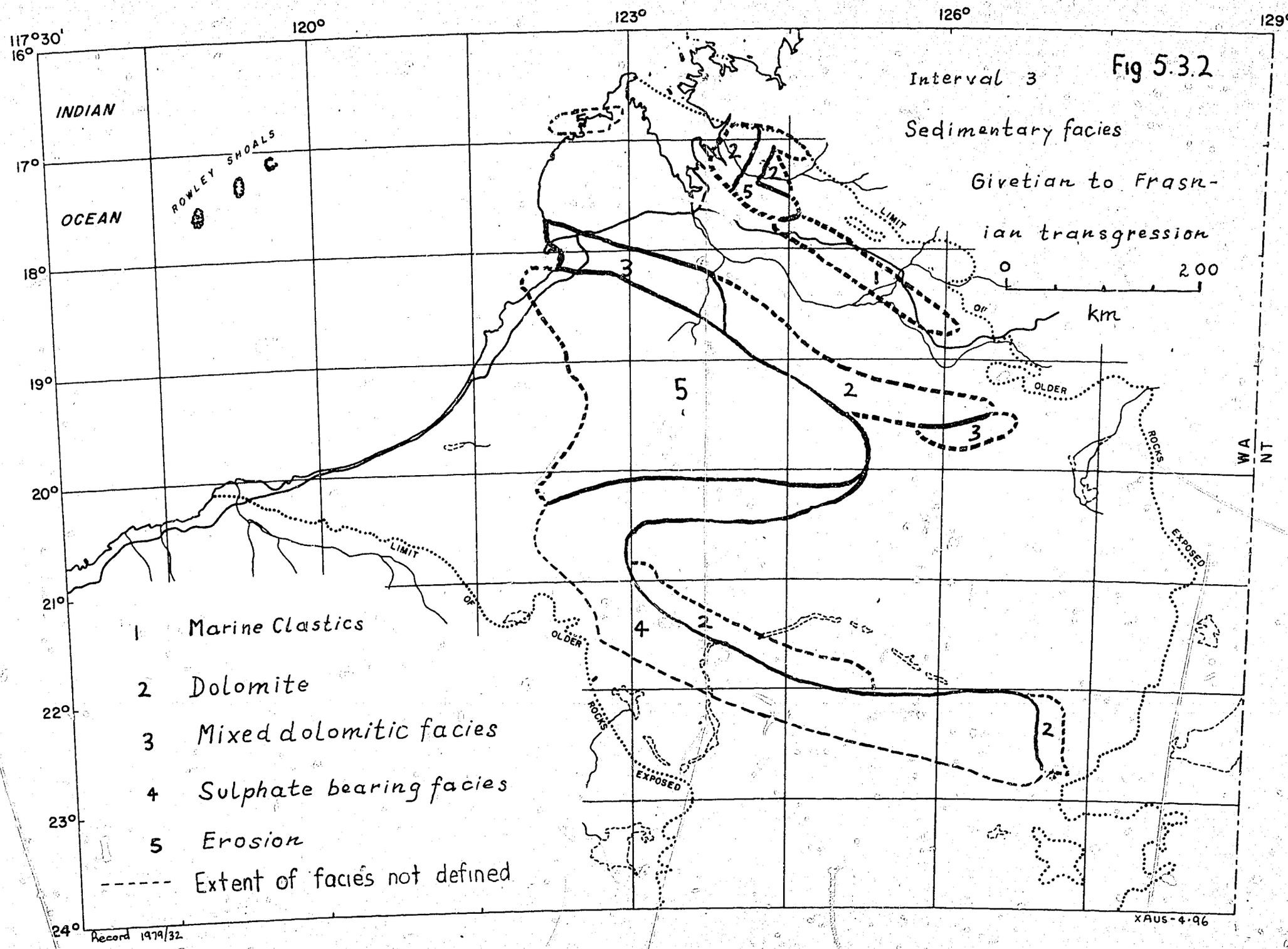
It is convenient to consider the sedimentation of this Middle Devonian to Early Carboniferous interval in four more or less distinct stages:

(1) the Givetian to Frasnian transgression;
(2) late Frasnian to early Famennian deepening and subsequent infilling;
(3) Famennian shallow-marine stage, and
(4) Late Devonian and Early Carboniferous regressions.

The Givetian to Frasnian transgression. The Canning Basin subsided in the Givetian, and the sea transgressed into the Fitzroy Graben, over the irregular topography northeast of the graben, and across gentle topography southwest of the graben. In the northeast the basal beds of the transgression are conglomeratic, whereas in the southwest the transgressing sea deposited laminated gypsum-bearing dolomites on supratidal and intertidal flats in which calcium sulphate was deposited (Mellingerie Formation; Fig. 5.3.2).

The maximum extent of this transgression is unknown owing to the effects of Carboniferous erosion, but it may have extended over most of the area of the Canning Basin. Local areas in the north of the basin and on the southern margin of graben, such as the Babrongan area, remained emergent until well into the Frasnian. Red dolomitic siltstone (the Babrongan Beds) showing evidence of subaerial exposure is preserved in the Babrongan area. The red staining of fluviatile and paralic sediments interbedded with shallow marine carbonates in the Pillara Formation of Windjana Gorge are also thought to reflect subaerial conditions (Read, 1973a).

The marine limestones on the northern margin of the basin have been closely studied (Teichert, 1939c, 1940, 1941a, b, e, 1942a, 1947, 1949a, c; Rattigan & Veevers, 1961; Playford & Lowry, 1966; Playford, 1967, 1969, 1976; Read, 1973a, 1973b; Logan & Semeniuk, 1976; Playford & others, 1975). Playford, 1976 suggested that the initial deposits were stromatoporoid and coral banks having little or no reef development around their margins and only low relief above their surroundings. These banks are generally characterised by retreating platform margins and are flanked by gently dipping marginal-slope deposits (Fig. 5.3.1a). Pronounced reefs grew on the platform margins in the early Frasnian, so that the platforms developed considerable relief above their


Fig 5.3.2
Interval 3
Sedimentary facies
Givetian to Frasnian transgression
117°30'
120°
123°
126°
129°
16°
17°
18°
19°
20°
21°
22°
23°
24°
INDIAN
OCEAN
ROWLEY SHOALS
LIMIT
OF
OLDER
ROCKS
EXPOSED
0
200
km
WA
NT
1 Marine Clastics
2 Dolomite
3 Mixed dolomitic facies
4 Sulphate bearing facies
5 Erosion
----- Extent of facies not defined
Record 1979/32
XAus-4-96

surroundings, possibly up to 200-300 m. These reefs grew almost vertically and were flanked by steeply dipping deposits containing large amounts of reef-derived talus. From time to time, as a result of abrupt subsidence, related to downfaulting of the Fitzroy Graben, the sea inundated the platforms; this caused the platform margins to retreat, and favoured the growth of patch reefs, which - with continued subsidence - grew into steep-sided pinnacles. These sediments, together with their marginal slope and basin deposits (Pillara Formation and Sadler Limestone), are flanked to the north by conglomeratic sediments derived from the Precambrian, and to the south by deeper-water sediments including the turbidite facies of the Gogo Formation in the Bugle Gap area and of the lowest rock unit penetrated in Mimosa No. 1.

South of the graben, the tectonics were less suited to reef development, and a dolomitised shelf and intertidal carbonate sequence evolved (Pillara Formation) flanked by the paralic Mellingerie Limestone.

During this stage the Fitzroy Graben was downfaulted along growth faults adjacent to its northern margin. Reverse drag-folds developed on the downthrow side of these faults, the troughs received thicker wedges of sediment, and the anticlinal crests of some of the folds were eroded.

Late Frasnian to early Famennian deepening. Playford (1976) considered this stage to be a gradual deepening of the sea. The deepening was accompanied by the growth of pinnacle reefs and culminated in their drowning. Deep-water stromatolitic bioherms grew over the drowned shallower reef carbonates at localities such as the Elimberrie Bioherms (Playford, 1976). The deepening may be marked by a condensed sequence or by a local disconformity over much of the area, especially south of the graben. The correlative section within the graben has not yet been drilled.

The Famennian shallow marine stage. Shallow-marine carbonate banks became widely established again during the Famennian. Playford (1967) has differentiated two formations which are distinct facies of this shallow-marine stage. The Windjana Limestone of the Lennard Shelf is regarded as a reef facies, whereas the Nullara Limestone is a back reef and bank unit. Playford considered that the sediments of the Napier Formation were deposited on slopes marginal to the Windjana Limestone, which advanced nearly horizontally over the Napier Formation early during sedimentation.

The Napier Formation, with its correlatives the Virgin Hills, Bugle Gap, and Piker Hills Formations are infilling slope deposits, and are composed of both terrigenous and carbonate material in an association of megabreccias and finer-grained interbeds.

Mixed carbonate and bioturbated shallow-marine terrigenous sediments of the Clanmeyer Siltstone and Luluigui Formation were deposited in the Fitzroy Graben during this stage. Limestone with birds-eye structure accumulated south of the graben.

Having reached their maximum extent, the platform deposits grew vertically with subsidence throughout the late Famennian until further growth was halted by a gradual regression.

Infilling by slope deposits resulted in shoaling and erosion of marginal areas to form the unconformity penetrated in Mimosa No. 1 and Blackstone No. 1. Some of the post-Frasnian erosion of the area south of the graben may also have occurred at this time. The areal exent and possible continuity of these unconformities has yet to be established.

Late Devonian and Early Carboniferous regressions. Druce & Radke (in press) have suggested that the sea occupied the Fitzroy Graben continuously throughout this stage while the Fairfield Group and Anderson Formation were being deposited, but that marine transgressions and regressions occurred over the shallower Lennard Shelf and adjacent terraces. The basal unit of the Fairfield Group as recognised by Druce & Radke (1978) is the Gum Hole Formation, which is a fine-grained laminated limestone with birds-eye structure. The formation is synonymous with part of the Nullara Limestone of Playford (1976). These sediments occur only locally. Elsewhere, Druce & Radke (in press) have recognised a shallow-marine sequence of intertidal, restricted platform, shoal, inter-shoal, and open platform sediments. Small open platform bioherms continued to grow locally, but there was a gradual change to an association of tidal channel sand, dolomitic supratidal siltstone, and intertidal calcareous silt and limestone (Yellow Drum Sandstone).

Lagoonal sediments (Laurel Formation) were deposited in the Early Carboniferous. They are overlain by restricted platform and open-marine sediments. A major regression followed, and the fluviatile medium-grained sandstone and minor interbedded coal of the Anderson Formation was deposited.

The Carboniferous erosion preceding the deposition of interval 4 resulted in the deep dissection of the sediments of interval 3 and their complete removal from much of the basin.

5.4 INTERVAL 4

Interval 4 comprises the Grant and Paterson Formations, Poole Sandstone, Noonkanbah Formation, and Liveringa Group, and their correlatives of Late Carboniferous and Permian age throughout the basin. Details of lithology, correlations and age, and relations with older units are given in Appendix 4. Thickness and lithology are summarised in Plate 10-4. To treat the whole of interval 4 as one unit does not give a valid picture of the palaeoenvironments, thickness trends, or overall lithology. The interval has therefore been divided into eight subintervals which are defined in Table 5.4.1.

Table 5.4.1 SUBINTERVALS AND STRATIGRAPHIC RELATIONS OF INTERVAL 4

Subinterval	Age	Stratigraphic components
4h	early Tatarian	Hardman Formation (including Kirkby Range Member, Hicks Range Member, Cherrabun Member), Godfrey Beds, and Chirup Formation* Fig. 5.4.9
4g	Kazanian	Condren Sandstone. Fig. 5.4.8
4f	Kungurian to late Artinskian	Lightjack Formation (including Balgo Member) and Triwhite Sandstone. Fig. 5.4.7
4e	Artinskian	Noonkanbah Formation (including Dora Shale). Fig. 5.4.6
4d	late Sakmarian to early Artinskian	Poole Sandstone (including Nura Nura Member and Cuncudgerie Sandstone). Fig. 5.4.4 and 5.4.5
4c	early Sakmarian	Grant Formation C (including Wye Worry Member, Millajeedee Member, and unnamed basal sandstone of Crowe & Towner, 1976a), Paterson Formation, Buck Formation, and Braeside Tillite. Fig. 5.4.3
4b	basal Sakmarian	Grant B Formation. Fig. 5.4.2
4a	Stephanian to basal Sakmarian	Grant A Formation. Fig. 5.4.1

* New name, proposed

Sand:shale ratios and thicknesses of each subinterval are described in Figures 5.4.1 to 5.4.9.

Subinterval 4a

Subinterval 4a is thickest (1654 m) in the central northwestern Fitzroy Graben and thins northwards (onlaps?) onto the Kimberley Block and southwards onto the Broome Arch. This abrupt thickness change is a direct consequence of active downfaulting or sagging of the graben between the Oscar-Pinnacle-Bannerman Fault System in the north and the Fenton Fault System in the south. Sediments are thin or absent on the higher parts of the Broome Arch. A secondary depocentre was located in the Kidson Sub-basin where over 500 m was deposited. The offshore extent of the subinterval is unknown, but is believed to parallel the onshore pattern, i.e. thickest in the graben. However, erosion in the offshore area has probably removed most of interval 4, which is absent in Wamac No. 1 and Lacepede No. 1A wells; in both these wells interval 6 overlies interval 3 directly.

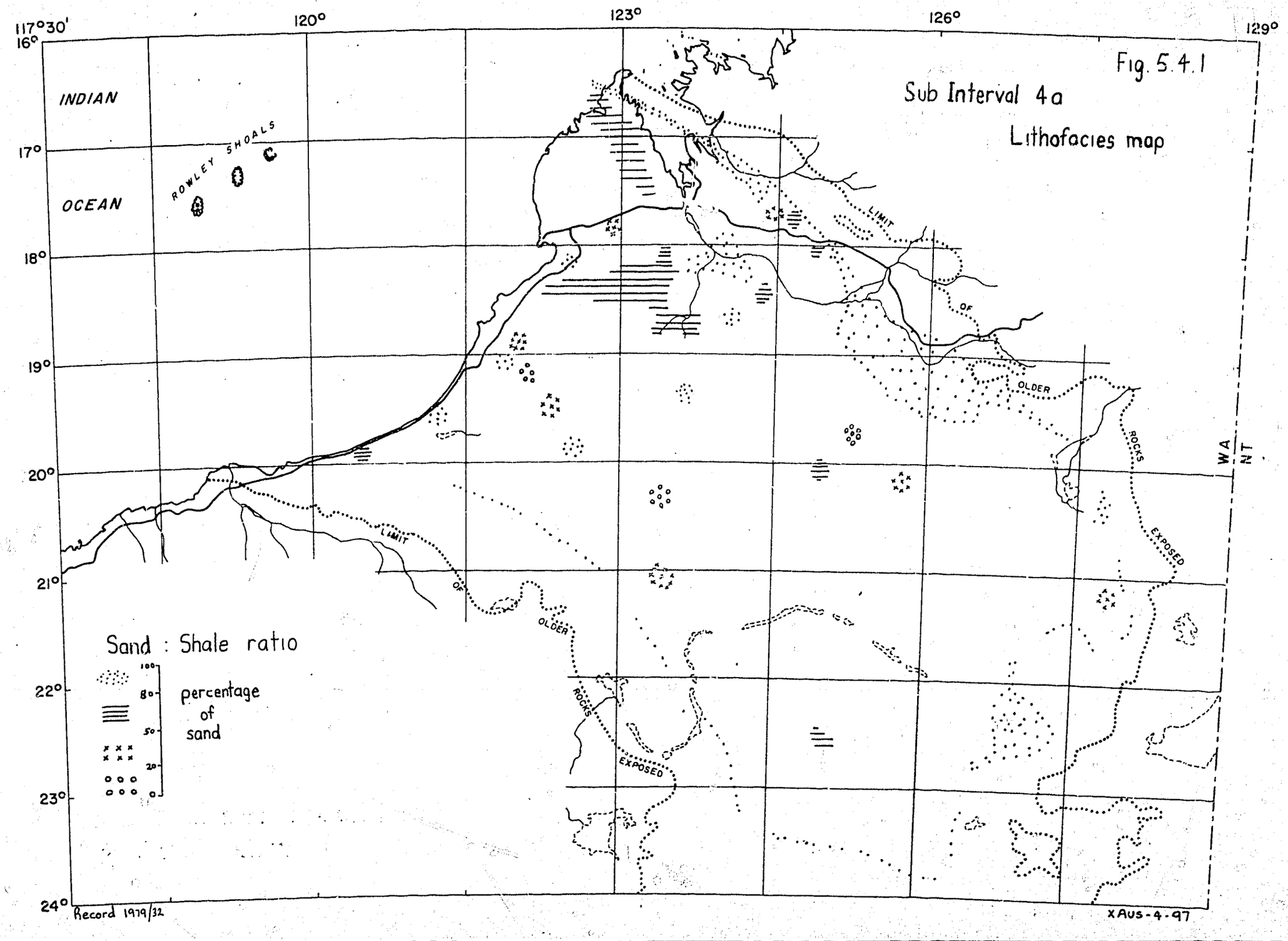
Most of the rocks of subinterval 4a have a low sand-to-shale ratio (Fig. 5.4.1). The increase in the amount of finer-grained clastics, evident in the Willara and Kidson Sub-basins, may be due to distance of transport from the source areas and also reflect the more stable tectonic environment in the southern Canning Basin compared with the seismically active Fitzroy Graben.

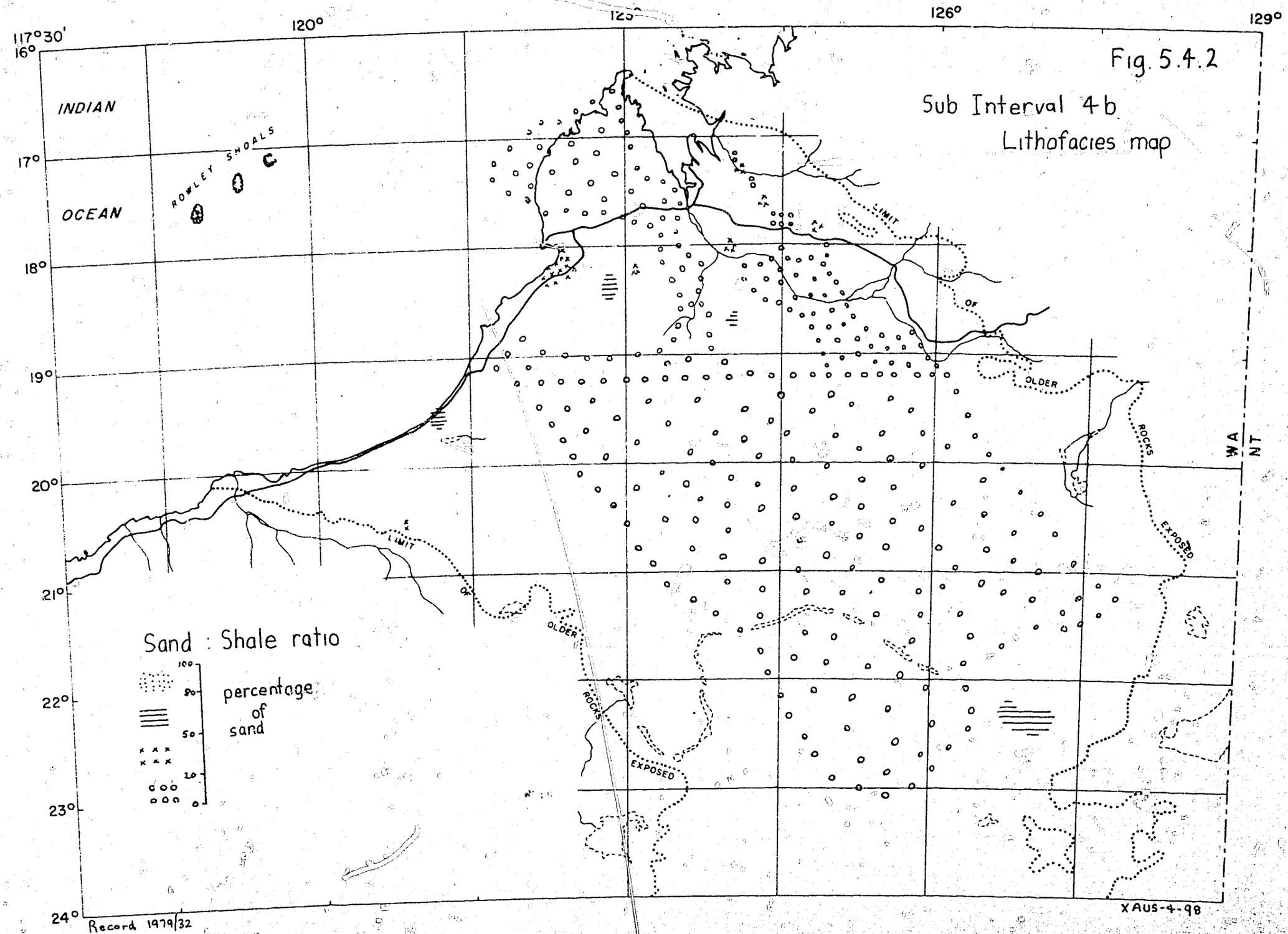
The initial thick, coarse-grained clastic sediments of subinterval 4a, contain a stage 1 microflora, and were deposited in the sea during the initial build up of a continental ice cap. The overlying thin fine-grained clastic sediments which contain a transitional stage 1-2 microflora were deposited in very cold water, and the upper coarser clastic deposits were deposited during the break up of the ice cap where there was more pronounced ice-rafting.

Subinterval 4b

Rocks of subinterval 4b are thickest (550 m) in the Willara Sub-basin and thin towards the Precambrian around the onshore margins of the Canning Basin. The Fitzroy Graben does not appear to have been active at this time. The offshore thickness of the subinterval is unknown, but it is believed to be substantially eroded.

The sand-to-shale ratio map (Fig. 5.4.2) shows that the sediments are mainly fine-grained clastics. No distinct trends are discernable except for a


Fig. 5.4.1
Sub Interval 4a
Lithofacies map
117°30'
120°
123°
126°
129°
16°
17°
18°
19°
20°
21°
22°
23°
24°
INDIAN
OCEAN
ROWLEY SHOALS
LIMIT
OF
OLDER
ROCKS
EXPOSED
WA
NT
Sand : Shale ratio
100
80
50
20
0
percentage
of
sand
Record 1979/32
XAus-4-97


Fig. 5.4.2
Sub Interval 4b
Lithofacies map
117°30'
120°
125°
126°
129°
16°
17°
18°
19°
20°
21°
22°
23°
24°
INDIAN
OCEAN
ROWLEY SHOALS
LIMIT
OF
OLDER
ROCKS
EXPOSED
WA
NT
Sand : Shale ratio
percentage of sand
100
50
20
0
Record 1979/32
XAUS-4-98

high sand area in the region of Babrongan No. 1 and Myroodah No. 1 wells. The reason for this anomalous area is unknown but it may indicate a nearby river mouth.

Subinterval 4b contains marine fossils, including arenaceous foraminifera, bryozoans, and shelly fossils indicating a warmer climate. Again, the presence of a more diverse stage 2 microflora suggests a retreat of the continental ice cap, but not an end to glaciation, as there are exotic clasts in the fine-grained clastic deposits indicating glaciation and ice-rafting. Thin limestones in the central basin area suggest shallow water. Continuing cold temperatures are inferred from arenaceous foraminifera but not necessarily extreme cold waters, because of the presence also of calcareous benthonic foraminifera (Crespin, 1958).

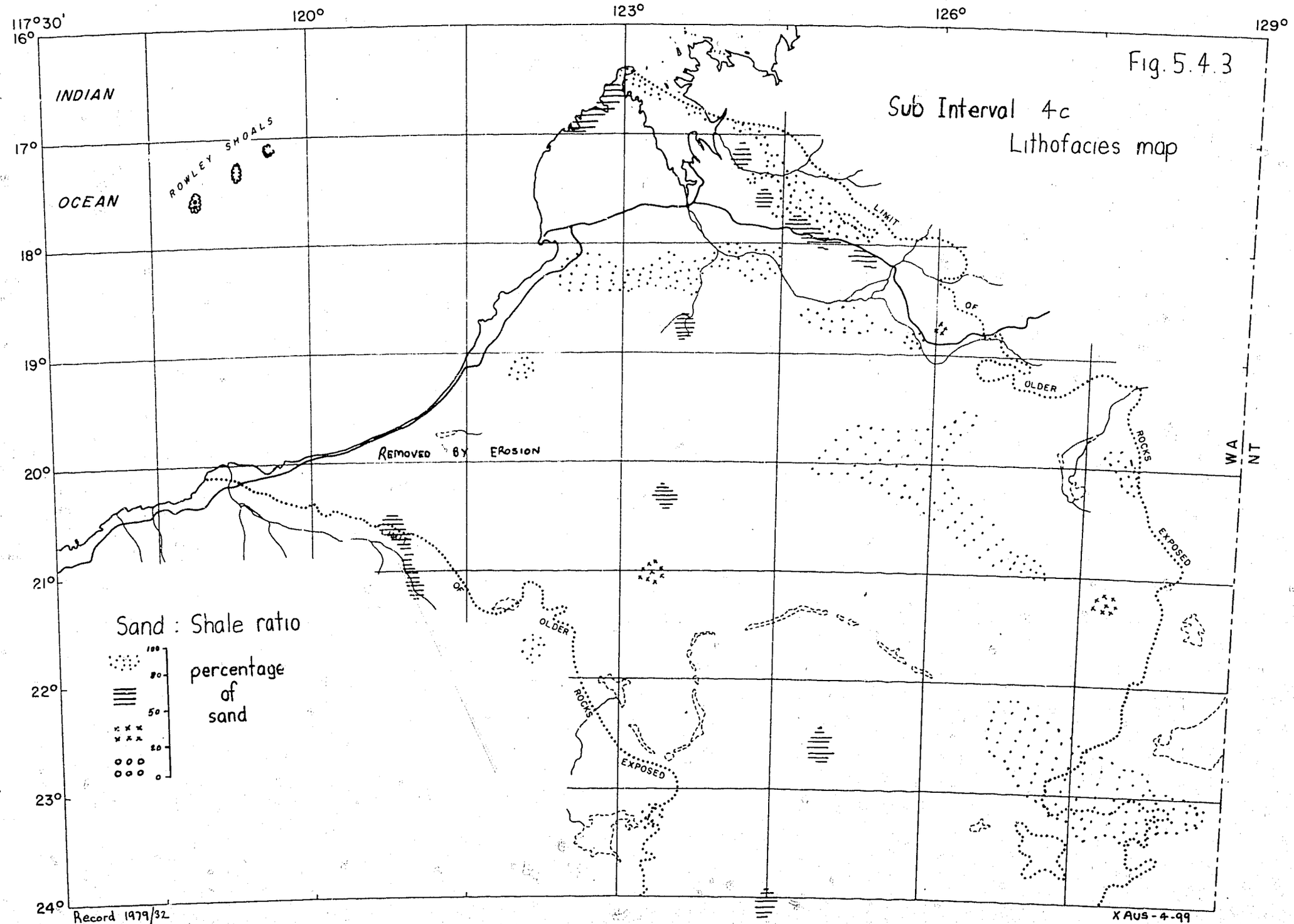
Subinterval 4c

Subinterval 4c is thickest in the northwestern Fitzroy Graben (562 m) and thins onto the Precambrian rocks where it is preserved at present as outliers. A secondary thickening occurred in the Kidson Sub-basin and probably the Wallal Embayment. Interpretation of thickness trends suggests that some minor down faulting may have occurred in the northwestern Fitzroy Graben. The subinterval is believed to be absent due to erosion offshore, but is probably present nearshore in the seaward extension of the Wallal Embayment.

Coarser-grained clastics are concentrated in the northwestern Fitzroy Graben (Fig. 5.4.3) supporting the other evidence for active downfaulting. Outside of this area, the sediments are generally finer-grained, especially in the Kidson Sub-basin.

Subinterval 4c was deposited during another glacial cycle, but one which was not as severe or long-lasting as that represented by subinterval 4a. Cold water faunas (Dickins & others, 1978) and the presence of diamictites with striated and facetted pebbles and boulders attest to the presence of glaciers in the margins of the basin. The central basin was occupied by a cold sea in which arenaceous foraminifera lived, and diamictite and thin limestone were deposited. The Millajeedee Member (Crowe & Towner, 1976a), and the continental deposits of the Buck and Paterson Formations and Braeside Tillite, contain tillite as well as fluviatile and lacustrine sediments that were deposited in the south and east as the ice retreated.

Evidence of a withdrawal of the sea in late Sakmarian time is provided by the presence of an unconformity between subintervals 4c and 4d. Slumping and


117°30'
120°
123°
126°
129°
16°
17°
18°
19°
20°
21°
22°
23°
24°
INDIAN
OCEAN
ROWLEY SHOALS
LIMIT
OF
OLDER
ROCKS
EXPOSED
REMOVED BY EROSION
WA
NT
Fig. 5.4.3
Sub Interval 4c
Lithofacies map
Sand : Shale ratio
100
80
50
20
0
percentage
of
sand
Record 1979/32
X AUS-4-99

faulting of the Grant Formation in the Grant and St George Ranges (Towner & Crowe, in prep.) may have occurred at this time. This faulting and slumping do not affect the overlying Poole Formation.

Subinterval 4d

The thickest measured section of Poole Sandstone - in subinterval 4d - occurs in the Fitzroy Graben (406 m at Nura Nura Ridge). This section is probably extensively faulted and the true thickness at this locality may be less than 350 m. The Poole Sandstone is generally less than 200 m thick. The Fitzroy Graben and the Kidson Sub-basin were the main depocentres of the Poole Sandstone and correlatives, which may have been deposited as a relatively even blanket over the entire onshore area at least. However, extensive erosion is believed to have stripped most of the subinterval from the southwestern area before the Early Jurassic.

Subinterval $4d_1$ (Fig. 5.4.4) is the Nura Nura Member of the Poole Sandstone. A carbonate-rich province is located in the northwest and the section becomes progressively more clastic towards the southeast and east. A concentration of coarser-grained clastics is evident near the limit of the Precambrian rocks and these may be nearshore or beach deposits.

Subinterval $4d_2$ (Fig. 5.4.5) is essentially composed of sandstone, except in the northwest and in the Kidson Sub-basin where finer-grained clastics are more common.

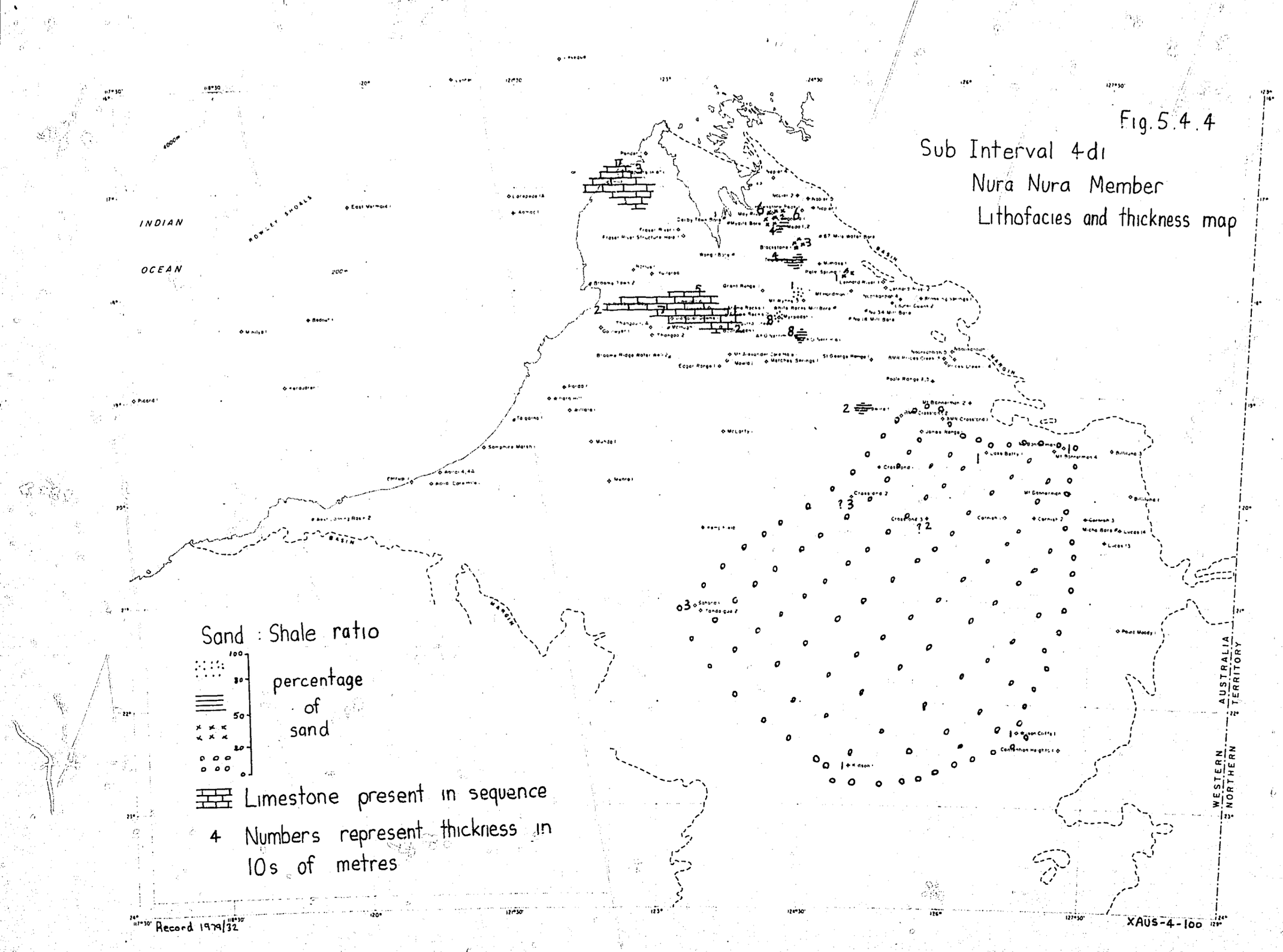
Deposition of subinterval 4d commenced with a marine transgression that inundated the major part of the Canning Basin. The basal, thin, discontinuous Nura Nura Member contains limestone and calcareous sediments in the northwestern area, but elsewhere consists of calcareous sandstone or carbonaceous siltstone and shale. In the northwestern area the Nura Nura Member contains calcareous and arenaceous foraminifera which probably lived in warm to temperate, moderately shallow, open seas (Crespin, 1958). The presence of ammonoids (Playford & others, 1975) and faunas with Tethyan affinities (Dickins, 1978; see also Dickins, 1963) support the foraminiferal evidence. Crowe & Towner (1976b) have recognised a northward facies change in the Nura Nura Member in the Noonkanbah 1:250 000 Sheet area. They demonstrated a facies progression from shallow-marine to lagoonal, deltaic, flood-plain, and braided stream environments towards the basin margin. Farther south and southeast, the presence of only arenaceous foraminifera, abundant carbonaceous material, and pyrite suggests a more restricted environment, and the correlative Cuncudgerie

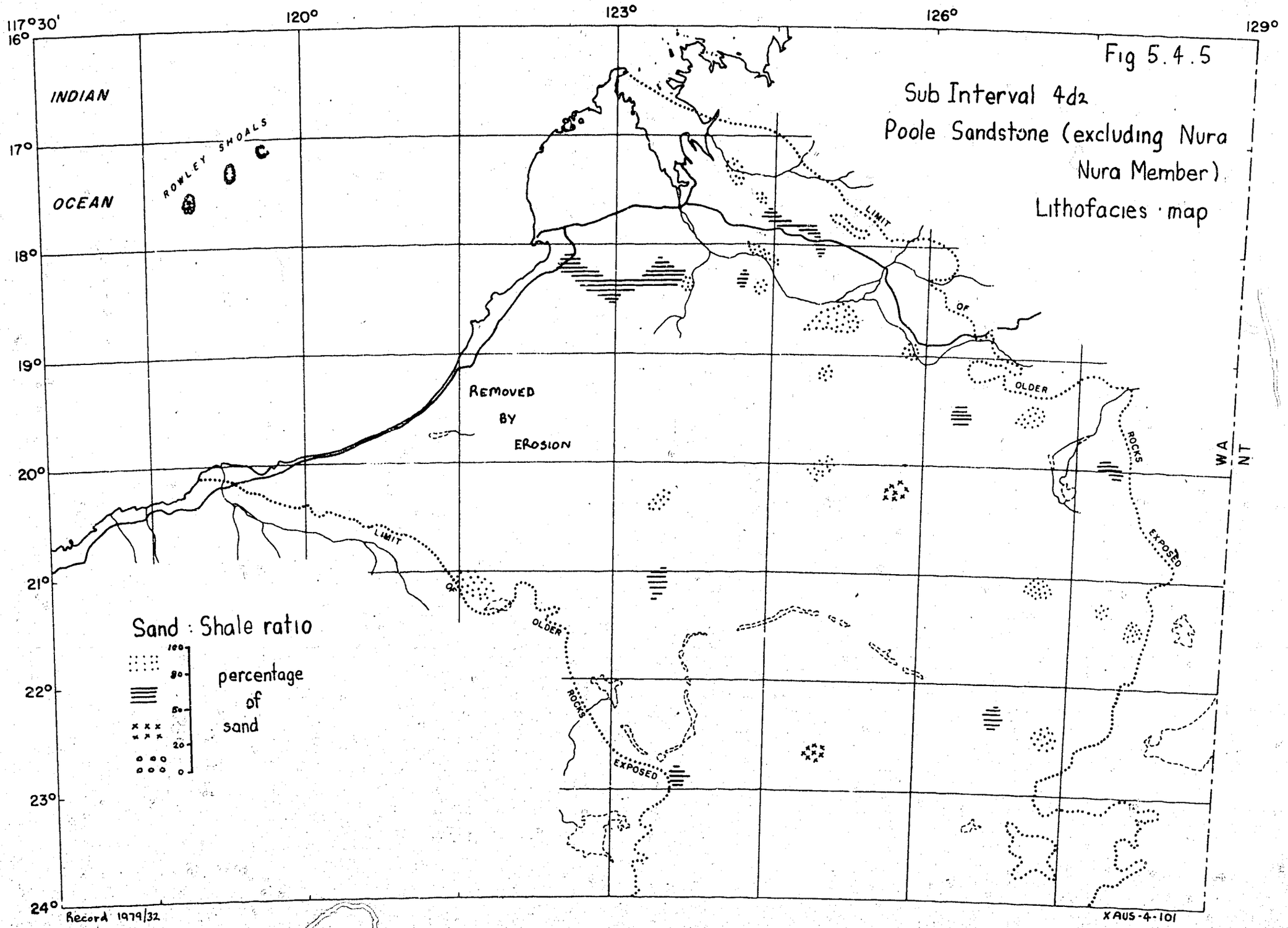
Fig. 5.4.4

Sub Interval 4d1

Nura Nura Member

Lithofacies and thickness map




117°30'
120°
123°
126°
129°
16°
17°
18°
19°
20°
21°
22°
23°
24°
INDIAN
OCEAN
ROWLEY SHOALS
Fig 5.4.5
Sub Interval 4d2
Poole Sandstone (excluding Nura Nura Member)
Lithofacies map
REMOVED BY EROSION
LIMIT OF OLDER ROCKS EXPOSED
LIMIT OF OLDER ROCKS EXPOSED
WA
NT
Sand : Shale ratio
100
80
50
20
0
percentage of sand
Record 1979/32
XAUS-4-101

Sandstone contains a marine fauna of gastropods, pelecypods, and the oysterlike bivalve Oriocrassatella sp. The Nura Nura Member is overlain by sandstone and minor fine-grained clastics. In the northwest and west the lower part of the Poole Sandstone (probably correlative in time with the basal Nura Nura Member) contains glauconite and marine fossils. Marine fossils also occur in the Cuncudgerie Sandstone adjacent to the southern margin but extensive post-Permian erosion has removed the Poole Sandstone from the intervening area in the west so continuity of the units is not established. In the eastern area the Poole Sandstone contains abundant plant fossils of the Glossopteris flora. Glossopteris appears to be more diverse than Gangamopteris, suggesting a warmer climate than the preceding subinterval. Part of the sequence is thin-bedded and extensively ripple-marked, indicating deposition in lakes.

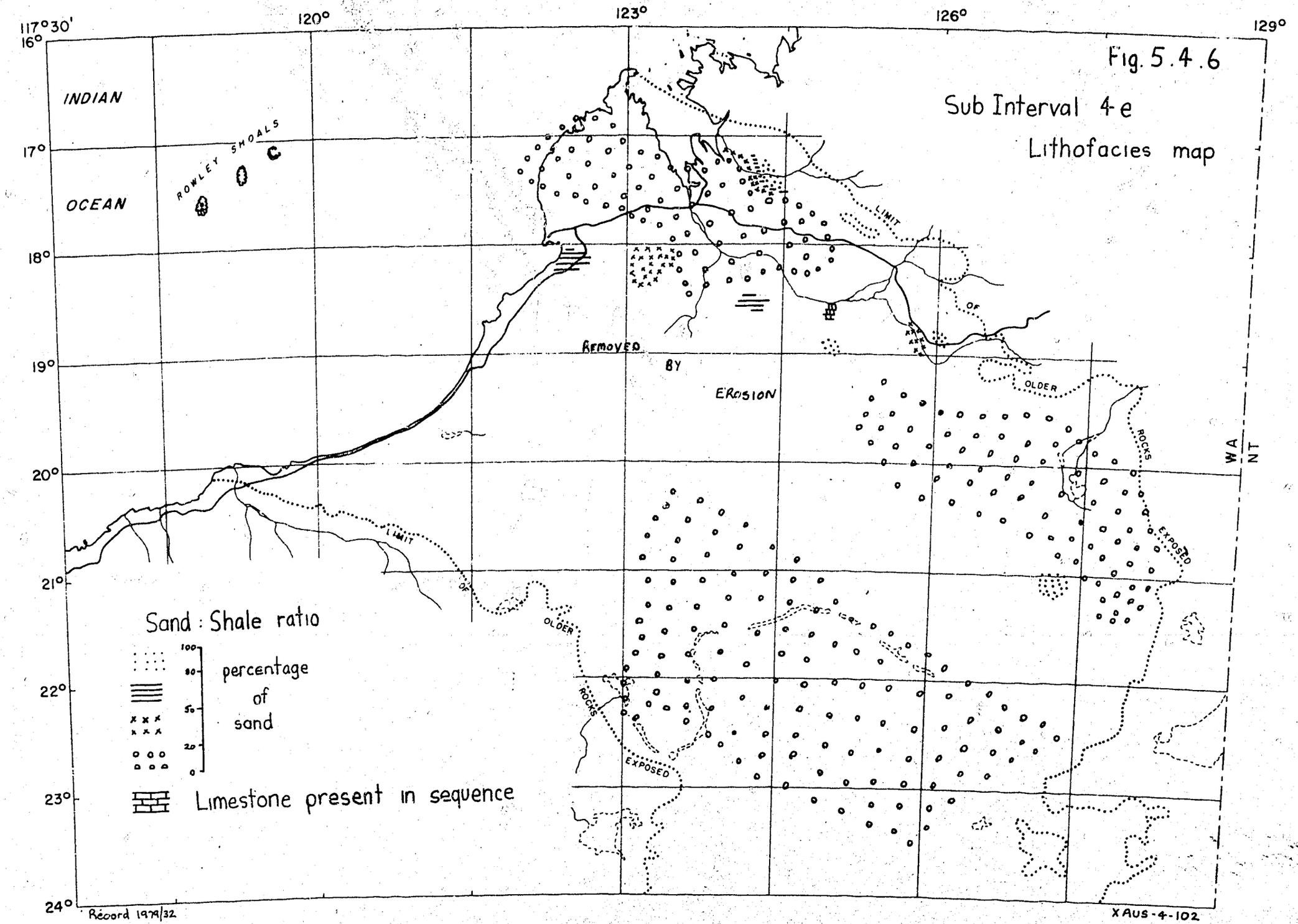
Subinterval 4e

Subinterval 4e is thickest in the Fitzroy Graben (over 400 m) and is over 360 m thick in the Kidson Sub-basin. It appears to be missing on the northern Broome Arch and southwest Canning Basin, and its offshore extent is unknown. This absence may be due to non-deposition or erosion.

The sand:shale ratio map (Fig. 5.4.6) indicates that the subinterval is composed mainly of fine-grained clastic sediments that are thought to have been deposited in a low-energy sea. Coarser-grained clastics near the zero isopach in the northwest are interpreted as nearshore sediments.

The sea again transgressed the basin and reworked the upper parts of the Poole Sandstone in later Artinskian time, and deposited the Noonkanbah Formation and the Dora Shale. Extensive post-Artinskian erosion has probably removed the unit from the southwestern area. The subinterval fines up from the transitional coarse-grained clastic beds into the characteristic black shales with minor calcareous sandstone and limestone lenses. The diversity and abundance of fossils suggests deposition in a warm to tropical sea.

Dickins & Jell (1974) recognised at least three biostratigraphical subdivisions in the Noonkanbah Formation, but Thomas (1958b) deduced only two faunal associations which he thought to be depth dependent: the Molluscan Assemblage, comprising pelecypods and less common brachiopods, bryozoans, and crinoids, lived in water 27-34 m deep and is probably a correlative of the Atomodesma sp. dominated community (Kauffman & Runnegar, 1975), which inhabited the inner sublittoral shelf zone; the Brachiopod Assemblage, (calcareous brachiopods, bryozoa, and minor corals, crinoids, and rare molluscs) inhabited deeper water, between 34 and 55 m (Thomas, 1958b).


117°30'
120°
123°
126°
129°
16°
17°
18°
19°
20°
21°
22°
23°
24°
INDIAN
OCEAN
ROWLEY SHOALS
REMOVED
BY
EROSION
LIMIT
OF
OLDER
ROCKS
EXPOSED
WA
NT
Sand : Shale ratio
100
80
50
20
0
percentage
of
sand
Limestone present in sequence
Fig. 5.4.6
Sub Interval 4-e
Lithofacies map
Record 1979/32
XAus-4-102

Open seas are suggested by the presence of goniatites as far east as the Balgo Hills area, where marine fossils - including bradydont holocephalan and acanthodian fishes - occur with non-marine palaeoniscids (G.C. Young, BMR, personal communication, 1972). The presence of freshwater and marine fish in close association suggests that a river entered the sea here.

Crespin (1958) suggested that the calcareous and arenaceous banthonic foraminifera in the Noonkanbah Formation and the Dora Shale inhabited a clear, moderately shallow, warm to temperate, open sea, confirming the macrofossil evidence.

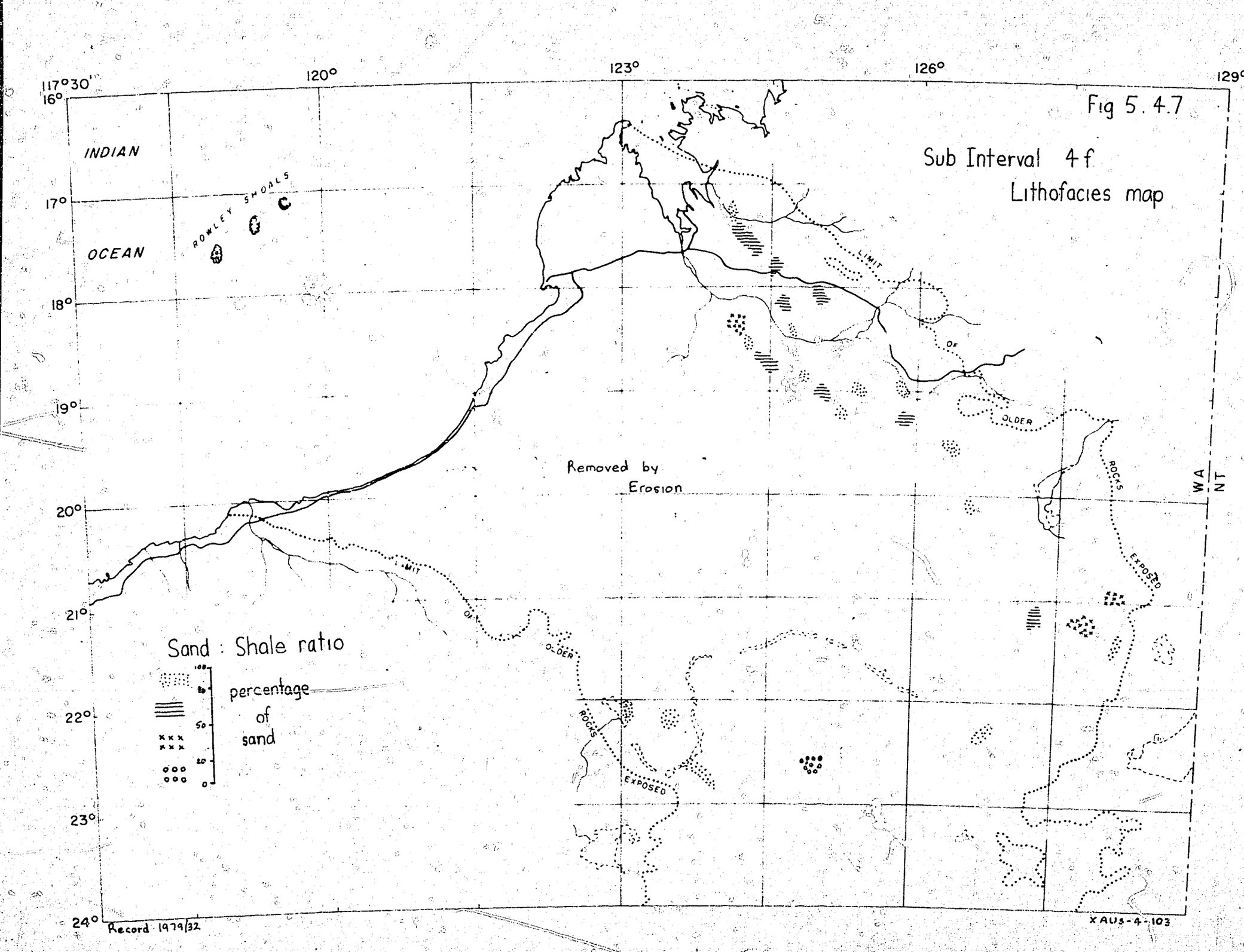
Oxygen isotopes studies (Compston, 1960; Lowenstam, 1964) gave water palaeotemperatures between 24-26°C for the Noonkanbah Formation. Similar water temperatures occur offshore from Derby today (Bowen, 1966), and a similar subtropical climate is inferred during Noonkanbah time.

Subinterval 4f

The Lightjack Formation reaches its maximum thickness (305 m) in a faulted outcrop in the central portion of the northwestern Fitzroy Graben. The formation is typically about 180 m thick and it thins rapidly to zero at its margins. It was deposited in the Fitzroy Graben and Kidson Sub-basin, and over the eastern extension of the Broome Arch. Some may have accumulated in the western part of the Canning Basin, but no deposits are presently known. The presence of reworked spores and pollen of this age in offshore wells and in Cretaceous sediments in the Officer Basin (Kemp, 1974, unpubl.) suggests that the subinterval was deposited over a more extensive area than its present limits of preservation.

The sand:shale ratio map (Fig. 5.4.7) shows that coarser-grained clastics predominate in the northwestern Fitzroy Graven, and that finer-grained sediments predominate in the southeastern part of the graben and in the Kidson Sub-basin, except near the limit of Precambrian rocks, where a high sand-to-shale ratio is preserved.

Subinterval 4f was probably deposited during a shallowing and partial regression of the sea. The Lightjack Formation (including Balgo Member) in the Fitzroy Graben and the Triwhite Sandstone in the Kidson Sub-basin were probably contiguous when originally deposited, but post-Kungurian erosion has removed them from the Broome Arch. Erosion probably also removed the subinterval from the southwestern Canning Basin.


Fig 5.4.7
Sub Interval 4f
Lithofacies map
117°30'
120°
123°
126°
129°
16°
17°
18°
19°
20°
21°
22°
23°
24°
INDIAN
OCEAN
ROWLEY SHOALS
LIMIT
OF
OLDER
ROCKS
EXPOSED
Removed by
Erosion
WA
NT
Sand : Shale ratio
percentage
of
sand
100
50
0
Record 1979/32
XAUS-4-103

The basal beds of the Lightjack Formation and the Balgo Member consists of fossiliferous limonitic oolites, pisolites, and concretions which may have been deposited as primary chamosite or goethite (Yeates & others, 1975b). Chamosite is deposited in shallow marine waters (commonly less than 60 m depth) at water temperatures of about 20°C (Porrenga, 1967), but goethite is precipitated at the freshwater/salt-water interface (Stanton, 1972). Because the nature of the primary precipitate is unknown, or if indeed the structures in this marker bed are a secondary weathering phenomenon, the only safe conclusion is that these fossiliferous iron-rich sediments were deposited in a shallow sea. Faunal elements of the Lightjack Formation belong to the Molluscan Assemblage, indicative of a water depth between 27 to 34 m (Thomas, 1958b).

Atomodesma sp. faunal assemblages are reported from the Balgo Hills area with other organic remains and trace fossils (Dickins & Jell, 1974), indicating a sublittoral environment (Kauffman & Runnegar, 1975). Ammonoids found in the northwestern part of the basin indicate an open sea but fossil wood in the area indicates a shoreline nearby (Casey & Wells, 1964). Marine fossils and oolites from outcrops of the Triwhite Sandstone (Veevers & Wells, 1961) suggest a warm, shallow, wave-agitated sea.

Continued regression of the Lightjack sea led to emergence of most of the Canning Basin, except the Fitzroy Graben, by the Kazanian.

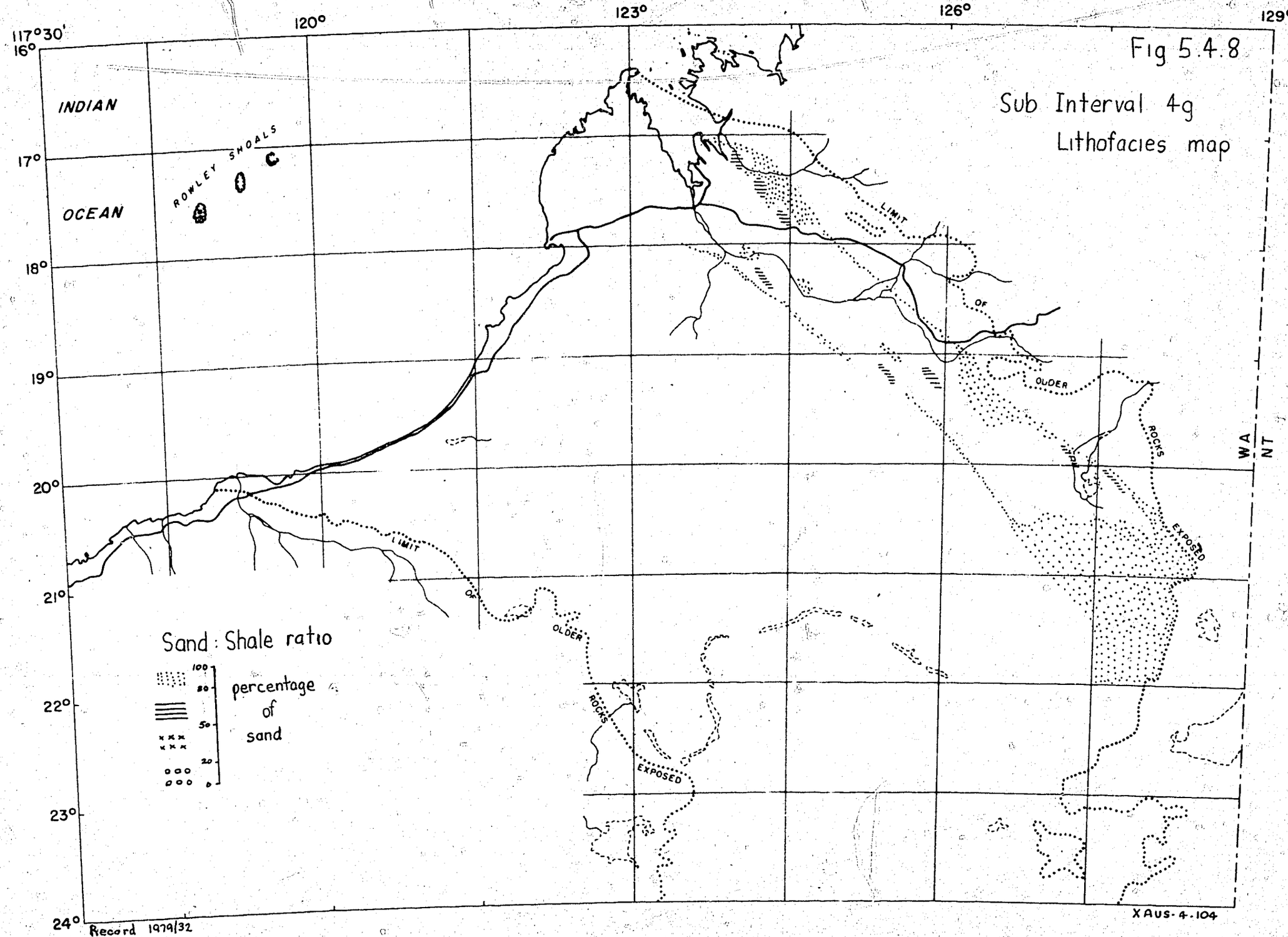
Subinterval 4g

Subinterval 4g is the Condren Sandstone of Kazanian age.

The thickest accumulation of the Condren Sandstone is in the central portion of the onshore Fitzroy Graben, where the unit may reach 300 m. A measured section of 610 m (WAPET, unpublished) is considered to be repeated by faulting. The unit is confined to the Fitzroy Graben and has been removed from the area west of Derby by pre-Triassic erosion.

The sand:shale ratio map (Fig. 5.4.8) shows an increase in fine-grained clastics towards the northwest and the sand facies concentrated in the east. This is thought to reflect a facies change from continental deposits in the east to deltaic and shallow marine westwards.

The Condren Sandstone was deposited in a complex of fluviatile, estuarine, deltaic, and shallow-marine environments. Cyclic bedding occurs in fining upward sequences in the Stansmore Range: basal sandstones containing high-angle cross-bedding and channel-lag conglomerates grade up into small-scale cross-laminated and parallel-laminated siltstone with plant remains and thin


Fig 5.4.8
Sub Interval 4g
Lithofacies map
117°30'
120°
123°
126°
129°
16°
17°
18°
19°
20°
21°
22°
23°
24°
INDIAN
OCEAN
ROWLEY SHOALS
LIMIT
OF
OLDER
ROCKS
EXPOSED
WA
NT
Sand : Shale ratio
100
80
50
20
0
percentage
of
sand
Record 1979/32
XAus-4-104

coal seams. Similar deposits occur in the Roberts Range. The cyclic bedding and sedimentary structures are considered to be features of meandering stream deposits (Allen, 1965).

Farther west the sandstone becomes finer-grained, better sorted, and contains a clay matrix. Cross-bedding is small-scale and low-angle. Some trough cross-bedding occurs with well-developed ripple marks, groove casts, and bioturbation. A bimodal distribution of current directions suggests shallow-marine or tidal-flat deposits. Still farther west the Condren Sandstone is thin or discontinuous, and marine fossils occur in correlative beds (Veevers & Wells, 1961); acritarchs in Mimosa No. 1. The subinterval is eroded west of May River but the sediments originally deposited there were probably more marine in character.

The occurrence of autumnal banks of Glossopteris spp. from the Condren Sandstone in the northwest corner of Millyit Range (White & Yeates, 1976) indicates a seasonal climate which may also be inherent in the meandering stream profiles - i.e., overbank deposits indicating periodic flooding.

Subinterval 4h

A further marine transgression occurred in the late Kazanian and early Tatarian during the deposition of the Hardman Formation, Godfrey Beds, and the Chirrup Formation (subinterval 4h).

The Hardman Formation is preserved in the Fitzroy Graben and in a small area on the Broome Arch. 308 m was measured in the Barbwire Range, but this may be a faulted sequence. The average thickness is 100 m.

The sand:shale ratio map (Fig. 5.4.9) shows that the formation is mainly sandstone, except in the northwest, where shale predominates.

Yeates & others (1975a) delineated three members of the Hardman Formation: the basal Kirkby Range Member, which was deposited in a low-energy shallow sea; the fluviatile Hicks Range Member, which prograded from the northwest, and the shallow-marine Cherrabun Member.. These three members are not always distinguishable outside the Noonkanbah and Mount Bannerman Sheet areas although it is possible to recognise similar units in wells on the Margaret Terrace.

Thomas (1958b) recorded the Brachiopod Assemblage from the Hardman Formation; they indicate a depth between 34 and 55 m. Molluscs are more common in the oolitic beds (Thomas, 1958b), and suggest warm temperatures in shallow wave-agitated water generally less than 2 m deep (Bathurst, 1967).

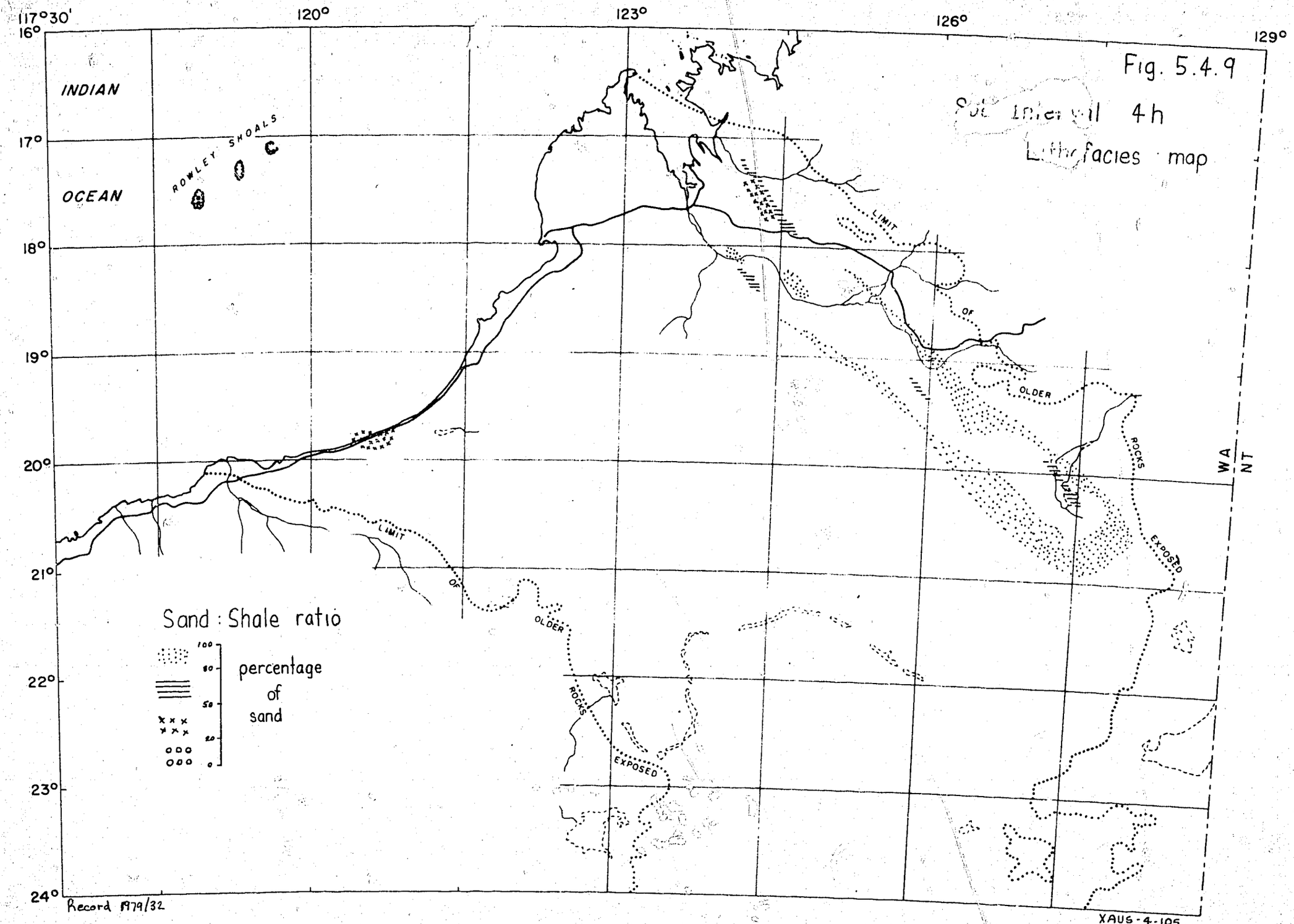


Fig. 5.4.9

Sub Interval 4h

Lithofacies map

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Acritarchs, indicative of open-marine conditions (Williams & Sargeant, 1967), are known from the Hardman Formation in Mimosa No. 1 (WAPET, 1973g) with shell fragments, a diverse spore assemblage (including spores and pollens of marsh plants), and lignite, suggesting near shore shallow-marine deposits. Acritarchs were also recovered from carbonaceous shale in BMR Crossland No. 1 (Yeates & others, 1975b), and suggest lagoonal conditions. No marine fossils were recovered from cores in the Hardman Formation of BMR Crossland No. 2 (Yeates & others 1975b), but the occurrence of gypsum and carbonate in bioturbated, ripple-marked, ripple cross-laminated, low-angle festoon cross-bedded sediments suggests a tidally influenced lagoonal area in a warm to hot climate.

The plant fossil ?Cladophlebis sp. from the Hardman Formation at Mount Wilson (White & Yeates, 1976) may indicate fern-dominated coastal marshes (Krassilov, 1973a, b).

The Godfrey Beds, which are confined to the Fitzroy Graben, contain the trace fossil Rhizocorallium sp. (Veevers & Wells, 1961) and bimodal current ripples (Yeates & others, 1975b), suggesting that they were deposited on a tidal flat. Intraformational clay pellets may indicate periods of desiccation and pebble conglomerates may mark tidal channels.

The Chirup Formation, which occurs in a small area around Wallal No. 4 and Chirup No. 1, contains well-preserved plant fragments and spores and pollen of coastal marsh plants. Marine fossils are absent. The fine-grained carbonaceous sediments were probably deposited in a swamp or a marsh, probably landward of a coastline located in the present offshore area, and indicate a probable marine transgression in the Bedout Sub-basin during the Tatarian.

Sedimentation ceased throughout the area of the present onshore Canning Basin in late Permian times, probably as a result of regression. Basalt may have been extruded along the Bedout High (around Bedout No. 1), and dolerite may have been intruded in the Fitzroy Graben (e.g., Wamac No. 1, Fraser River No. 1, Barlee No. 1) at this time.

5.5 INTERVAL 5

Introduction

Interval 5 comprises the Millyit, Culvida, and Erskine Sandstones, the Blina Shale, and unnamed rocks of Triassic age offshore. It disconformably and unconformably overlies older units and is unconformably overlain by younger

units. Details of lithology, thickness, correlation, age, and distribution are given in Appendix 5. Time correlation of the interval is summarised in Figure 5.5.1 and the thickness and lithology in Plate 10-5.

Thickness

The interval is up to 700 m thick onshore in the Fitzroy Graben, where it is extensively folded, faulted, and eroded. The Bedout Sub-basin and the Rowley Sub-basin were actively subsiding during deposition of interval 5, and thick sequences were deposited in each area. Over 3000 m is preserved in the Bedout Sub-basin onlapping the Bedout High to the north, and a northwesterly thickening wedge occurs in the Rowley Sub-basin onalpping the Bedout High to the south. Upper Triassic rocks rest directly on ?Upper Permian rocks in Lynher No. 1. Distribution and thickness of the interval have not been mapped in the northern and northwestern part of the basin offshore.

Lithology

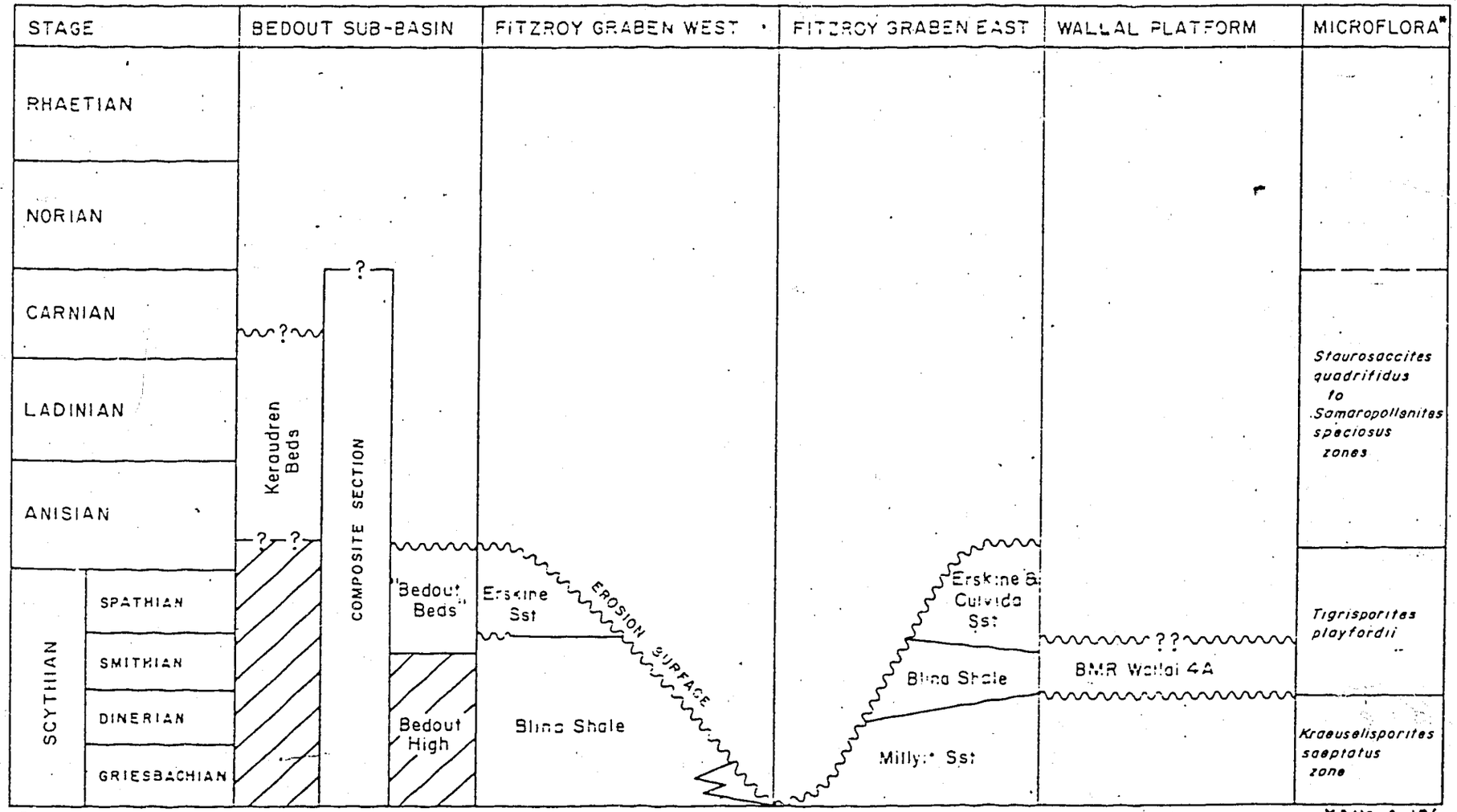
The marine Blina Shale, at the base of the interval, occurs in the northwestern part of the onshore Fitzroy Graben and at one locality onshore in the southwest Canning Basin (BMR Wallal No. 4a). The shale presumably extends offshore but this has not been confirmed by drilling. The proportion of sand to shale increases in the southeast Fitzroy Graben, reflecting deposition in a delta. Interbedded sandstone and shale occur in deltaic sequences in the upper part of the interval onshore and offshore, but there is insufficient lithological data to determine reliable trends.

Depositional environments

In Early Triassic time a shallow estuary occupied the Fitzroy Graben, and a shortlived delta complex prograded from the southeast. The Millyit Sandstone represents the deposits of the delta complex, laid down at the same time as both the lower Blina Shale in the northwest and the marine sediments of Early Triassic age in the Bedout Sub-basin.

Palaeocurrent data from Erskine Hill (McKenzie, 1961) and the presence of Cyzicus spp. (Brunnschweiler, 1954) suggest that an intermittent northward-flowing river existed in the area of the present Jurgurra Creek. A proto-Oakover River may similarly have entered the southwestern embayment near BMR Wallal Nos. 4 and 4A.

Fig 5.5.1 TIME CORRELATION - INTERVAL 5



1979/32

Later in the Early Triassic this delta complex was transgressed by the Blina sea. Because of the gentle regional slope, the transgressing sea probably advanced quite rapidly and reached its maximum extent at the beginning of the late Scythian.

By latter Scythian times the sea began to regress to the northwest, and a delta-plain environment became dominant. Fluviatile sediments were deposited over the estuarine sediments in the Fitzroy Graben and Bedout Sub-basins; these are represented by the Erskine and Culvida Sandstones, and contemporaneous sediments penetrated by Keraudren No. 1 and Bedout No. 1 wells in the Bedout Sub-basin.

Palaeolatitudes, as deduced by Embleton (1973), show that the Canning Basin lay at about 47°S. Despite the high palaeolatitude there is no evidence from either the flora or fauna of a cold climate (Brown, Campbell, & Crook, 1968); instead, the fauna suggest a temperate to subtropical climate. Seasonality of climate with partial drying up of watercourses is indicated by the lungfish Ceratodus. Non-perennial rivers drained into the shallow gulf, around which marshlands with brackish-water faunas flourished. The environment suggested by the biota is that of a shallow estuarine gulf bordered by lowlands and local swamps and deltas in the Fitzroy Graben, and higher lands around the headwaters of the estuary in the southeast. The lack of stenohaline marine organisms implies dilution of normal marine water in the estuary. Coal and abundant swamp plants suggest at least seasonal high rainfall. The dolomitic calcilutite, red sediments, and coal in the offshore wells suggest high rainfall coupled with desert climates in the Bedout Sub-basin.

5.6 INTERVAL 6

Introduction

Interval 6 includes the Wallal Sandstone, the Alexander, and Jowlaenga Formations, the Jarlemai Siltstone, and their correlatives of Jurassic age. The interval overlies older rocks unconformably and is disconformably overlain by rocks of intervals 7 and 8.

Details of thickness, lithology, contacts, correlation, and age are discussed in Appendix 6, and are illustrated in Plates 10-6, 11-1 to 11-8, 12-1, 12-5, and 14, and Figures 5.6.3 to 5.6.9.

Thickness

The interval overlies a large area onshore, except in the northeast (Pl. 10-6), and thickens offshore to about 2500 m in the Rowley Sub-basin. Embayments occur south of the Bedout High and overlying the offshore Fitzroy Graben; the sediments are thinner over the Bedout High and the offshore Broome Arch. The zero isopach outlines the preserved limit of mainly fluvial sediments deposited in the Late Jurassic.

Lithology

The interval is entirely composed of clastic material ranging from shale to conglomerate. Meaningful lithology trends cannot be deduced from Plate 10-6 because the nature and locus of sedimentation varied from place to place with time. Generally the sediments are coarser-grained towards the base and the top of the interval, and the fluvial deposits on the whole are coarser than the marine and deltaic sediments. The fluvial deposits become coarser-grained towards the main source areas - the Kimberley and Pilbara Blocks and the eastern edge of the Jurassic sediments.

Environmental interpretation

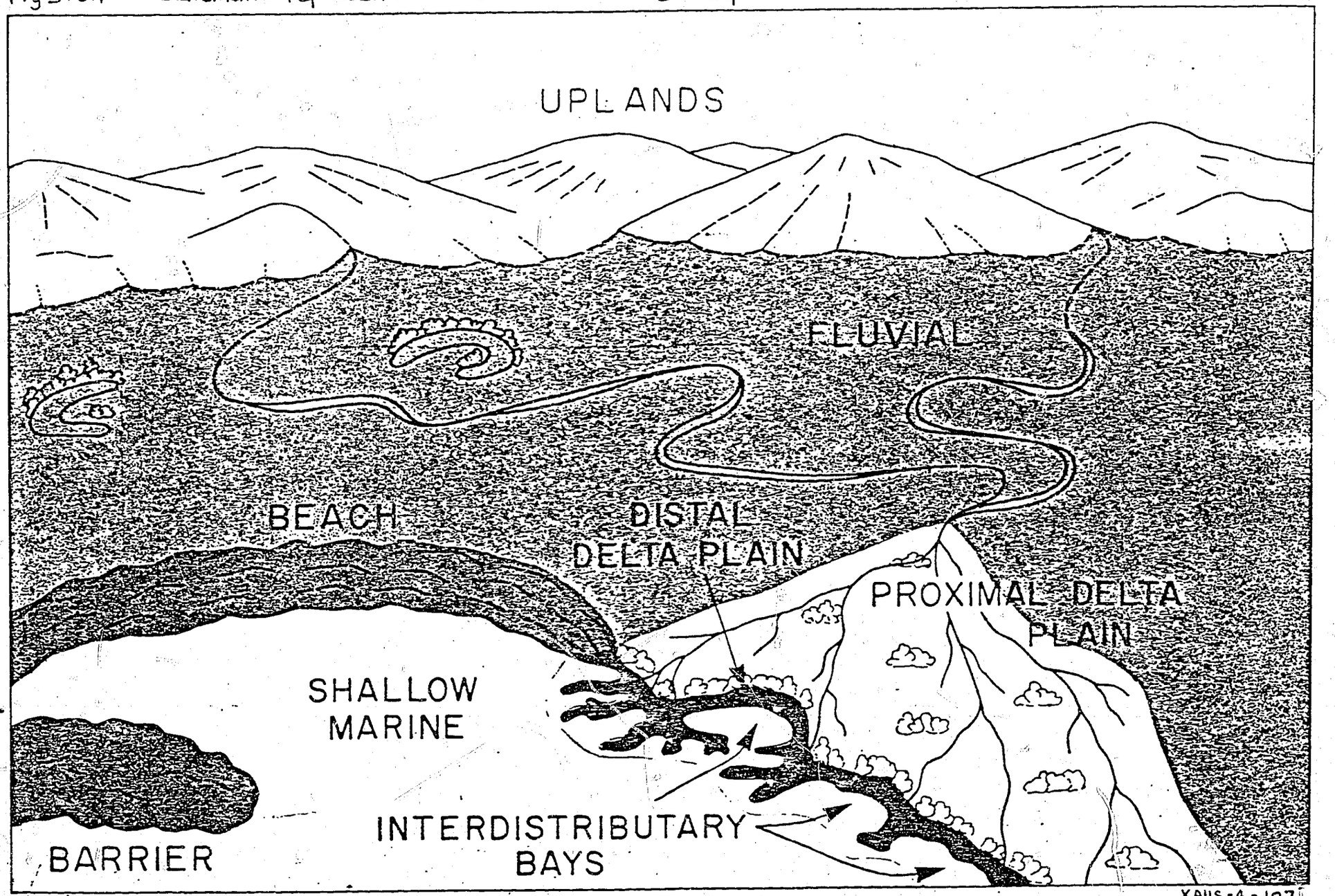
Palaeomagnetic data places the Canning Basin between latitudes 40°S and 50°S during the Mesozoic (Embleton, 1973). The Lower and Middle Jurassic sediments were deposited mainly offshore in a complex of deltaic environments, whereas the Upper Jurassic sediments were deposited during a major marine transgression following continental break up adjacent to the Exmouth Plateau.

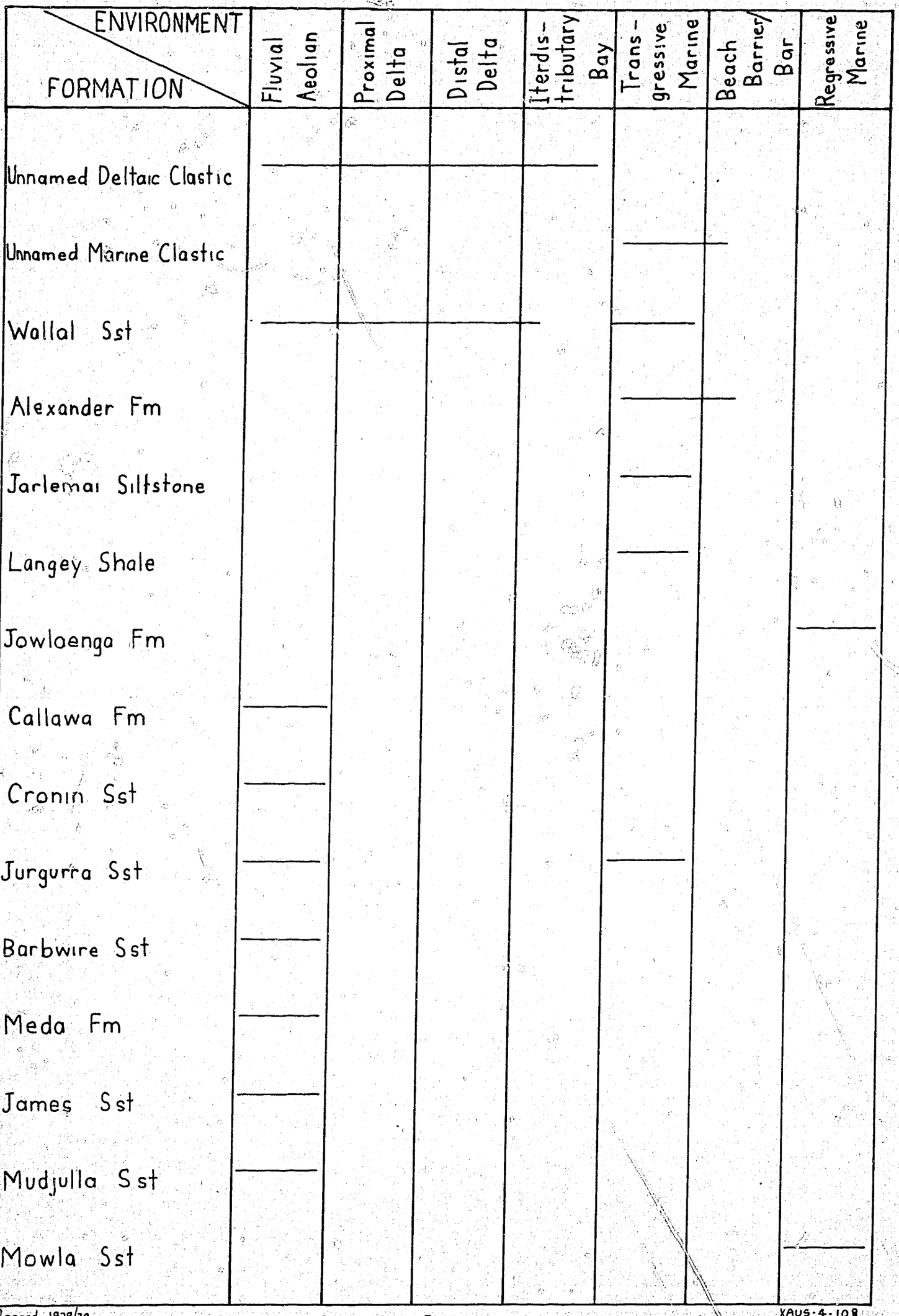
Six gross environments of deposition are recognised; Figure 5.6.1 shows the relations of the different environfments, and Figure 5.6.2 shows the environment of deposition for each formation.

Fluvial: containing wholly continental sediments.

Proximal delta plain: these sediments were deposited near the shoreline but are mainly non-marine, although they may contain rare marine fossils. Abundant coal is present, as well as spores and pollen, and some marsh plants.

Fig 5.6.1 Schematic representation of Interval 6 depositional environments.





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Fig.5.6.2 Diagram Relating Jurassic Formations and their Environment of Deposition

Distal delta plain: sediments contain a greater marine component and commonly contain glauconite and marine fossils. Coal, spores, pollen, and minor wood are still present, but are often less abundant than in the proximal delta plain environment.

Interdistributary bay: similar to distal delta plain environment, but sediments are mainly finer-grained and were deposited in a low-energy environment.

Beach shoreline sand, barrier bar: sediments are mostly sandstone, often glauconitic, and may be well sorted, especially near the top of the sequence.

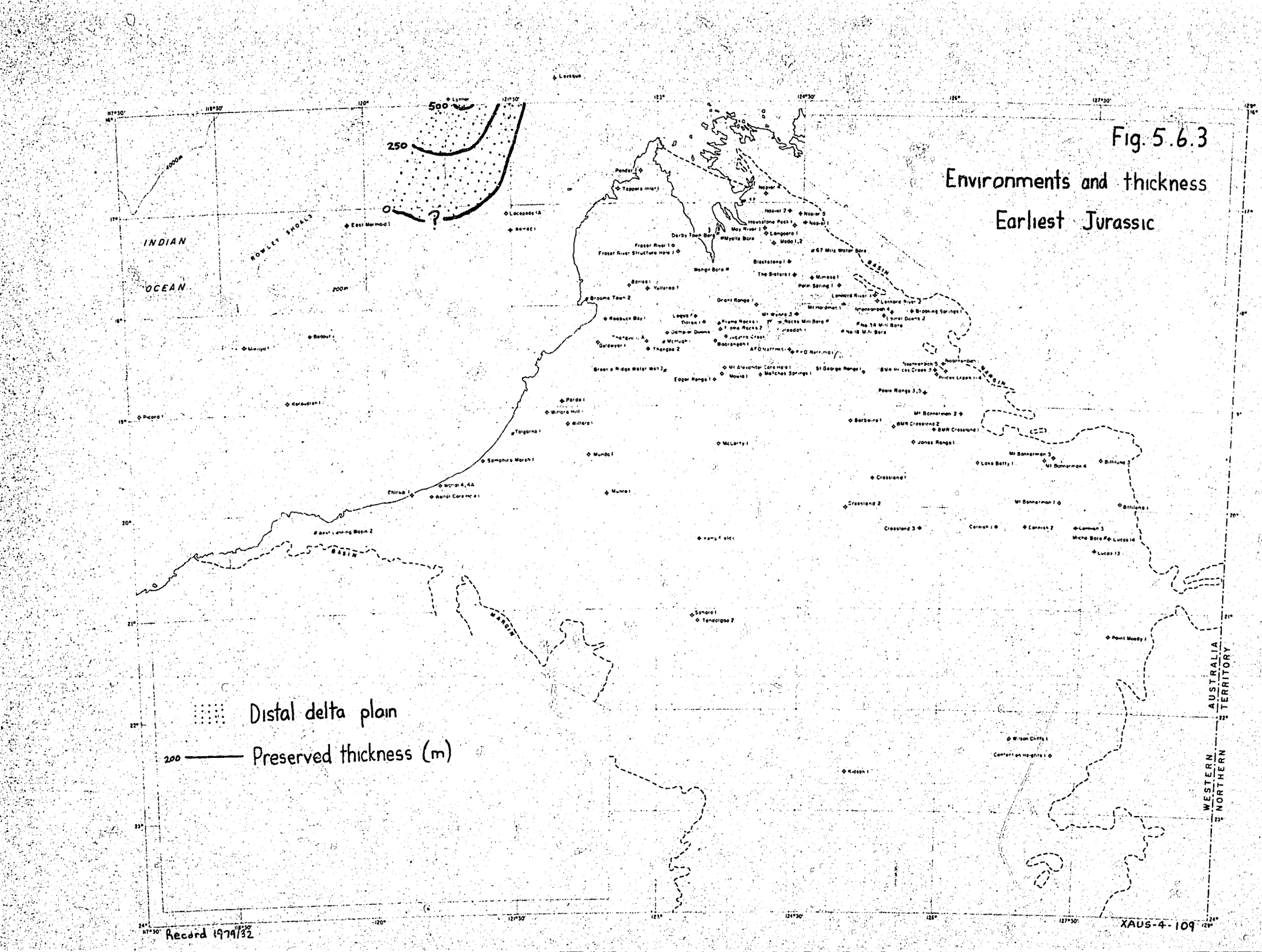
Marine: sediments predominantly glauconitic and contain abundant marine fossils.

Deltaic complex. At the beginning of the Jurassic, sediments were deposited in a distal delta plain which covered the northwestern part of the Rowley Sub-basin (Fig. 5.6.3).

A delta complex built up and covered most of the present offshore Canning Basin in the Early Jurassic (Fig. 5.6.4); the thickest sediments were deposited over the area of the offshore Fitzroy Graben. The multicoloured claystone and fine-grained sandstone within this complex were transported northward off the Pilbara Block.

By the Middle Jurassic the eastern margin of the delta complex had retreated easterly to the present onshore area as a result of continued subsidence, and the proximal delta-plain environment covered the western part of the onshore Canning Basin and most of the offshore part of the basin including the eastern Bedout Sub-basin (Fig. 5.6.5). The depocentre by now had shifted farther south. Sediment was being transported from the central Canning Basin as well as the Kimberley Block. The Leveque Arch, an earlier source area, had ceased to be an important source of sediment.

Early in the Late Jurassic the area covered by interval 6 sediments reached a maximum (Fig. 5.6.6). Continuing subsidence and eastward retreat of the deltaic complex is indicated by the spread of the distal delta plain onshore. Fluviatile sandstone was probably deposited over the southern part of the basin. During this period the depocentre shifted south again, and is


Fig. 5.6.3
Environments and thickness
Earliest Jurassic
500
250
?
INDIAN
OCEAN
ROWLEY SHOALS
BASIN
MARGIN
AUSTRALIA
WESTERN
NORTHERN
TERRITORY
Distal delta plain
200 —— Preserved thickness (m)
Record 1979/32
XAUS-4-109
87%

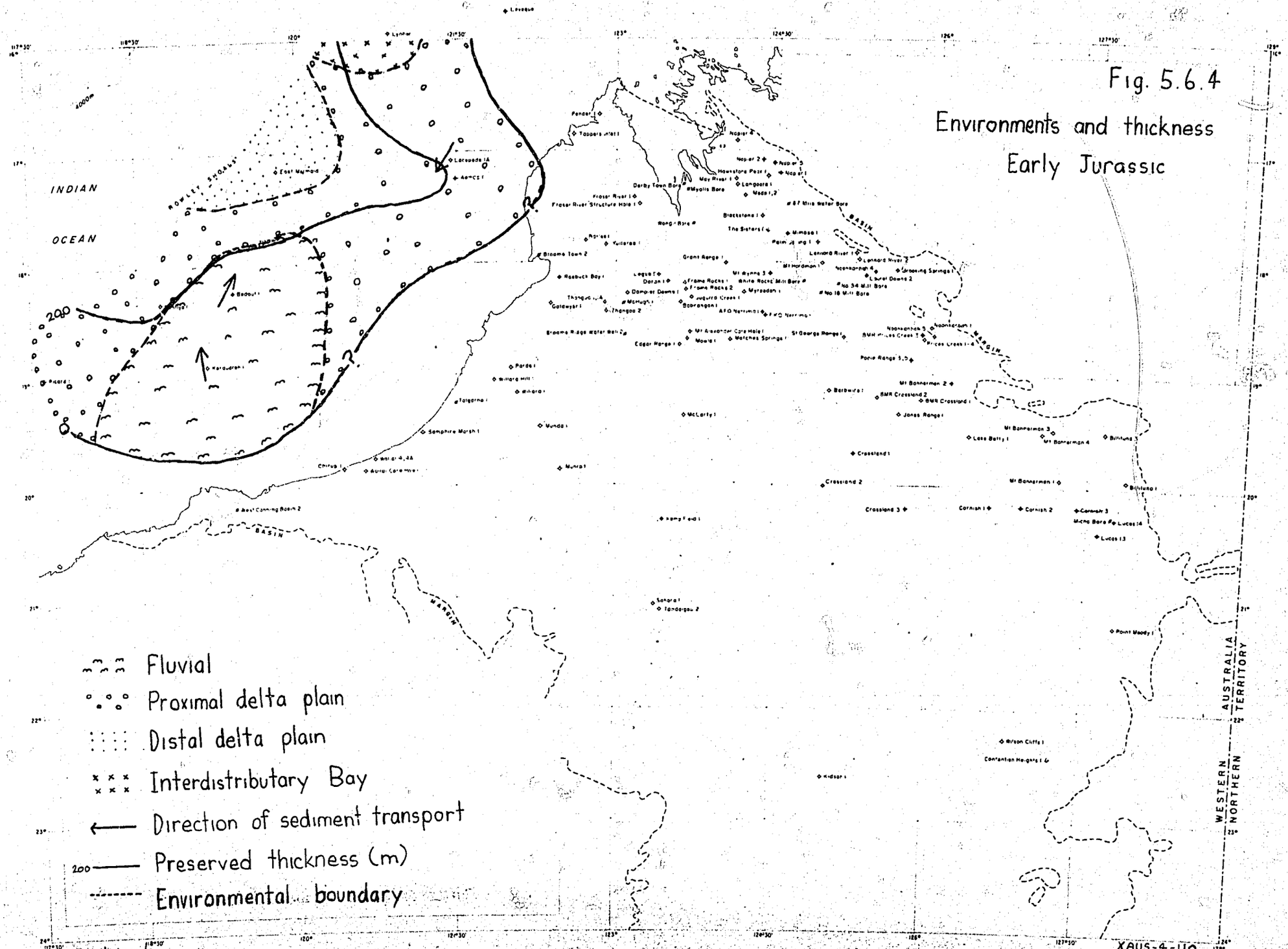
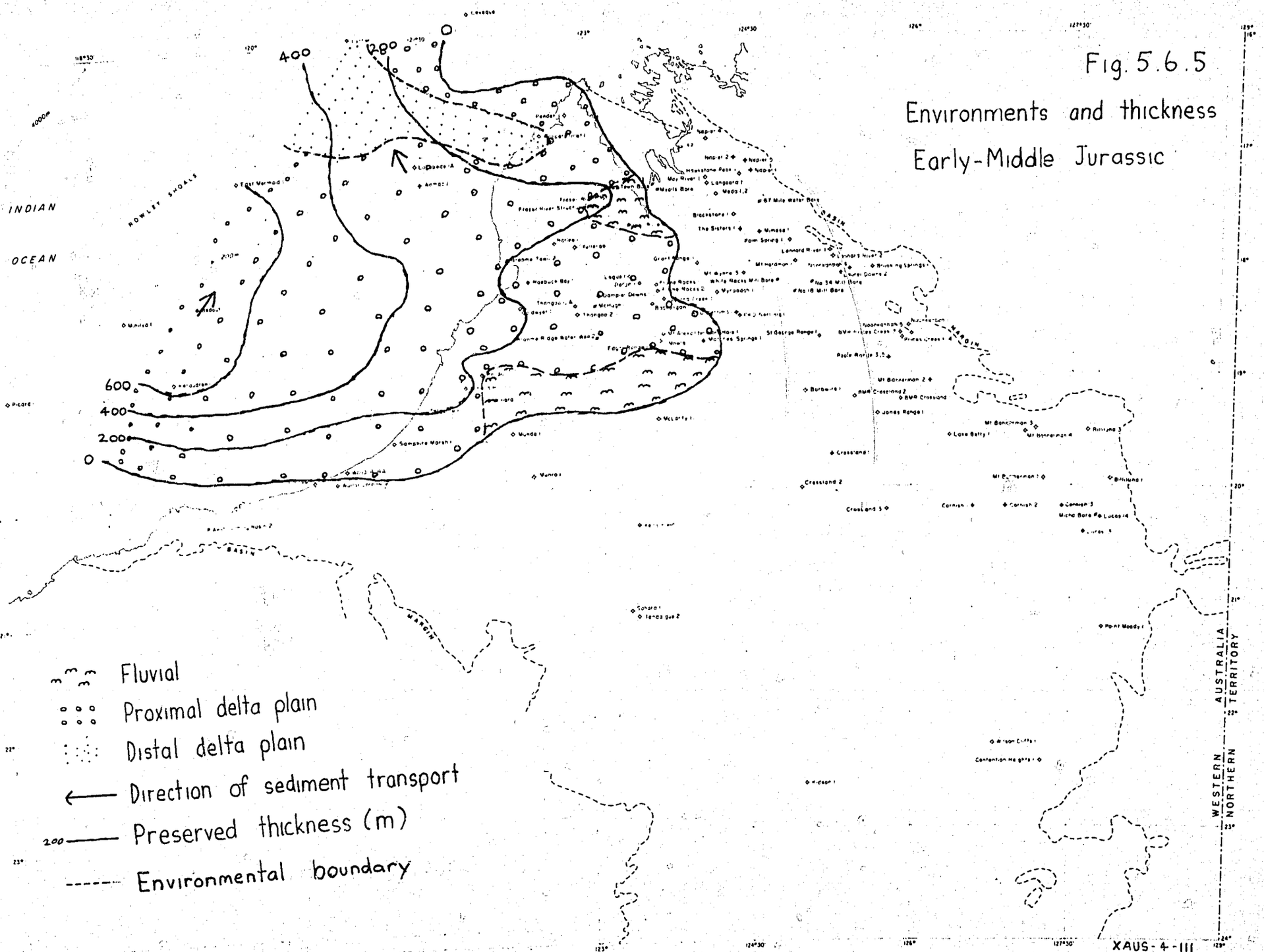
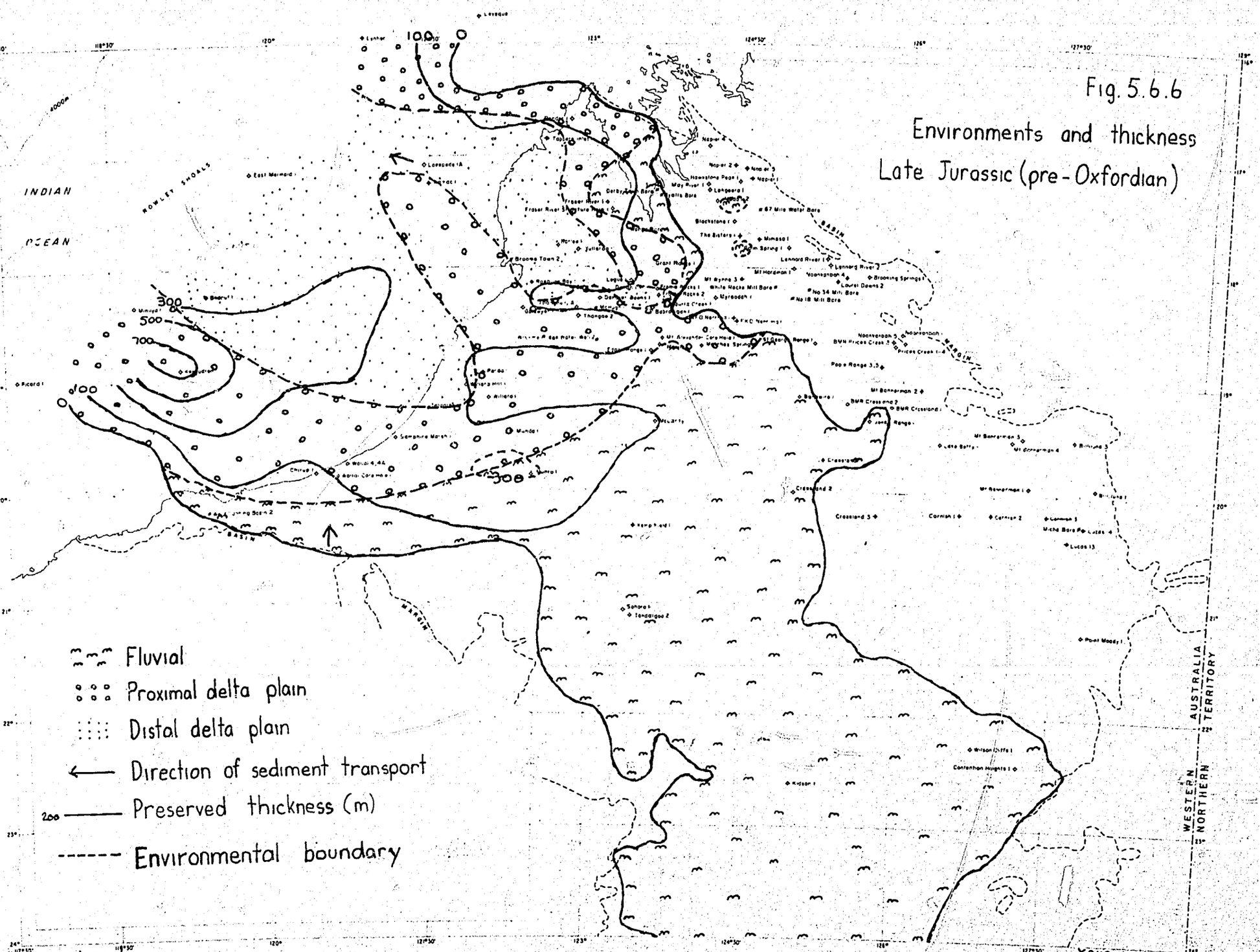


Fig. 5.6.4

Environments and thickness

Early Jurassic

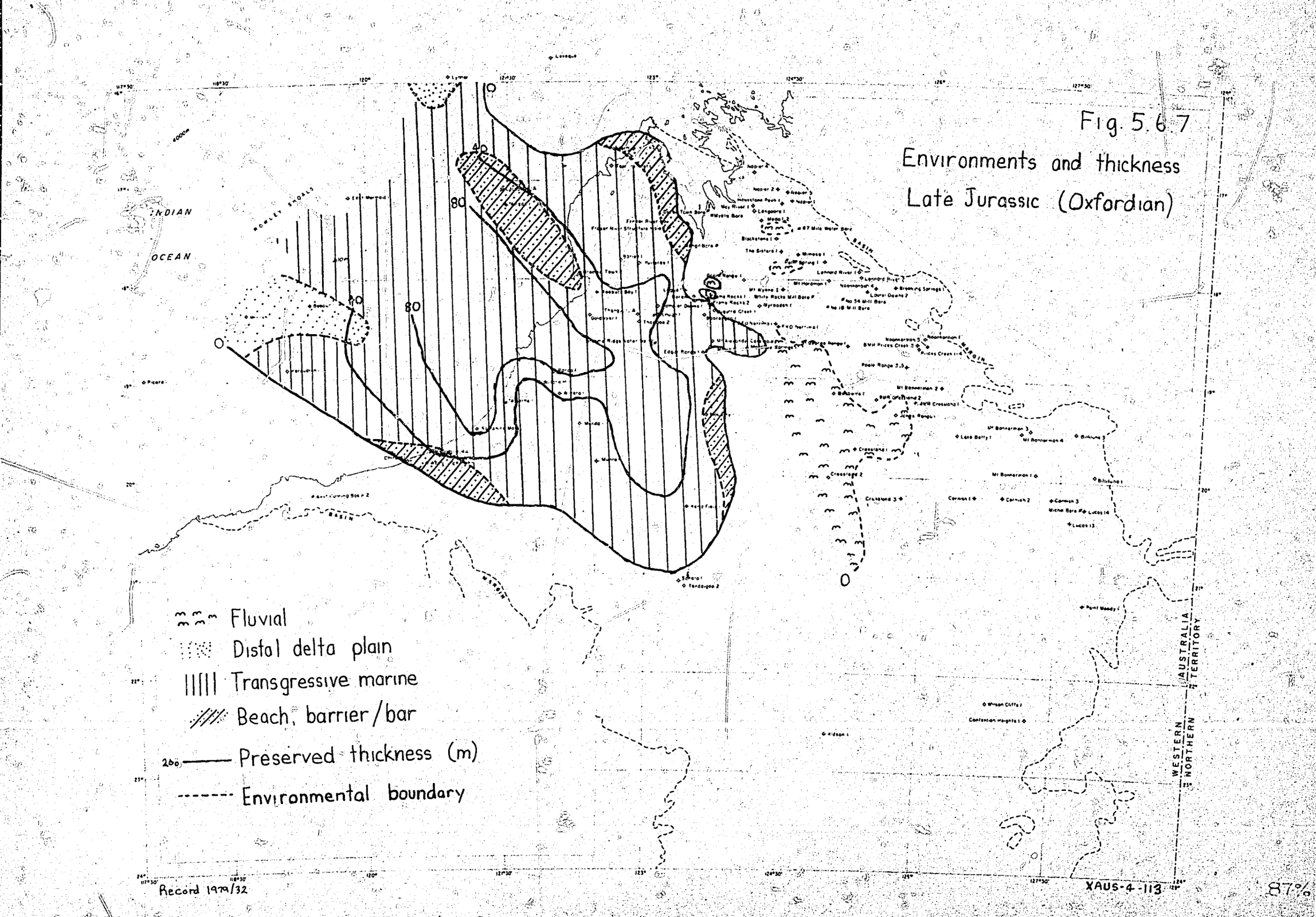

Fig. 5.6.5
Environments and thickness
Early-Middle Jurassic
INDIAN
OCEAN
ROWLEY SHOALS
BASIN
MARGIN
AUSTRALIA
TERRITORY
WESTERN
NORTHERN
400
200
600
400
200
0
Fluvial
Proximal delta plain
Distal delta plain
Direction of sediment transport
200 Preserved thickness (m)
Environmental boundary
XAUS - 4 - III
Record 1979/32

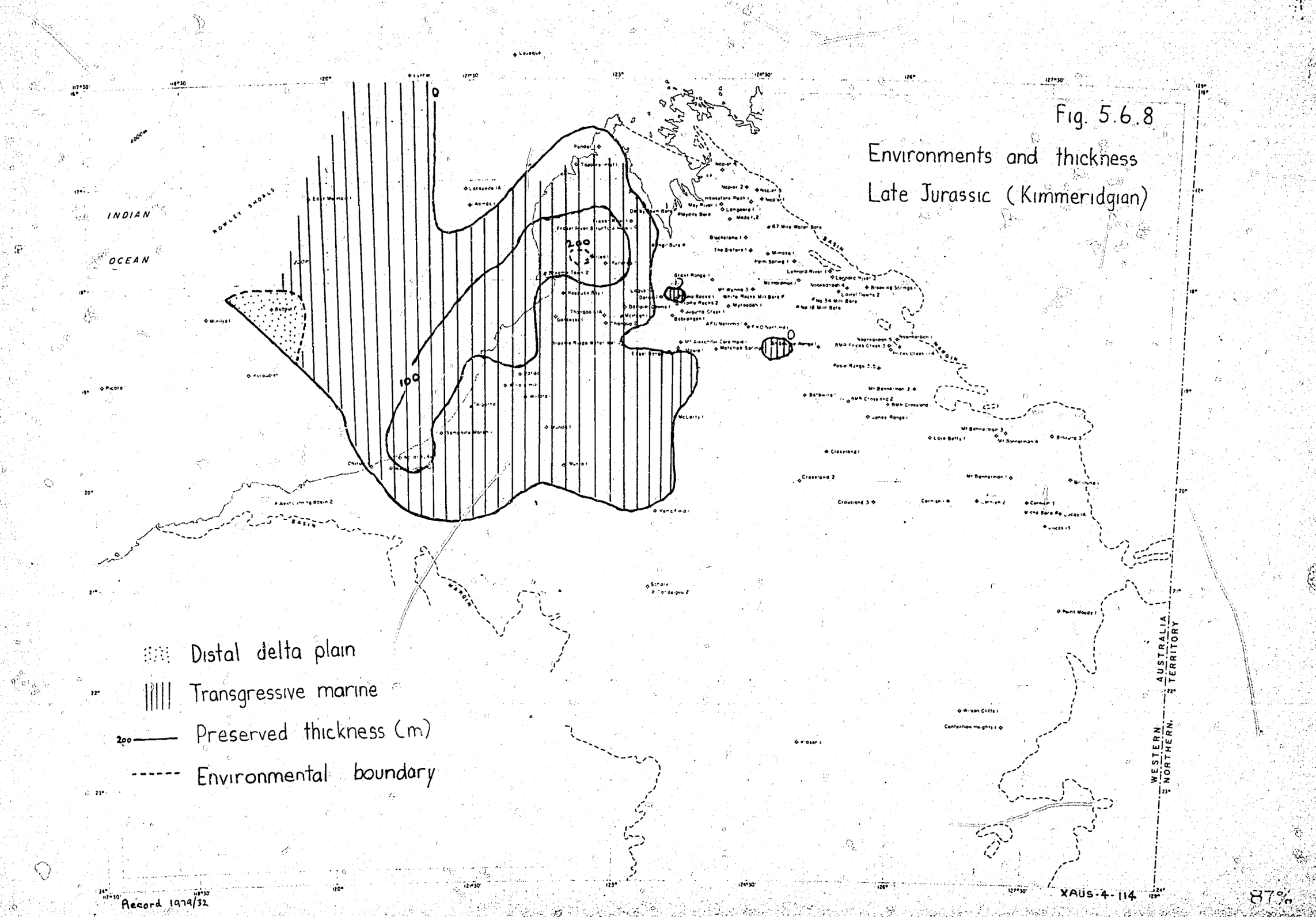

Fig. 5.6.6
Environments and thickness
Late Jurassic (pre-Oxfordian)
INDIAN
OCEAN
ROWLEY SHOALS
BASIN
MARGIN
AUSTRALIA
WESTERN
NORTHERN
TERRITORY
100
300
500
700
900
Fluvial
Proximal delta plain
Distal delta plain
Direction of sediment transport
200 Preserved thickness (m)
Environmental boundary

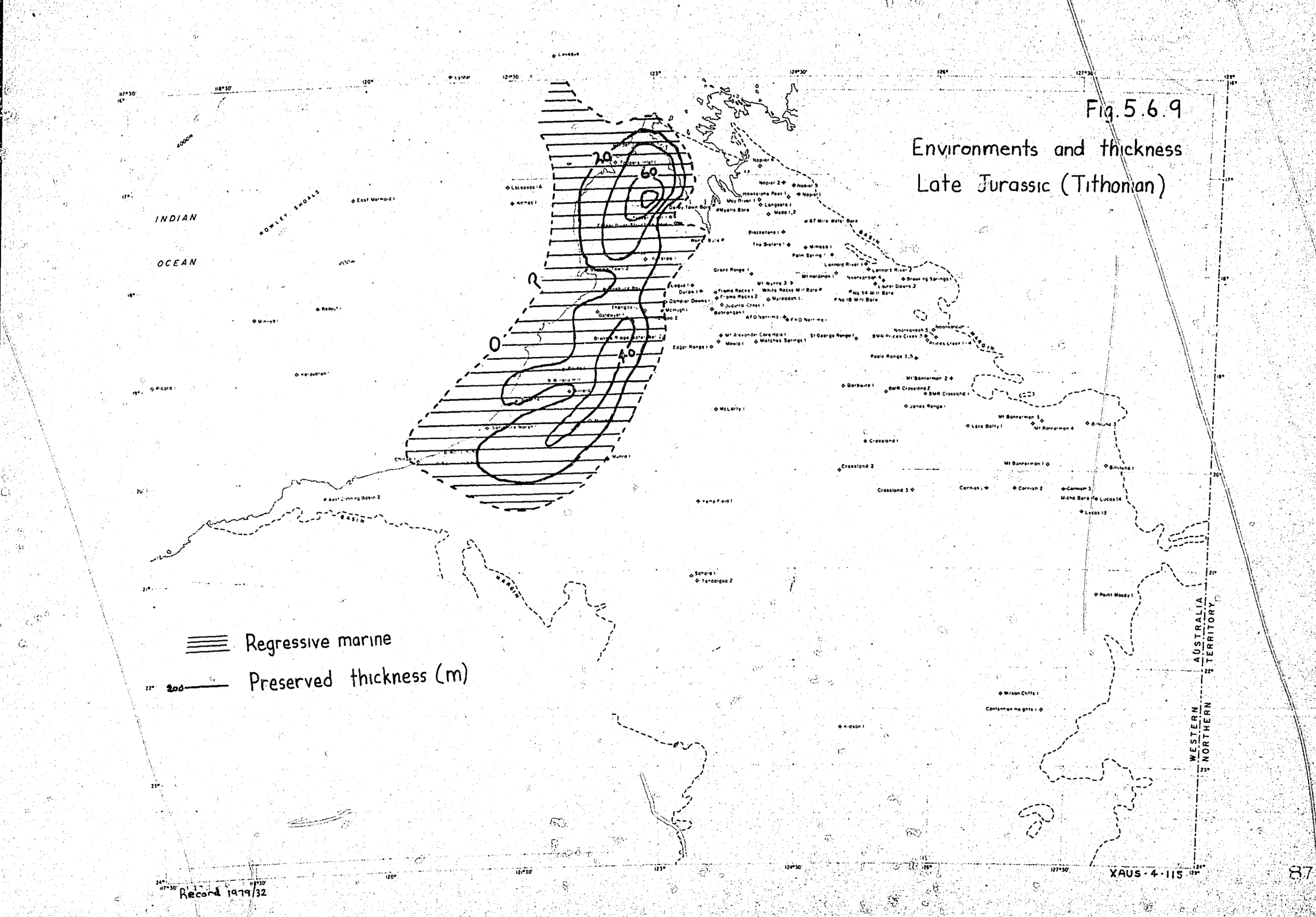
located in the southern Bedout Sub-basin and the southern part of the onshore Canning Basin.

Marine transgression. The deltaic complex was drowned by a major transgression of the sea from the west in the Late Jurassic (Oxfordian; Fig. 5.6.7). The depocentre shifted eastwards towards the present shoreline. Reworked delta sand (Alexander Formation) was spread over most of the western part of the basin, while farther east fluviatile sands were probably still being transported into the basin and deposited along beaches. Remnants of the delta were still active in the eastern Bedout Sub-basin and the northwestern edge of the basin, but the location of the shoreline surrounding the emergent area is speculative. By the end of the Kimmeridgian, holomarine conditions prevailed over most of the basin (Fig. 5.6.8), and the main sediments laid down were siltstone and claystone. The location of the shoreline at this time is unknown, but isolated outliers occur well east of the main area of outcrop of the Jarlemai Siltstone. The facies change from sandstone to mainly siltstone or claystone may indicate either lower relief in the source areas, or deposition in deeper and lower-energy waters; thus, sandstone may have been deposited farther east and later removed by erosion. The depocentre during the Kimmeridgian lay just off the present coastline and was centred over the Fitzroy Graben area. Of note is the absence of the Jarlemai Siltstone from most of the offshore area; either it was deposited, then removed by erosion, or the west-northwestern part of the Canning Basin was emergent in the Kimmeridgian.

The sea regressed in the Tithonian, when the marine sandstone of the Jowlaenga Formation was deposited (Fig. 5.6.9). Marine sandstone of Tithonian age occurs in Lyhner No. 1, but correlative rocks are absent from most of the offshore area, suggesting that this area was emergent and that the sea regressed to the northwest.


Fig. 5.6.7
Environments and thickness
Late Jurassic (Oxfordian)
Fluvial
Distal delta plain
Transgressive marine
Beach, barrier/bar
200 Preserved thickness (m)
Environmental boundary
INDIAN OCEAN
BASIN
MARGIN
AUSTRALIA
WESTERN
NORTHERN
TERRITORY
0
40
80
200


Fig. 5.6.8
Environments and thickness
Late Jurassic (Kimmeridgian)
INDIAN
OCEAN
ROWLEY SHOALS
BASIN
MARGIN
AUSTRALIA
NORTHERN TERRITORY
WESTERN
0
100
200
Distal delta plain
Transgressive marine
200 Preserved thickness (m)
Environmental boundary


Fig. 5.6.9
Environments and thickness
Late Jurassic (Tithonian)
INDIAN
OCEAN
ROWLEY SHOALS
BASIN
AUSTRALIA
WESTERN
NORTHERN
TERRITORY
20
60
0
40
Regressive marine
200
Preserved thickness (m)
Record 1979/32
XAUS-4-115
87

5.7 INTERVAL 7

Introduction

Interval 7 is the Baleine Formation*, ranging from late Tithonian to early Neocomian in age (Fig. 5.7.1). The interval is disconformable on older rock units and is overlain both disconformably and conformably by younger rock units. Details of lithology, contacts, correlation, and age are given in Appendix 7 and are illustrated in Figures 5.7.1, 5.7.3, and 5.7.5 and Plates 10-7, 11-1, 12, and 14.

Thickness

The interval is known only offshore and thickens westwards from a zero isopach of uncertain location somewhere near the present coastline (Pl. 10-7). The thickest sediments occur in the Rowley Sub-basin (900 m) and over the offshore part of the Fitzroy Graben (800 m). The Bedout high appears to have been elevated during sedimentation and is covered by less than 200 m of Baleine Formation. Thickness changes that occur across several faults in the Fitzroy Graben indicate movement on the faults between deposition of intervals 6 and 8. The locations of the Tithonian and Neocomian coastlines (Figs. 5.7.2 and 5.7.6) are speculative because no terrestrial rocks are known in the interval and the eastern edge is eroded.

Lithology

The interval is made up mainly of silty to arenaceous marine claystone, but interbedded siltstone and sandstone occur in the upper part in the wells (Keraudren No. 1 and Lacepede No. 1A) nearer to the present coastline (Pl. 10-7). Lithofacies maps (Figs. 5.7.3 and 5.7.5) demonstrate an increase in sandstone towards the southeast in the Neocomian part of the sequence.

The lack of coarse-grained clastics adjacent to the Bedout high and the North Turtle Arch (Pl. 15) suggests that both features had low relief and were not important source areas.

* New name submitted to the Stratigraphic Nomenclature Committee for approval.

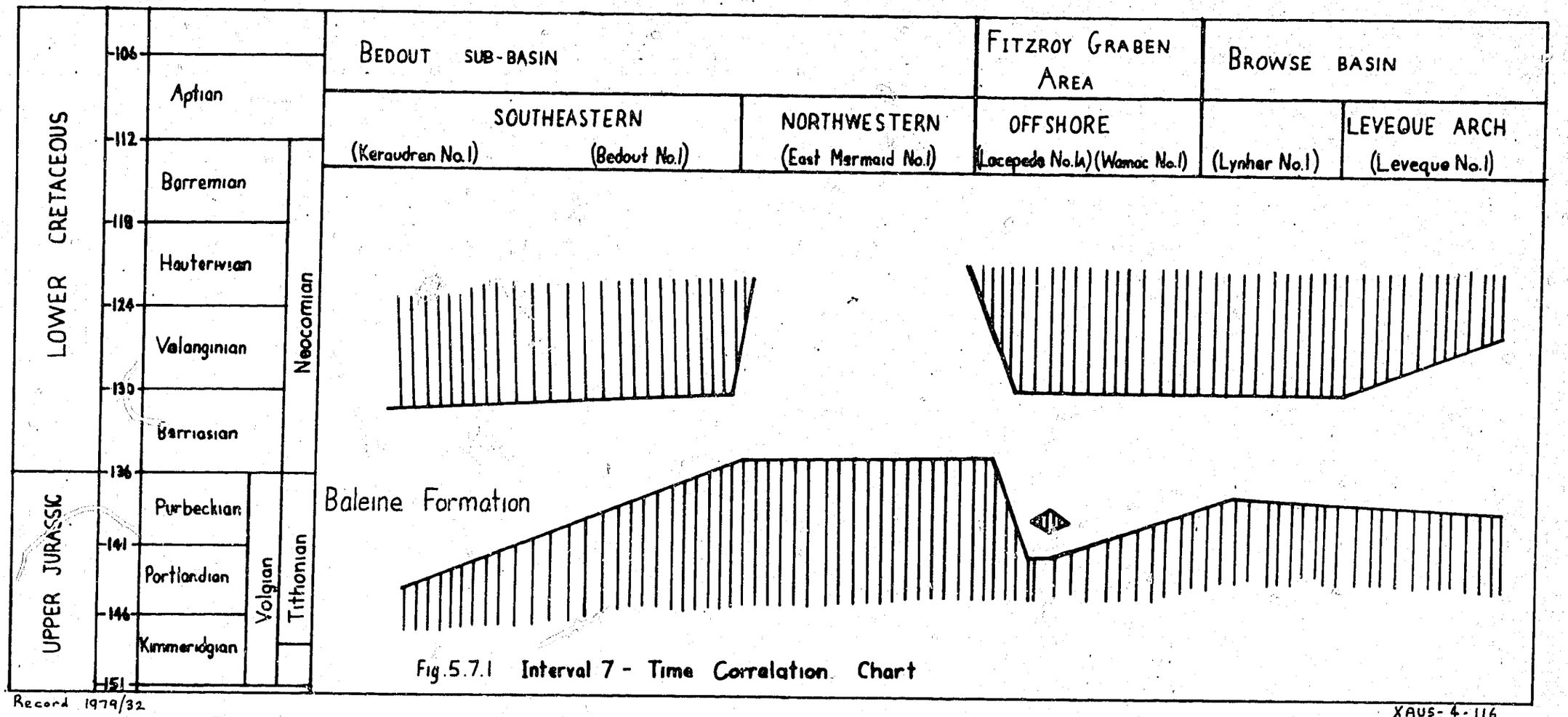


Fig.5.7.1 **Interval 7 - Time Correlation Chart**

Record 1979/32

XAUS-4-116

Environmental interpretation

Sediments of interval 7 were deposited during a transgression and eventual inundation of the present offshore area and a regression.

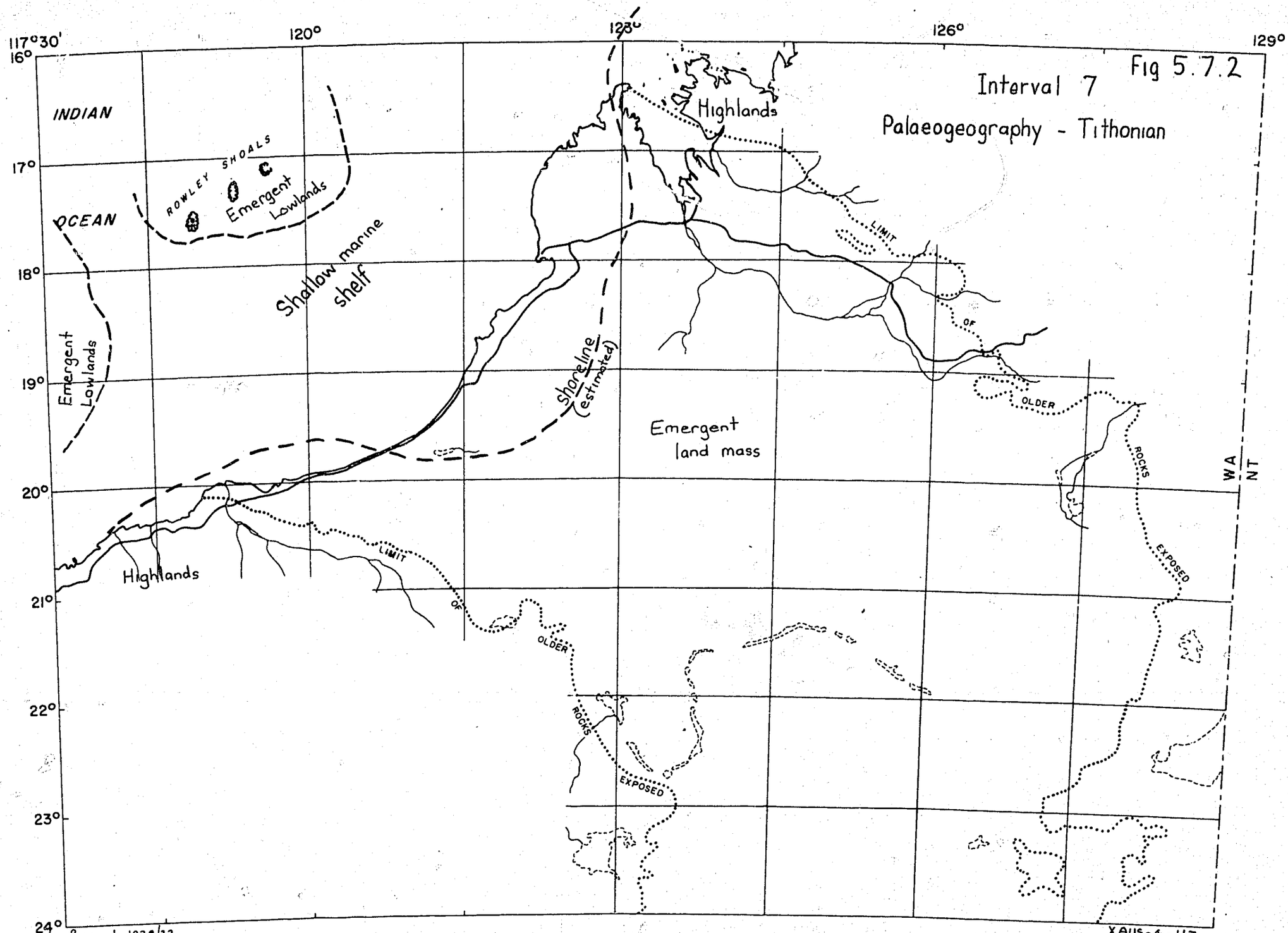
Transgression. Time correlation (Fig. 5.7.1) shows that the oldest sediment is the grey to black marine claystone that occurs in Keraudren No. 1, and that the base of the interval becomes younger to the north and west. This suggests that the marine transgression commenced with an invasion of the sea from the south.

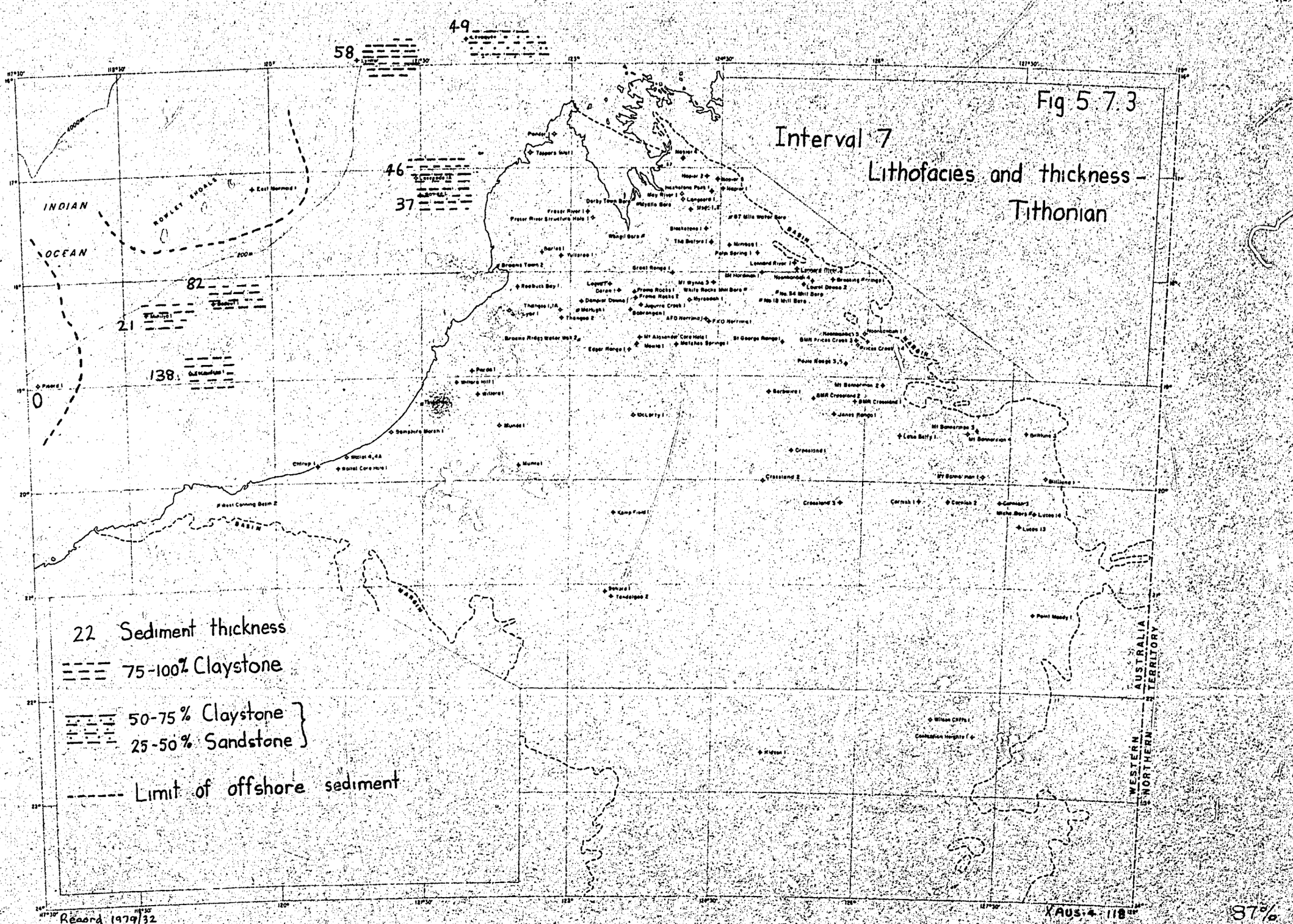
Most of the area was probably rapidly covered by the transgressing sea. Except in Leveque No. 1, where a basal quartzitic conglomerate is preserved, there is no evidence of reworking of the underlying sediments, and the microplanktonic fauna in the basal claystone indicates deposition in a holomarine environment. Over the Leveque Shelf, however, the presence of a basal conglomerate and a fining upwards clastic sequence indicates either a slower transgression or else proximity to the new shoreline (Fig. 5.7.2).

All the offshore area was inundated during the Tithonian, except part of the Rowley Sub-basin and the North Turtle Arch (Fig. 5.7.2), which remained emergent until the Early Cretaceous. Grey to black claystone and minor beds of siltstone and sandstone with a microplanktonic fauna were deposited during the Tithonian (Fig. 5.7.3). The presence of glauconite, commonly up to 10 percent, in the claystone and the absence of coarse terrigenous material suggest deposition in waters over 30 m deep (Porrenga, 1967). The absence of structures other than minor lamination suggest that the depositional interface lay below wave base. Thus throughout the late Tithonian fine-grained clastic sediments were laid down on a broad shelf in an open sea.

Fine-grained clastic sediments and a marine fauna in Lynher No. 1 and Leveque No. 1, similar to that in the Canning Basin, show that the Canning and Browse Basins were connected. The submergence of the Leveque Shelf during interval 7 time removed the barrier that previously separated them.

Early in the Neocomian the sea spread west, inundating the rest of the Rowley Sub-basin. Black to grey glauconitic siltstone with traces of carbonate and mica at the base of East Mermaid No. 1 (the only well in the area) and the occurrence of microplankton in greater abundance than spores and pollen indicate a shallow-marine environment similar to that which existed in the rest of the basin during the Tithonian and earliest Neocomian. The source area for this siltstone is unknown, but may have lain to the west or northwest.


Fig 5.7.2
Interval 7
Palaeogeography - Tithonian
117°30'
120°
123°
126°
129°
16°
17°
18°
19°
20°
21°
22°
23°
24°
INDIAN
OCEAN
ROWLEY SHOALS
Emergent Lowlands
Shallow marine shelf
Emergent Lowlands
Shoreline (estimated)
Highlands
Emergent land mass
LIMIT OF OLDER ROCKS EXPOSED
Highlands
LIMIT OF OLDER ROCKS EXPOSED
WA
NT
Record 1979/32
XAUS-4-117



Record 1979/32

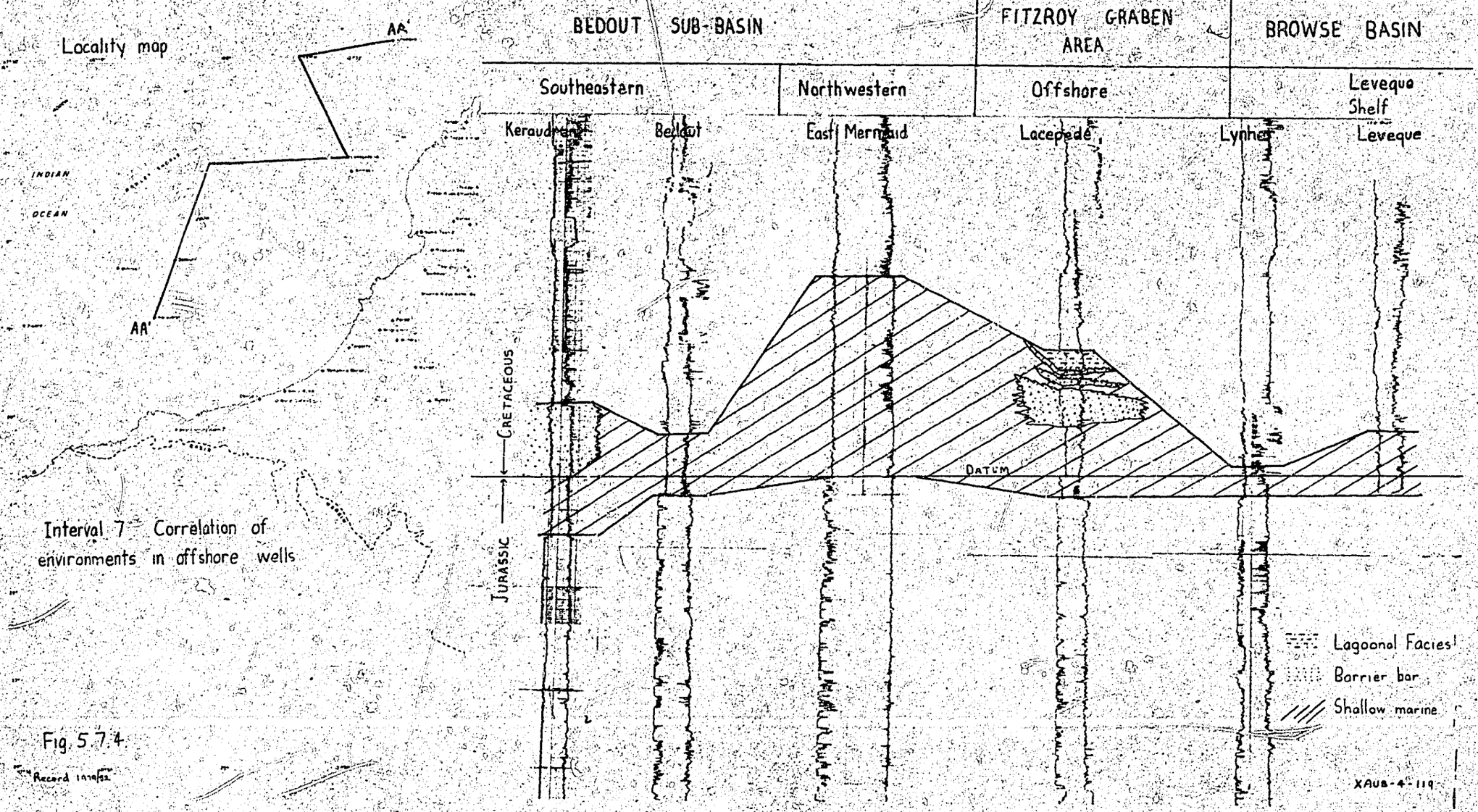
XAus. 4 118

87%

Claystone occurs in wells between the Rowley Sub-basin and the known emergent areas to the east and south, such as the North Turtle Arch and the Kimberley and Pilbara Blocks. The landmass postulated by Warris (1973) to the west of the Browse Basin may therefore be the source area for the siltstone. The relative movement northward away from the Canning Basin that Warris postulated for this landmass in Late Jurassic to Early Cretaceous time may also be the cause of the inundation of the western Bedout Sub-basin in the Early Neocomian. These hypotheses, however, cannot be confirmed without additional data.

Regression. Early Neocomian regression is indicated by a change from the late Tithonian microplankton fauna to abundant spores and pollen and the appearance of sedimentary features such as burrowing, mottling, lamination, bedding, and cross-bedding. In Keraudren No. 1, Lacepede No. 1A, and Wamac No. 1 the claystone in the lower part of the interval grades up to coarser-grained clastic sediments, mainly sandstone (Fig. 5.7.4). This sandstone coarsens upward from very fine-grained to medium and coarse-grained with a corresponding decrease in the degree of sorting. The lower contact of the sandstone is gradational and the upper one is more sharply defined. In Lacepede No. 1A the lower part of the sandstone sequence contains traces of carbonate cement and up to 20 percent of glauconite. A core cut in this section from the same well has sedimentary dips up to 15°, lamination, bioturbation, and limonite concretions. The sandstone higher in the sequence is mainly unconsolidated and glauconite appears less common. The geometry of the sandstone body cannot be reliably determined from only three wells, but it may be a barrier/bar similar to those described by Shelton (1967) in the Eagle Sandstone of central Montana in the United States of America. If so the sandstone is part of the lower and middle shoreface sequence (Davies, Etheridge, & Berg, 1971). Both the upper shoreface-beach and aeolian sequences are absent, but they may have been removed by the erosion that preceeded the deposition of interval 8 in this area. In the offshore Fitzroy Graben the middle shoreface sediments are overlain by sandy to argillaceous siltstone that may be a fine-grained lagoonal facies (Fig. 5.7.4). Arenaceous and calcareous foraminifera in Lacepede No. 1A and glauconite in Wamac No. 1 and Lacepede No. 1A indicate close proximity to the sea.

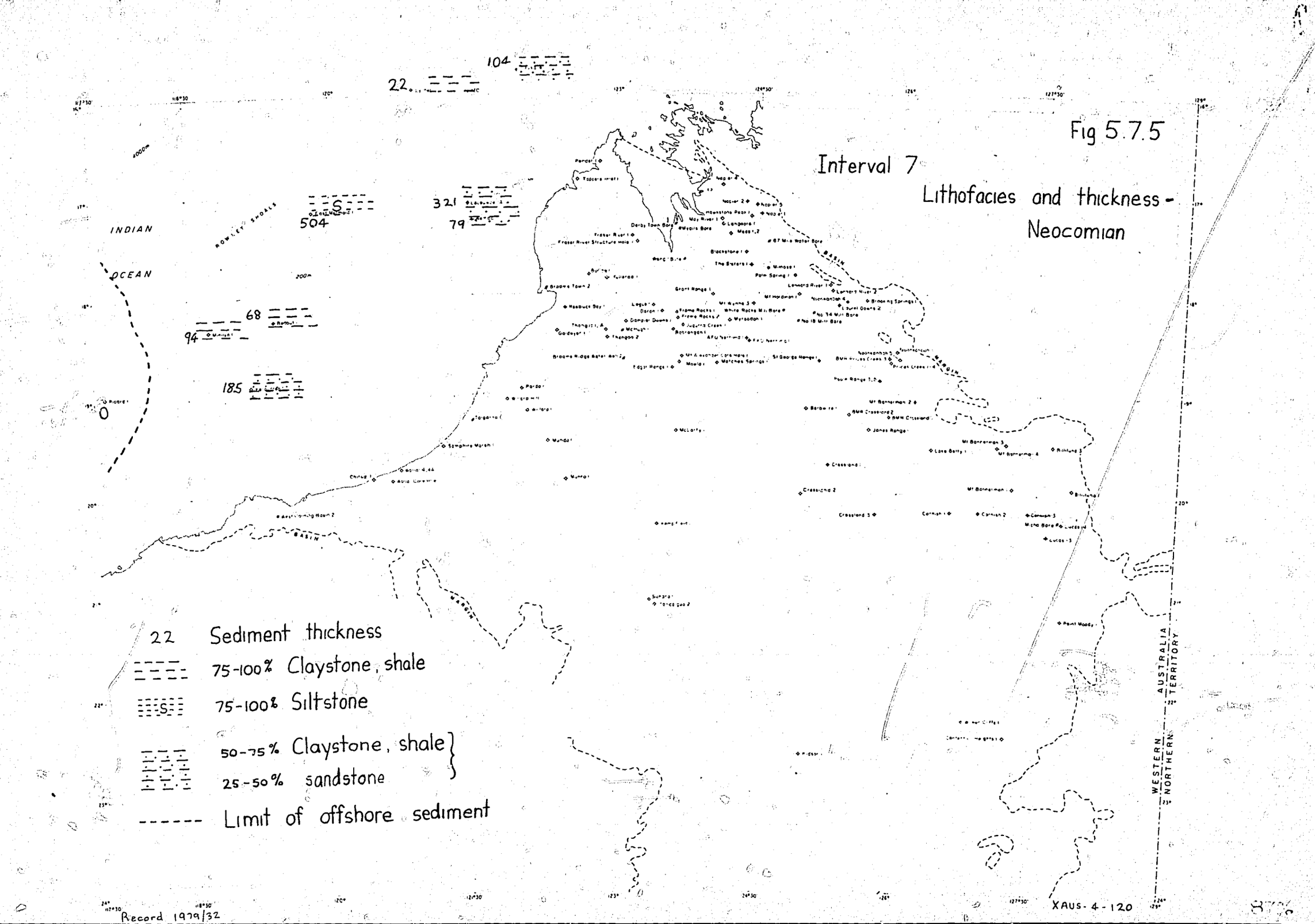
The Kimberley and Pilbara Blocks were probably the main sources for the clastic detritus (Fig. 5.7.5), and the onshore Canning Basin may have been a minor source area. Certainly the interval 6 sediments in coastal wells are not deeply eroded but, farther east all the interval 6 sediments have been eroded (Pl. 11-2, 11-7).

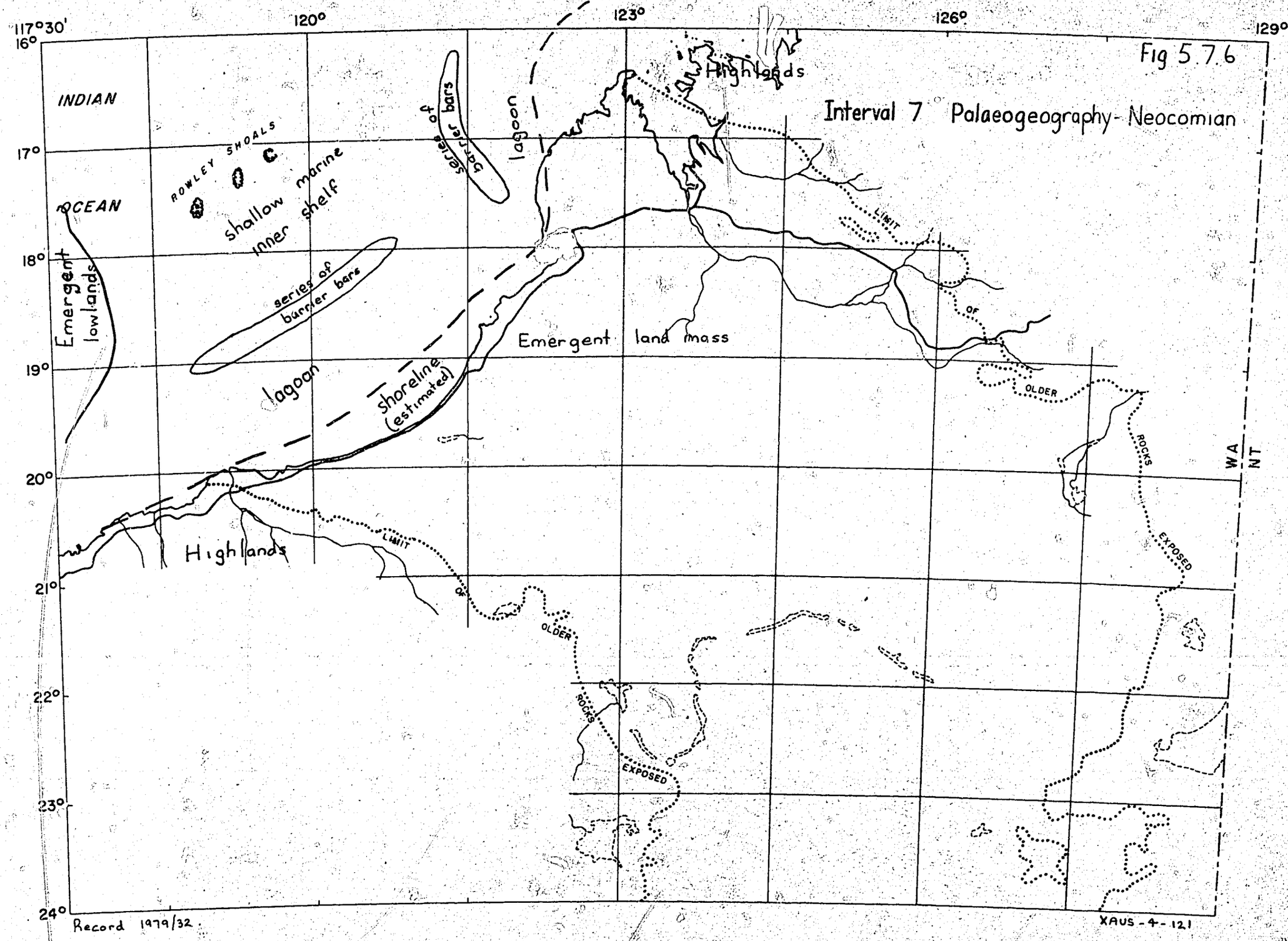


Interval 7 Correlation of environments in offshore wells

Fig. 5.7.4

Record 1979/52


Fig 5.7.5
Interval 7
Lithofacies and thickness -
Neocomian
INDIAN
OCEAN
ROWLEY SHOALS
BASIN
AUSTRALIA
NORTHERN
TERRITORY
WESTERN
22 Sediment thickness
75-100% Claystone, shale
75-100% Siltstone
50-75% Claystone, shale
25-50% sandstone
Limit of offshore sediment
XAUS-4-120
Record 1979/32


Fig 5.7.6
Interval 7 Palaeogeography - Neocomian
117°30'
120°
123°
126°
129°
16°
17°
18°
19°
20°
21°
22°
23°
24°
INDIAN
OCEAN
ROWLEY SHOALS
shallow marine
inner shelf
series of barrier bars
lagoon
Highlands
Emergent land mass
Emergent lowlands
series of barrier bars
lagoon
Shoreline (estimated)
Highlands
LIMIT OF OLDER ROCKS EXPOSED
LIMIT OF OLDER ROCKS EXPOSED
WA
NT
Record 1979/32
XAUS-4-121

During the early Neocomian fine-grained clastic sediments were laid down in a regressing sea on a subsiding shelf dipping gently west; shoreward, a thick sequence of sandstone was deposited in a series of offshore barrier/bars that may have trended parallel to the present shoreline (Fig. 5.7.6). The sea finally withdrew westwards to the Rowley Sub-basin and erosion of the emergent area began.

5.8 INTERVAL 8

Introduction

Interval 8 consists of the Broome, Melligo, Frezier, Leveque, and Mowla Sandstones, the Parda, Anketell, and Samuel Formations, the Bejah Claystone, and unnamed upper Neocomian to lower Cenomanian rocks in the offshore area (Fig. 5.8.1). The lithology and thickness of interval 8 are shown in Plate 10-8; stratigraphic relations and structures are shown in Plate 12-1, 11-7, and 11-6 and Figures 5.8.1 and 5.8.2.

Thickness

The isopach map (Pl. 10-8) shows that interval 8 sediments thin over the offshore Leveque shelf and thicken westwards to over 1300 m in the Rowley Sub-basin. Faulting is prominent around the Leveque Hingeline and the depocentre is west of this. Minor faulting is evident along the margins of the Fitzroy Graben, where the sediments thicken towards the west.

The Bedout Sub-basin is well marked by the isopachs, and has a maximum thickness of over 500 m of interval 8 sediments. The interval thins southwards to less than 200 m over the North Turtle Arch and eastwards to an interpreted zero isopach. Thinning is evident on the offshore extension of the Broome Arch, from over 600 m near the Rowley Shoals to less than 100 m offshore from Admiral Bay. A marked thickening to about 200 m is interpreted onshore in a north-south-trending feature extending from Admiral Bay in the south to near Broome in the north. Whether this feature represents a true depocentre or is a product of erosion is unknown, but the former view is favoured because both Neocomian and Aptian sediments are known from the area (e.g., Frezier Sandstone, Anketell Formation, and Parda Formation) and only Aptian sediments (Anketell Formation) to the east of the area. The offshore thinning is believed to be erosional.

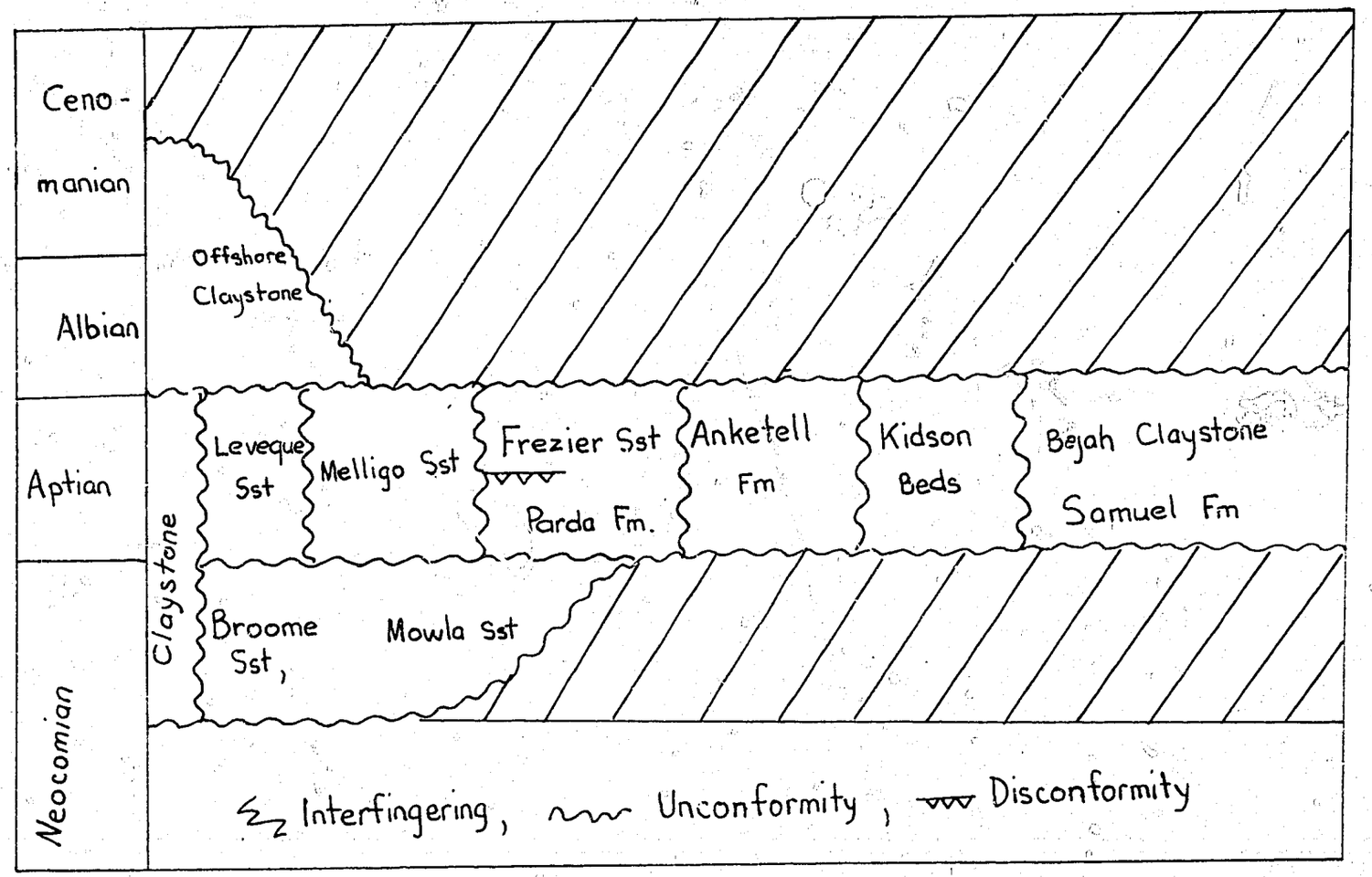


Figure 5.8.1 Time correlation of rock units within interval 8

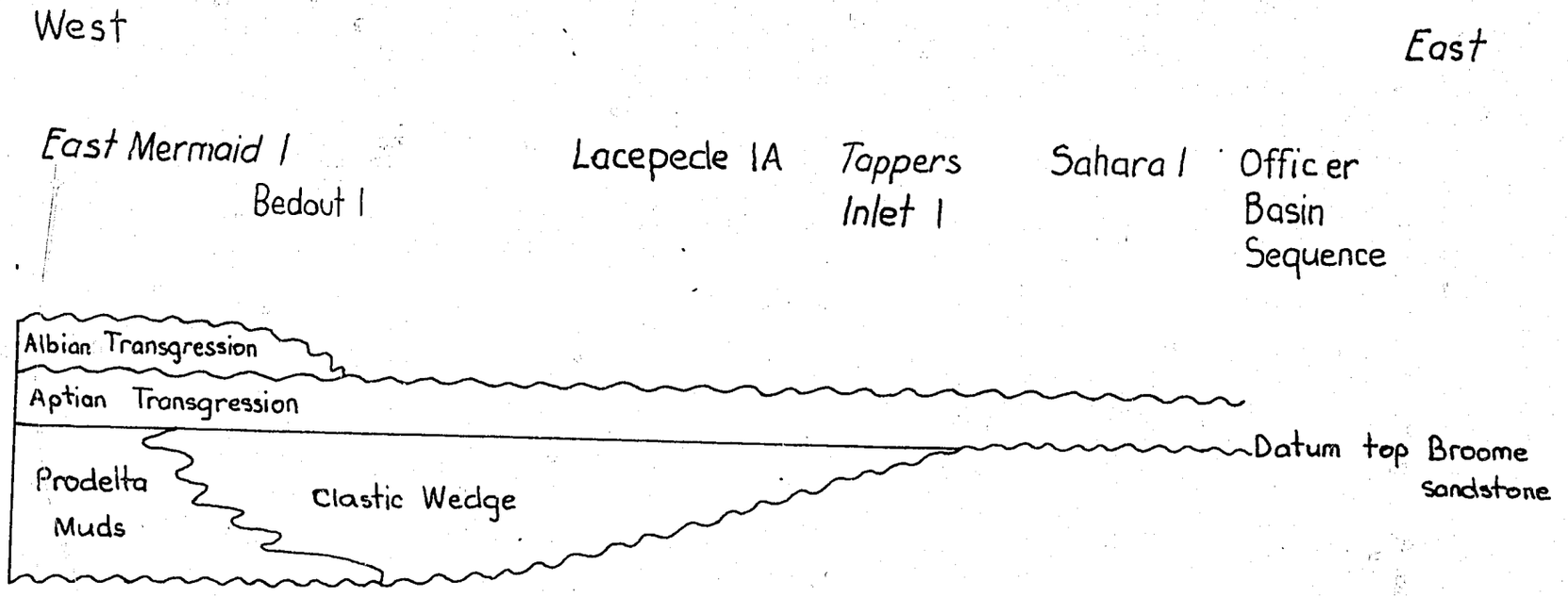


Fig. 5.8.2 Stratigraphic relationships of rock units within interval 8

The thickest onshore occurrence is 274 m in Tappers Inlet No. 1. Rapid thinning towards the east is evident. The interval subcrops in shallow water offshore. This is interpreted as an eroded thickness of Broome Sandstone with Aptian sediments removed. Thicknesses in this area, between Tappers Inlet and the Lacepede area, are interpreted to increase from a minimum of 200 m westwards, but may be less on the Baskerville Anticline, where there is evidence that the sediment may be as thin as 50 m.

Not many conclusions can be drawn from an interpretation of the isopach map because the sediments have undergone two periods of erosion and were deposited possibly during three cycles of transgression and regression the first and last of limited extent, and the second extending over a large portion of the present onshore area.

Lithology

The distribution of lithology depicted in Plate 10-8 is difficult to explain because there has been overstepping of fine-grained sediments of the second transgression over coarser-grained coastal plain sediments (Broome Sandstone and correlatives) and erosion during and after the second regression. The fine-grained Aptian clastics have been eroded from above the coarse-grained coastal-plain sediments in the east. Well control is sparse in the Rowley and the Bedout Sub-basins to the west, but in general finer-grained clastic sediments predominate in the areas of thickest sediments and in the northwest.

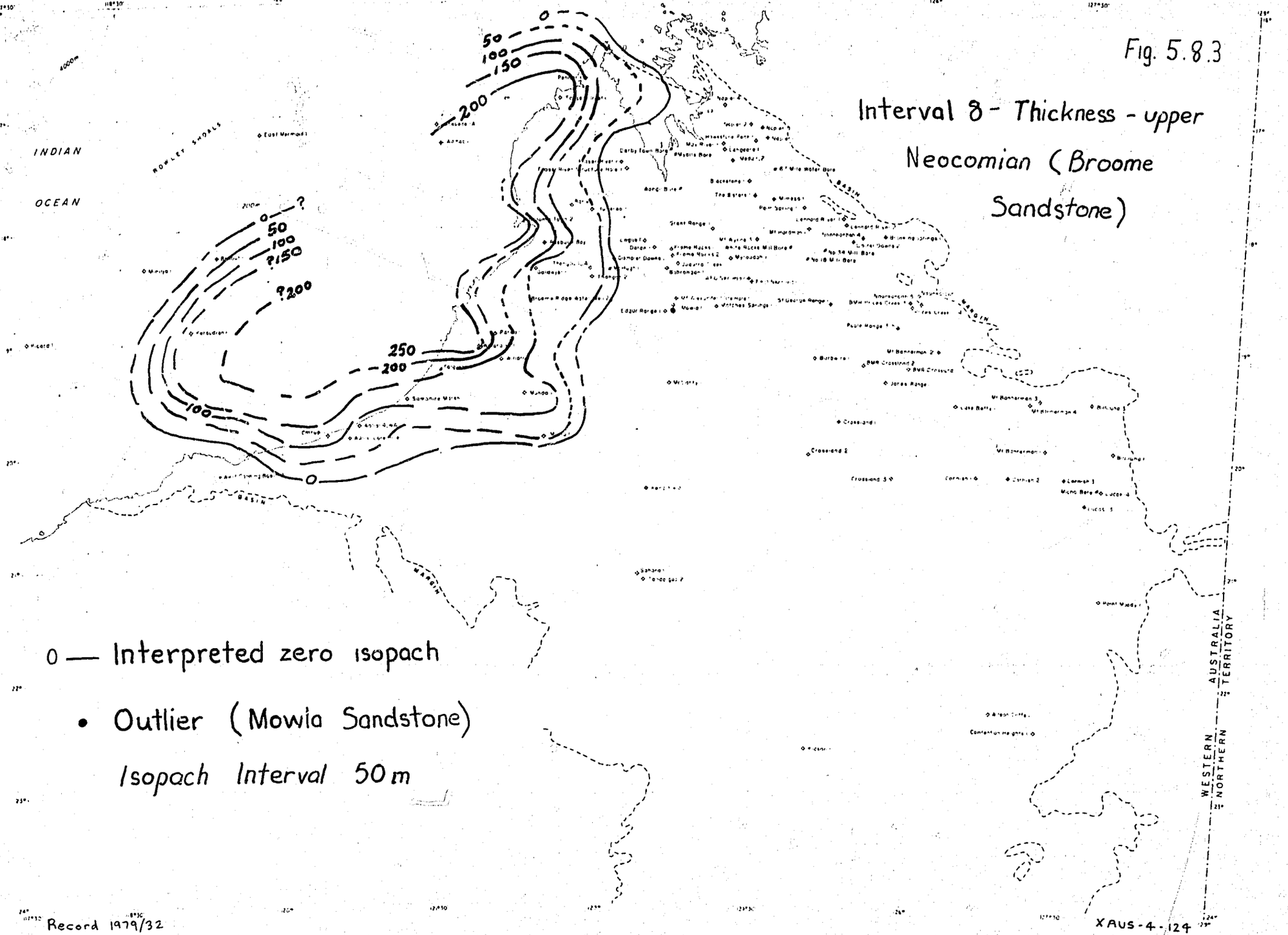
Depositional environments

The sediments were deposited during possibly three cycles of transgression and regression. During the initial limited transgression deltas prograded into a subsiding marine basin in the west. These deltas were drowned in the second major transgression that went on to inundate the Kidson Sub-basin, and the last transgression was restricted to the Bedout and Rowley Sub-basins.

Initial restricted transgression. The absence of microfloral assemblages in the Bedout Sub-basin indicates a brief hiatus before deposition of interval 8. Fine-grained marine sediments were deposited in the western part of the basin during the transgression, and a deltaic clastic wedge, up to 200 m thick, prograded westwards over the marine deposits (Fig. 5.8.3). The eastern part of the basin provides the source for these sedimentary rocks.

Fig. 5.8.3

Interval 8 - Thickness - upper Neocomian (Broome Sandstone)



0 — Interpreted zero isopach

• Outlier (Mowla Sandstone)

Isopach Interval 50 m

Prodelta deposits: The lithology of these sediments is detailed in Appendix 8. The dark colour of the claystone, and the presence of thin lenses of sandstone, glauconite, and marine fossils, indicate that they were laid down in a shallow sea. In Keraudren No. 1 and Bedout No. 1 these claystones are overlain by coarse-grained clastics, suggesting that they were prodelta muds. Fossils include arenaceous foraminifera, dinoflagellates, and miospores.

Deltaic deposits: Interpretation of gamma-ray logs shows that coarsening-upward sequences, characteristic of delta progradation, occur in the Broome Sandstone. In Bedout No. 1 a coarsening upward-sequence at the base of the sandstone unit is overlain by a fining-upward sequence interpreted as a fluviatile channel fill. Similar sequences occur within the Broome Sandstone at other locations (e.g., Willara No. 1, Goldwyer No. 1, and Lacepede No. 1A).

Interpretation of the dipmeter log (Fig. 5.8.4) suggests that the sandstone sequence in Bedout No. 1 prograded to the northwest. The sandstone sequence in Lacepede No. 1A prograded to the west. Low-angle westerly dipping reflectors on seismic sections are interpreted as delta foresets.

The Broome Sandstone contains arenaceous foraminifera (Bedout No. 1, Lacepede No. 1A) microplankton, miospores, plants, and reptilian tracks (Colbert & Merilees, 1967). Fossil wood from the Broome Sandstone was identified by White (in Veevers & Wells, 1961) and Brunnschweiler (1960) as an Otozamites, Sphenopteris, and Cladophlebis association, indicating a fern-dominated coastal marsh area, with Nilssonia, which suggests stream border communities, and Ptilophyllum swamp forests (Krassilov, 1976c).

Major transgression. The sea transgressed through the Canning Basin into the northern part of the Officer Basin to at least latitude 26°S in the Aptian (Fig. 5.8.5). The transgression probably resulted from a eustatic rise of sea level caused by elevation of oceanic ridges during seafloor spreading (Veevers & Evans, 1973).

The thin sequence of shale and claystone (Bejah Claystone and Parda Formation) contains shelly fossils and radiolaria (Lloyd, A.R., 1963) and was probably deposited in a calm sea flanked by relatively low-lying landmasses. The common occurrence of Rhizocorallium trace fossils in the Kidson Beds suggests a shallow marine to intertidal environment (Veevers, 1962). The occurrence of both calcareous and planktonic foraminifera in the Bedout Sub-basin suggests a deeper marine environment than that farther east. The bivalve Inoceramus occurs only in the west, where it lived on the continental shelf in waters less than 150 m deep (Kauffman, 1969). Certain foraminifera, such as

BEDOUT NO.1

AZIMUTH FREQUENCY DIAGRAMS

N

Upper Neocomian



Structural dip

All dips recorded
1417 - 1464 m
Argillaceous section

Upper Neocomian



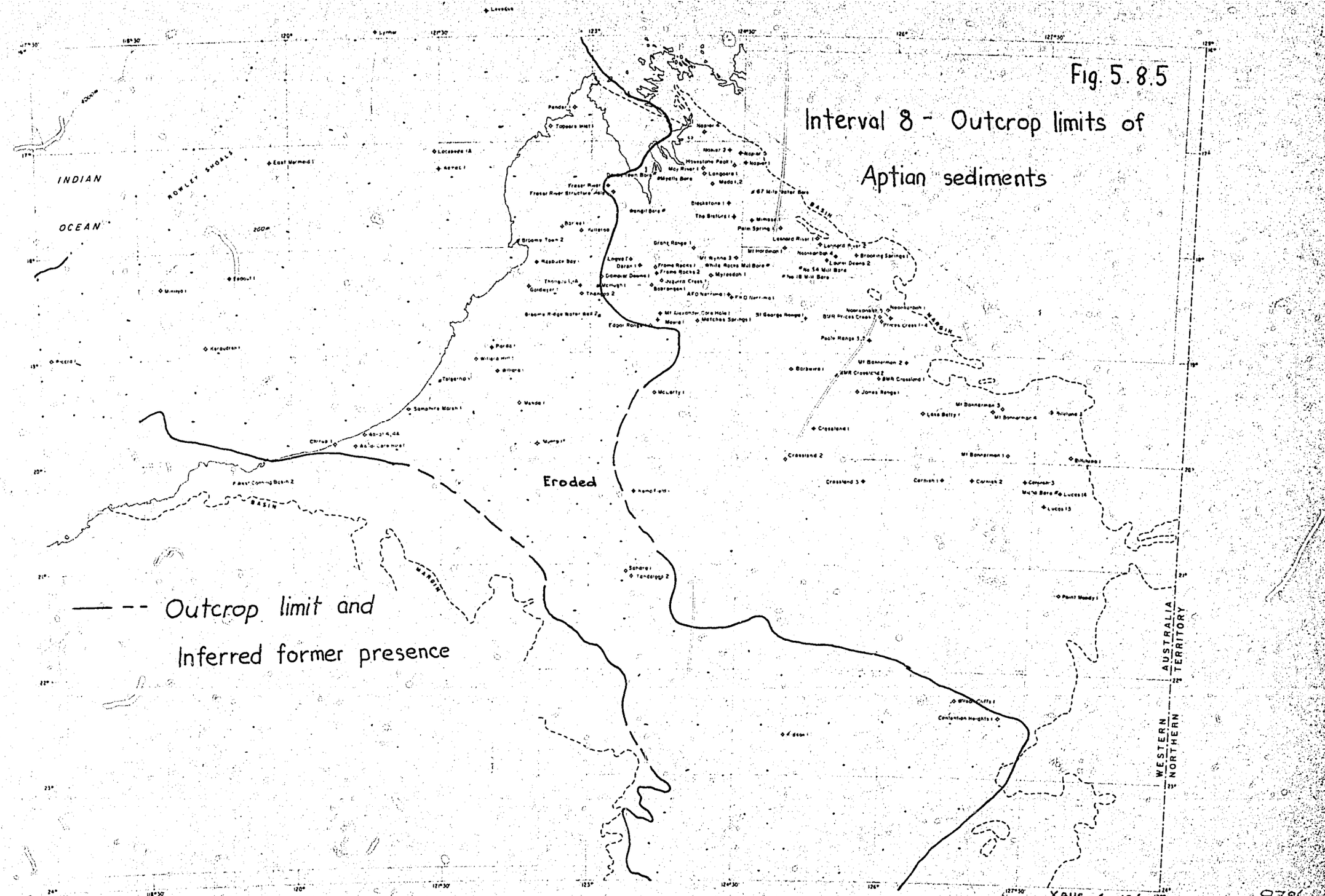
All dips recorded
1494 - 1529 m
Broome Sandstone

SEDIMENTARY AND STRUCTURAL DIPS

Fig 5.8.4 *Interval 8*

Fig. 5.8.5

Interval 8 - Outcrop limits of Aptian sediments



—— -- Outcrop limit and

Inferred former presence

Record 1979/82

XAUS-4-126

87

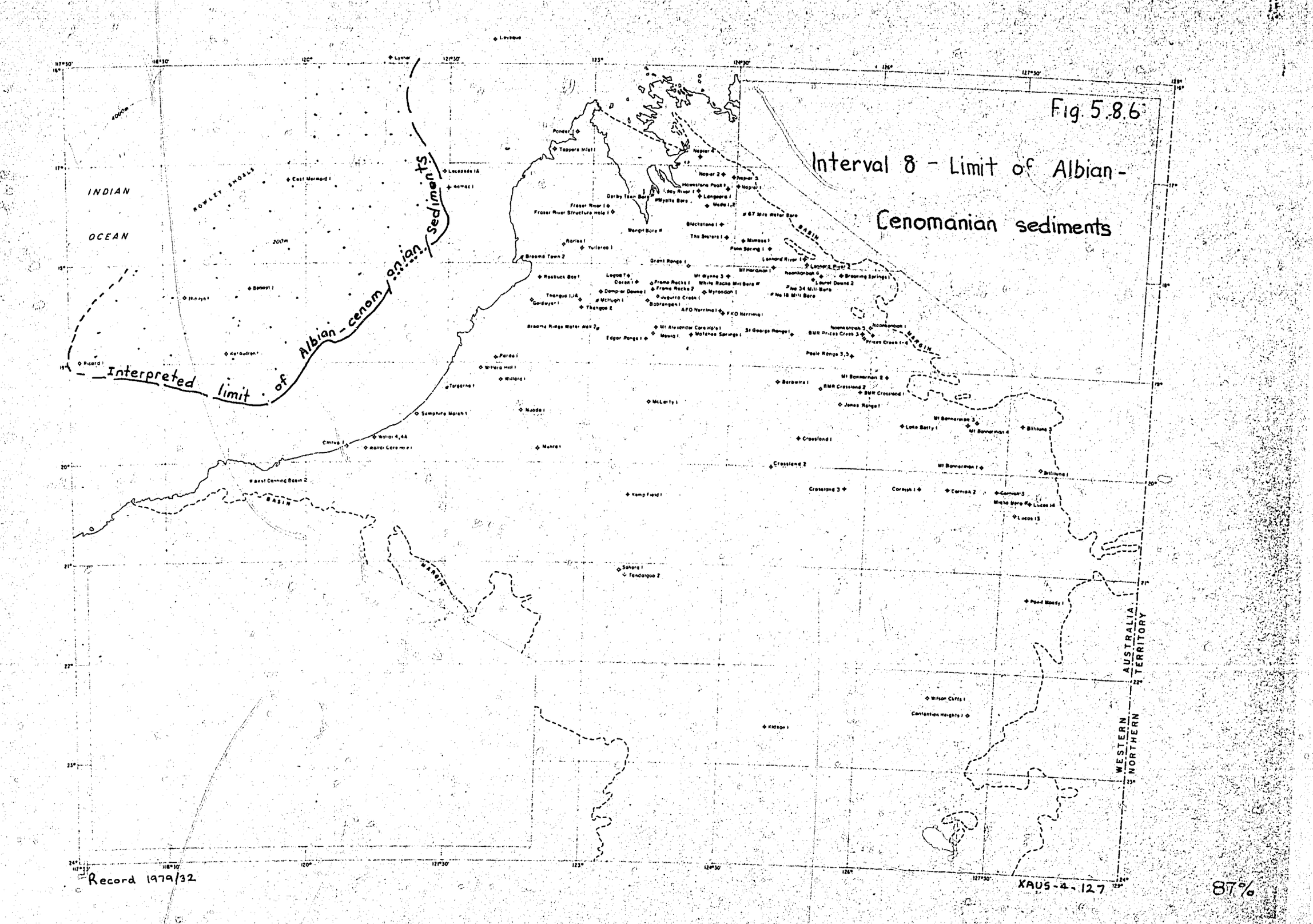
Reophax lenticulina in East Mermaid No. 1, suggest deposition in cold temperate waters 100-150 m deep on the outer shelf. Similar faunas occur in Bedout No. 1, Lacepede No. 1A, and Keraudren No. 1. However, the presence of Trochammina and Ammobaculites, shallow-water inner shelf to intertidal forms, is puzzling. Possibly these forms had wider environmental tolerances in the Early Cretaceous than they do at present.

The sea regressed from the Canning Basin in the late Aptian, and as a result there is an hiatus in the microplankton and foraminifera zonation in all wells drilled.

Final restricted transgression. During the Albian and early Cenomanian the sea inundated the Rowley and Bedout Sub-basins (Fig. 5.8.6), but did not reach as far east as Lacepede No. 1A or the present coastline. The claystone deposited in this sea contains foraminifera, radiolaria, and glauconite. The foraminifera probaly lived on the outer shelf in calm, moderately deep water (150 m). The sea withdrew westwards during the Cenomanian.

Lower Cretaceous climate

On the basis of faunas in the Bejah Claystone, Frezier Sandstone, and Samuel Formations of the Canning Basin (Skwarko, 1967), and similar faunas in the Great Artesian Basin (Day, 1969), a cool climate has been postulated over what is now northern Australia in the Early Cretaceous. The name species of Balme's Microcachryidites Assemblage, from the Broome Sandstone (Balme, 1964), has closely comparable aspects to the extant Microcachrys species, which inhabits cool temperature climates (Dettman & Playford, 1969). The dinosaur, Megalosauropus broomensis, which left tracks in the Broome Sandstone near Broome (Colbert & Merrilees, 1967) probably had endothermic metabolism and could have lived in a cool climate (Ostram, 1969). Bowen (1966) considered that Cretaceous temperatures reached a maximum in the Albian and became cooler in the Cenomanian. The latitude of the Canning Basin has been calculated as 45-47° during the Early Cretaceous (Embleton, 1973), a calculation which supports the palaeontological evidence for a cool climate.



Record 1979/32

XAUS-4-127

87%

5.9 INTERVAL 9

Introduction

Interval 9 includes unnamed rocks of Turonian to Paleocene (Danian) age penetrated only in offshore wells. The stratigraphy is summarised in Appendix 9. Thickness and lithology are summarised in Plate 10-9.

Thickness

Interval 9 is thickest offshore in the Rowley Sub-basin (1000 m) and the Bedout Sub-basin (900 m) and thins over the offshore extension of the Broome Arch between these depocentres (Pl. 10-9). It thins to the southeast to an interpreted zero isopach close to and parallel to the present coastline.

Lithology

Interval 9 is a succession of marine sandstone, siltstone, claystone, marl, and calcilutite. The lithology of the component units is discussed in the following section.

Depositional environments

Interval 9 is divided into five units (Appendix 9). The depositional environment of these units is as follows:

Unit e. The basal Upper Cretaceous unit (claystone and marl unit) is mainly claystone in the southernmost well (Keraudren No. 1), but marl becomes increasingly abundant northwards until it is dominant (Lynher No. 1), and grades into calcilutite nearer to shore (Leveque No. 1). This northward increase in carbonate content partly reflects climatic gradient: i.e., the Leveque area was nearer the palaeoequator than the southern Bedout Sub-basin.

Unit e contains benthonic foraminifera of a type indicative of an open-sea environment on the outer shelf. Inner shelf deposits have not been conclusively recognised but may be present in the calcilutite facies at Leveque No. 1. The environmental tolerances of Recent species of foraminifera (Murray, 1973) suggest that foraminifera of unit e inhabited cool water more than 100 m deep with a muddy seafloor. Sporomorphs of the Microcachryidites assemblage

probably indicate cool temperatures onshore and possibly a moderate rainfall (Dettman & Playford, 1969).

Unit d. Unit d is correlated on lithology with the Toolonga Calcilutite of the Carnarvon Basin. It is mainly calcilutite, but contains minor marl and has nearshore siltstone equivalents (in Lacepede No. 1A). It transgressed eastwards. Foraminiferal evidence suggests that it, or at least the calcareous part, is an open-marine outer-shelf facies deposited in a cool climate. Tethyan influences are present, but palaeomagnetic data (Embleton, 1973) places the palaeolatitude of the offshore Canning Basin at about 45 to 47° south, supporting the equivocal faunal evidence for a cool climate. The bivalve Inoceramus sp. comprises up to 20 percent of the sediment in places, and other benthic invertebrates include echinoids, bivalves, sponges, and radiolaria. The presence of large numbers of radiolaria also supports the argument that the unit was deposited in an outer-shelf environment.

Unit c. Unit c - the claystone unit - occurs only in the outer Bedout Sub-basin and has a sandstone facies equivalent in Lynher No. 1. It may have been deposited in the area of Lacepede No. 1A, Wamac No. 1, and Leveque No. 1, but if so it has since been removed by erosion. It is mainly glauconitic claystone and contains appreciable amounts of Inoceramus prisms and other shelly material. Foraminifera indicate that the claystone was deposited on the outer shelf in water over 100 m deep. Porrenga (1967) has advanced evidence to suggest that glauconite is deposited generally in waters between 30 and 2000 m deep at temperatures less than about 15°C. The sandstone in Lynher No. 1 may have been deposited in shallower water closer to the shore.

Unit b. The siltstone and claystone unit contains foraminifera and radiolaria that suggest deposition on the outer shelf in water over 100 m deep. Pyrite and a lack of benthonic organisms near the top of the unit in Keraudren No. 1 suggest stagnant bottom conditions in the Bedout Sub-basin. Glauconite occurs throughout.

Unit a. Where preserved, Unit a is glauconite-rich, except in East Mermaid No. 1, where it is a calcareous claystone. The fauna suggest deposition on the outer shelf in water over 100 m deep. Gypsum occurs in the unit at East Mermaid No. 1, but is probably a secondary diagenetic product. Inoceramus prisms occur in the unit at Minilya No. 1.

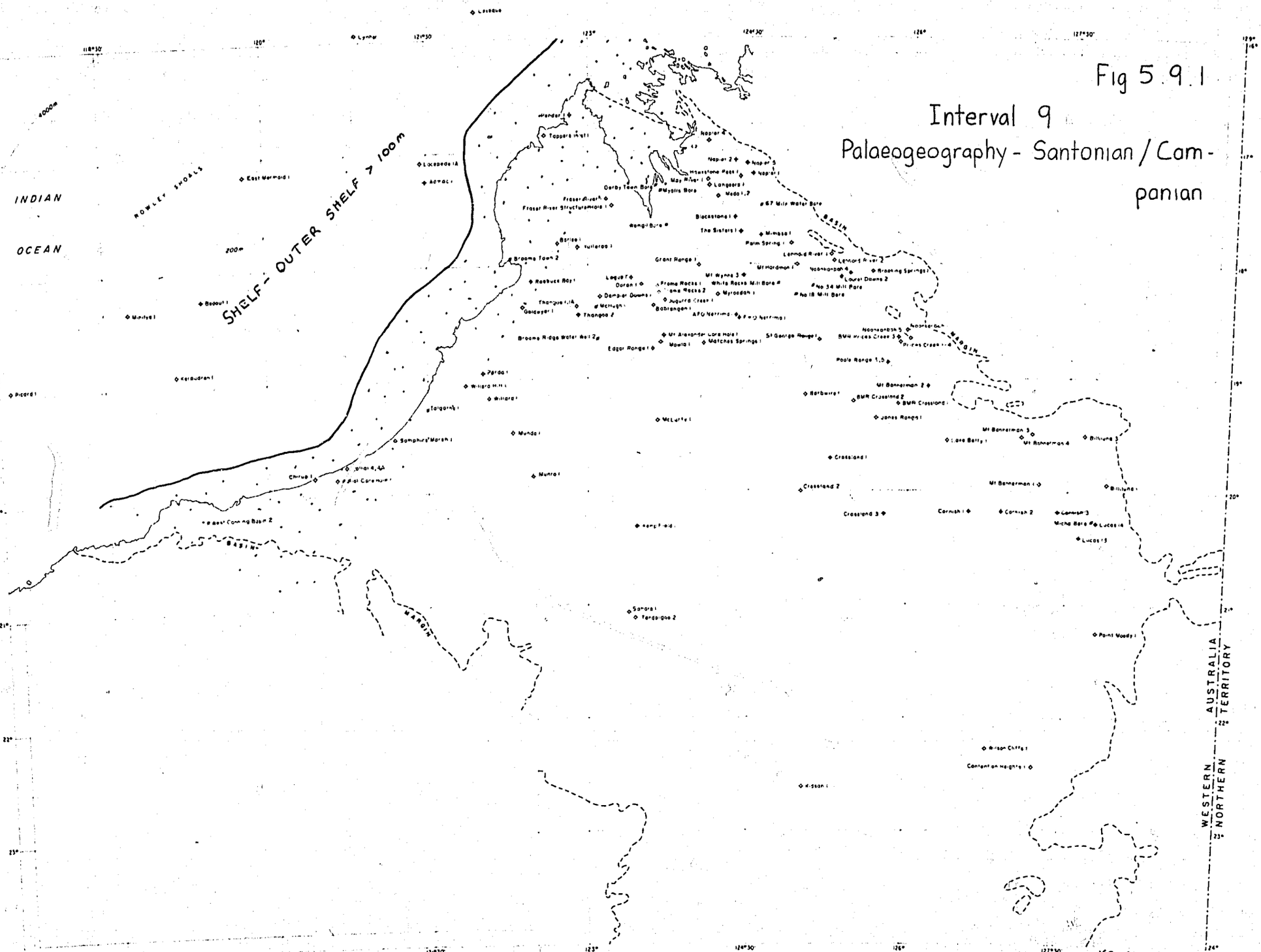


Fig 5.9.1

Interval 9

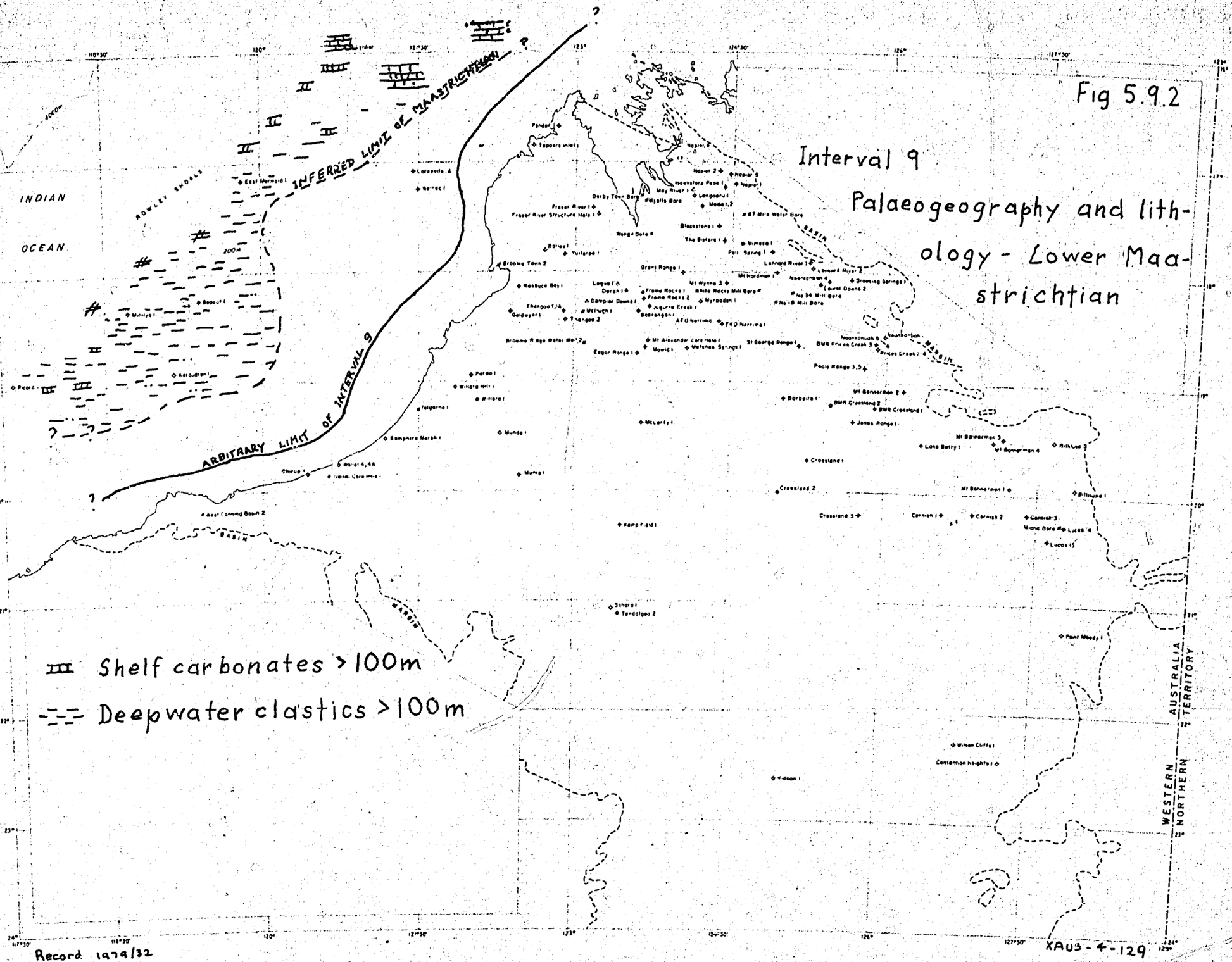
Palaeogeography - Santonian / Campanian

Record 1979/32

XAUS-4-128

87

Fig 5.9.2



Record 1979/32

XAUS-4-129

87%

Conclusions

Foraminiferal evidence indicates that the preserved part of interval 9 was deposited in a cool climate on the outer shelf in water over 100 m deep. The palaeolatitude of the basin in the Upper Cretaceous, at about 45 to 47° south, also indicates a cool climate, but the presence of Tethyan elements in the fauna indicates some warmer influences, probably warm water currents.

The presence of these outer shelf sediments close to the present shoreline suggests that the Late Cretaceous sea transgressed the onshore Canning Basin. However, no deposits of this age are known onshore - probably they have been eroded away.

A palaeogeographic map (Fig. 5.9.1) has been drawn on a datum approximating the Santonian-Campanian boundary. At this time, the sea occupied the offshore region and carbonate muds were deposited in water over 100 m deep. The nearshore siltstone facies at Lacepede No. 1A, may indicate the presence of a river mouth nearby. The high percentage of miospores and the large amount of reworked and abraded microfossils in the siltstone (BOCAL, 1970d) support this hypothesis.

A lithofacies map drawn for the early Maastrichtian (Fig. 5.9.2) indicates that the calcilutite of unit d was deposited in the north at the same time that the fine-grained clastics of units b and c were deposited in the southwest. The northwards contraction of the lime facies results from a lowering of temperatures in the region of the Canning Basin at that time. The fine-grained clastic sediments in the southwest were deposited in water over 100 m deep and the marl present in the wells farther offshore (Minilya No. 1, Picard No. 1) may have been a coccolith ooze, suggesting open circulation. The wells closer to the shore in the southwest (Keraudren No. 1) contain siltstone, indicating closer proximity to source than the claystones farther offshore. Nearshore sediments are unknown and have probably been eroded.

5.10 INTERVAL 10

Introduction

Interval 10 consists of the Emeriau Sandstone, Pender Bay Conglomerate, Lake George Beds, and Lampe Beds onshore and an unnamed sequence of Paleocene and Eocene age offshore. The interval overlies lower Paleocene rocks of

Interval 9 offshore with a distinct but short time break. The stratigraphy of the constituent rock units is described in Appendix 10 and illustrated in Plates 10-10, 11-1, 11-7, and 12-5.

Thickness

The interval reaches a maximum thickness of 900 m offshore to the west of the present shelf break (Pl. 10-10).

Lithology

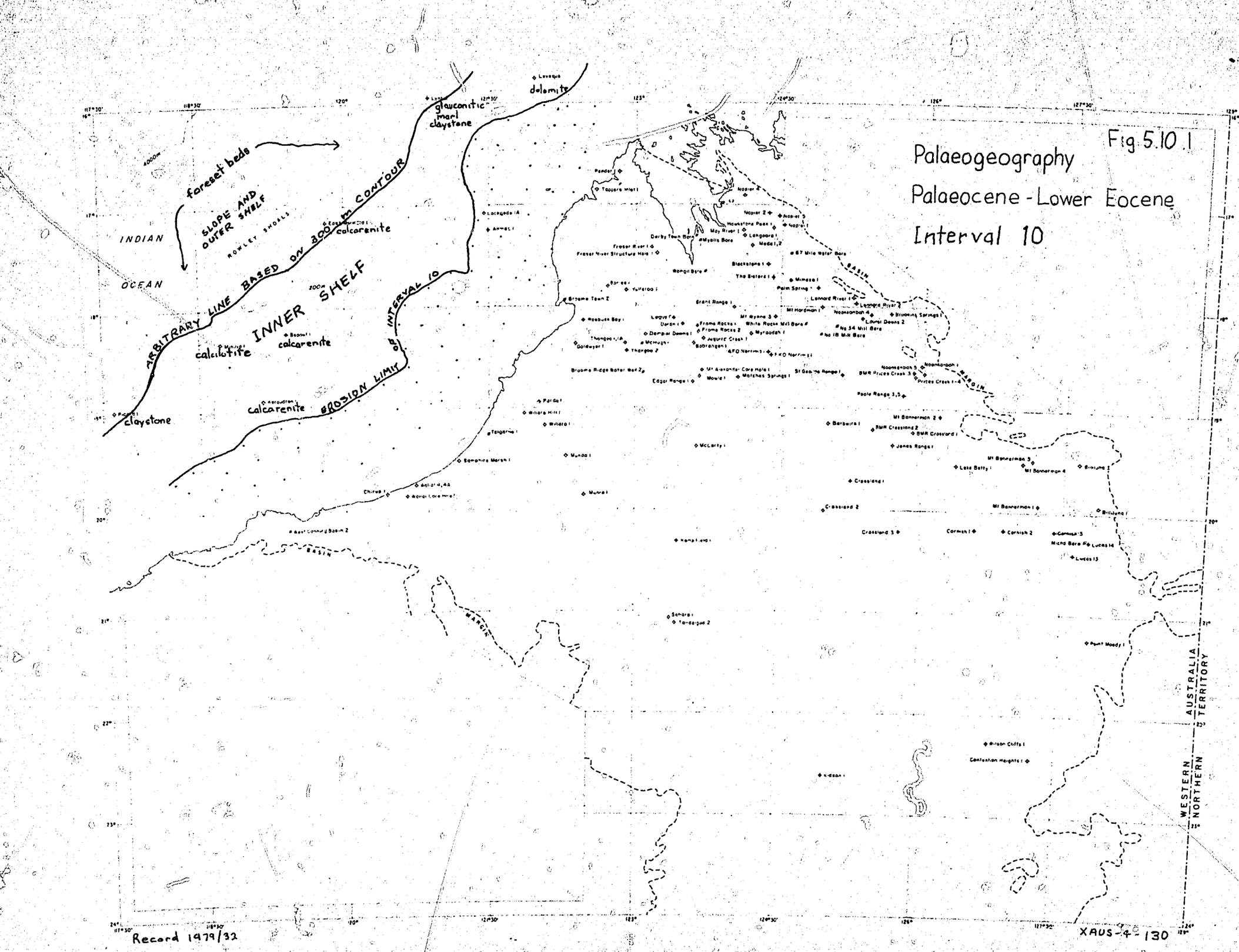
The interval consists of calcilutite and calcarenite with minor dolomite and claystone interbeds. Sandstone is interbedded at Lynher No. 1, in the Browse Basin.

Depositional environment

Deposition of interval 10 (Fig. 5.10.1) began with a marine transgression over a dissected surface of Upper Cretaceous and Danian rocks in the early Paleocene. Calcarenite, calcilutite, and minor claystone were deposited in the Rowley and Bedout Sub-basins (Pl. 10-10). The sediments contain shallow-water benthonic foraminifera of genera known to inhabit shelf to inner shelf environments in temperate to subtropical climates at the present time. The land was probably abundantly vegetated. The presence of thin dolomite in Bedout No. 1 indicates periods of subaerial exposure, further suggesting that the sea was shallow. Gypsum (Keraudren No. 1) may indicate deposition of evaporites, possibly in lagoons during periods of higher temperature. Skeletal debris which makes up about 40 percent of some of the calcarenite in Bedout No. 1 may have accumulated in shell banks along barrier bars. Clasts of limonite and quartz may have been derived from a dissected lateritised surface, perhaps a pre-Eocene laterite profile (Condon, 1968). Similar lithologies occur within the Giralia Calcarenite in the Carnarvon Basin (Condon, 1968).

At Lynher No. 1 to the north the older sediments are mainly marine glauconitic marl and claystone with minor calcareous siltstone. The foraminifera within the sediments probably inhabited a shallow inner shelf.

Carbonates were the main lithologies deposited during later interval 10 time (Fig. 5.10.2). Bedout No. 1 contains a basal calcarenite, composed of up

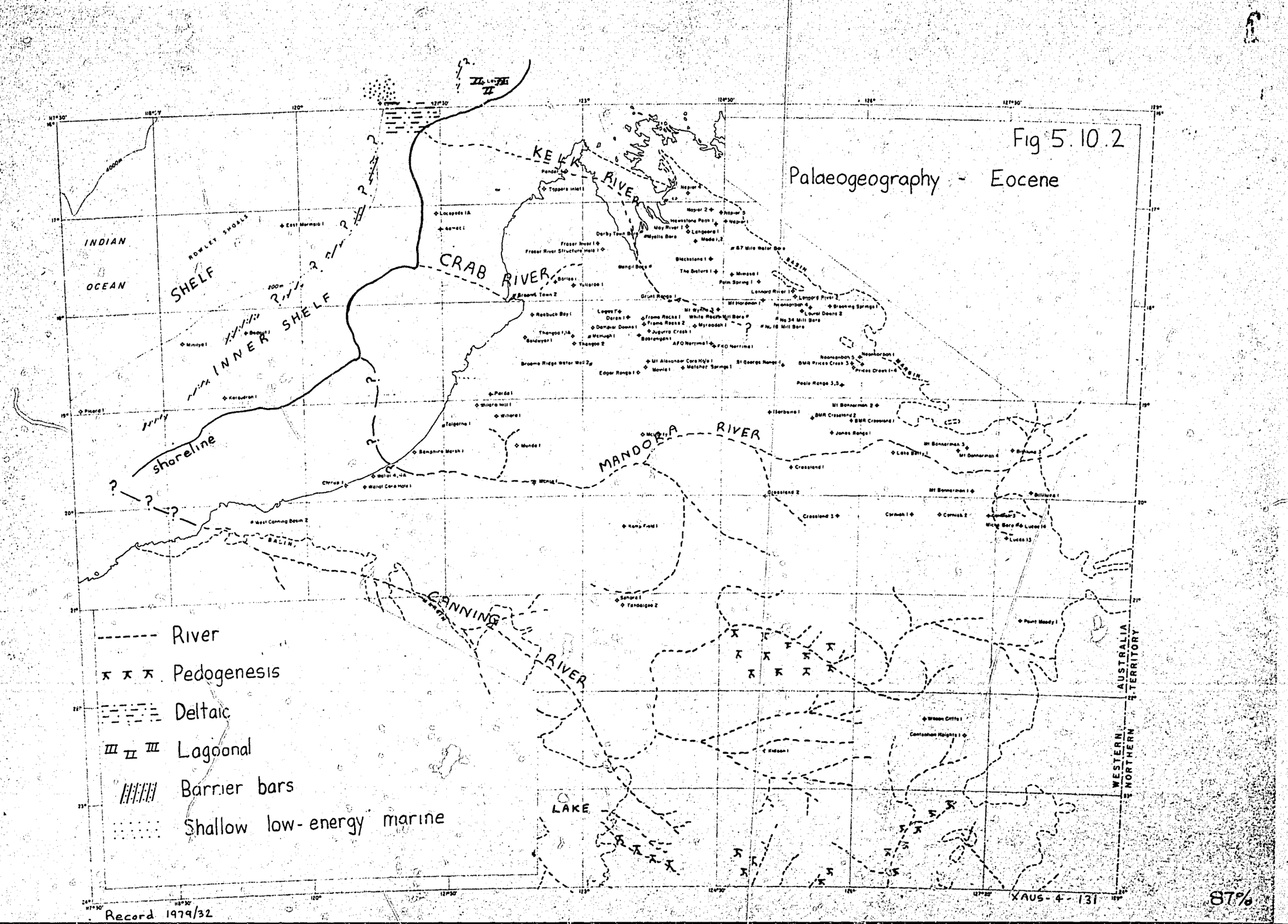

Fig 5.10.1
Palaeogeography
Palaeocene - Lower Eocene
Interval 10
INDIAN OCEAN
foreset beds
SLOPE AND OUTER SHELF
ROWLEY SHOALS
ARBITRARY LINE BASED ON 200m CONTOUR
INNER SHELF
calcilutite
calcarenite
calcarenite
BRODIAN LIMIT OF INTERVAL 10
claystone
glauconitic marl claystone
dolomite
BASIN
MARGIN
AUSTRALIA
WESTERN
NORTHERN
TERRITORY

to 85 percent skeletal debris overlain by a mottled silty claystone. The vertical facies change suggests regression of the sea and seaward advance of barred lagoons in which the mottled claystone was deposited. Dolomite was deposited in a subtropical climate in the areas behind the bars (Bedout No. 1, Leveque No. 1).

A coarsening-upward glauconitic, bioclastic carbonate sequence in East Mermaid No. 1 may be a barrier bar deposited in the westerly regressing sea. Calcareous sandstone with skeletal fragments, glauconite, and foraminifera occur in Lynher No. 1 to the northwest. The lithology and the contained fauna indicate deposition in a shallow sea. The sand was fed into the sea by the 'Kelk River' (Fig. 5.10.2) whose mouth probably lay about 80 km to the east of Lynher No. 1.

The Emeriau Sandstone and Pender Bay Conglomerate are fluviatile sediments deposited by a westerly flowing river that crossed the Dampier Peninsula (the 'Kelk River' of Brunnschweiler, 1957). In Figure 5.10.2 the 'Kelk River' crosses the western tip of the Dampier Peninsula, and is an ancestor of the lower reaches of the present day Fitzroy River, which now debouches into the King Sound sunklands. Brunnschweiler (1957) thought that the ancestral Fitzroy River probably reached the sea at Roebuck Bay, but the criteria of Beard (1973) suggests that this is unlikely. A river did pass through Roebuck Bay, but its upper reaches probably lay near the now intermittent Crab and Deep Creeks, and its lower reaches are probably marked by the canyons, 5 to 12 m deep, incised in the floor of Roebuck Bay (Inner Anchorage-Roebuck Deep) and the conspicuous notch in the zero isopach at 17°35's, 121°15'E, where it probably entered the Early Tertiary sea. It is proposed that this drainage be called the 'Crab River' in keeping with the precedent of Brunnschweiler (1957).

The palaeodrainage of the southern Canning Basin has been described by Beard (1973), who postulated two major westerly flowing river systems. He called the northern river system the 'Mandora River' for which the evidence is only tentative. He stated that there is 'a strong suggestion' that Sturt Creek may once, through a system of salt lakes, have reached the sea via an estuary in the vicinity of Mandora station. Mulcahy & Bettenay (1972) suggested the outlet lay north of Wallal Downs. However, our data suggests that the Early Tertiary coastline might have laid as much as 160 km to the west of the present coastline (Eighty Mile Beach), and we suggest the possibility that the mouth of the river is marked by a notch in the zero isopach at 19°20'S, 119°E. However, there is no bathymetric evidence of an incised ancestral channel to the west of Eighty Mile Beach.



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There is more evidence for the existence of the 'Canning River' (Beard, 1973), to the south (Fig. 5.10.2). The river flowed westwards from near Point Moody, through a chain of salt lakes (Percival Lakes) to Lake Dora and Lake Waukarlykarly and then linked up with the Oakover and De Grey Rivers. The location of the river mouth is unknown. Soil profiles were deposited in fluviatile deposits (Lake George Beds) of the 'Canning River' in the region of Percival Lakes (Towner & others, 1976; Fig. 5.10.2).

Lowry & others (1972) thought that the Lampe Beds in the southeastern Canning Basin had been deposited by southerly flowing river systems. Two major southerly flowing systems, one arising near Contention Heights and the other in Precambrian rocks northeast of Ryan Buttes (Fig. 5.10.2) are marked by outcrops of Lampe Beds. Beard (1973) considered that the rivers in the southwest flowed westwards into Lake Disappointment.

These large river systems and extensive laterite profiles indicate a warm, humid climate during the Early Tertiary. The climate became drier probably by the late Miocene (Bunting & others, 1974; Beard, 1973), and the river systems ceased to flow and are now represented by chains of salt lakes.

The palaeolatitude of the Canning Basin during the early Tertiary has been determined at about 45°S (Irving, 1964). As the continent drifted northwards the Canning Basin entered a zone of higher and more consistent rainfall during the Early Tertiary, and then entered the zone of low rainfall and aridity, which it presently occupies.

5.11 INTERVAL 11

Introduction

Interval 11 is made up of unnamed Miocene to Recent carbonates offshore, and a number of sedimentary units and chemical weathering products onshore, including: Oakover Beds, Lawson Beds, Chimney Rock Oolite, North Head Limestone, Bossut Formation, Border Sandstone, Wolf Gravel, Warrimbah Conglomerate, Lake Gregory Beds, pisolitic ironstone, ferricrete, silcrete, calcrete, limonite, hardpan, laterite, sand, and alluvium. Interval 11 is disconformable on interval 10 offshore. The stratigraphy is summarised in Appendix 11 and illustrated in Plates 10-11, 11-1, and 12-1, 12-2, and 12-5.

Thickness

The interval gradually thickens seawards from a thin veneer in the coastal area to about 1000 m at the shelf break (Pl. 10-11). At the Rowley Shoals reefs the thickness increases to 1200 m.

Lithology

The main lithologies are sand and alluvium onshore and carbonates and sandstone offshore.

Depositional environments

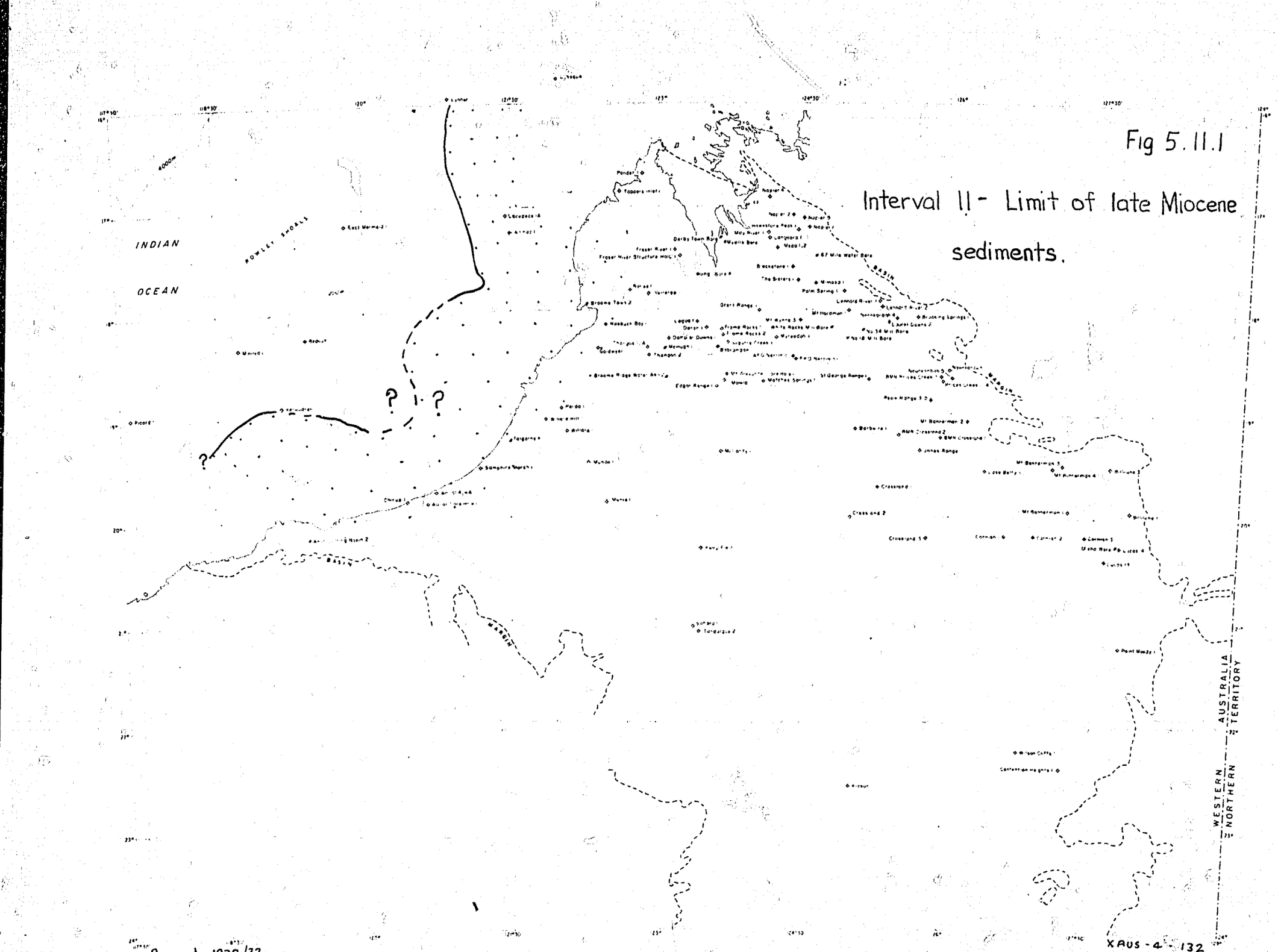
The sediments of intervall 11 can be divided into two subintervals separated by the R_1 unconformity of Veevers (1973a). Although the exact age of the erosion surface is unknown it is thought to have developed on the present continental shelf and Rowley Terrace (Fig. 1.4.1) during the Upper Miocene. It is clear from seismic data that in some locations the Miocene and older sediments were tilted, folded, and eroded before the Pliocene and Recent sediments were deposited. Veevers (1973a) thought that the R_1 unconformity (surface 4 of Jones, 1973) was caused either by uplift during the collision of the Australian and Asian continental plates or by the 'Messinian' eustatic low sea levels during the late Miocene. The surface may correspond to dolomitised zones above 442 m in Bedout No. 1 and is correlated with a similar zone at 640 m in East Mermaid No. 1 and at 549 m in Minilya No. 1.

Miocene (interval between the R_1 and R_2 unconformities of Veevers, 1973). Figure 5.11.1 shows the preserved limit of Miocene rocks visible on seismic sections. Picard No. 1, East Mermaid No. 1, and a marked unconformity between flat-lying younger (Pliocene-Recent) sediments and older sediments visible on seismic sections southeast of Rowley Shoals and adjacent to the Leveque Hingeline were used for control. Tracing such shallow horizons is difficult and the map is tentative offshore from Eighty Mile Beach.

The Miocene transgression must have extended farther east than the preserved limit of sediments shown in Figure 5.11.1. Erosion is inferred by the presence of fossil hills and valleys visible on the seismic sections, and is proved by the angularity of the unconformity visible near the Leveque Hingeline.

Fig 5.11.1

Interval 11 - Limit of late Miocene sediments.



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The contained foraminifera probably lived in normal marine waters, 10 to 40 m deep, on the inner shelf with areas of shoals and reefs. Seismic interpretation and the presence of the reef-dwelling foraminifera (Amphistegina, Cycloclypeus) suggest that the Rowley Shoals reefs began to grow at this time (see also Jones, 1973). Many of the foraminiferal species (Elphidium, Discorbis, Amphistegina) are forms that live attached to sea-grasses, suggesting that sea grasses were an important part of the benthonic communities.

The foraminiferal species are tolerant of a water temperature ranging from 10 to 30°C, indicating a subtropical to tropical climate. Murray (1973) found that the genus Amphistegina is restricted to equatorial regions where the average summer temperatures get no lower than 25°C. Present water temperatures off Derby are about 26°C (Bowen, 1966), so the climate at the present day and during the Miocene must have been quite similar.

Late in the Miocene the sea withdrew from the shelf area, faulting occurred to the southeast of the Rowley Shoals, and faulting, tilting, and erosion occurred adjacent to the Leveque Hingeline. At the same time the upper carbonate rocks of the subinterval were dolomitised.

Pliocene to Recent. The Pliocene to Recent sediments were deposited during a marine transgression, probably initiated by westward tilting of the continental shelf during the early Pliocene. Three present day structural and morphological provinces - the continental shelf, Rowley Terrace, and Exmouth Plateau (Figure 1.4.1) - have been delineated offshore by earlier workers.

The Rowley Terrace supports four marginal atolls, one of which is completely submerged and may record an earlier sea level. The sediments of the terrace (East Mermaid No. 1) are mainly carbonates, and contain foraminifera which indicate deposition on the outer shelf in normal marine waters about 120 m deep. As present-day water depths near the marginal atolls are of the order of 400 m (Pl. 2) it is clear that subsidence has outpaced deposition and that the sedimentation rate since the Miocene has been low (Jones, 1973).

Jones (1973) has recorded at least three erosion surfaces above his surface 4 on the Rowley Terrace. He suggested that surface 1 was probably exposed during the last low level of the Pleistocene (Wisconsin?) and that this surface, and surface 2, form the present sea-floor on the continental shelf with only a thin cover of Recent sediments.

The sediments between surface 4 and the sea-floor were penetrated by seven wells on the continental shelf. Leveque No. 1 and Lacepede No. 1A penetrated carbonates with little terrigenous debris, suggesting that onshore

drainage was minimal. Foraminifera indicate that the carbonate rocks were deposited on the inner shelf in conditions very similar to the present day.

Jones (1973) has correlated a notch at a depth of 120 m (Fig. 5.11.2) with the last low-level still-stand accompanying the late Wisconsin glacial maximum (Fig. 5.11.3), which occurred about 17 000 years ago - immediately before the late Pleistocene transgression.

Haq (1973) considered that temperatures were as much as 6 to 8°C cooler during the Pliocene-Pleistocene polar glaciation than in the Miocene, so the onshore Canning Basin probably became both cooler and wetter. The ancestral Paleocene-Eocene drainage system may have developed into strings of shallow lakes, and the Fitzroy River and its tributaries may have been perennial rivers. Late Pleistocene lacustrine sediments were deposited in the valley of the Oakover River and in Lake Gregory, and probably in other lakes such as Waukarlycarly, Disappointment, Percival, Betty, Lonergan, and Jones. The Lawford Beds were probably deposited in a lake within the Christmas Creek drainage basin. Evidence to support a perennial Fitzroy River and tributaries include the 150-m-deep Windjana Gorge cut through the Napier Range by the Lennard River, and high-level gravels along the lower reaches of the Fitzroy River (Warrimbah Conglomerate). Fossils of the larger marsupial herbivores (Diprotodon, Protemnodon, and Phascolonus), which probably became extinct about 20 000 years ago, occur within the lake deposits and high-level gravels, and indicate the probability of a savannah vegetation onshore.

With deglaciation the temperature has risen again to present-day levels and the lakes have dried up. The presence of the 120-m notch and the existence of submerged strandlines coastwards from it indicate that the sea rose as a consequence of deglaciation after the still-stand and transgressed eastwards to inundate a narrow strip along the present coastline. The Bossut Formation, Chimney Rock Oolite, North Head Limestone, and raised calcareous beach rock and sand dunes along the Dampier Peninsula and Eighty Mile Beach were deposited onshore as a result of this transgression (Fig. 5.11.4). A series of up to four beach ridges, present along the Eighty Mile Beach suggest that the sea level fluctuated markedly. Marine fossils (including Discorbis and Elphidium) in calcareous sandstone at Racecourse Plain, southeast of Broome, indicate that this area was also transgressed (Crespin, 1948, note on file). According to radiocarbon dates obtained on sea-bed samples (Jones, 1973) the transgression occurred 12 000-12 500 years ago.

Further evidence of the encroachment of the sea into the Fitzroy River-Lennard River-May River area is provided by the presence of freshwater-adapted

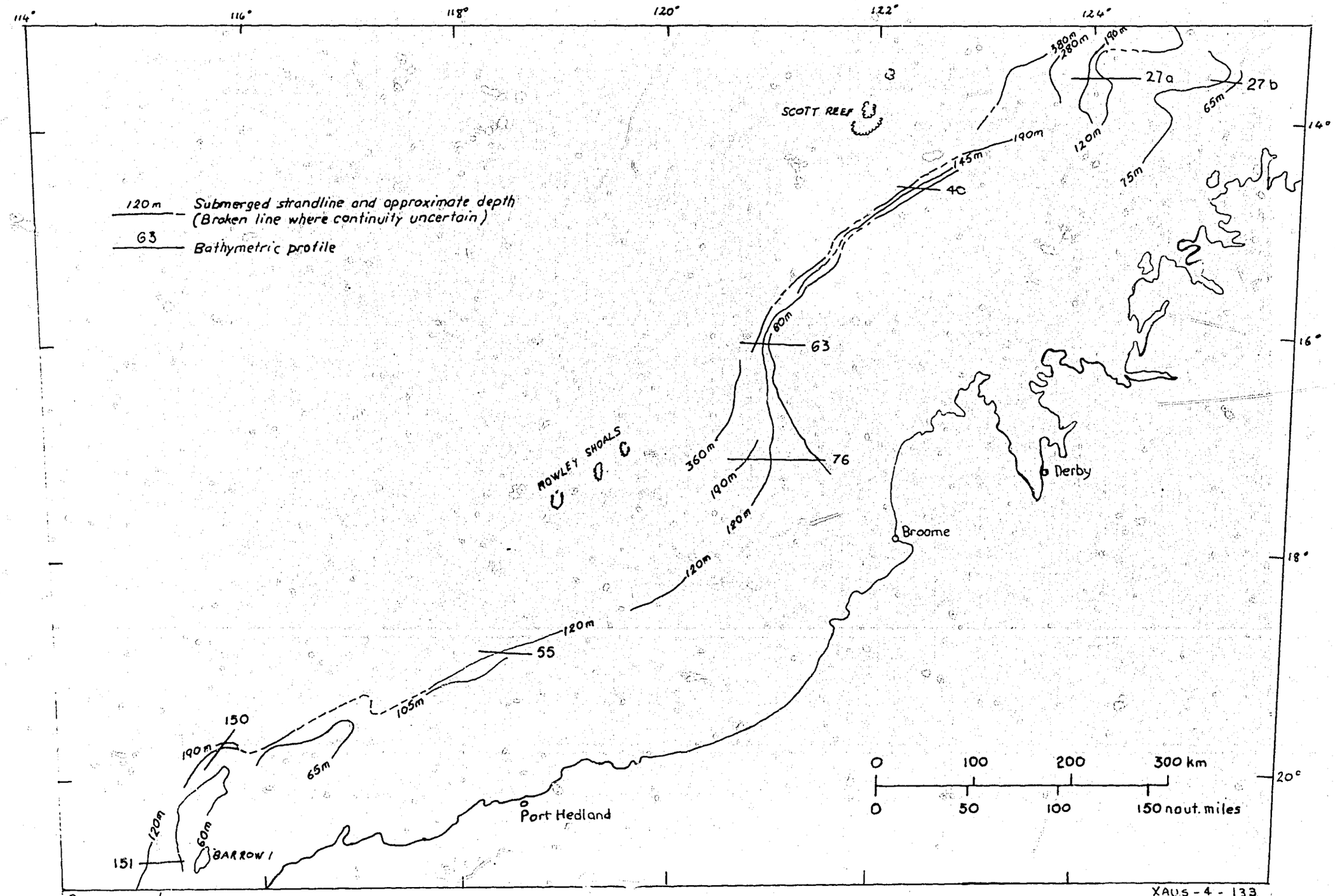


Fig. 5.11.2 Distribution of submerged strandlines. (Jones, 1973)

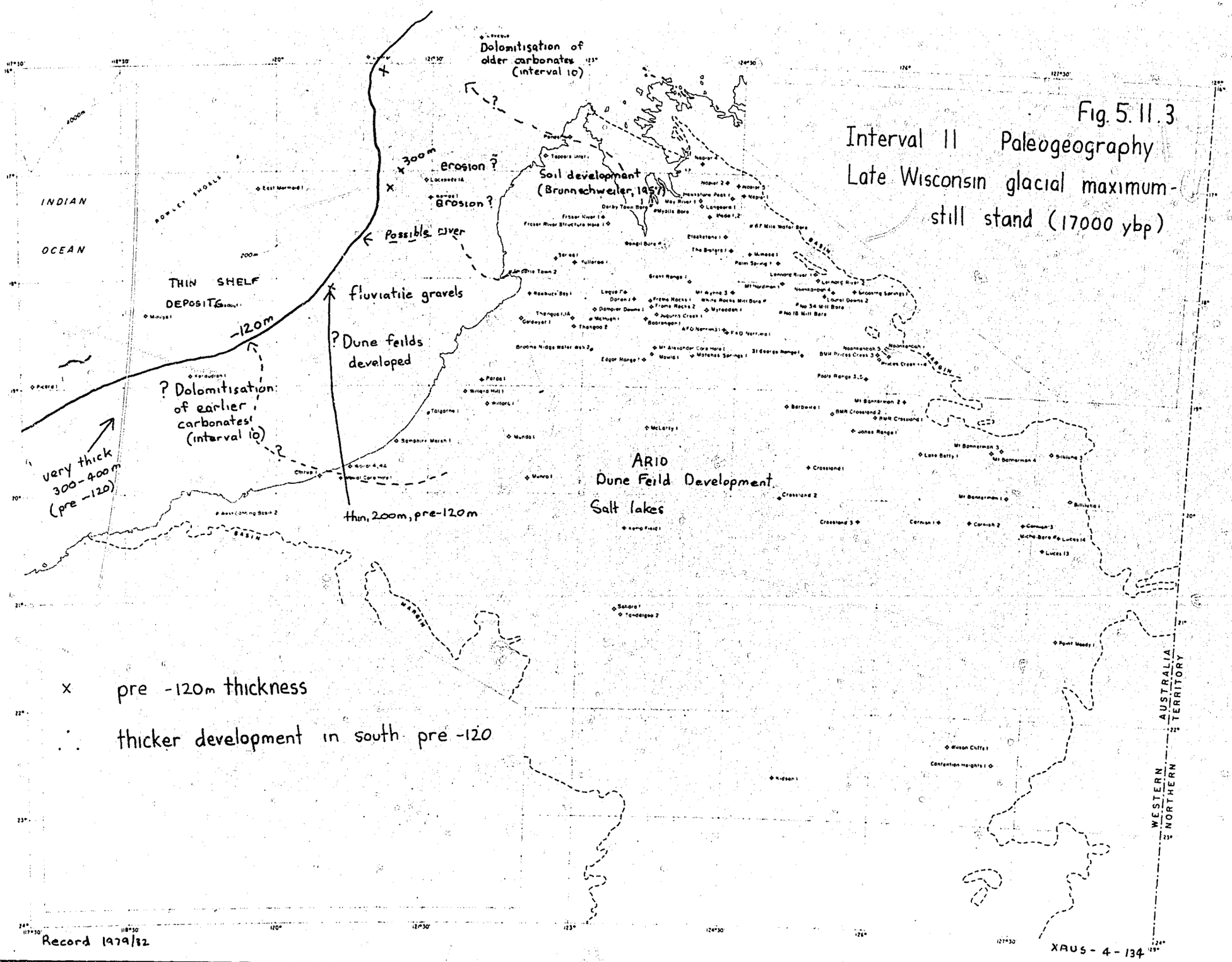


Fig. 5.11.3
Interval 11 Paleogeography
Late Wisconsin glacial maximum-still stand (17000 ybp)

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87%

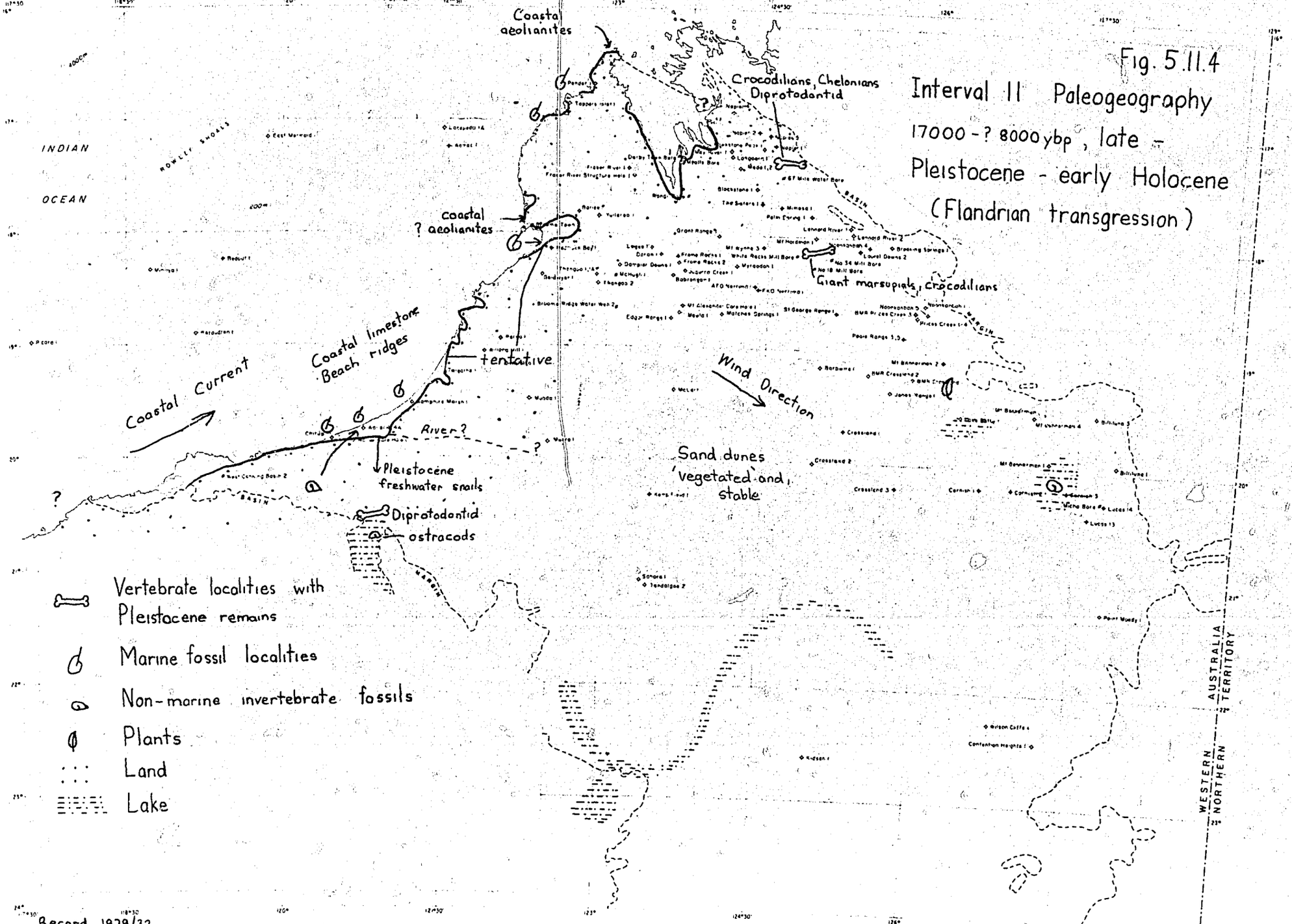


Fig. 5.11.4

Interval 11 Paleogeography

17000 - ? 8000 ybp, late - Pleistocene - early Holocene (Flandrian transgression)

Record 1979/32

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87%

sawfish and sharks as much as 200 km inland - in the Lennard River at Windjana Gorge and in the Fitzroy River upstream from the Camballin rice research station.

Possible minor uplift during the early Holocene (or a minor return of polar glaciation?) led to the regression of the sea to the present level. Brunnschweiler (1957) suggested that the inland sand dunes on the Dampier Peninsula developed during an 'earlier Pleistocene arid cycle' (presumably during the deglaciation preceding the Wisconsin glacial maximum). Dunefields may have developed inland at that time, but there is no clear evidence of them. Certainly the inland dunes were active during the early Holocene until comparatively recently. The main strike of the dunes and the common tuning-fork junctions indicate prevailing wind directions from the east (Yeates & others, 1975b). In the last few thousand years the dunes have become stabilised by vegetation, and are now inactive.

5.12 INTRUSIVE IGNEOUS ROCKS

Four wells (Table 5.12.1) have penetrated mafic igneous rocks of possible Late Permian age. It seems from the few penetrations of these rocks that igneous activity was not widespread in the onshore Canning Basin, but was confined largely to the offshore area, and the northwestern part of the onshore Fitzroy Graben. Interpretation of magnetic data indicates that the mafic igneous rocks in Bedout No. 1 cover an area of about 250 km^2, whereas those in Wamac No. 1 may occur over about 1000 km^2.

In addition to the Palaeozoic rocks, intrusive leucite lamproites (Prider, 1960; Veevers, 1958) crop out at 30 localities in or adjacent to the Fitzroy Graben (Fig. 5.12.1). Most occurrences are in the western part of the Noonkanbah Sheet area; others are in the Lennard River and Derby Sheet areas, and in one drillhole - Nerrima No. 1. The lamproites intrude rocks of Precambrian (Gellatly, Sofoulis, Derrick, & Morgan, 1974) to Early Triassic age (Prider, 1960). Wellman (1973) considers that they are of early Miocene age.

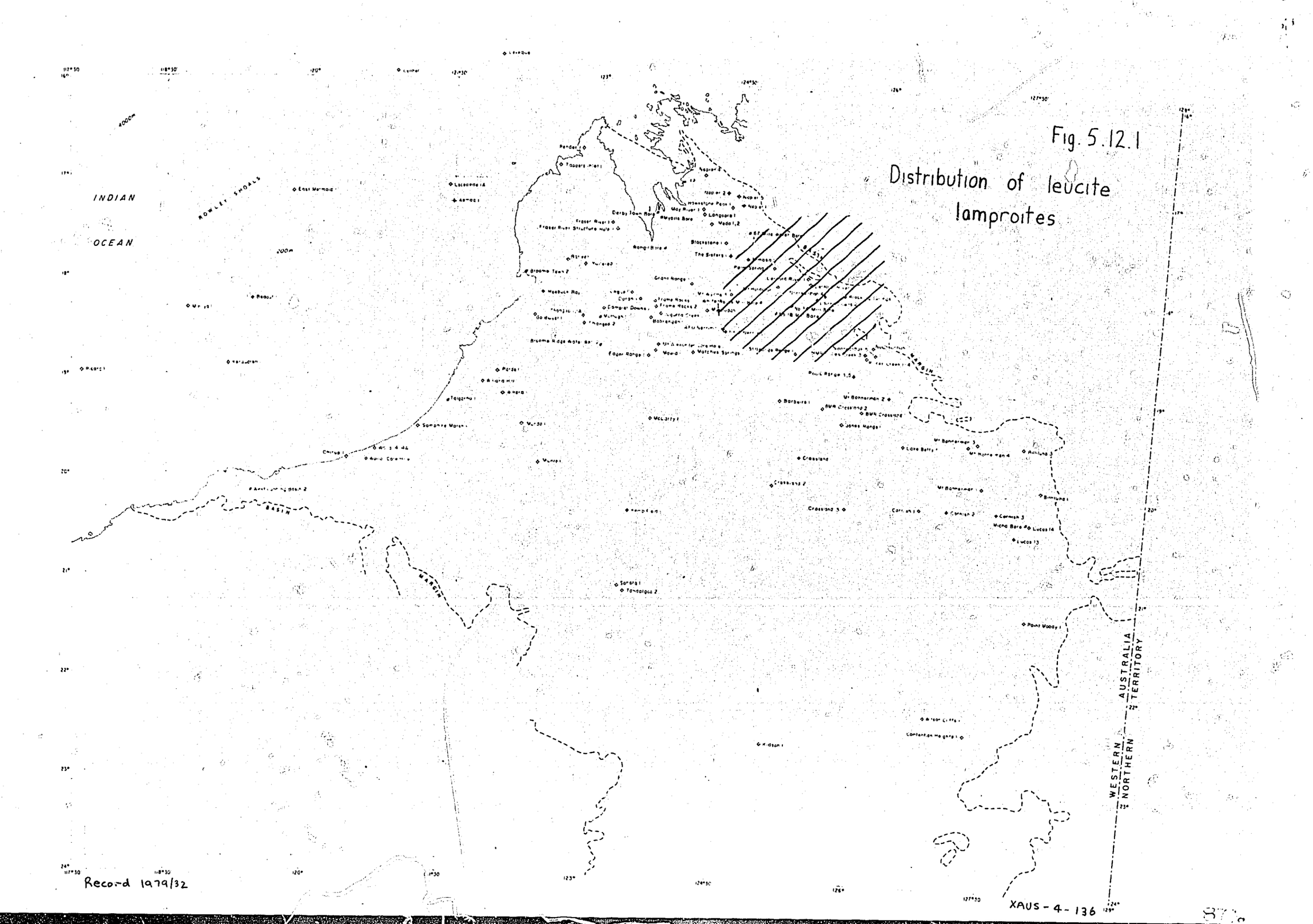


Fig. 5.12.1

Distribution of leucite lamproites

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TABLE 5.12.1 PALAEOZOIC IGNEOUS ROCKS PENETRATED BY DRILLHOLES

Well name	Station number	Depth range (bsl)	Total depth bsl (m)	Rocks penetrated	*Age
Wamac No. 1	2	2236-2247	2754	Dolerite	Late Permian
		2357-2461		"	
		2535-2555		"	
		2662-2672		"	
		2716-2754		"	
Fraser River No. 1	12	2859-2861	3069	Igneous intrusion	Late Permian
		3004-3069		Quartz gabbro	
Barlee No. 1	16	2277-2280		Unidentified igneous rock	Late Permian
		2362-2372	2447	Dolerite	
Bedout No. 1	239	2992-3017	3044	Volcanic conglomerate	Late Permian
		3017-3044		Basalt	

* A discussion of the age of these rocks is contained in Appendix 4.

6. STRUCTURAL GEOLOGY

6.1 MAJOR STRUCTURES

The structure contour maps at 1:2 500 000 scale (Pls. 13-1 to 13-11), the depth to basement or magnetic basement map (Pl. 15) and the regional cross sections (Pl. 14) show the major structural features.

The major structure in the area is the Fitzroy Graben, which extends west-northwesterly through the northern part of the basin for over 850 km. Various gravity faults and hingelines form the margins of the Fitzroy Graben (Pl. 14). The northeastern margin is formed by the Leveque Hingeline and the Markham and Pinnacle Faults, which separate the graben from the Leveque Shelf, Lennard Shelf, and the Kimberley Block, and by the Mueller Fault, which separates the graben from the Billiluna Shelf and the Granites-Tanami and Arunta Blocks in the east. A possible remnant of the graben extends past the Mueller Fault into the Northern Territory. The southwestern margin of the graben is a hingeline along which faults commonly occur or are suspected; the most prominent of these faults is the Fenton Fault. Most faulting on the margin of the graben occurred before the Grant Formation (interval 4) was deposited. In the northwest (offshore) the identity of the graben is lost on the seismic sections beneath a thickening sequence of Mesozoic and Cainozoic sediments, although the Leveque

Hingeline appears to bend northwards into the Browse Basin. The graben, which is the most intensely deformed area of the Canning Basin, contains a system of folds and associated faults that developed after the sediments of interval 4 were deposited.

Directly to the south, the graben is paralleled by an anticlinal welt, the Broome Arch. The basin deepens again to the south between the arch and the Lambert and Tabletop Shelves on the margin of the Pilbara Block. The deeper parts of this irregular synclinal zone have been called the Kidson Sub-basin and the Willara Sub-basin. There is some evidence that the Lambert Shelf is actually a small arch and sub-basin, referred to by earlier workers as the Ankatell Ridge and the Samphire Depression.

The Canning Basin is separated from the Ord Basin by the Billiluna Shelf, and from the Palaeozoic sediments of the Amadeus Basin by an arch of late Precambrian sedimentary rocks. The Leveque Shelf partly separates the Canning and Browse Basins, and in the south the North Turtle Arch partly separates the Canning and Carnarvon Basins. The Palaeozoic and Mesozoic sediments of the Canning Basin probably continue into the Officer Basin to the south. No arch is known in these sediments to serve as a convenient boundary between the basins, although gravity and magnetic interpretations suggest there is an arch of crystalline rocks beneath underlying ?Precambrian sediments. It is this suspected arch that has been adopted as a boundary by earlier workers and is herein named the Warri Arch. We stress however that it has no validity as a boundary to the Palaeozoic or Mesozoic Canning Basin, and the overlying sediments of the Canning Basin overlie the Tabletop Shelf.

The floor of the basin generally deepens offshore towards the edge of the present-day continental shelf; the major exception to this generalisation is the Bedout Fault Zone, along which the northwest block is tentatively considered to have moved up (correlation of deeper horizons across the Bedout Fault is based only on matching deep seismic reflection character across the zone). In the northwest, offshore, the Mesozoic and Cainozoic sediments strike northeasterly in the Bedout and Rowley Sub-basins, but the more complex structure of the Palaeozoic rocks has not been resolved.

6.2 PROCESSES RESPONSIBLE FOR THE STRUCTURE

6.2.1 Introduction

The Fitzroy Graben, and the folds and faults within and adjacent to it have developed over a considerable period of time, as proved by the presence of growth faults and unconformities within the sedimentary succession, and by the changing pattern of depocentres. Unconformities within the Fitzroy Graben developed at least as early as the Late Devonian, and the last earthmovement that produced a major unconformity in the area occurred late in the Triassic or early in the Jurassic. Rifting is also believed to have occurred along the northwestern margin of the continent (Warris, 1973) - probably beginning late in the Carboniferous - leading up to continental separation by seafloor spreading in the Middle Jurassic (Falvey, 1974; Powell, 1976). The fault patterns on the structure contour maps, sedimentary thickness variations on isopach maps, and the unconformities in the Bedout and Rowley Sub-basins and adjacent areas, reflect this influence.

6.2.2 Palaeozoic gravity faults

The Markham, Pinnacle, Mueller, and Dummer Range Faults (Pl. 13-1) all appear to be major gravity faults with a long history of growth. The system of faults to the south of the Markham Fault (referred to collectively as the Pinnacle Fault System) also may be gravity faults. All these faults have similarities that are worth while discussing in general. Each fault is moderately to steeply dipping towards its downthrow side, and each appears to be paralleled for at least part of its length by an anticline on its downthrow side. This geometry is illustrated in Figures 6.2.2.1 and 6.2.2.2. A salt pillow occurs within the anticline on the downthrow side of the Dummer Range Fault (Fig. 6.2.2.2). Antithetic faulting is also common. Hamblin (1965) and Cloos (1968) suggest that the anticline (called reverse drag) and the antithetic faults may develop by normal movement along a curved fault plane. The normal movement tends to pull the blocks apart as well as to displace them vertically, and subsidence, to fill the incipient gap, may produce antithetic faults or reverse drag. Repeated movements on one of these faults are recorded either by unconformities, if erosion follows the movement, or by wedges of sediment adjacent to the fault, if sedimentation occurred during and after movement.

SW

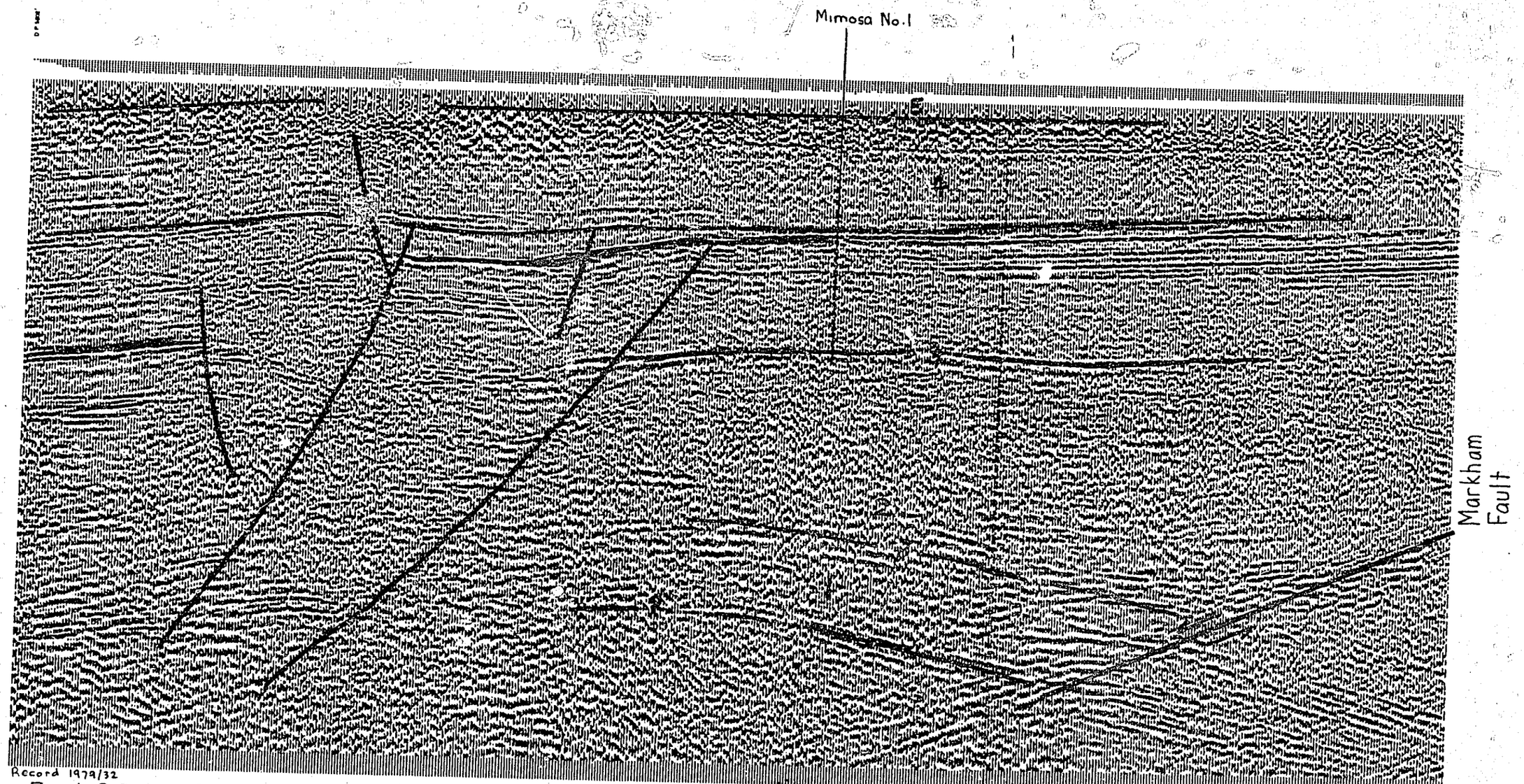


Fig. 6.2.2-1 Seismic section showing basinward-dipping faults, and an anticline that has formed on the downthrow side of the Markham Fault

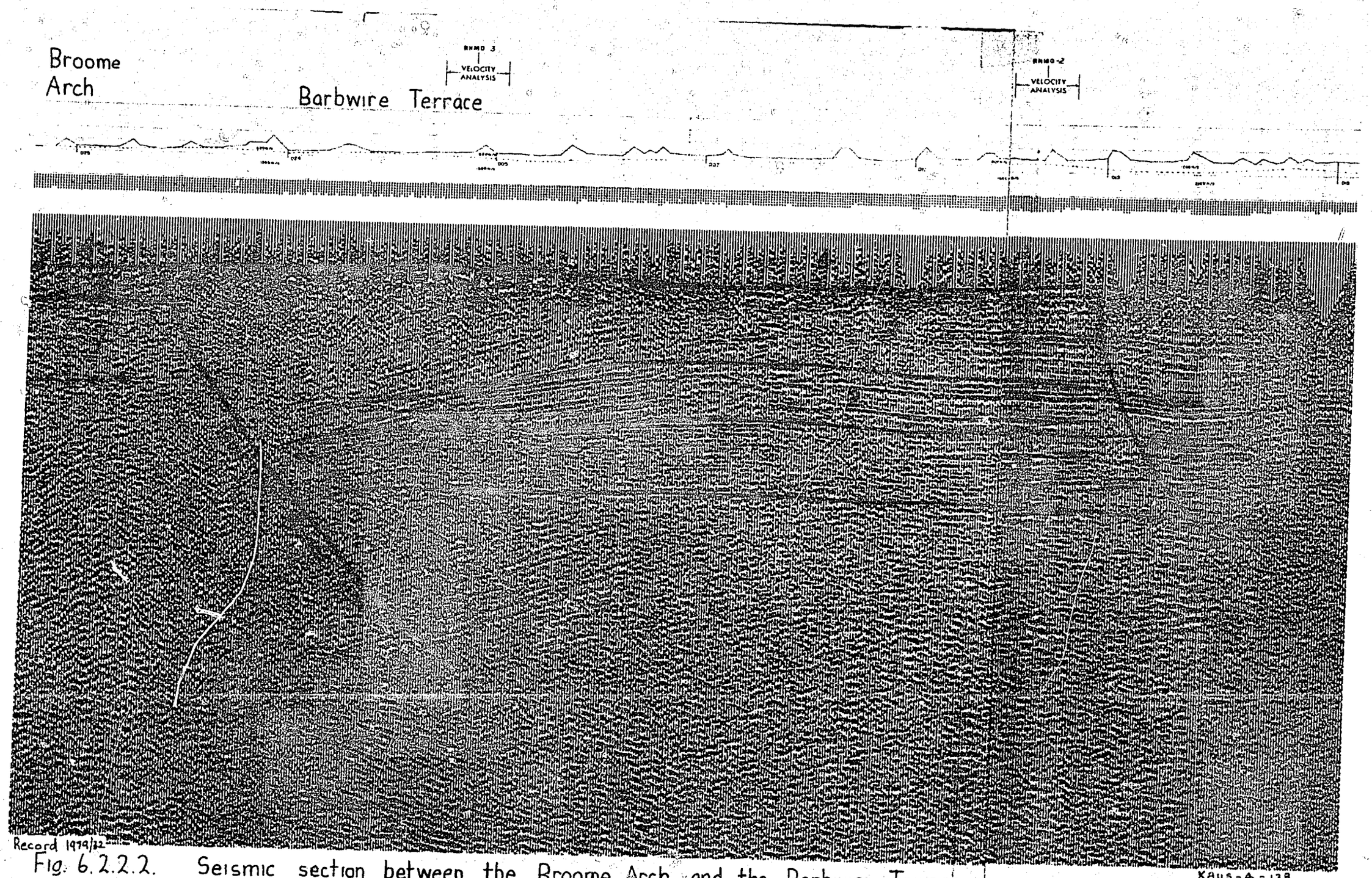


Fig. 6.2.2.2. Seismic section between the Broome Arch and the Barbwire Terrace

The history of movement on each fault can therefore be deciphered by determining the age and the stratigraphic and structural relations of the sediments along the fault. In many areas the available seismic data, or the well control, is too poor for reliable interpretation. The best data we have is illustrated in Figures 6.2.2.1 and 6.2.2.2 from across the Markham Fault and the Dummer Range Fault. Palm Spring No. 1, Mimosa No. 1, Blackstone No. 1, and Tappers Inlet No. 1 all appear to have been drilled on a reverse drag anticline adjacent to the Markham Fault. Possible reverse drag structures also occur offshore adjacent to the younger Bedout Fault Zone.

The Leveque Hingeline is thought to be a fault because of its position on the northern margin of the Fitzroy Graben, but we have not been able to confirm this on the seismic data.

Interpretation of seismic data indicates that movement on the gravity faults may have begun after interval 1 sediments were deposited, that considerable movement occurred during the deposition of interval 3 sediments, and that, in most places, the last movements occurred before interval 4 sediments were deposited. The Fenton Fault, which occurs along the southwestern margin of the graben for part of its length (Playford & others, 1975), is believed to have undergone normal movements in the Palaeozoic, but may also have undergone some reverse movement in the Mesozoic.

6.2.3 Mesozoic folds and faults

In some locations (e.g. north of Roebuck Bay No. 1) interval 4 may be traced continuously from the Broome Arch into the Fitzroy Graben, where it thickens and has been folded - together with any interval 5 sediments - into a series of anticlines and synclines. Interval 6 sediments overlie the interval 4 and interval 5 sediments with a strong angular unconformity. It seems, therefore, that the graben was downwarped (not downfaulted, except locally) in the Late Carboniferous, Permian, and Triassic and that the sediments that accumulated there were folded and faulted late in the Triassic or early in the Jurassic, although some folding may have occurred in the Permian.

The anticlines and synclines, which trend about 100°, are broad and gentle, but the interlimb angle of the anticlines is generally sharper (up to about 120°) than that of the synclines. The configuration of the basement and of the deeper sediments is difficult to decipher in the northwestern part of the Fitzroy Graben where the folds are best developed. Tentative interpretation of seismic line AC (Pl. 5) in the offshore part of the graben, where basement

appears shallower, suggests that the basement folding is more gentle that that of interval 4, that pillows could have been developed within interval 2 during sedimentation, and that subsequent removal of the salt led to the collapse of the overlying sediments and the development of a pseudo-anticline. Indeed, salt movement and removal may have contributed to the development or modification of many of the Mesozoic folds and faults. However, halokinesis alone cannot account for their geometry, length, and regularity, which indicate a compressional origin - perhaps gravity gliding, or wrenching between the cratonic blocks flanking the graben. Gravity gliding would move sediments away from the margins of the graben, but extensive Mesozoic gravity faults are not visible there.

The Fenton Fault is shown extending over a considerable length (Pls. 13-1 to 13-5), but in many parts of this distance interval 4 is unfaulted; at other locations interval 4 is faulted. Hence the Fenton Fault is better thought of as a hingeline separating the Broome Arch and the Fitzroy Graben. Because interval 4 is not faulted at various locations, the Fenton Fault (as indicated in Pls. 13-1 to 13-5) cannot mark the site of any major strike-slip fault that may be invoked to explain the Mesozoic folds. The growth faults and reverse drag anticlines adjacent to the northern margin and the Dummer Range Fault in the south had largely ceased their growth before interval 4 sediments were deposited and are similarly not the sites of major strike-slip faults.

Rattigan (1967) and Smith (1968) - the first to discuss the genesis of the fold and fault pattern - suggested that it could result from right-lateral wrench movements of the two Precambrian cratonic blocks flanking the graben. Both authors were refering to the western part of the graben (Fitzroy Depression and Fitzroy Trough of their terminology). Smith (1968) believed that the Halls Creek Mobile Zone forms the southeastern terminus of the Fitzroy Trough and separates it from a tectonic terrain, the Northeast Canning Basin, that is more typical of the platform-like Canning Basin. More recent data shows that the Fitzroy Graben probably does extend to the southeast, as shown on Plate 15.

Willcox, Harding, & Seely (1973) discussed the basic features of wrench tectonics and gave the Fitzroy Trough as an example of a divergent right-lateral wrench graben.

6.3 EVIDENCE OF DIASTROPHISM RECORDED BY UNCONFORMITY AND DISCONFORMITY

A complex record of diastrophism is preserved in and beneath the sedimentary rocks of the Canning Basin. A complete discussion of Precambrian diastrophism is outside the scope of this study and only the last major event to

have affected the basement rocks before interval 1 sediments were deposited is discussed. As the events in the Canning Basin have not been named they are referred to, where possible, by names of correlative events in the Amadeus Basin.

6.3.1 Petermann Ranges Orogeny

The term Petermann Ranges Orogeny was used (Forman in Wells & others, 1970) for the isoclinal and recumbent folding, overthrusting, and metamorphism that occurred along the southwestern margin of the Amadeus Basin late in the Precambrian or early in the Cambrian. Forman & Shaw (1973) described a close relationship between the metamorphism, structure, and Bouguer gravity anomalies: an easterly trending zone of positive Bouguer anomalies over the granulites between the Officer and Amadeus Basin is flanked to the north by a deep gravity trough over a retrograde belt which contains the nappes in the margin of the Amadeus Basin. They suggested that the gravity high associated with the Petermann Ranges zone of crustal dislocation might extend westward along the northern margin of the Pilbara Block. Tucker (this volume) also suggests that the high-grade metamorphics can be traced beneath the Warri Arch into the Paterson Province and farther northwest into the subsurface offshore. Also, late Precambrian sediments, with the decollement style of folding so typical in the Amadeus Basin, occur to the north of this zone in the Morris 1:250 000 Sheet area beneath the Kidson Sub-basin. The folded late Precambrian sediments are overlain unconformably by the Ordovician sediments of interval 1.

There is also evidence of severe diastrophism in the northern part of the Canning Basin during the Petermann Ranges Orogeny. Outcrops of late Precambrian sediments within the King Leopold Mobile Zone are intensely deformed (Plumb & Gemuts, 1976), and a 600-m.y. isotopic age (Bennett & Gellatly, 1970) of metamorphism is correlated with the major overfolding at Yampi. Gravity and magnetic anomalies (Tucker, this volume) show that the mobile zone underlies at least the northern part of the Canning Basin, and it crops out as an inlier within the Oscar Range.

According to Plumb & Gemuts (1976) the total cumulative displacement across the Halls Creek Mobile Zone is at least 110 km sinistrally. A shortening of 80 km has been calculated across the exposed King Leopold Mobile Zone in the Yampi area (Sofoulis & others, 1971); this is almost the magnitude required to absorb a southward (relative) movement of the Kimberley Block by folding and thrusting across the King Leopold Mobile Zone. However, Plumb & Gemuts (1976)

considered that this model is too simple, because each zone has been deformed independently of the other, and at different times; where the zones meet, major structures of one truncate structures of the other and hence the mobile zones do not form an orocline. Major movements took place on the Halls Creek Mobile Zone about 1700 m.y. and 1050 m.y. ago, as indicated by isotopic mineral ages (Bofinger, 1967), and considerable late Palaeozoic movement also occurred at about the time of the Alice Springs Orogeny (see later), when the Stuart Block may have been pushed northwards relative to the Kimberley Block. The Halls Creek Fault probably joins with the Pinnacle Fault System at the northern margin of the Fitzroy Graben.

Strongly folded upper Precambrian sediments crop out in the eastern margin of the Canning Basin. In the Amadeus Basin, these are folded over a decollement within the Bitter Springs Formation. In the Stansmore and Webb Sheet areas, the different map patterns of the comparatively gently dipping basal quartzite and the overlying strongly folded sediments imply that a decollement is present. A similar, though less obvious, structural relation occurs in the Billiluna 1:250 000 Sheet area. These northerly trending folds and faults and the northerly trending basement high in the east of the Ryan 1:250 000 Sheet area almost certainly developed during the Petermann Ranges Orogeny and provided a source area for Cambrian sediments to the east and later for the Ordovician sediments of the Canning Basin in the west.

6.3.2 Rodingan Movement

Cook (in Wells & others, 1970) gave the name Rodingan Movement to the uplift that preceeded deposition of the Mereenie Sandstone in the Amadeus Basin. This diastrophism probably correlates with the event that caused uplift, faulting, and mild folding of interval 1 sediments before interval 2 sediments were deposited in the Canning Basin.

Koop (1966) suggested that the Carribuddy Formation and the Tandalgoo Red Beds were deposited during a tectonically induced, regressive cycle which commenced in the Late Ordovician, when a regressive evaporite sequence was deposited, and which culminated with the deposition of postorogenic red beds in the Silurian and the Devonian. However, since then, McTavish (in Broad, 1973) has recognised that the regressive evaporites of the middle Ordovician are probably separated from the halite-bearing Carribuddy Formation by an hiatus of the order of 40 million years. Evidence for the hiatus rests on the incomplete

fossil record and a suggestion of minor unconformity or disconformity from wire line log interpretation (Appendix 2).

There are no major clastic deposits nor marked angular unconformities at the base of the Carribuddy Formation in the south of the basin to indicate substantial diastrophism, except adjacent to the Munro and Admiral Bay Faults (Pls. 10-1, 13-1). It is most likely therefore that the disconformity or unconformity mainly records a period of slow arid erosion with removal of fine comminuted debris by wind. Some of this material may now be incorporated in the Mereenie Sandstone of the Amadeus Basin.

6.3.3 Pertnjara Movement

Forman (in Wells & others, 1970) used the name Pertnjara Movement for the Middle to Upper Devonian event that produced unconformity between the Mereenie Sandstone and the Pertnjara Group in the central northern and north-eastern part of the Amadeus Basin. Unconformities relating to the Pertnjara Movement also occur beneath the Mount Eclipse Sandstone of the Ngalia Basin and Upper Devonian (Frasnian?) marine sandstone in the Ord Basin. In the Canning Basin it is the event that probably marks the main initiation of movement on faults along the margins of the Fitzroy Graben and is recorded in some areas of the basin by disconformity between intervals 2 and 3.

6.3.4 Alice Springs Orogeny

The name Alice Springs Orogeny was originally applied to the event that resulted in the deposition and subsequent deformation of the Pertnjara Group in the Amadeus Basin (Forman, 1966; Forman & others, 1967). It was redefined as the event during which the Pertnjara Group in the Amadeus Basin was folded either late in the Devonian or in the Carboniferous (Wells & others, 1970). Nappes developed on the northern margin of the Amadeus Basin, and the sediments within the basin were folded over decollement surfaces within the upper Precambrian Bitter Springs Formation and the Cambrian sediments. Several other unnamed movements occurred during deposition of the Pertnjara Group. The sum total of the Pertnjara Movement, the unnamed movements, and the Alice Springs Orogeny was to uplift a major anticlinorium between the Amadeus and Ngalia Basins and to produce major overthrusts along the northern margins of the Amadeus and Ngalia Basins. Forman & Shaw (1973) described a clear relationship

between this structure and an easterly trending zone of positive Bouguer anomalies that may be traced to the eastern margin of the Canning Basin.

In the Canning Basin the event that faulted and folded interval 3 and older sediments before interval 4 sediments were deposited is correlated with the Alice Springs Orogeny. Movement continued on the faults flanking the Fitzroy Graben at times during deposition of interval 3 sediments (see section 5.3), and culminated in major gravity faulting on the margins of the graben (Alice Springs Orogeny) before interval 4 sediments were deposited. Hence the Pertnjara Movement and the Alice Springs Orogeny are linked in their origins, and, if Forman & Shaw (1973) and Plumb & Gemuts (1976) are correct, strike-slip movement occurred on the Halls Creek Fault and gravity faulting occurred along the Pinnacle Fault System and elsewhere in the basin throughout both events and at times in between them.

6.3.5 Bedout Movement

The event that produced uplift, faulting, and tilting, and intrusion and extrusion of mafic igneous rocks, late in the Permian or early in the Triassic, and - together with erosion - unconformity and disconformity between intervals 4 and 5, is here named the Bedout Movement. The intensity of deformation is greatest offshore in the Bedout Sub-basin, Bedout High, and Rowley Sub-basin. The diastrophism is widespread on the Northwest Shelf and is probably an episode of early rifting preceeding the continental separation that occurred to the northwest in the Middle Jurassic (Callovian).

6.3.6 Fitzroy Movement

The event that produced the major faulting and folding of sediments of intervals 4 and 5 is here named the Fitzroy Movement. The diastrophism produced a set of east-trending en-echelon anticlines and synclines and northwest-trending fault blocks within the thick sediments of the graben (Rattigan, 1967; Smith, 1968) and salt pillows within the Willara Sub-basin, late in the Triassic or early in the Jurassic. The movement and subsequent deep erosion produced the regional unconformity at the base of interval 6. Offshore the unconformity appears largely restricted to the Canning Basin and the Exmouth Plateau. The Fitzroy Movement was probably most intense in a zone that extended along the Fitzroy Graben and along the present northern margin of the plateau.

6.3.7 Break-up unconformity

During the Callovian major faulting and tilting occurred in the southwest adjacent to the eastern edge of the Exmouth Plateau. This movement corresponds to the break-up unconformity of Powell (1976), but is not apparent over large areas of the Canning Basin, where the sediments of interval 6 appear to form a conformable sequence.

6.3.8 Unnamed diastrophisms

Disconformities between intervals 6 to 11, and within some intervals, record regional uplift and erosion in between transgressions of the sea. The Neocomian disconformity, separating intervals 7 and 8, may correlate with the separation of the Indian and Australian continents.

A marked unconformity occurs within the sediments of interval 11 to the southeast of Rowley Shoals and on the northerly trending part of the Leveque Hingeline. The sediments beneath the unconformity are faulted and tilted and reverse drag structure is developed on the Mermaid Fault to the southeast of Rowley Shoals (Pl. 10-10). The overlying Pliocene to Recent sediments are flat-lying. Veevers (1971a) thought that this R_1 unconformity was caused either by uplift during the collision of the Australian and Asian continental plates or by the Messinian eustatic low sea levels during the late Miocene.

Exon, Willcox, and Petkovic (1975) considered that the present day features of the Exmouth Plateau and the Cape Range Anticline had fully formed by the early Miocene and correlated these movements with the erosion of the offshore Canning Basin.

The Fitzroy Lamproites are thought to have been intruded in the early Miocene (Wellman, 1973).

Minor faulting appears to have affected the sediments of intervals 6, 7, and 8 offshore in the area overlying the Fitzroy Graben (Pls. 10-6, 10-7, and 10-8), particularly adjacent to the Leveque Hingeline. Very little faulting has affected the sediments of intervals 9, 10, and 11.

7. GEOLOGICAL HISTORY

The Canning Basin developed on a floor of Precambrian crystalline rocks over all but its northeastern and southeastern extremities. In these areas, the Phanerozoic basin overlies late Precambrian sediments up to about 7 km thick. The upper part of this sequence was extensively deformed into a series of mainly northerly trending anticlines and synclines by decollement within an evaporitic sequence during the Petermann Ranges Orogeny late in the Precambrian or early in the Cambrian. After the orogeny, basalts were extruded in the Officer Basin to the south, in the Ord Basin to the north, and in the Wiso Basin and the extension of the Canning Basin in the Northern Territory, but none are known in the Canning Basin in Western Australia, which appears to have undergone a long period of erosion lasting to the Ordovician.

Ordovician sediments (interval 1, Pl. 10-1) accumulated on a mainly low-relief gently downwarped surface of Precambrian rocks in which three depocentres evolved: the Willara Sub-basin, the embryo Fitzroy Graben, and the Kidson Sub-basin. The first sediments were deposited during a shallow-marine transgression which migrated across the Canning Basin in a general southeasterly direction during the Tremadocian and early Arenigian. The basal sandstone, limestone, and shale of this sequence were covered between the middle Arenigian and early Llanvirnian with marine sediments that extended over most of the basin. By this time the sea had inundated the elevated areas of the Broome Arch and Munro Fault, and continued across into the Amadeus Basin. A variety of sediments were deposited. In the south of the Canning Basin they are dominantly carbonates, which thin markedly over basement highs. To the north, fine-grained terrigenous sediments predominate. The absolute and relative depositional depths of these lithofacies have not been determined with any certainty, but there is a suggestion that basinal facies were deposited in the Fitzroy Graben.

The sea retreated westwards and northwards during the middle and late Llanvirian, and deposited a regressive sequence culminating in associations of dolomite, anhydrite, and red shale. The regression may have continued into the Caradocian.

Northwesterly trending faults were active after interval 1 sediments were deposited, particularly the Admiral Bay Fault. The Fitzroy Graben may have developed at this time or earlier, for there is a suggestion of deeper-water sediments in it. A gap in the palaeontological record, together with evidence of unconformity in Kidson No. 1 and Willara No. 1, indicates an erosional period of at least 40 million years (from the Caradocian to at least the Early

Devonian) after interval 1 sediments were deposited. The event correlates in time with a period of uplift and erosion within the Amadeus Basin called the Rodingan Movement.

The precise length of this break in sedimentation cannot be estimated as at least 50 m of the oldest sediments of interval 2 have not been dated. These sediments, assumed to be of Early Devonian age, are dominated by deposits of a restricted, evaporating sea, and comprise dolomite, anhydrite, and halite. The greatest accumulation developed in the Kidson Sub-basin, which was probably subsiding at this time. Salt deposition extended across into the Fitzroy Graben as far as Blackstone No. 1.

During the late Early Devonian the sea retreated before an advancing desert and thick dune sands interpersed with minor lacustrine and possibly also marginal marine deposits (Tandalgoo Red Beds) were deposited in the South Canning Depression (see section 1.5). Desert conditions also existed to the east in the Amadeus Basin, where the Mereenie Sandstone was deposited.

Several marine incursions occurred in the north of the Canning Basin towards the close of the early Middle Devonian (toward the end of interval 2 sedimentation).

The main diastrophism during the Early Devonian was the downwarping of the Kidson Sub-basin. Movement may also have occurred on the bounding faults of the Fitzroy Graben during this time but the evidence is not clear; most movement occurred in the middle Devonian after interval 2 sediments were deposited. The disconformable and unconformable relations between the sediments of intervals 2 and 3, their comparative distribution, and interpretation of seismic data indicates major development of the northern margin of the Fitzroy Graben at least and a period of erosion. This Middle Devonian event may correlate with the Pertnjara movement of the Amadeus Basin.

Interval 3 sedimentation began in the late Givetian during a transgression of the sea that had spread over much of the basin (Fig. 5.3.2), with the possible exception of the Willara Sub-basin, by the early Frasnian (Pl. 10-3). The basal deposits of this transgression were anhydritic carbonate and dolomite containing birds-eye structures, both characteristic of paralic sedimentation. Major subsidence occurred at this time in the Fitzroy Graben, in which the deeper-water terrigenous turbidite sequence that accumulated constitutes the oldest sequence so far penetrated. Toward the northwestern margin of the basin, red fluviatile conglomerate was laid down; as the shoreline migrated, the conglomerate was eventually inundated. Euphotic carbonate platform sediments were deposited in the warm sea on the margin of the

graben; to the north, at least, these interdigitate with supratidal and fluviatile sediments. Faulting may have uplifted the southern part of the Canning Basin above sea level in the middle Frasnian. The only Devonian sediments younger than this are preserved within the graben; these include probable deeper-water terrigenous clastics deposited by turbidity currents, and mixed shallow-marine carbonate and terrigenous sediments at the margins. The terrigenous clastics were dispersed into deeper water through gaps between carbonate buildups with growing talus slopes that grew laterally and sometimes coalesced.

Growth faults were active on either side of the graben during sedimentation, and earlier platform carbonates were eroded from tilted fault blocks, giving rise to megabreccia slope deposits.

Nowhere in the subsurface of the Canning Basin do Famennian sediments clearly overlie Frasnian sediments conformably, although they may in the extreme north of the Lennard Shelf. In many places on the margins of the graben there is an unconformity at the base of the Famennian section. The Famennian marked the end of sedimentary wedge accumulation adjacent to growth faults, and of turbidite accumulations. Platform carbonates and shallow-marine clastics accumulated on the margins of the graben.

In the latest Famennian through to the Early Carboniferous there was a much higher input of terrigenous material into the sea. Detrital limestone, grey shale, siltstone, and sandstone were deposited in shallow water on platforms and in lagoons or sounds of more restricted circulation, and shales are presumed to have been deposited in deeper water within the graben. This influx of material, which probably reflects uplift of the source area, took place during a regression of the sea, which shallowed during the latest Famennian. Transgression followed in the early Tournaisian, and a regression during the late Tournaisian. With this final regression the sea withdrew completely from the Canning Basin, marking the end of interval 3 sedimentation and the beginning of a major period of diastrophism and erosion.

The diastrophism may be correlated with the major overthrusting of the Alice Springs Orogeny of central Australia. By contrast, the main diastrophism in the Canning Basin was tensional, and the last major movements occurred on most of the faults bounding the graben. Reverse drag structure adjacent to the Dummer Range Fault were accentuated by movement of Devonian salt during this diastrophism and during the movements that accompanied interval 3 sedimentation.

With the beginning of interval 4 sedimentation in the Late Carboniferous, the Canning Basin was situated at a latitude of about 60°S, and the margins of the basin were occupied by glaciers. Glacial debris, associated with glaciated pavements carved in Precambrian rocks, occurs to the south and east on the margins of the basin, but within the basin the sediments are mainly marine (Pl. 10-4). The glacial period persisted until the earliest Permian; it comprised two glacial cycles and an interglacial phase. These climatic oscillations are superimposed on an overall transgressive and regressive cycle and downwarping of the Fitzroy Graben. The transgression produced successive onlapping of sediments over the elevated areas of the Broome Arch and the basin margins. During this period fine to coarse-grained clastic sediments (including tillite) and minor carbonates were deposited. Late in the Permian, marine conditions probably persisted over much of the basin, the shorelines of the seas migrating back and forth across the central part of the basin. Hence fluviatile sediments accumulated in the east and marine in the west. The upper part of the Permian has been removed from the present offshore area of the Canning Basin by pre-Jurassic erosion.

The history of the latest Permian events is uncertain. There was an hiatus in sedimentation over much of the basin before interval 5 sediments were deposited in the Triassic, and major erosion or non-deposition is evident in Lynher No. 1, where Upper Triassic sediments rest directly on ?Upper Permian sediments. Faulting and tilting occurred offshore during the Bedout Movement, and basalt was extruded in a period of early rifting that preceded the continental separation that occurred to the northwest in the Jurassic.

The earliest Triassic seas (Scythian) deposited thin sands and muds of interval 5 in the western part of the Fitzroy Graben, while in the eastern part coarse clastics were laid down in a paralic/deltaic environment. Thick marine siltstone was deposited in the Bedout Sub-basin and onlapped the Bedout High. Following the withdrawal of the sea in the Middle Triassic, a braided system of meandering rivers deposited coarse clastics in the Fitzroy Graben, and red beds with minor carbonates in the Bedout Sub-basin. These fluviatile sediments continued to accumulate into the Carnian. Similar Triassic sediments are believed to extend into the Rowley Sub-basin.

Interval 5 sedimentation was curtailed late in the Triassic or early in the Jurassic by the uplift, folding, and faulting of the Fitzroy Movement and erosion. The main folding and faulting, which occurred in the Fitzroy Graben, may have been caused by right-lateral wrenching of the adjoining basement blocks. A set of east-trending en-echelon anticlines and synclines and

northwest-trending fault blocks developed within the thick sediments of the graben. Folding within the graben was probably assisted by salt movement and decollement at depth, and salt pillows developed simultaneously in the Willara Sub-basin. This diastrophism and subsequent deep erosion over the entire basin breached many anticlines and formed the regional unconformity at the base of interval 6.

Interval 6 sedimentation began in the Early Jurassic. Lower and Middle Jurassic sediments were deposited in a complex of deltaic environments which retreated eastwards to cover a large area of the onshore Canning Basin early in the Late Jurassic. During the Callovian major faulting and tilting occurred in the southwest adjacent to the eastern edge of the Exmouth Plateau. These movements correspond to the break-up unconformity of Powell (1976), but are not apparent over large areas of the Canning Basin. In the Oxfordian, following break-up, the sea occupied the Beagle Sub-basin, of the Carnarvon Basin, and then spread east and north to inundate most of the delta systems by the Late Jurassic (Tithonian). The Bedout Suu-basin was the last area to be transgressed. The transgression left basal sandstone overlain by siltstone and mudstone. The sea regressed northwards in the early Tithonian, and the area adjacent to Wamac No. 1 was eroded.

Interval 7 sedimentation began in the late Tithonian, when a transgressing sea moved northward from the Carnarvon Basin and occupied the eastern part of the present offshore area (Pl. 10-7), establishing a depocentre in the eastern Bedout Sub-basin and an eastern shoreline just east of the present-day shoreline. The sea spread north and west, covering most of the offshore basin, including the Bedout High and the Leveque Arch, by the end of the Tithonian. Submergence of the Leveque Arch removed the barrier between the Canning and Browse Basins, permitting open circulation between the two areas. The north Turtle Arch and Rowley Sub-basin and the western Bedout Sub-basin, however, remained emergent. The sea advanced farther westward in the early Cretaceous, and the main centre of deposition shifted northwest as the Rowley Sub-basin rapidly subsided. In the early Neocomian the sea probably regressed westward and thick marine sands were deposited in depocentres in the east. By the end of interval 7 sedimentation the sea had retreated to the western Bedout Sub-basin, and faulting occurred in the western part of the Fitzroy Graben. This period of diastrophism may correlate with the separation of the Indian and Australian continents.

Interval 8 sediments were deposited after a brief hiatus within the Neocomian. A clastic wedge up to 200 m thick was deposited in a westerly prograding delta in the area of the Bedout Sub-basin and extended into the present onshore area. A major marine transgression through the Canning Basin into the Officer Basin occurred in the Aptian, when a fine-grained basal sand and overlying clay and mud were deposited. The sea rapidly retreated westward beyond the present day Mermaid Shoals in the latest Aptian, and briefly transgressed the Bedout and Rowley Sub-basins in the Albian to early Cenomanian, during which a marine clay was deposited. An hiatus of 10 million years followed before the first sediments of interval 9 were deposited.

Interval 9 is a comparatively thin wedge of sediments, thickening offshore, which was deposited in three phases between the Turonian and early Paleocene. A thin sequence of foraminiferal glauconitic mud was deposited at the base during the first phase - a transgression of the sea to a position near that of the present coast. During the second phase a shallow-marine sequence - consisting of a basal micrite overlain by a claystone and siltstone sequence - was deposited. The third, a regressive phase, deposited thin glauconitic clay.

Minor unconformities in the section may reflect scouring caused by marine currents in the Turonian after the separation of India and Australia.

A marine transgression inundated the present offshore Canning Basin in the middle Paleocene, at the start of interval 10 sedimentation. Gypsum and dolomite indicate possible paralic facies of the transgression. Bioclastic carbonate and minor clay were deposited in the Bedout Sub-basin into the early Eocene, and marl, clay, and minor sand accumulated in the Rowley Sub-basin. Slope environments probably existed at the western margin of the Canning Basin.

During the middle and late Eocene a sequence of carbonate, clay, and then dolomite accumulated; this is interpreted as a seaward migration of barriers sheltering a possible sabkha environment.

Fluviatile sandstone of uncertain age accumulated on the Dampier Peninsula and in the southwestern Canning Basin, probably during the Early Tertiary, as the offshore area became emergent at the close of interval 10 time.

During the Oligocene or early Miocene extensive laterites developed by chemical weathering onshore.

Upper Tertiary rocks are confined mostly to the present offshore area. After subsidence in early Miocene or latest Oligocene times (beginning interval 11), a marine transgression moved eastwards across an earlier Oligocene erosion surface, progressively overstepping Lower Tertiary and Lower to Upper Cretaceous rocks.

Pleistocene marine rocks are presently exposed along the coast, and lacustrine and fluviatile rocks form a thin cover onshore.

Both the intervall 11 rocks offshore and the coastal marine limestones are mainly calcareous, and consist of calcirudite, calcarenite, calcilutite, marl, and minor dolomite. Subordinate rock types are glauconitic sandstone and claystone. The sequence is richly fossiliferous, and was deposited under clear, open-circulation, shallow-marine shelf to littoral conditions. The temperature was probably warm to tropical and close to the present climate.

The Lower Tertiary section has a general seaward dip with some faulting along both the Leveque Arch and the northwestern side of the Bedout Sub-basin.

8. PETROLEUM POTENTIAL

The petroleum prospects of the undrilled structures located in Figures 2.5.1-6 are summarised in Table 8.1, and an explanation for the apparent absence of hydrocarbons in the wells drilled to date is summarised in Table 8.2.

Shows of hydrocarbons within the sediments of interval 1 (Pl. 16 and Table 2.6.1) are very largely confined to the northwestern and southeastern Broome Arch, the Willara Sub-basin, the Pender, Margaret, and Betty Terraces, and the southeastern Kidson Sub-basin. There is little porosity in the fine-grained clastic and carbonate rocks of the Ordovician, and the majority of shows are staining, cut, and fluorescence. Thangoo No. 1, Mowla No. 1, Goldwyer No. 1, Edgar Range No. 1, Tappers Inlet No. 1, and Prices Creek Nos. 1, 2, and 3 are the only wells where free oil occurs, generally from bleeding cores; never, disregarding the 1922 Prices Creek bores, has oil been recovered from formation testing. Pinpoint fluorescence was observed in tight limestone in McLarty No. 1, and fluorescence and free oil were observed in generally very tight carbonates in the Willara and Goldwyer Formations in Munro No. 1 and Parda No. 1. In Edgar Range No. 1, Nambeet dolomite vugs bled oil, and a small gas show was recorded in the Nambeet Formation; in addition, fluorescence was observed in Goldwyer carbonates in this well. A zone of fluorescence was observed in tight dolomite of the Nita Formation in Matches Springs No. 1. Permian rocks in Thangoo No. 1A, on the Broome Arch, yielded traces of oil where the rocks directly overlie Ordovician rocks.

These and the other Ordovician shows shown in Plate 16 suggest that the Ordovician has some potential and is mature in some areas. Organic carbon determinations suggest that Lower Ordovician rocks in two wells have very good source potential, and vitrinite-reflectance measurements show that they are

presently in the oil mature zone. This conclusion is supported by Burne & Kanstler (1977), who suggested that interval 1 rocks are now mature for oil generation over ~~a large area~~ only part of the basin, ~~except in the graben and offshore~~ including part of the Broome Arch and the Willara Sub-basin, ~~where they are at least at the high-temperature gas phase~~. Beyond the graben, optimum maturation was probably reached in the Permian, by which time diagenesis had probably destroyed Ordovician reservoirs.

The Ordovician rocks are almost entirely lacking in reservoir properties. There is no evidence in any tested part of the basin that Ordovician sandstone and carbonates have well-developed and predictably continuous primary porosity. The relatively rare occurrences of porosity and permeability in both clastic and carbonate rocks are inconstant, both laterally and vertically. One of the best Ordovician reservoirs so far encountered occurs at Wilson Cliffs No. 1. Here, in the Goldwyer and Middle Formations, sandstones have porosities up to 7 percent and rare thin streaks of permeability up to 124 md. Commonly however, porosity is in the order of 2-3 percent, and permeability is generally less than 0.1 md, owing to the presence of interstitial clay and siliceous cement. Open-hole testing at this well failed to produce a measurable flow of formation fluid.

Thus, the absence of hydrocarbons in Ordovician reservoirs is seen to centre both on the lack of potential reservoirs as well as the high degree of maturation of fine-grained clastic sediments of Ordovician age in the Fitzroy Graben.

Interval 2 rocks tend to be oxidised and lacking in biogenic remains. There are only two lower Devonian shows - pyrobitumen and methane at Napier Nos. 1 and 5 (Pl. 16, Table 2.6.1). Burne & Kanstler (1977) considered that the interval lies within the oil-generating window over the Willara and Kidson Sub-basins and north of the Fitzroy Graben.

In interval 3, carbonates and coarse clastics predominate over siltstone and shale which characteristically have a low organic content, except the Anderson Formation which does contain some organic-rich material. Twelve shows - ranging from free oil in the hole at Meda No. 1, and live oil at Tappers Inlet No. 1 and Sisters No. 1 (one 'spot' in core 12, Luluigui Fm, tight fine-grained clastics), to widespread fluorescence - have been recorded (Table 2.6.1 and Pl. 16) in the Upper Devonian and Lower Carboniferous, mostly centred in the northwestern part of the basin, the Broome Arch, Fitzroy Graben, and Lennard Shelf. Many of these shows are stains, fluorescence, asphalt, and bitumen; indications that oil and gas have moved through the section and of a high level of organic maturity (especially in the graben). The sediments lie within the

oil-generating window over much of their area of preservation. In the Fitzroy Graben anticlines, however, the temperatures estimated to be suitable for the generation of oil (Burne & Kanstler, 1977) have been exceeded, whereas in the extreme north of the Lennard Shelf these temperatures have not yet been reached by sediments of interval 3.

With porosities up to 30% and permeabilities commonly up to several darcies, the laterally persistent dune sands of the Lower Devonian Tandalgoo Red Beds are unquestionably the best Lower Palaeozoic reservoir rocks in the Canning Basin. Overlapping Upper Devonian fine-grained clastics or in some areas carbonates, could provide a source and seal to make the Tandalgoo Red Beds a worthwhile objective in timely structures.

The Poulton Formation, the correlative on the Lennard Shelf of the Tandalgoo Red Beds, appears to have an erratic porosity - mostly low - but in the Napier wells shown in Plates 11-4, 11-5, and 11-7 the porosity and permeability values are promising, although detailed core analysis shows that permeable zones are thin. At Napier No. 4, a formation test covering a part of the Poulton Formation, in which permeabilities are as high as 244 md and porosity is about 20 percent, flowed 88.8 bbl of fresh water per day. Test results, especially the build-up curve, suggest a low effective permeability, possibly because the streaks of permeability within the formation are not laterally persistent. Although a number of holes have tested the Poulton Formation along the northern shelves of the Fitzroy Graben, reservoir data is nonetheless sparse, and there is as yet no obvious explanation why porosity is only locally developed. On present evidence the reservoir properties of the formation are unpredictable; and it is not rated highly as a major objective in further exploration.

The evaporites and clastics of the Lower Devonian Carribuddy Formation are generally impermeable all over the basin, although an isolated water-saturated permeable sandstone (log-derived porosity 16 percent) was penetrated in Matches Springs No. 1 (Pl. 11-8).

Except for the localised development of porosity and permeability in Upper Devonian conglomerates on the Lennard Shelf (e.g., Van Emmerick Conglomerate, porosity 18% and permeability 13-19 md), predictably continuous and economically significant porous beds are unknown in rocks of this age. Nonetheless, solution porosity is evident in the Nullura Limestone at widely scattered locations on the shelf adjoining the graben - for example, Napier No. 4, May River No. 1, and Matches Springs No. 1. However, the main problem in developing a Nullura reservoir play is the lack of seal above the Nullara over

much of the basin. Porous and productive Upper Devonian reef reservoirs may eventually be discovered on the Lennard Shelf (Fig. 3.1.4), although results from the only two reefs so far tested (Meda No. 1 and Hawkestone No. 1, sections E and G in Pls. 11-5 and 11-7) have been disappointing. At Meda No. 1, a small (850-2800 m^3/day) flow of gas was obtained on open-hole testing, and at Hawkestone Peak No. 1, a somewhat more permeable reef dolomite yielded 1000 B/D of fresh water on testing. Although other buried reefs undoubtedly exist on the Lennard Shelf, their detection will require more sophisticated seismic surveying or processing than that previously used. At this stage of exploration the porosity of these buried reefs on the Lennard Shelf cannot be predicted. In particular, the degree to which porosity is preserved where vugs and interstices are filled with oil remains an unknown factor.

Despite the recovery of a small quantity of oil from Meda No. 1, where testing has shown the oil sand in the Laurel Formation to have very low permeability, the reservoir characteristics of Lower Carboniferous rocks are locally unpredictable and often discouraging (Pl. 11-7). Reservoir sandstones of economic interest are known in the Anderson Formation on the Lennard Shelf (e.g., Langoora No. 1, section D - porosity 3-21 percent, permeability 3-3300 md, no seal), but similar reservoirs have not yet been discovered in the Laurel Formation, a more likely part of the section for the occurrence of a sealed reservoir (Pl. 11-5). Nonetheless, reference to sections C, D, E, F, and G (Pls. 11-3, 4, 5, 6, 7) will show that the Anderson Formation is generally tight. The reservoir properties of this formation are not easily predicted - but the very limited control available suggests that the formation, although a potential source, is not an attractive reservoir target.

Interval 4 consists of clastic sediments reaching thicknesses of nearly 3 km in the Fitzroy Graben. The majority of hydrocarbon shows in interval 4 are bitumen and asphalt, occurring principally in the graben. Minor shows are recorded on the Jurgurra Terrace, northwestern Broome Arch, and Willara Sub-basin. Most of these shows are in Grant Formation A - the basal part of the formation; the major exception is in Thangoo No. 1A, where free oil was found in Grant Formation C.

Shales within the Grant Formation, the Nura Nura Member of the Poole Sandstone, and particularly the Noonkanbah Formation, may be source rocks. The Noonkanbah Formation shows consistently high total organic carbon, up to 6 percent, in the wells sampled. At the shallow depths encountered on the shelf and terrace areas the formation is not mature (VR = 0.49 in Meda No. 1). In

Point Moody No. 1 high total organic carbon (2.3 percent) and vitrinite reflectance of 0.82 percent suggests that the formation is a mature source rock and that more deeply buried structures containing unflushed Poole Sandstone reservoirs should be sought in the eastern graben. Burne & Kanstler (1977) considered that the interval is mature in parts of the Fitzroy Graben and the Kidson Sub-basin. Offshore, where the interval is deeply buried beneath Mesozoic sediments, it is probably supermature.

Potential reservoirs occur in the Grant Formation and the Poole Sandstone. Porosity and Permeability within the Grant Formation are usually highest in the basal A unit, approaching 30 percent and 2 darcies in Sahara No. 1. Similar porosities exist in unit C, but the absence of absolute permeability measurements makes an overall comparison of reservoir properties difficult.

With only three exceptions - Willara No. 1, Mimosa No. 1, and Point Moody No. 1 - there appear to be no significant salinity variations between units A and C, and this must cast some doubt on unit B as a seal (Pls. 11-1 to 11-8). This does not necessarily mean that unit B is not an effective seal locally, but rather that the degree of post-Permian and pre-Jurassic erosion is widespread and has in places cut down into Unit A. Covered by permeable Jurassic sands, such eroded areas allow the free fluid communication between and the flushing of units A and C in many parts of the basin. Anomalously saline formation water in Willara No. 1 may be due to solution of the underlying evaporites of the Caribuddy Formation, but saline formation water in unit A in Mimosa No. 1 and Point Moody No. 1 cannot be explained this way and may be due to connate water trapped beneath unit B. There are no shows in unit A where unit B is thin or absent, an observation which also suggests that unit B may be a local seal.

The youngest reservoir of interest in the onshore Canning Basin is the Poole Sandstone, which rests conformably on a thin widespread calcareous marker (the Nura Nura Member of WAPET terminology, variously a shaley limestone, and/or a calcareous shale which is a potential cap for Grant Formation reservoirs). The Poole Sandstone is widespread, and predictably porous throughout the basin, but many anticlines that contain it have been breached by erosion. The Noonkanbah Formation which overlies it is a potential seal and source rock.

As with potential Grant Formation traps, Poole Sandstone prospects are confined to those areas where the target sands are relatively deeply-buried and protected from flushing. The only areas of the onshore basin which may possibly fill these requirements are the central and southeastern parts of the Fitzroy Graben - a region where seismic coverage is generally sparse or lacking.

A large doubly-plunging anticline, the Baskerville Anticline, is mapped at base 4 (Fig. 2.5.1, Pl. 13-4) in the offshore part of the Fitzroy Graben. However, it appears that the Poole Sandstone has either been removed from the structure by pre-Jurassic erosion or is shallow-lying and lacks a seal. Elsewhere in the offshore basin, seismic data is of too poor quality and there is insufficient well control for reliable prediction of the Palaeozoic section, although (Pls. 11 and 14) the Poole and Grant reservoirs are thought to have been breached or removed from much of the area by post-Palaeozoic erosion.

The Triassic of interval 5 has negligible petroleum potential onshore, where the section is thin, deeply-eroded, and consists mostly of fine-grained clastics. Despite the fact that fluorescence as well as minor gas shows were observed in wet sands at Keruadren No. 1, the five drill intersections made offshore to date show little promise for hydrocarbons, at least for the top several hundred metres of the Triassic, owing to the apparent lack of favourable source rock. The varicoloured shale and siltstone in this part of the section in the Keraudren and Bedout Wells appear to have low source potential, although interbedded sandstone has moderate porosity. However, thicker Triassic sediments may occurfarther offshore and fine-grained clastics within this presently unknown part of the section might contain source rocks. Seismic interpretation shows that the entire Mesozoic section thickens offshore to the northwest of the wells drilled to date, raising the possibilities of both discrete Triassic plays and truncated Upper Triassic sand prospects with source and seal provided by a more mature organic-rich Lower Jurassic shale. There is no reliable information concerning the degree of maturity of these offshore sediments.

So far there have been no shows worth testing in interval 6 and all sands appear to be water-saturated. The structures drilled, to judge from the moderately-high salinities, do not appear to be flushed, and therefore, if we assume that most of the tests are located within closure, lack of mature source or the timeliness of closure itself must be suspect. Burne & Kanstler (1977) considered that the Jurassic sediments are mostly immature, even at temperatures of 70°C. However, interval 6 thickens to the northwest of the present offshore wells (Pl. 10-6) and, as the centre of the delta spoon is approached, interval 6 sands may interfinger with thick, deeply-buried shales - which may have significantly higher level of organic maturity.

Post-interval 6 rocks are too immature for oil generation; interval 7 rocks (Barbwire Formation) have reached only the early methane generation stage. Thus, though the shale of interval 7 would be an excellent seal for Interval 6 sands, it is probably an immature oil source.

General discussion

Oil exploration in the Canning Basin must now be regarded as high risk. More than eighty wells have been drilled and, even discounting those that have been poorly sited, a great variety of structural traps and reservoir sequences has been tested, with the most encouraging show to date being a few gallons of oil from a Lower Carboniferous sandstone. Nonetheless, there is little doubt that considerable quantities of oil have been generated over geological time - especially in the Fitzroy Graben, where the Phanerozoic sediments are over 10 km thick. Some of this oil should have found its way via the bounding, well-developed, normal fault systems (Price, 1976) into traps adjoining the graben. Most of the holes drilled within the graben or close to its margins have encountered traces of bitumen and asphalt, evidence of former accumulations or migrating oil that were cracked to supermaturity presumably before uplift in the Triassic. Oil may yet be discovered in reservoirs such as Devonian reefs on the adjoining Margaret and Pender Terraces, or in either one of the two sheet clastic reservoirs - the Poole Sandstone or the Tandalgoo Red Beds. However, a seal is lacking over both these formations over large areas of their distribution. Again, the Tandalgoo Red Beds are not in obvious juxtaposition to a source. Other negative features are the widespread breaching of anticlines by pre-Jurassic erosion and the fact that the anticlines developed in the Triassic would have been too late to receive oil generated in earlier times.

Offshore, temperatures in the Palaeozoic of the Fitzroy Graben appear to be too high for oil generation to be still continuing, whereas the Mesozoic section has not yet reached temperatures adequate for the generation of oil.

All these points indicate that the best potential onshore rests with the testing of Devonian reef trends, Permian Poole Sandstone plays in the southeast Fitzroy Graben, and Lower Devonian Tandalgoo Red Beds plays in areas of suspected seal and source. Offshore, the best potential may well be with the unknown and untested Triassic section.

TABLE 8.1

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PLATES

TABLE 8.1 [illegible]. UNDRILLED STRUCTURE ANALYSIS

Structure Number	Nearest Deep Test	Type of Structure	Vertical Closure (Metres)	Areal closure at mapped horizon in km²	Depth to top of structure in metres	Age of structure - Company; Age of structure - Basin Studies	Probable stratigraphy	Timing of maturity and thermal surfaces (T°C) vs age	Thermal gradient (present day) °C/100m (Extrapolated from nearest reliable data)	Potential source rocks	Potential reservoir rocks	Potential seal	Potential trap type	Time of formation of traps	Time of maturation and migration	Probable hydrological histories	Petroleum potential	Production potential	Remarks
1	Lake Betty; Point Moody	Faulted anticlines	200	7.5	2600	① pre-Permian ② Late Triassic folding and faulting	Surface: Poole or Grant C (P) ?Poulton (L.D.) Ordovician clay (L-M.Ø)	Insufficient data, but on present thermal gradient all above Lulu-igju Formation on likely to be immature	2-3°C/100m (probably closer to 2°)	Lulu-igju Fm (supernature at Lake Betty 1)	Sands in Poole Formation or Grant Formation C		? Anticlinal if closure; but stratigraphic range up-dip unlikely due to increase in sands towards source	Anticline is probably Late Triassic	Migration likely to have occurred during Permian when thickest sediment pile developed.	Water wells in vicinity suggest fresh water in Permian	Must be considered as very low, as traps are untimely	Nil		Seismic data inadequate to show closure
2	Lake Betty; Point Moody	Faulted anticline	600	17.5	1650	① pre-Permian	Surface: Poole or Grant C (P) Lulu-igju (U.D) ?Poulton (L.D.) Ordovician (L-M.Ø)	Insufficient data, but Lulu-igju Formation maybe mature on present thermal gradient	2 3°C/100m	Lulu-igju Formation (supernature at Lake Betty 1)	Sands in Poole Formation or Grant Formation C		? Anticlinal	Pre-Fammenian on seismic evidence faulting pre-Fammenian possibly some late Triassic warping	Migration likely to have occurred during Permian when thickest sediment pile developed	Water wells in vicinity suggest fresh water in Permian	Must be considered as very low, as traps are untimely	Nil		Seismic data inadequate to show closure
3	Lake Betty; Point Moody	Faulted anticline	350	7.5	1425	① pre-Permian	Surface: Noonkanbah (P) Poole (P) Grant C (P) Lulu-igju (U.D) Poulton (L.D) Ordovician (L-M.Ø)	Insufficient data, but present thermal gradient suggests Upper Devonian mature	2-3°C/100m	Lulu-igju Formation	Sands in Poole Formation or Grant Formation C		Anticlinal closure possible in pre-Fammenian (probably supernature)	Pre-Fammenian anticlinal trap Possibly some late Triassic warping and fault rejuvenation	Permian when sedimentary pile at maximum	Water wells in vicinity suggest fresh water in Permian		Nil		Seismic data inadequate to show closure
4	Lake Betty; Point Moody	Closed anticline	250	approx 10	5700	① pre-Permian	Surface: Noonkanbah (P) Poole (P) Grant C (P) Anderson (L.C.) Poulton (L.D) Ordovician (L-M.Ø)	50°C in ? Lower Permian 75°C in ? Devonian 100° in ? Devonian	2°C/100m	Lulu-igju Formation	Sands in Poole Formation or Grant Formation C	Impermeable shale and limestone within Noonkanbah Formation. However fresh waters encountered in Poole and Grant suggest that the Noonkanbah is often breached	Possibly Late Triassic anticlinal folding (untimely)		Probably during Permian for Lulu-igju Formation hydrocarbons	Poole and Grant C shielded	Timeliness of anticlinal structure unsuitable Permian flushed	Low to Nil		Seismic coverage poor
5	Lake Betty; Point Moody	Fault controlled closure in pre-Permian rocks	350	17.5	2700	① pre-Permian ② possible late Triassic warping	Surface: Erskine, Blina, Millyit } L-M. Triassic Liveringa Group (U.P.) Hardman (U.P.) Condren (U.P.) Lightjack (U.P.) Noonkanbah (L.P) Poole (L.P.) Grant C (L.P) Grant B (L.P.) Grant A (U.C.-L.P.) Anderson (L-M.C.) Fairfield Group (U.D-U.C) Lulu-igju and Clamungan (U.D) ? Baberongan Pillara (M.D) Poulton (L.D) Ordovician (L-M.Ø)	On the present thermal gradient Ordovician, Devonian and lower Permian rocks are expected to have matured. Vitrinite reflectance data from Lake Betty 1 suggest Upper Devonian supernature	2°C/100m	Lulu-igju Formation, Fairfield Group, Anderson Formation, Grant Group and Poole Formation	Sands in the Fairfield Group, Anderson Formation, Grant Group and Poole Formation	Noonkanbah Formation over Poole Formation, Yarra Yarra Member of Poole over Grant C, Grant B over Grant A and siltstone and shale horizons in Anderson Formation and Fairfield Group	Anticlinal traps and stratigraphic traps developed in Anderson formation and Fairfield Group	Anticlinal faulting, Lower Triassic but may be partly folding during Permian as elsewhere in Graben	Lower Carboniferous to Late Permian or Triassic for Upper Devonian to Lower Permian hydrocarbons	In Pt Moody 1 the Grant A Formation contains salt water below Grant B seal, but at Lake Betty 1 is flushed.	Experience elsewhere in Graben localities to expection of gas cycle in pre-Permian section. The same is probably true for Grant Group, but young sediments presently immature	Gas possible in Lower Carboniferous liquid hydro. reason nil		Insufficient seismic coverage to determine closure
6	As in 5	Anticlinal	600	12	4650	As at 5	As at 5	As at 5	As at 5	As at 5	As at 5	As at 5	As at 5	As at 5	As at 5	As at 5	As at 5	As at 5	As at 5
7	As in 6	Faulted anticline	400	21	3000	① post-Permian ② Late Triassic	Surface: Fm Grant A (P) Anderson Formation (L.C.) Fairfield Group (U.D-L.C) Lulu-igju Formation Clamungan Formation (U.D) ? Baberongan Beds ? Pillara Formation equiv (M.D) ? Poulton Formation equiv (L.D.) Ordovician (L-M.Ø).	50°C ? 75° ? Poulton Formation, (L.D) 100° ? Lower Devonian	2 6°C/100m	L-M. waters from Lake Betty 1 and Point Moody suggest Lulu-igju Formation and Fairfield Group supernature and experience elsewhere in Graben suggests Grant Group also matured. Source rocks include Lulu-igju Formation shales and silts ... Fairfield Group shale in Grant A and Grant B.	Grant A probably as oil close to surface, and therefore accumulated sands in the Anderson Formation and Fairfield Group	Probable trap exists and present in the Anderson Formation and Fairfield Group sandstone in Graben.	Stratigraphic traps in Anderson formation and Fairfield Group are possible where sands pinch out and flowage pinch outs occur, previously not recognised in this environment. Anticlinal	Any structure pre-mature present until Late Triassic Mirra growth fracturing occurs in the pre-Permian section sandstones in the graben and such anticlines may have trapped early oil	Lower Carboniferous and Late Permian on present thermal gradient and most mature sedimentary thicknesses	Grant A on surface and probably flushed. The Anderson formation in the up-faulted blocks is probably also flushed	The history of the structure is unfavourable. Residual gas accumulations may be present in the Fairfield Group and Anderson Formation which are supernature. Similar gas deposits may occur below Grant B cap in deeper unflushed, down faulted blocks of Grant A. Liquid hydrocarbons are considered unlikely due to the supermaturity of most source rocks.	Liquid hydrocarbon-nil Gas - low		Seismic cover inadequate to delineate closure

TABLE 8.14. UNDRILLED STRUCTURE ANALYSIS (Contd)

Structure Number	Nearest Deep Tests	Type of structure	Vertical Closure (Metres)	Areal closure at mapped horizon in Km^2	Depth to top of structure in metres	① Age of structure - Company ② Age of structure - Bean studies	Probable stratigraphy	Thermal maturity and thermal maturation ages (°C/Eyes ago)	Thermal gradient (present day) and temperature from nearest wells	Potential source rocks	Potential reservoir rocks	Potential seal	Potential trap type	Time of formation of trap	Time of maturation and migration	Probable hydrocarbon type	Petroleum Potential	Production potential	Remarks
8	Point Moody 1 Wilson Cliffs 1	anticline (concealed)	50	7.5	3,500	① Post Ordovician ② Could be Late Triassic - Tertiary movement on old structure	Surface - Grant A B C ? Mellingerie Limestone Tandalgee Red Beds Carribuddy Formation Ordovician	Lower Devonian to Lower Permian mature - Ordovician probably supermature 50°c in Lower Permian 75°c in Lower Devonian 100°c in Lower Devonian	2.5°c /100m	Ordovician shales but probably supermature (Grant B shales possibly suitable in case cooling but unlikely to have much organic material	Tandalgee red beds - shelf arenite and permeability but probably lacking source and ? melly structure Grant A probably thin and silty Grant C breached	Carribuddy salt dolomitic Mellingerie if present	Anticlinal only	Devonian according to company possibly Late Triassic movement also	Methane only in Ordovician (oil migration has occurred) probably in Devonian time or Permian at latest when maximum burial probable	Permian flushed probably also true for Tandalgee as Mellingerie cap missing	No favourable juxtaposition of source, seal, reservoir or timing	Nil	Seismic fair but insufficient to delineate closure
9, 10, 11, 12		anticlines with faulting (post-Permian)				Post Permian													Downgraded prospectivity because 1. Supermature Ordovician 2. Young post Ordovician heating 3. Red beds and salt lithology 4. Immature Permian 5. Permian breached by faulting and erosion Seismic coverage lacking
13	Wilson Cliffs 1 Contention Hayrick 1 Kidson 1	faulted anticline (concealed)	150	17.5	1150	① Permian ② Probably Late Triassic	Surface - Poole Formation Grant C B A Mellingerie Limestone Tandalgee Red Beds Carribuddy Formation Ordovician	Ordovician is over mature (only gas at Wilson Cliffs 1 and Contention Heights) Permian probably immature 50°c 75°c 100°c } Lower Permian	2.5°c /100m	Ordovician shales possibly gas at B, down dip	Tandalgee Red Beds, Grant C, A	Mellingerie limestone ? Grant B	Anticline ? fault traps	Late Triassic	Ordovician and possibly Devonian, or Late Permian when maximum overburden	Permian probably flushed Tandalgee Red Beds may be unflushed below Mellingerie seal	Favourable juxtaposition of seal and reservoir but no suitable source or structure	Nil	Closure based on 2 seismic lines
14	Lake Betty 1 Jones Range 1 St George Range 1	closed anticline	230	12.4 ?	5700	Post Permian	Surface - Barbwire Sandstone ? Poole Formation or Grant C (thin) Grant B Grant A Anderson Formation Fairfield Group Leonard River Group Poulton Formation Ordovician	mature below the Grant Formation (? probably supermature in the past) 50°c lower Carboniferous 75°c lower Devonian 100°c upper Devonian Dry gas and bitumen in Grant A at ③ Gurong Range), suggest Grant Formation mature	2.8°c /100m	Shales in Anderson Formation (gas only) Fairfield Group (gas and oil) Grant C, B, (gas)	Grant Formation sand, Anderson Formation thin sands, Fairfield Group sands if present	(Grant B) shales in Anderson and Fairfield Group	Anticlinal	Post Permian fold traps, but may be structural growth in Anderson or earlier time	Grant Formation probably produces hydrocarbons by late Triassic when maximum overburden, Anderson and Fairfield Group, possibly earlier	Anderson and Grant Formations flushed	Unfavourable flushing history, main structure development and probable humic nature of source rock material suggest no accumulation	Nil for oil Very low for gas	Conjectural only, one seismic line defines coverage
16 similar to structure 14	[with	attendant lobe	Thinner		faulting	and partial	removal of	tongue	down to the	Kennaint	formation]								
17	Jones Range 1 Barbwire 1 Crossland 1	closed anticline	250	17	1750	① Devonian	Surface? Barbwire Sandstone on thin Grant D Pillara Formation or Mellingerie Limestone Tandalgee Red Beds Carribuddy Ordovician	Permian and Devonian mature on present depth 50°c lower Permian 75°c Devonian 100°c lower Devonian	2.8°c /100m	? Mainly carbonates but supermixed origin probably unsuitable ? Ordovician shales	Tandalgee Red Beds ? wings developed in Devonian carbonates	Pillara Formation or Mellingerie Limestone	Anticlinal, fault traps below Permian possible	Late Carboniferous Late Triassic	Probably in Late Permian times when maximum overburden however Ordovician oil may have migrated during Devonian	Tandalgee and Grant A probably flushed	Unfavourable juxtaposition, source and reservoir, structure and hydrological history	Nil	Fair quality seismic data
18 Structure 24 is similar in structural, thermal and depositional history	Crossland 1 Crossland 2	anticline (may be related to salt solution)	60	10	1200	① pre-Permian ② Permian or younger	Surface - Barbwire Sandstone Grant B (thin) Grant A Tandalgee Red Beds Carribuddy Formation Ordovician	? Mature from Ordovician to Permian 50°c Permian 75°c lower Devonian 100°c lower Devonian	2.3°c /100m	Possibly only Ordovician shales	Tandalgee Red Beds	—	Anticlinal	Permian or younger	Ordovician hydrocarbons probably migrated by Devonian	Grant Flushed lack of Mellingerie seal probably untrue Tandalgee also flushed,	Unfavourable juxtaposition of source, seal, lack of suitable reservoir parameters	Nil	poor seismic data quality
19		only	apparent	at	base	of Permian	in fault controlled structures on Barbwire Terrace												
21	St George Range 1 Poole Range 3 & 5 BMR Prices Creek 3	fault controlled closure in ? Ordovician	950	20 (a) Anderson	2600	lower structure pre-Middle Devonian probably lower Devonian upper structure Middle Devonian and lower Carboniferous and late Triassic	Surface - Grant C (south of fault) ? Anderson Formation (thin) Fairfield Group Leonard River Group Poulton Formation Ordovician	mature Ordovician to Permian 50°c in ? Permian 75°c in ? Anderson Formation 100°c in ? Leonard River Group	1.8°c - 2.4°c/100m	Ordovician shale Devonian shales (Isopropic probably but with humic component suitable for oil and gas)	Possibly sands in the Anderson Formation	Shales in the Anderson Formation	Fault traps in Ordovician, Devonian Anderson Formation sealed up dip against the faults possible reservoir against master fault.			Anderson Formation and Grant Flushed in nearby wells		Comparable to Lease 17 ?	More seismic needed to define extent of closure
22, 23, 24		surface anticline in Permian outcrop																Several dry holes in this play	
25, 26?																			
27 (two structures)	Mimosa 1 MH Hardman 1	Faulted anticlines	200	13	1400	① pre-Permian ② possibly as young as late Triassic	As in Mimosa 1 but with addition of Anderson Formation below Grant Formation	Ordovician and Devonian are mature (present day) possibly lower Permian also. 50°c 75°c 100°c in Devonian	1.8°c /100m	See section C-	Sands in the Laurel Formation Findoo no Formation	Siltstones and shales in the Anderson Formation and Fairfield Group	Fault traps - porous sands sealed up dip against Fault	Block faulting pre Permian, Anticlinal folding Late Triassic	Probably in Permian when maximum burial achieved	Possibility of flushing in Anderson Formation due to breaching	Dependent on development of suitable reservoir sands - LCM Late Permian mainly wells suggest gas only	Low for gas	inadequate seismic coverage poor to fair quality Similar to section penetrated in Mimosa 1 except that 1500m of Anderson Formation present below Grant Formation
28?																			
29, 30	Grant Range 1 Blackstone 1 Fraser River 1	Salt(s), plunging anticlines	S 29 200m S 30 150m	15 11	2010 2500	Late Triassic	Surface: ? Jurassic sands Triassic Liveringa Group Jourdan Tongue Formation Poole Formation Grant C, B, A Anderson Formation Fairfield Group Leonard River Group Poulton Formation Ordovician	Devonian to Lower Carboniferous is mature Grant A Formation is mature 50°c Permian rocks 75°c lower Carboniferous 100°c Upper Devonian	1.2°c /100m	Tullunga Formation shales in Anderson and Willanee Formations (Grant B, C, Anderson Formation shales may be source - suspect the latter and most minor contributor from Grant C and Anderson Formations)	Permeable sands in Anderson and Fairfield Group, Grant C, A	Shales in Anderson Formation, Fairfield Group, Grant B, ? Nunn Member Aloombah Formation	Anticlinal	Late Triassic	Devonian hydrocarbons from late Carboniferous or Permian time Grant hydrocarbons ? in Triassic when maximum burial	Anderson and Grant, Poole sands water flushed	Possibly no structure for Devonian hydrocarbons but structure provide for Grant and Anderson hydrocarbons reservoir parameters critical	Liquids Nil Gas and condensate low, dependent on reservoirs	insufficient seismic to establish closure
33		salt dome structures				post dates Poole Formation pre dates middle Jurassic (Walloi sandstone) (seismic evidence) (late Triassic)													Inadequately explored by seismic
40	Parda 1 Goldwyer 1 Thangoo 1, 19, 2	closed anticline	25	10	1275	① lower Devonian ② Artinskian to Jurassic	Surface: Sand Walloi sandstone Grant A Carribuddy Formation Nita Formation Goldwyer Formation Willara Formation ? Nambeet Formation Ordovician	Ordovician, lower Devonian and Permian rocks mature 50°c Permian 75°c Ordovician 100°c Ordovician	3°c /100m	Goldwyer shales	porous carbonate in Nita or Willara Formation but both probably tight	? Carribuddy over or in the Goldwyer over Willara	Anticlinal and ? Fault traps	Lower Devonian and possible Late Triassic rejuvenation	Probably Ordovician but maybe Z° in Lower Devonian when overburden pressures increased		Migration and structural development not conducive to entrapment	Nil	Seismic coverage poor
44	Barlee 1 Yulleroo 1	faulted anticline (conjectural)	700	16	2500	post Permian	Surface Walloi Sandstone or scarp Nookenbah Formation (thin or absent) Poole Formation Grant A B C Anderson Formation Fairfield Group Leonard River Group Poulton Formation Ordovician	pre-Permian rocks are mature 50°c in Lower Permian 75°c in lower Carboniferous 100°c in Devonian or lower Carboniferous	1.8-1.9°c/100m	As above, but also shales in Grant A, B	As above, but also Grant C, A Poole Formation	As above but Grant B also possibly Nunn Member and Nookenbah Formation (breached up dip)	Anticlinal possibly some fault traps	Late Triassic	Possibly late Carboniferous to Triassic when maximum burial (if earlier unlikely to be structure)	Poole, Grant and Anderson probably flushed	Flushing of Anderson and the possibility of no structure until Late Triassic suggest no potential	Nil	Closure not demonstrated by seismic
47	Fraser River 1 Bindler 1 Yulleroo 1 Pepper Inlet 1	anticlinal	800	?	700	pre Jurassic probably late Triassic	Surface: Grouse sandstone Jurassic Anderson Formation (thin) Fairfield Group Leonard River Group Poulton Formation Ordovician	Fairfield Group and Anderson Formation probably mature 50°c in ? Jurassic 75°c in Fairfield + older Devonian 100°c ? in older Devonian rocks	1.6°c - 1.8°c/100m	Liveringa Formation shales mature shales in Anderson Formation	Anderson sands, Fairfield sands possibly Poulton carbonate if not tight	Shales in Anderson and Fairfield Groups	Anticlinal	Late Triassic	Possibly Late Carboniferous to Triassic when maximum burial (if earlier unlikely to be structure)	Anderson Formation likely to be flushed as breached by Late Triassic unconformity	Flushing of Anderson and the probability of no structure until Late Triassic suggest no potential	Nil	uncertain size

TABLE 8.2. DRY-HOLE ANALYSIS

Well Name	Station No.	Basis for test	Target	Closures	Age of structure	Reason for failure	Comments
Pender No. 1	8	Strat. test. Pre-Permian structural anomaly	Top Permian Interval 4 928 m	?	Pre-Permian	Basement underlies Permian, flushed	
Napier No. 1	52	Strat. test. Probable closed anticline	585 m Interval 3 Devonian carbonate	?	Upper Devonian		
Napier No. 2	47	Strat. test. Small structural high which correlates with a gravity low	305 m Interval 3 Devonian carbonate	?	Upper Devonian	Fresh water encountered. Closed structure probably absent	
Napier No. 4	43	Strat. test. Closed structure coincides with gravity high	845 m Interval 3 Devonian carbonate	?	Upper Devonian	?	
Napier No. 5	48	Closed anticline	142 m and 633 m Interval 3, Devonian carbonate	?	Carboniferous?	?	
Hawkstone Peak No. 1	53	Test for hydrocarbon potential of Devonian reef	450 m reef complex of Interval 3	?	Upper Devonian	Reef not encountered, high basement	
May River No.	44	Devonian reef on elevated Precambrian basement	1637 m Interval 3 Devonian reef		Upper Devonian	Reef structure not encountered	
Langoora No. 1	45	Test Devonia reef and Lower Carboniferous sediment	1180 m and 1600 m, Interval 3 Devonian carbonate		Upper Devonian	Reef not encountered	
Meda No. 1	46	Small anticline suspected to be Devonian reef	1700 m Interval 3		Upper Devonian	Water saturation in lower Carboniferous >50%. Only about 5 m of reef facies intersected, probably drilled off structure	Several gallons of oil recovered from the Laurel Formation and several gas zones were intersected within Upper Devonian carbonate section
Meda No. 2	46	As for Meda 1	Interval 3 Upper Devonian and Lower Carboniferous		Upper Devonian	Reef structure not encountered, drilled off target	
Munro No. 1	220	Closed anticline	1500 m, Ordovician Interval 1		Post Permian-pre-Jurassic	Lack of adequate reservoir	
Tappers Inlet No. 1	5	Anticline	1615 m Interval 3 (lower Carboniferous, Devonian) ? m Interval 1 (Ordovician)		Lower Carboniferous-Permian	Carboniferous rock absent, tight Devonian limestones, no show in porous Devonian sandstones	

Well Name	Station No.	Basis for test	Target	Closures	Age of structure	Reason for failure	Comments
Blackstone No. 1	58	Devonia reef on a large anticline	1568 m Devonian carbonate of Interval 3, Ordovician Interval 1		Upper Devonian reef, pre-U/D anticline	Reef not encountered, good reservoir absent. Closure at Poulton Formation breached	
Mimosa No. 1	60	Devonian carbonate bank on older fold	1150 m, Interval 3, Middle Devonian		Upper Devonian	Absence of good reservoir	
Palm Spring No. 1	80	Strat. test	Interval 3				
Laurel Downs No. 2	100	Strat. test	Interval 3				BMR
BMR Prices Creek No. 3	123	Strat. test	Ordovician Interval 1				BMR
Lacepede No. 1A	3	Strat. test, closed anticline	1300 m Interval 6 2000 m Interval 3		Interval 6 - post Jurassic, Interval 3 - Upper Triassic		
Wamac No. 1	2	Closed anticline with pre-Jurassic	3000 m Interval 3 Palaeozoic		?	Target not reached. Reservoir and probably closure absent	
Frazer River No. 1	12	Large anticline	Pre-Permian		Upper Triassic	Permian and Triassic closures breached, effective seal absent	
Barlee No. 1	16	Closed anticline	2700 m Interval 3 Devonian		Upper Triassic	Thick unprospective Carboniferous overlies target. Permian closure breached	
Yulleroo No. 1	15	An anticline	2000 m Interval 3 Devonian		Upper Triassic	As for Barlee No. 1	
Sisters No. 1	59	Surface anticline	Permian Interval 4 and Devonian Interval 3		post-Permian		
Grant Range No. 1	62	Surface anticline	Devonian Interval 3		post-Permian		
Mt Wynne No. 3	74	Surface anticline	Permian Interval 4		post-Permian		
Mt Hardman No. 1	79	Faulted anticline	1670 m Interval 3 Devonian		probably Carboniferous		

Well Name	Station No.	Basis for test	Target	Closures	Age of structure	Reason for failure	Comments
Myroodah No. 1	65	Surface anticline	Permian Interval 4		Upper Triassic		
AFO Nerrima No. 1	68	Surface anticline	Permian Interval 4 Carboniferous Interval 3		Upper Triassic		
KFO Nerrima No. 1	69	Surface anticline	Devonian Interval 4		Upper Triassic		
St. George Range No. 1	108	Surface anticline	4500 m Interval 3 Carboniferous and Devonian sections		Upper Triassic		
Prices Creek Nos 1-4		To investigate source of oil presence in water wells	Ordovician Interval 1				
Poole Range No. 3	121	Surface anticline	Permian Interval 4				
Poole Range No. 5	121	Surface anticline	Permian Interval 4				
Jones Range No. 1	118	Anticline	1560 m to top Devonian carbonate. Interval 3	154 km^2	Upper Triassic?	Target section (Devonian) not reached. Carboniferous & younger sediments flushed	
Lake Betty No. 1	154	Faulted anticline	1600 m Carboniferous, 2300 m Devonian Interval 3		Devonian to late Permian		
Point Moody No. 1	189	Strat. test on surface anticline	Lower Permian Interval 4	90 km^2	Probably Permian		Closure is not adequately defined
Logue No. 1	36	Closed anticline	1326 m Millinjerie Lst. Interval 3	50 km^2	Upper Triassic		
Doran No. 1	35	Strat. test on faulted anticline	Permian, Interval 4		Upper Triassic		
Frome Rocks No. 1	34	Pre-Permian structural high	Ordovician Interval		Probably Upper Triassic		Salt dome below Mesozoic
Frome Rocks No. 2	33	Test same structure as above	Ordovician Interval 1		Target not reached		

Well Name	Station No.	Basis for test	Target	Closures	Age of structure	Reason for failure	Comments
Jurgura Creek No. 1	32	Strat. test					
Babrongan No. 1	31	Closed anticline	164 m Permian Interval 4, 518 m Devonian Interval 3	≈ 10 km^2	Probably late Permian		
Munda No. 1	219	Strat. test on closed anticline	Salt core ?Interval 2		Post-Permian pre-Jurassic	?	
Matches Springs No. 1	67	Mapped structural high on faulted block. Strat. test	670 m Devonian, Interval 3 2440 m Ordovician Interval 1		?		
Barbwire No. 1	111	Strat. test on a host block	701 m, Ordovician Interval 1		?	Absence of adequate reservoir	
Crossland No. 1	155	Strat. test	390 m, Devonian Interval 3				
Crossland No. 2	156	Strat. test	430 m, Devonian-Silurian, Interval 2				
Crossland No. 3	157	Strat. test	460 m, Ordovician Interval 1				Target not reached
Roebuck Bay No. 1	19	Strat. test?	Ordovician Interval 1				
Thangoo No. 1	21	Closed small anticline	680 m, Ordovician Interval 1		Pre-Permian		Target not reached due to mechanical failure
Thangoo No. 1A	21	As for Thangoo 1	"			Absence of closure?	
Thangoo No. 2	22	Faulted low relief anticline	1030 m, Ordovician Interval 1			Ordovician Structure breached	
Goldwire No. 1	20		Ordovician Interval 1				No data available
Parda No. 1	229	Strat. test on a closed anticline	1036 m, Ordovician Interval 1			Absence of adequate reservoir	

Well Name	Station No.	Basis for test	Target	Closures	Age of structure	Reason for failure	Comments
Mowla No. 1	29	Closed structure	724 m, Ordovician Interval 1			Devonian limestone water saturated (flushed)	Original target not reached
Edgar Range No. 1	26	Poorly defined closed structure	1200 m, Ordovician Interval 1			No reservoir	
McLarty No. 1	218	Closed structure	1980 m, Ordovician Interval 1			Tight reservoir	
Contention Height No. 1	196	Surface anticline	1750 m, Ordovician Interval 1			Reservoirs flushed	
Willara Hill No. 1	228	Anticline	655 m, Permian Interval 4			Absence of seal	
Willara No. 1	227	Strat. test	1220 m, Devonian 1950 m, Ordovician Interval 1			Absence of reservoir in Interval 1, Permian and younger sediment flushed	
Samphire Marsh No. 1	233	Strat. test on anticline	Devonian Interval 3				
Wallal No. 4/4A	234	Strat. test					
Kemp Field No. 1	216	Anticline	726 m, Devonian Interval 2				
Sahara No. 1	215	Strat. test	Paleozoic				
Kidson No. 1	204	Strat. test on closed anticline	Paleozoic				
Wilson Cliffs No. 1	195	Faulted anticline	Devonian Interval 3 Ordovician Interval 1			Reservoir either tight or flushed	
East Mermaid No. 1	1	Closed anticline	Jurassic Interval 6				
Bedout No. 1	239	Closed anticline	Mesozoic				
Minilya No. 1	240	Faulted anticline					
Kerandren No. 1	238	Faulted anticline	3614 m, Triassic Interval 5			Reservoir flushed	Target not reached

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APPENDIX 1. STRATIGRAPHIC UNITS OF INTERVAL 1

Interval 1 comprises the Nambeet, Willara, Goldwyer, Nita, Emanuel, and Gap Creek Formations, the Carranya Beds, the Roebuck Dolomite, and the 'Middle Formation'.

NAMBEET FORMATION

Named from: Nambeet well, near Samphire Marsh No. 1.

Defined by: Formally defined by Playford & others (1975). Johnstone (1961) described the section. Koop (1966) first published the name Nambeet Formation for this sequence but did not define the formation.

Status of name: Formally defined.

Type section: 4069-6610 feet (1240-2015 m) in Samphire Marsh No. 1. Station 233 (Appendix 12).

Previous name: Referred to as 'Lower Ordovician' by Johnstone (1961).

Redundant Synonyms: WAPET used the informal names 'Lower Formation' in the Kidson Sub-basin, the 'Unnamed Sandstone Formation' in McLarty No. 1, and the 'Nambeet Formation Equivalent' in Willara No. 1.

Modifications: Previously included in the Thangoo Limestone in Thangoo No. 1A and Edgar Range No. 1, and in the Willara Formation in Munro No. 1.

Outcrop: None described.

Distribution: Samphire Marsh No. 1, Willara No. 1, McLarty No. 1, Thangoo Nos. 1A and 2, Tappers Inlet No. 1, Munro No. 1, Edgar Range No. 1, Wilson Cliffs No. 1, and Contention Heights No. 1. Its widespread distribution suggests that it extends over most of the Canning Basin south of the Fenton Fault; it probably covers much of the Fitzroy Graben too, where - however - only Tappers Inlet No. 1 on the Pender Terrace has penetrated it. Its northern limit is the Lennard Shelf. Its eastern limit in the graben cannot be estimated. South of the Fenton Fault, it is missing from part of the Broome Arch.

Thickness variations: Six wells intersected complete sections of the formation Edgar Range No. 1 (161 m), Thangoo No. 1A (49 m), Thangoo No. 2 (71 m), Munro No. 1 (93 m), Tappers Inlet No. 1 (632 m), and Wilson Cliffs No. 1 (540 m).

The thickest section is 775 m - the incomplete type section eroded at the top in Samphire Marsh No. 1. Willara No. 1 penetrated 761 m of Nambeet Formation before it reached total depth still in Nambeet Formation. Isopach mmpping of the Ordovician (Pl. 10-1) suggests that the Nambeet Formation may be more than 1000 m thick south of the Admiral Bay Hingeline; thus the thickest accumulation of the formation would be in the Willara Sub-basin. Isopach thicknesses may be greater in the centre of the Kidson Sub-basin but cannot be substantiated owing to the lack of seismic and drilling data. The thickness at Tappers Inlet No. 1 and isopach contours suggest that the Nambeet Formation is thicker to the south in the Fitzroy Graben than on the Pender Terrace. The thinnest accumulation is on the Broome Arch. This is supported by the absence of the formation in areas of thinnest Ordovician isopach contouring.

Relations with other units: The formation is everywhere unconformable on Precambrian rocks, which are granite in Samphire Marsh No. 1 and Munro No. 1; schist in Edgar Range No. 1; gneiss in Thangoo No. 2; phyllite in Thangoo No. 1A; metamorphosed igneous in Tappers Inlet No. 1; and weakly metamorphosed ?Upper Proterozoic ferruginous shale in Wilson Cliffs No. 1 in the Kidson Sub-basin.

Except in Samphire Marsh No. 1, the formation is conformably overlain by Ordovician limestone: Willara Formation south of and possibly in the Fitzroy Graben; Gap Creek Formation on the Pender Terrace; and 'Middle Formation' in the Kidson Sub-basin. The top of the Nambeet Formation is diachronous within the Lower Ordovician (Arenigian). In Samphire Marsh No. 1, the top of the Nambeet Formation is eroded, and unconformably overlain by the Permian Grant Formation.

The formation is equivalent to the Carranya Beds on both lithology and age. Apart from its basal Ordovician sandstone in BMR Prices Creek No. 3, the Emanuel Formation is a time equivalent of the Nambeet Formation. The 'Lower Formation' (of WAPET) is included as part of the Nambeet Formation because of its lithological similarity, stratigraphic position, and relative age. Creevey (1969) noted a resemblance between the Nambeet Formation and the Pacoota Sandstone of the Amadeus Basin.

Subdivision: Although the sequences of the Nambeet Formation in Samphire Marsh No. 1, Tappers Inlet No. 1, and Munro No. 1 are similar - basal sandstone, middle interbedded limestone or carbonate and sandstone and/or shale, and upper shale mainly - it has not been formally subdivided.

Lithology: Mainly grey to green shale with interbedded limestone and a basal fine-grained sandstone. In the Kidson Sub-basin and on parts of the Broome Arch the formation is wholly sandstone. Samphire Marsh No. 1 encountered the following sequence:

262 m Shale; fossiliferous grey-green micaceous lenses of fine crystalline limestone and fine sandstone constitute 20-30% of the rock.

145 m Shale and limestone as above. Limestone content is up to 40% in the lower part. Sandstone is absent.

231 m Micaceous, fossiliferous reddish brown to grey fine sandstone interbedded with grey green shale, limestone, and micaceous siltstone. The proportion of siltstone to shale increases with depth giving a coarser texture to the rock. Reddish brown colour in the shale and siltstone becomes more common with depth.

26 m Grey-green to white micaceous dolomitic sandstone grading into sandy dolomite. Fossiliferous with lenses of siltstone.

111 m Hard, well-cemented, siliceous, calcareous sandstone. Grainsize varies from fine to coarse. Colour ranges from grey-green to white and reddish brown. Lateral lithological variations of the formations are shown in Plate 10-1.

Age: Early Ordovician (Tremadocian-Arenigian). The Nambeet Formation has a faunal assemblage including trilobites, graptolites, brachiopods, gastropods, and conodonts, and contains the oldest dated Phanerozoic rocks in the Canning Basin. The Nambeet Formation is known to extend into the Tremadocian only in Samphire Marsh No. 1, where J. Gilbert-Tomlinson (in Johnstone, 1961) suggested the fauna may be as old as latest Cambrian. Veevers (1967b) has exluded the possibility of Cambrian rocks.

The formation is strongly diachronous south of the Fenton Fault; it becomes younger southeast and northeast of Samphire Marsh No. 1. The youngest section is in Tappers Inlet No. 1, on the Pender Terrace. The age of the Nambeet Formation in the Fitzroy Graben is unknown, but is probably older than that on the Pender Terrace. The age of the Emanuel Formation, its equivalent to the east, suggests that the Nambeet Formation in the graben may be as old as the section in Samphire Marsh No. 1.

WILLARA FORMATION

Named from: Willara No. 1 exploration well, 50 km east of Cape Missiesy.

Defined by: R.A. McTavish (in Playford & others, 1975).

Status of name: Formally defined.

Type section: 8563-10 308 feet (2510-3142 m) in Willara No. 1 (19°10'48"S, 122°4'14"E). Station 227 (Appendix 12).

Previous name: Thangoo Limestone (R.M.L. Elliott in Pudovskis & Willmott, 1961).

Modifications: Basal sandstone or shale included in the Thangoo Limestone in Thangoo No. 1A and Edgar Range No. 1, and in the Willara Formation in Munro No. 1, has been removed and placed in the Nambeet Formation. The type section (of the Thangoo Limestone) has been moved from Thangoo No. 1A to Willara No. 1.

Outcrop: None described.

Distribution: Edgar Range No. 1, Thangoo Nos. 1, 1A and 2, Goldwyer No. 1, Parda No. 1, Willara No. 1, Munro No. 1, and McLarty No. 1. It is present over all the onshore Canning Basin south of the Fenton Fault excluding the Kidson Sub-basin and Samphire Marsh No. 1. It may also extend over the southern part of the Fitzroy Graben but its northern limit is south of the Pender Terrace and Lennard Shelf. The offshore limit is unknown and the eastern onshore limit is uncertain.

Thickness variations: It is thickest - 532 m - in Willara No. 1, the type section. Other wells intersected sections between 200 and 450 m thick. Eight wells encountered complete sections - Edgar Range No. 1 (401 m), Goldwyer No. 1 (343 m), McLarty No. 1 (280 m), Munro No. 1 (211 m), Parda No. 1 (285 m), Thangoo No. 1A (446 m), Thangoo No. 2 (454 m), and Willara No. 1 (532 m) - and indicate that the formation thins to the east and locally on the southern Broome Arch. Unlike the Nambeet Formation, the Willara Formation is thick on the north part of the Broome Arch, which therefore, was probably higher in the south than in the north at this time.

Relations with other units: The Willara Formation overlies the Ordovician Nambeet Formation conformably, and Precambrian granite (in Goldwyer No. 1) and gneiss (in Parda No. 1) unconformably. The contact with the Nambeet Formation is variable - gradational in some wells such as Munro No. 1 and Edgar Range No. 1, and sharply defined as in Thangoo No. 2 and McLarty No. 1.

The Goldwyer Formation conformably overlies the Willara Formation. R.M.L. Elliot (in Pudovskis & Willmott, 1961) and Young & O'Shaughnessy (1973b) have suggested that the contact between them is disconformable in Thangoo Nos. 1, 1A, and 2 because the Goldwyer Formation is thin and the Willara Formation comprises thin cavernous sandstone near the top. Pudovskis & Willmott (1961) discounts the thinning of the Goldwyer Formation as evidence of a disconformity, and J. Gilbert-Tomlinson (in Pudovskis & Willmott, 1961) recorded no fossil evidence for the break. WAPET has not recorded a disconformity at the top of the Willara Formation in any other wells. If the disconformity exists, it must be only local on part of the Broome Arch.

The age and stratigraphic position of the Willara Formation indicate that it is a correlative of the Gap Creek Formation and the 'Middle Formation'. It is diachronous, and is a time equivalent of the upper Nambeet Formation and the lower Goldwyer Formation in some parts of the basin (Pl. 12-2).

Subdivision: The formation has not been formally subdivided, though an informal three-fold subdivision is evident in Goldwyer No. 1, McLarty No. 1, Munro No. 1, Parda No. 1, and Willara No. 1: a middle member of interbedded limestone and shale separates upper and lower members mainly of limestone which is usually more massive and clean than the middle member. The relative thickness of each member varies.

Lithology: Limestone - white to grey, crystalline, dolomitic, and fossiliferous - with interbedded shale and siltstone.

The Willara Formation comprises mainly limestone, which is often massive, dense, crystalline to microcrystalline, and partly recrystallised from calcarenite or coquina. It is silty in places, pyritic, dolomitic in places, and fossiliferous. Grey to black shale interbeds are fossiliferous, micaceous, pyritic, and calcareous. In some wells the shale grades to siltstone or sandstone, and is contorted and slumped. The shale is most abundant and may predominate in the middle of the formation or towards the base.

The limestone within the formation as well as from well to well is highly variable. It ranges from a clean massive limestone - composed of bioclastic and carbonate debris and pellets in a sparry calcite matrix - to thin-bedded or nodular to lensoidal limestone - which is silty and micaceous, and interbedded with or surrounded by shale. On the Broome Arch the limestone grades to dolomite, especially in the upper part of the formation. Veins of white coarsely crystalline dolomite cut the limestone and dolomite beds in Thangoo No. 1A.

Porosity and permeability are very low in most of the wells. Primary porosity in the limestone was destroyed by the drusy growth of calcite and calcite cement. Vugular porosity and permeability have developed in the dolomite veins in Thangoo No. 1A, and intergranular porosity was recorded from some of the dolomite beds. Young & O'Shaughnessy (1973b) reported a cavernous porosity of 10 to 20% in Thangoo No. 2. Non-commercial oil (stains and fluorescence) and gas were recorded in the formation.

The type section has the following lithology:

94 m Limestone, white, brown, and grey brown, microcrystalline to aphanitic, partly recrystallised; dolomitic, pyritic, and fossiliferous; silty with minor beds of shale in places. Styolites are common; some are filled with black shale. Medium to coarse crystalline calcite form thin hair-like veins in the limestone. The shale is grey to black, micaceous, pyritic, and calcareous, and grades to siltstone or sandstone in places; it forms irregular laminations and pods within the limestone.

186m Interbedded limestone and shale. The limestone is mainly grey to brown, microcrystalline to finely crystalline, pyritic, and dolomitic, and has traces of crystalline calcite and glauconite. In places the limestone is buff or white, aphanitic, and argillaceous or silty. The shale is dark grey to black, micaceous, and silty and fossiliferous in places. The limestones form thin beds that are lensoid or podlike interbedded with contorted shale. In the lower part the shale predominates.

252 m Limestone and minor shale as above. Toward the base the shale content increases to 20-40%.

Age: Late Arenigian to Llanvirnian. The Willara Formation contains an abundant fauna of graptolites, trilobites, brachiopods, gastropods, bryozoan, nautiloids, conodonts, and ostracods. At the type section the formation is Arenigian (Early Ordovician). In Munro No. 1 the age is Early to middle Ordovician and indicates that the formation is diachronous from west to east. In McLarty No. 1 the Willara Formation is wholly Arenigian.

Although the formation is probably slightly diachronous from west to east, it is youngest near the limits of the formation or topographically higher areas.

GOLDWYER FORMATION

Named from: Goldwyer No. 1 exploration well, 38 km east of Cape Villaret, the well in which the formation was first described.

Defined by: R.M.L. Elliot (in Pudovskis & Willmott, 1961).

Status of name: Formally defined.

Type section: 2782-3477 feet (848-1060 m) in Thangoo No. 1A (18°22'47"S, 122°22'58"E). Station 21 (Appendix 12).

Previous name: None.

Modifications: None.

Outcrop: None described.

Distribution: Blackstone No. 1, Matches Springs No. 1, Edgar Range No. 1, Thangoo Nos. 1, 1A, 2, Goldwyer No. 1, Parda, No. 1, Willara No. 1, Munro No. 1, Barbwire No. 1, McLarty No. 1, Contention Heights No. 1, Wilson Cliffs No. 1, and Kidson No. 1. It extends over most of the Canning Basin south of the Fenton Fault and more than half of the area north of the fault. The known northern limit is the Lennard Shelf, Billiluna Shelf, and Pender Terrace. Its presence on the Margaret Terrace is confirmed by Blackstone No. 1. Although it has not been penetrated in the Fitzroy Graben its presence north and south of the graben strongly support the assumption that it also occurs there. Its eastern limit is uncertain, but it probably covers most if not all of the Kidson Sub-basin. Its offshore limits are unknown.

Thickness variations: Willara No. 1 encountered the thickest section of the Goldwyer Formation - 736 m. Most other wells in the basin have intersected much thinner sequences, ranging from 134 m in Kidson No. 1 to 430 m in Edgar Range No. 1. The apparent thinning in the Kidson Sub-basin and on the Broome Arch is probably erosional rather than depositional. Wells on the terraces suggest that the Goldwyer Formation thickens toward the Fitzroy Graben.

Relations with other units: The Goldwyer Formation conformably overlies the Willara Formation and is conformably overlain by the Nita Formation in most of the basin. R.M.L. Elliot (in Pudovskis & Willmott, 1961) and Young & O'Shaughnessy (1973b) suggested that the basal contact is disconformable in Thangoo Nos. 1, 1A, 2 (see under Willara Formation). In the Kidson Sub-basin, however, the formation conformably rests on the 'Middle Formation' and is overlain disconformably by the the Carribuddy Formation. Erosion has stripped much of the Palaeozoic sediments from parts of the western end of the Broome Arch, where the Goldwyer Formation is unconformably overlain by the Permian Grant Formation (Pl. 11-8). North of the Fitzroy Graben the Gap Creek Formation may conformably underlie the Goldwyer Formation but is unconfirmed in this area; no deep drilling has reached the base of the Goldwyer Formation.

The Goldwyer Formation is a diachronous unit; its lower part is a time correlative of the upper part of the Willara and Gap Creek Formations, and its upper part is a time correlative of the Nita Formation south of the Fenton Fault (Pl. 12-2).

Subdivision: The Goldwyer Formation has not been formally subdivided, though an informal threefold subdivision is evident in several of the wells. Where the carbonate is abundant enough to be identified as a distinct zone it forms a middle member - mainly limestone containing interbeds of shale - which separates and grades into the upper and lower member of shale. The relative thickness of each member varies.

Lithology: Mainly shale, green to black, fossiliferous, calcareous, pyritic, with interbedded limestone and dolomite, and minor lenses of siltstone. The shale is generally uniform across the basin. Slickensides and jointing were recorded in wells from the Kidson and Willara Sub-basins. Traces of anhydrite and phosphatic debris are present in Wilson Cliffs No. 1, and gypsum in Kidson No. 1. Siltstone, usually a minor constituent, is most abundant near the base of the formation; in the Kidson Sub-basin, and in Thangoo No. 2 on the Broome Arch, the siltstone grades to a sandstone at the base of the formation.

The carbonate is usually limestone, grey to white, crystalline, argillaceous, dolomitic in places, commonly dense and tight, forming pods, lenses, and beds. In Edgar Range No. 1 these beds are nodular and lenticular. Dolomite partly replaces the limestone in a few of the wells; it forms thin beds interbedded with limestone or shale as in Barbwire No. 1 and Blackstone No. 1, and more massive beds as in Thangoo Nos. 1 and 1A.

Generally, the sandstone and limestone beds in the Goldwyer Formation exhibited low porosity and little if any permeability. Porosities average 4%, and permeabilities from 11 to 23 md. A few very thin reservoirs are present in the sandstone beds in Wilson Cliffs No. 1. Primary porosities are not evident in the limestone beds. Porosity is evident in vugs in dolomite veins at the base of the dolomite in Thangoo No. 1A, where - however - permeability is poor. Several wells had hydrocarbon shows (stains and fluorescence (Table 2.6.1)).

The type section in Thangoo No. 1A is incomplete and not representative of the formation in most of the basin. A more typical section is that from Edgar Range No. 1, which contains:

177 m Shale, grey to black, fissile, hard, fossiliferous, with thin limestone beds. The interbedded limestone is grey, hard, fine-grained, nodular, and lenticular.

100 m Limestone, grey, argillaceous, fine-grained, hard, with interbeds of black to grey shale that constitute up to 50% of the lithology.

153 m Shale, grey to black, slightly silty, micaceous, pyritic in part, and calcareous. A few thin limestone stringers are present in the upper part, and the lower part becomes more silty.

Age: Llanvirnian (middle Ordovician). The abundant fauna includes trilobites, graptolites, brachiopods, nautiloids, ostracods, bivalves, conodonts, chitinozoans, and acritarchs. The formation is strongly diachronous across the basin (Pl. 12-2).

NITA FORMATION

Names from: Nita Downs homestead, 22 km southeast of Cape Missiessy.

Defined by: R.A. McTavish (in Playford & others, 1975).

Status of name: Formally defined.

Type section: 3821-4165 feet (1165-1269 m) in Parda No. 1 (18°56'08"S, 122°00'34"E). Station 229 (Appendix 12).

Previous name: 'E Member' of Carribuddy Formation; 'Evaporite Sequence' of Carribuddy Formation (lower part) in Willara No. 1; 'Unit A' in Blackstone No. 1.

Synonym: Roebuck Dolomite.

Modification: The sequence 3821-4165 feet in Parda No. 1 has been removed from the Goldwyer Formation and 'Red and Green Claystone' and defined as the type section of the Nita Formation. The 'E Member' has been removed from the Carribuddy Formation in Edgar Range No. 1, Matches Springs No. 1, and McLarty No. 1, and is now considered to be Nita Formation.

Outcrop: None known.

Distribution: McLarty No. 1, Barbwire No. 1, Munro No. 1, Willara No. 1, Parda No. 1, Edgar Range No. 1, Matches Springs No. 1, and Blackstone No. 1; Broome Arch, Barbwire and Margaret Terraces, and Willara Sub-basin. The eastern limit is uncertain. The formation was not identified in any of the wells that were drilled in the Kidson Sub-basin, but it may be present in the western part of the Sub-basin where the wells did not penetrate the Ordovician rocks. The formation is assumed to be present on the Jurgurra Terrace and possibly in the Fitzroy Graben.

Thickness variations: The thickest section is 250 m in Matches Springs No. 1. All other wells that encountered the formation intersected complete sections ranging in thickness from 52 m to 239 m: McLarty No. 1 (52 m), Barbwire No. 1 (52 m), Munro No. 1 (84 m), Willara No. 1 (137 m), Parda No. 1 (106 m), Edgar Range No. 1 (172 m), and Blackstone No. 1 (239 m). The Nita Formation appears to thicken to the north and thin to the east. It has not been identified on the western onshore Broome Arch, though the Roebuck Dolomite a lithological and time correlative is present in both Dampier Downs No. 1 and Roebuck Bay No. 1. Any inferences made from its thickness variations can only be tentative owing to the effects of erosion, particularly on the eastern Broome Arch, and the absence of data in the Fitzroy Graben.

Relations with other units: The Nita Formation conformably overlies the Goldwyer Formation. Their contact is gradational in several of the wells and more sharply defined where the basal lithology of the Nita Formation is a relatively clean limestone, as in McLarty No. 1. In Blackstone No. 1 their contact is difficult to pick owing to the relatively high proportion of shale in the Nita Formation (well column, Pl. 13-3). South of the Fitzroy Graben, their contact is gradational: it is picked at the base of a dominantly dolomite sequence; below this contact the lithology is wholly more than 50% shale.

The Carribuddy Formation unconformably overlies the Nita Formation south of the Fitzroy Graben. North of the graben, only Blackstone No. 1 intersected the Nita Formation, which is unconformably overlain by the Devonian Poulton Formation. The unconformity between the Carribuddy and Nita Formations is based on meagre dating of the Carribuddy Formation, which

suggests a hiatus encompassing the Late Ordovician and the Silurian; lithologically the contact appears to be conformable and, in places, gradational.

The formation is both a lithological and time correlative of the Roebuck Dolomite (Pl. 12-2) which should perhaps be considered part of the formation. In the Kidson Sub-basin, and in Blackstone No. 1 on the Margaret Terrace, the top of the Goldwyer Formation is a time correlative of the Nita Formation south of the Fitzroy Graben (Pl. 12-2). The Nita Formation in Blackstone No. 1 has no known time equivalents in the Canning Basin.

Anhydrite is most abundant in association with the dolomite near the top of the formation, and comprises up to 25% of the upper unit in Willara No. 1, but is absent from Edgar Range No. 1. In Blackstone No. 1, the formation is much more argillaceous than in the southern part of the basin, but, although it has a similar sequence of dolomite overlying limestone, anhydrite is again absent from the upper member.

Dolomitisation of the limestone is probably secondary or even tertiary. In Edgar Range No. 1, successive periods of dolomitisation are evident in some zones.

Generally the porosity is low and permeability is very low or not developed. The middle and lower units are uniformly tight, and show little or no signs of porosity or permeability, but vugs in the upper dolomite give some porosity to the formation. In Edgar Range No. 1 the vugular porosity in less argillaceous zones in which dolomite has replaced fossils of almost pure limestone is up to 12%. Porosity is best developed at former shell bed levels, where, however, permeability is low to non-existent.

Age: Llanvirnian to Llandeilian (middle Ordovician). Conodont studies by R.A. McTavish (Broad, 1973) restrict the Nita Formation to the middle Ordovician. Conodonts include Phragmodus sp. cf. P. inflexus, Ozarkodina spp., Chirognathus spp., Amorphognathus, and Panderodus gracilis (Playford & others, 1975). A middle Ordovician age is supported by microflora which yield a similar age. Bivalves from the Nita Formation including Ctenodonta suggest a slightly younger age - middle to early Late Ordovician.

EMANUEL FORMATION

Named from: Emanuel Creek, along which the type section is located.

Defined by: Guppy & Opik (1950); amended by Guppy & others (1958).

Status of name: Formally defined.

Type section: 594 m outcropping at Emanuel Creek (18°39'S, 125°55'E). Station 123 (Appendix 12).

Previous name: Emanuel Limestone.

Group: Forms the lower part of the Prices Creek Group.

Modifications: Originally measured by Guppy & Opik (1950) as 509 m thick. It was amended to 610 m by Guppy & others (1958), who restricted it to the limestone sequence: 594 m exposed, and an additional 15 m in a drillhole. Veevers & Wells (1961) included an additional 152 m intersected in BMR Prices Creek No. 3 to that of the exposed section, giving the formation a total thickness of 746 m.

Outcrop: Along Emanuel Creek on the south side of Emanuel Range and as low rises. Most of the outcrop is poorly exposed; the best exposures are along the creek.

Distribution: Prices Creek area around the Emanuel Range.

Thickness: 594 m in outcrop and 152 m in BMR Prices Creek No. 3 give a total composite thickness of 746 m.

Relations with other units: The base is not exposed in outcrop, and is obscured by faulting at the type section. Elsewhere the base is hidden by overlapping Permian rocks. In BMR Prices Creek No. 3 the formation unconformably overlies a tuff of possible Cambrian or Precambrian age. The Ordovician Gap Creek Formation conformably overlies it. It is a time equivalent of the Nambeet Formation (Pl. 12-2).

Lithology: Nodular grey fossiliferous limestone interbedded with silty sandstone and calcareous grey siltstone and shale. Glauconite is present in the limestone, especially near the base of the outcrop. Sandy grey dolomite and a basal grey to pale brown arkose underlie the fossiliferous limestone. Glauconite is also present in the dolomite and arkose of the subsurface section which has yielded no fossils.

Subdivision: The formation has not been formally subdivided, though an informal three-fold subdivision is evident in many of the wells, including the type section. The lower unit is interbedded shale and limestone in equal proportions or with limestone slightly more predominant. The middle unit is limestone (dolomite in Barbwire No. 1) with minor thin shale interbeds. The upper unit is a dolomite, often massive, interbedded with shale; the shale content may increase up to or exceed 50% at the top. The relative thickness of each member varies.

Lithology: The Nita Formation is chiefly a grey massive crystalline carbonate containing both limestone and dolomite in different proportions from well to well. Subordinate amounts of grey shale are interbedded with carbonate, and are most abundant at the base and at the top of the formations. Parda No. 1, the type section, encountered the following lithology, which is typical of the formation:

33m Dolomite, light to dark grey, finely massive, crystalline, argillaceous, calcareous, and anhydritic. Thin beds of grey shale and light grey crystalline limestone are interbedded with the dolomite. Traces of quartz and anhydrite are common; ghosts of macrofossils are less common.

52 m Limestone, pale grey, finely crystalline, dolomitic in part, fossiliferous, and massive. Interbedded with thin dark beds of grey shale.

21 m Limestone and shale interbedded. The limestone is light grey and crystalline; the shale is dark grey and thin-bedded.

The upper unit is missing in McLarty No. 1, where the formation is thin (57 m); its absence may be due to postdepositional erosion. Only dolomite - no limestone was recorded from the section in Barbwire No. 1. Whether this represents local development or postdepositional alteration is uncertain. This section is also abnormally thin although no direct relationship between the lithology and the thickness of this section is established.

Age: Early Ordovician (Tremodocian to Arenigian). The outcrop section contains an abundant fauna, Guppy & Opik (1950) recorded brachiopods, trilobites

(asapids, agnostids, pliomerids), gastropods, graptolites, nautiloids, ostracods, and conodonts, and erected four faunal stages. The oldest (stage I) contains the brachiopod Obulus, and is Tremadocian. Stage II contains the trilobite Xenostegium, and is Arenigian; so too is the younger stage III, which yielded a rich faunal assemblage. Guppy & Opik dated stage IV as early middle Ordovician.

Teichert & Glenister (1954) described the diverse nautiloid fauna, which includes Kyminoceras, Eothinoceras, Loxochoanella, Anthoceras, and Hardmanoceras. From their study they concluded that Guppy & Opik's stage IV is late Arenigian - not middle Ordovician - thus restricting the Emanuel Formation to the Early Ordovician. McTavish (in Playford & others, 1975) identified Distacodus expensus, Drepanodus proteus, and Scandodus furnishi, in the abundant conodont assemblage, and agreed that the formation is wholly Early Ordovician.

Other Emanuel Formation fossils which have an Arenigian age include the graptolites Didymograptus, Tetragraptus, and Clonograptus described by Thomas (1960); the cystoid Cheirocrinus described by Brown (1964); and the gastropod Teiichispira (Gilbert-Tomlinson, 1973).

GAP CREEK FORMATION

Named from: Gap Creek, near the type section.

Defined by: Guppy & Opik (1950); amended by Guppy & others, (1958).

Status of name: Formally defined.

Type section: 192 m outcropping near Gap Creek (18°35'S, 125°55'E), in the Noonkanbah 1:250 000 Sheet area. Station 123 (Appendix 12).

Previous name: Gap Creek Dolomite.

Redundant Synonym: 'Unnamed Carbonate Unit' in Tappers Inlet No. 1.

Group: Forms the upper part of the Prices Creek Group.

Modifications: Originally measured as 780 feet (239 m) by Guppy & Opik. Amended to 630 feet (192 m) by Guppy & others (1958).

Outcrop: Crops out on the south side of the Emanuel Range as strike ridges displaying well-marked bedding. Massive dolomite forms prominant ridges; the less resistant beds are usually obscured.

Distribution: Prices Creek area in the Emanuel Range between Prices Hill and Emanuel Creek. The middle Ordovician carbonate sequence in Tappers Inlet No. 1 is tentatively assigned to the Gap Creek Formation; if this correlation holds, the formation may be present over much of the north flank of the Fitzroy Graben and may extend south into the centre of the graben.

Thickness variations: 192 m is exposed in outcrop at the type section. In Tappers Inlet No. 1 it is 187 m thick. As these two stations are so widely separated, any discussion of thickness variations would be based on conjecture. The unit is presumed to thin or to be faulted out to the north, and to thicken to the south.

Relations with other units: The Gap Creek Formation conformably overlies the Emanuel Formation in the Prices Creek area, and the Nambeet Formation on the west coast. Strike faulting is suspected at the base of the outcrop section in the Prices Creek area. The Poulton Formation unconformably overlies the Gap Creek Formation in Tappers Inlet No. 1. In the Prices Creek area, an angular unconformity ranging in dip from 5° to 40° separates it from the overlying Devonian Pillara Formation.

The Gap Creek Formation is a partial lithological correlative of the Willara Formation, and a time equivalent of the lower part of the Goldwyer Formation and the upper part of the Willara Formation. Although it also has some lithological similarities to the Nita Formation, its age and relative stratigraphic position support correlation with the older Ordovician carbonate sequence of the Willara Formation rather than the Nita Formation. Veevers & Wells (1961) equated it to all the Goldwyer Formation and the upper part of the Willara Formation intersected in Thangoo Nos. 1 and 1A.

Subdivision: None.

Lithology: Predominantly a carbonate sequence with interbedded sandstone, siltstone, and shale.

At the type section the main rock type is massive crystalline grey dolomite which weathers light brown and has a granular texture due to the

dolomite rhombs on the surface. It is interbedded with light grey calcarenite, red siltstone, and calcareous dolomitic sandstone. The basal section is a thin-bedded fossiliferous limestone. Near the top the sandstone content increases. Several levels in the formation have yielded fossils, which, however, are commonly silicified and less abundant than in the underlying Emanuel Formation.

In Tappers Inlet No. 1 the carbonate is a fine crystalline dolomitic and argillaceous limestone rather than dolomite, as in the type section. It is fossiliferous in part, and commonly contains finely disseminated pyrite. Near the base the limestone becomes slightly more arenaceous and thin beds of dolomite are evident. The upper part is mainly red to brown calcareous, micaceous, silty shale with minor beds of limestone. The shale becomes darker with depth, ranging from brown to grey to black.

The upper shale sequence of rocks is missing at the type section, probably as a result of postdepositional erosion.

Age: Latest Arenigian to early Llanvirnian. The Gap Creek Formation forms the youngest sequence, stage V of Guppy & Opik's (1950) faunal stages. The fauna is more restricted than that in the underlying Emanuel Formation and commonly silicified. Guppy & Opik (1950) recorded an assemblage containing trilobites (including Bumastus), brachipods (Spanodonta hoskingae), gastropods, and ostracods from the type section, and assigned a late Llandeilian age (late middle Ordovician) to it. Teichert & Glenister (1954) assigned the formation to the Llanvirnian (early middle Ordovician) from their study of the nautiloid assemblage. Gilbert-Tomlinson (1973) described the gastropods, and agreed with the Llanvirnian age. However, R.A. McTavish (in Playford & others, 1975) studied the conodonts and placed the Gap Creek Formation in the latest Arenigian (lower than any previous worker). The conodont assemblage in Tappers Inlet No. 1 yielded an age of late Arenigian to early Llanvirnian (P.G. Quilty in Crank, 1971), and WAPET assigned the rocks in Tappers Inlet No. 1 to the middle Ordovian.

The formation appears to be diachronous from east to west between Gap Creek and Tappers Inlet No. 1, but may well represent later deposition on the Pender Terrace. Farther south the formation probably has a similar age to that at the type section.

CARRANYA BEDS

Named from: Carranya Station, in the Billiluna 1:250 000 Sheet area.

Defined by: R.A. McTavish (Playford & others, 1975). It was originally described by A.T. Wells (Wells, 1962c; Casey & Wells, 1964) but was not named.

Status of name: Formally defined.

Type section: 107 m outcropping 14 km west of Wolf Creek Meteorite Crater in the Billiluna 1:250 000 Sheet area (19°11'00"S, 127°40'00"E). Station 168 (Appendix 12).

Previous name: None given.

Modifications: The type section is 107 m thick, and has a basal sequence of fine-grained, well-sorted sandstone (Yeates & others, 1975b). Recent mapping by BMR geologists (Blake, Hodgson & Muhling, in press) has included some rocks previously mapped as Precambrian Kearney Beds in the Carranya Beds, but excluded rocks south of the type section originally mapped as Ordovician.

Outcrop: The Carranya Beds crop out as low-lying, widely separated rises along the basin margin on the Billiluna Shelf. The beds dip between 5° and 40° and are flanked by pebbles and scree.

Distribution: They are exposed only in the Billiluna and Mount Bannerman 1:250 000 Sheet areas. They have not been identified in any well sections, so their subsurface limits are unknown, but are probably confined to the Billiluna Shelf.

Thickness variation: The thickest measured section is an eroded one of 135 m that crops out 15 km west of the type section. The Carranya Beds are estimated to have a maximum thickness of 500 m (Yeates & others, 1975b). Outcrop thicknesses suggest the beds thicken to the west and away from the basin margins.

Relations with other units: The Carranya Beds lie with angular unconformity on Proterozoic (Carpentarian) Baines Beds (Blake & others, in press). Their lower contact is generally concealed, but where exposed occurs on a scree-covered slope. Their upper contact is uncertain: the top is eroded and exposed everywhere in outcrop. Regional relations suggest that the Carranya Beds are unconformably overlain by the Devonian Knobby Sandstone, which crops out west and south of the Carranya Beds in the Billiluna 1:250 000 Sheet area. Farther west, in the Mount Bannerman 1:250 000 Sheet area, the Carranya Beds are unconformably overlain by the Permian Grant Formation. Yeates & others (1975b) suggest that they are unconformably overlain by Upper Ordovician to Lower Devonian rocks in the subsurface.

Both the Emanuel and Nambeet Formations are time equivalents of the Carranya Beds. The Carranya Beds also have some lithological similarities to the Nambeet Formation in Wilson Cliffs No. 1 and the basal sandstone of the Emanuel Formation in BMR Prices Creek No. 3.

Subdivisions: None proposed.

Lithology: Mainly sandstone, white to brown, fine to medium-grained, with subordinate thin beds of rounded pebble and cobble conglomerate and intraformational claystone conglomerate. It is thin to medium-bedded with some low-angle small-scale cross-bedding and thin bands of ferruginised and silicified sandstone. The basal section is a fine-grained, well-sorted bioturbated sandstone, which grades up into a more poorly sorted coarser-grained sequence of sandstone and interbedded conglomerate. The conglomerate consists of well-rounded quartz and quartzite pebble and cobbles in a quartz sandstone matrix. Macrofossils and trace fossils are abundant in the basal sandstone.

Age: Arenigian (Early Ordovician). Only the type section has yielded fossils. Collections include the trilobite Dikelokephalina (Gilbert-Tomlinson, BMR, personal communication 1976; Casey & Wells, 1964), the gastropod Ophileta sp. (Gilbert-Tomlinson, BMR, 1971, personal communication), and indeterminate trace fossils and pelecypods.

ROEBUCK DOLOMITE

Named from: Noted stated, but probably named after Roebuck Bay No. 1, which contains the type section.

Defined by: McWhae & others (1958); amended to Thangoo Limestone by R.M.L. Elliot (in Pudovskis & Willmott, 1961).

Status of name: Formally defined.

Type section: Originally defined by McWhae & others (1958) as 3660-4000 feet (1116-1219 m) in Roebuck Bay No. 1 (station 19, in Appendix 12) where it comprises Ordovician and Devonian sediments. A better type section would have been between 2625-3028 feet (800-923 m) in Dampier Downs No. 1 (18°18'00"S, 123°06'00"E; station 25), where the section identified as Roebuck Dolomite is wholly Ordovician in age.

Previous names: 'Unnamed Formation' in Dampier Downs No. 1 and 'Unnamed Dolomite' in Roebuck Bay No. 1.

Modifications: R.M.L. Elliot (in Pudovskis & Willmott, 1961) defined the name Thangoo Limestone to replace the combined Thangoo Calcarenite and Roebuck Dolomite. The type section chosen for the Thangoo Limestone in Thangoo No. 1A was later found not to be equivalent to either formation, so Playford & others (1975) retained the name Roebuck Dolomite and reinstated the original definition. Conodont dating by McTavish (Broad, 1973) suggests only the basal 9 m (3980-4010 feet) of the type section is Ordovician and the rest is Devonian.

The Roebuck Dolomite is both a lithological and time equivalent of the Nita Formation. Because it has been identified in only two wells and closely resembles the dolomitic part of the Nita Formation, it is recommended that the name Roebuck Dolomite be dropped and those sections now identified as Ordovician Roebuck Dolomite be included in the Nita Formation.

Outcrop: None described.

Distribution: Dampier Downs No. 1 and Roebuck Bay No. 1. Its distribution is therefore restricted to a local area on the onshore western Broome Arch.

Thickness variation: Neither well reached the base of the formation. Dampier Downs No. 1 penetrated 123 m of the Roebuck Dolomite before reaching total depth.

Relations with other units: The Roebuck Dolomite is assumed to conformably overlie the Goldwyer Formation. In Roebuck Bay No. 1 the Devonian part of the Roebuck Dolomite unconformably overlies it. The formation as defined by McWhae & others (1958) is unconformably overlain by the Thangoo Calcarenite. In Dampier Downs No. 1 the Grant Formation unconformably overlies it.

The Roebuck Dolomite is a time equivalent and a lithological equivalent (at least of the upper part) of the Nita Formation and should be included in the Nita Formation.

Subdivision: None.

Lithology: In the original definition, McWhae & others (1958) described the lithology as dolomite, pale grey to greenish grey, forming a monotonous sequence. The section in Dampier Downs No. 1 consists of:

123 m Dolomite, light grey to white, fine to coarse-grained, crystalline, granoblastic texture, vugular with drusy calcite and dolomite crystals in the vugs, which are 1-3 mm in diameter and unconnected. Vugs were not recorded in the 9 m of Ordovician Roebuck Dolomite in Roebuck Bay No. 1. The porosity and permeability are entirely due to fractures and fissures.

Age: Llanvirnian (middle Ordovician). Conodonts and brachiopods from both the abovementioned wells date the Roebuck Dolomite as Early Ordovician. Glenister & Glenister (1958); the conodonts include Drepanodus homocurvatus, Acontiodus arcuatus, Paltodus sp., Gothodus sp. nov., Oepikodus sp., and the brachiopods, Pomatotrema. R.A. McTavish re-examined Glenister & Glenister's conodonts and examined a new conodont fauna from the formation, and determined the age of the formation as no older than middle Ordovician (Playford & others, 1975). Crespin and Condon (1956) tentatively assigned the type section in Roebuck Bay No. 1 to the Devonian.

'MIDDLE FORMATION'

Named from: Middle sequence of rocks of Ordovician age in Wilson Cliffs No. 1.

Defined by: Not defined.

Status of name: Informally used in the Kidson Sub-basin. Not defined.

Type section: None.

Previous name: Thangoo Limestone equivalent in Kidson 1.

Modifications: None.

Outcrop: None identified.

Distribution: Wilson Cliffs No. 1, Contention Heights No. 1, and Kidson No. 1. It is known only in the Kidson Sub-basin and Ryan Shelf from wells in the eastern and southern parts of the basin. The western limit is unknown, but is probably within the sub-basin. No other wells in the sub-basin drilled deep enough to intersect the unit.

Thickness variation: Both Wilson Cliffs No. 1 (110 m) and Contention Heights No. 1 (93 m) intersected complete sections. Kidson No. 1 was abandoned 19 m into the unit and did not reach its base. On the evidence of the two wells that intersected complete sections, the 'Middle Formation' thins to the east; it probably thickens significantly to the west and south of these wells and may attain a maximum thickness similar to that of the Willara Formation.

Relations with other units: It conformably overlies the 'Lower Formation' (now Nambeet Formation) in the Kidson Sub-basin; in Wilson Cliffs No. 1 the lower boundary is the lithological change from sandstone to dolomite. The carbonate sequence is missing in Contention Heights No. 1, where the lower boundary is placed at the base of dolomitic sandstone. The Goldwyer Formation conformably overlies the top of the formation.

The 'Middle Formation' is a time equivalent of the Willara Formation. Creevey (1969) correlated it with the Horn Valley Siltstone of the Amadeus Basin.

Suvdivision: None proposed.

Lithology: Mainly sandstone and dolomite. In Wilson Cliffs No. 1 the formation consists of:

72 m Sandstone, white, fine-grained, silicified, calcareous, and pyritic, with minor amounts of glauconite, grading to white quartzitic siltstone near the top. Grey argillaceous limestone and dolomite form rare patches and interbeds, but are more common towards the base. Dark shale forms rare interbeds. Porosity and permeability are low.

38 m Limestone and dolomite, fossiliferous pyritic, glauconitic, slightly silty, with phosphatic debris and traces of gypsum. Grey to black shale interbeds are present in the upper part.

The lower carbonate sequence is missing in Contention Heights No. 1. It consists of a dolomitic sandstone which is more dolomitic near the base. Kidson No. 1 did not penetrate the basal section.

Age: Arenigian to Llanvirnian (Early to middle Ordovician). A core at the base of the Wilson Cliffs No. 1 section yielded echinoderms, pelecypods, brachiopods, ostracods, and trilobites. Chitinozoa microfauna from the same core yielded a Llandelian-Llanvirnian age, whereas the conodont assemblage suggests a late Arenigian to early Llanvirnian age. Creevey (1969) assigned the unit to the middle Ordovician. Recent dating of conodonts by McTavish and macrofauna by Legg (Broad, 1973) restrict the 'Middle Formation' to the late Arenigian.

APPENDIX 2. STRATIGRAPHIC UNITS OF INTERVAL 2

Interval 2 comprises three formations: the Carribuddy Formation, Tandalgoo Red Beds, and Poulton Formation.

CARRIBUDDY FORMATION

Named from: Carribuddy Springs, 16 km northeast of Sahara No. 1.

Defined by: Koop (in Singleton, 1965).

Status of name: Formally defined.

Type section: 1727 m to 2120 m (total depth) in Sahara No. 1 (station 215 in Appendix 12).

Previous name: Previously unknown.

Modifications: McTavish & Legg (1976) have transferred parts of the original Carribuddy Formation in Parda No. 1, Willara No. 1, McLarty No. 1, Edgar Range No. 1, and Matches Springs No. 1 to the Nita Formation.

Outcrop: None described.

Distribution: Matches Springs No. 1, Edgar Range No. 1, Parda No. 1, Willara No. 1, McLarty No. 1, Kemp Field No. 1, Sahara No. 1, Kidson No. 1, Wilson Cliffs No. 1, Crossland No. 2, Munda No. 1, Barbwire No. 1, Contention Heights No. 1, Munro No. 1.

The formation is bounded by the southern limits of the Kidson Sub-basin and disappears to the northwest on the Broome Arch. Its possible extension north of the Fenton Fault has not been described. The diapiric salt in Frome Rocks No. 1, and parts of Poulton Formation in Blackstone No. 1 may be parts of the Carribuddy Formation.

Thickness variation: Five wells have penetrated the full section of the formation, Kidson No. 1 (1709 m), Contention Heights No. 1 (432 m), Wilson Cliffs No. 1 (319 m), Barbwire No. 1 (296 m), and Matches Springs No. 1 (241 m). The incomplete sections, with the exception of Sahara No. 1 and Kempfield No. 1, all show erosion of the upper part of the formation.

Relations with other units: The formation overlies the Ordovician Nita Formation in Parda No. 1, Willara No. 1, McLarty No. 1, Edgar Range No. 1, and Matches Springs No. 1, and the Goldwyer Formation in Kidson No. 1, Wilson Cliffs No. 1, and Contention Heights No. 1. Originally the 'E Member' of the Carribuddy Formation (now redefined as the Nita Formation) was thought to be a regressive sequence in the lowermost part of the formation conformable below the rest of the formation in Parda No. 1, McLarty No. 1 and Edgar Range No. 1; however, an unconformity apparently separates the base of the Carribuddy red bed facies and the top of what is now referred to as the Nita Formation in Willara No. 1.

WAPET geologists in Kidson No. 1 described the lower boundary of the Carribuddy Formation as 'sharp on both the induction and gamma ray/sonic logs', but ditch samples showed no immediate change in lithology. The continuous dipmeter survey indicated that the dip of the bedding varies from the northeast to the northwest in the Carribuddy Formation to a dominant northeast in the Goldwyer Formation. Hence the boundary between the units is moderately disconformable. In Contention Heights No. 1 the boundary between these two formations is also inferred to be an unconformity, although here, as in Wilson Cliffs No. 1, there is no information to support this interpretation. In Matches Springs No. 1, there is no lithological evidence for a disconformity between the formation and the underlying Nita Formation (the 'Unnamed Formation' of Jaque, Stobel, & Sweeney, 1970). Similarly Munro No. 1 lacks lithological evidence of a disconformity below the Carribuddy Formation.

The upper contact of the formation is the unconformable base of the Permian in all wells except Kemp Field No. 1, Sahara No. 1, Kidson No. 1, Wilson Cliffs No. 1, and Contention Heights No. 1, where it is conformably overlain by the Tandalgoo Red Beds, and Matches Springs No. 1, where it passes conformably up into the Tandalgoo Red Beds equivalent.

The Carribuddy Formation boundary with the Tandalgoo Red Beds is probably diachronous. Biostratigraphic data imply a hiatus between the deposition of the Nita Formation and that of the Carribuddy Formation, although available evidence is insufficient to discount the possibility of this boundary also being diachronous. The Carribuddy Formation may have time equivalents in the basal Devonian red beds to the north of the Fitzroy Graben.

Subdivision: The incomplete type section of Sahara No. 1 comprise two minor lithologic units:

unit A - 613 m, spotted shale
unit B - 89 m, interbedded evaporites.

In Kidson No. 1, the thickest complete section of the Carribuddy Formation comprises five units:

unit A - 376 m, mainly dolomite
unit B - 542 m, mainly halite
unit C - 428 m, mainly grey claystone
unit D - 164 m, red-brown claystone with dolomite and halite interbeds
unit E - 207 m, red claystone and minor halite.

This subdivision has been applied to all wells, except Munro No. 1 and Barbwire No. 1.

Lithology: Kidson No. 1 comprises the following lithologies:

Unit A. Dolomite with minor interbedded dolomitic siltstone, shale, and rare sandstone beds. The dolomite, mistaken for a siltstone at the well site, is hematite stained with local centimetre-scale green spots. Silt and fine quartz grains are common, and the lithology grades into dolomitic siltstone. Anhydrite is scattered throughout as inclusions and fracture fillings. The sandstone is very fine-grained, and shallow-water sedimentary structures are present.

Unit B. Halite with minor dolomitic siltstone grading downwards to dolomite. The halite is hematite-stained, brown to colourless, and contains fine-grained detrital inclusions and scattered sand grains. The siltstone and dolomite are similar to that of Unit A. Swelling clays are present.

Unit C. Grey calcareous and dolomitic claystone grading locally into limestone, dolomite, or siltstone, and interbedded with minor halite at the top and bottom and rare sandstone. Anhydrite, collophane, and sparry calcite are scattered through the claystone. The sandstone is fine-grained and rounded with a calcareous and argillaceous matrix. The halite is clear to brown with inclusions of the other lithologies.

Unit D. Red-brown claystone and dolomite with halite interbeds. The claystone has local grey to green streaks and mottling. It is calcareous and dolomitic, and grades to argillaceous dolomite and occasionally to a very fine argillaceous sandstone. Rare inclusions of anhydrite occur. Halite occurs as interbeds and scattered crystals throughout the claystone.
Unit E. A continuation of unit D, but with a low evaporite content. Interbedded and gradational red-brown claystone and argillaceous dolomite contain rare thin beds, veins, and scattered crystals of halite and anhydrite.

Age: Sparse Devonian spores are found in Parda No. 1, poorly preserved Endothyrid forams are found in Kidson No. 1, and Lower Devonian, and Middle and/or Upper Devonian spores and pollens, together with a conodont related to the Ordovician morphotype, Trucherognathus distortus, are known from the Contention Heights No. 1. The age span of the formation cannot be precisely delineated.

POULTON FORMATION

Named from: Poulton Pool on the May River, 22 km north-northwest of Blackstone No. 1.

Defined by: Playford & others (1975).

Status of name: Used informally by WAPET. Reserved for formal definition Playford & Cope in 1970. Used in the Annual Report of the Geological Survey of Western Australia in 1970.

Type section: Taken to be that of the informally proposed Blackstone Beds (Johnson, 1968) between 1914 m and 2220 m in Blackstone No. 1 (station 58 in Appendix 12).

Redundant synonyms: Blackstone Beds (Johnson, 1968), which had already been used in Queensland, and Station Creek Beds (defined in Newstead & Temple, 1971).

Outcrop: None described.

Distribution: Blackstone No. 1, Napier Nos. 1, 2, 4, and 5, Tappers Inlet No. 1, Lake Betty No. 1, and Meda No. 1.

Thickness variations: True thicknesses are not preserved in known sections. The preserved thicknesses increase from 67.36 m in Lake Betty No. 1 and 65.22 m in Tappers Inlet No. 1 to 401 m in Napier No. 1.

Relations with other units: In Meda No. 1 and Napier Nos. 1, 2, 4, and 5, the formation rests unconformably on the Precambrian. In Blackstone No. 1 and Tappers Inlet No. 1 the formation is unconformable on the Ordovician. Lake Betty No. 1 did not reach the base of the formation. The Van Emmerick Conglomerate in Napier Nos. 1 and 5, and the Pillara Formation in Tappers Inlet No. 1, Napier No. 4, and Meda No. 1, overlie the formation unconformably. In Lake Betty No. 1 the overlying Luluigui Formation is presumed to be faulted against the Poulton Formation.

The Carribuddy Formation is probably a time equivalent of the lower part of the Poulton Formation, and the Tandalgoo Red Beds are probably also a time equivalent of part of the formation. Other age equivalents are probably represented in the section at the base of Noonkanbah No. 5, and possibly the Mellinjerie Limestone.

Subdivision: None.

Lithology: The thickest section, in Napier No. 1, comprises the following lithologies:

30 m Red siltstone and interbedded red cross-bedded sandstone with some animal burrows

7 m Sandstone, coarse angular to subrounded, chloritic

29 m Siltstone, grey to dark-brown, with thin stringers of hard dolomitic sandstone

96 m Sandstone, grey, red, or white, fine to coarse, with interbedded siltstone, red-brown, grey, and grey-green.

45 m Sandstone, pink, fine to medium, angular, with occasional grey-green siltstone (partly carbonaceous) and local grey brown shale

103 m Sandstone, white, arkosic, subangular, fine to coarse, chloritic pyrobituminous, commonly slumped, interbedded with fossiliferous limestone and hard dolomite, grey-green and red shale, and grey siltstone

91 m Sandstone, medium to coarse, partly pebbly conglomeratic at base, with interbedded red shale, rare thin limestone, and rare gypsum in red beds. Channel filling is common.

In Blackstone No. 1 a rise in the salinity of the drilling fluid during penetration of the Poulton Formation is thought to have been due to the dissolution of salt from the formation.

Age: Middle Devonian spores have been recovered from Napier No. 1, Lake Betty No. 1, and Blackstone No. 1, where the flora is older than any other known Devonian flora in Western Australia. Tappers Inlet No. 1 yielded Givetian/Frasnian spores.

TANDALGOO RED BEDS

Named from: Tandalgoo Rock Hole, 8 km north-northeast of Sahara No. 1.

Defined by: Koop (in Singleton, 1965); Koop (1966).

Status of name: Formally defined.

Type section: From 1128 m to 1727 m in Sahara No. 1 (station 215 in Appendix 12).

Previous names: Previously unknown.

Modifications: None.

Outcrop: None described.

Distribution: Kemp Field No. 1, Sahara No. 1, Kidson No. 1, Wilson Cliffs No. 1, Barbwire No. 1, and Contention Heights No. 1. Matches Springs No. 1 contains Tandalgoo Formation equivalents. Except in Matches Springs No. 1 and Barbwire No. 1 the Tandalgoo Red Beds are known only from the Kidson Sub-basin; they were probably eroded from the Carribuddy Formation stations in the Willara Sub-basin.

Thickness variations: The true thickness of the beds has been penetrated at all subsurface stations. The thickest section is in Kidson No. 1 (803 m), and the unit thins to the east (61 m) in Contention Heights No. 1, and to the northwest. (395 m in Kemp Field No. 1).

Relations with other units: The Tandalgoo Red Beds have a conformable, often abrupt lower boundary with the Carribuddy Formation, and a conformable and gradational upper boundary with the Mellinjerie Limestone in all wells but Matches Springs No. 1; both contacts are probably diachronous. In Matches Springs No. 1 the Tandalgoo Red Beds equivalent conformably overlies the Carribuddy Formation and is overlain by an unnamed carbonate unit lithologically similar to the Mellinjerie Limestone. The formation is equivalent to part of the Poulton Formation.

Subdivision: The type section comprises four informal units:

transition unit A - 72 m
red sandstone unit B - 160 m
shaly unit C - 58 m
red sandstone unit D - 309 m

This subdivision has been applied to the unit in both Kemp Field No. 1 and Matches Springs No. 1, and other subdivisions have been proposed at Wilson Cliffs No. 1 (three-fold) and Barbwire No. 1 (four-fold). The unit has not been divided in Kidson No. 1 and Contention Heights No. 1.

Lithology: The type section, Sahara No. 1, comprises the following lithologies:

Transition unit A - 72 m

Limestone, cream, partly silty, rarely fossiliferous, interbedded with sandy siltstone grading to fine sandstone, red shale, and white to chocolate medium sandstone.

Red sandstone unit B - 160 m

Sandstone, orange-red to white, fine to rarely coarse, with minor red to grey siltstone grading to chocolate to light-green shale, slightly carbonaceous.

Shaly unit C - 58 m

Shale interbedded with sandstone - white to maroon, fine, rounded, well-sorted - and siltstone - red-brown to grey, anhydritic.

Red sandstone unit D - 309 m

Sandstone, red, brown, and white, very fine to medium; and subordinate siltstone, red, brown, and white, anhydritic, with rare grey lithographic limestone.

Age: The unit has yielded Middle Devonian spores in Matches Springs No. 1, Givetian to Frasnian conodonts and spores in Barbwire No. 1, and Devonian spores and Dittonian to late Downtonian fish scales (Gross, 1971) in Kidson No. 1.

APPENDIX 3. STRATIGRAPHIC UNITS OF INTERVAL 3

The most recently published comprehensive account of the stratigraphy of the rocks of this interval (Playford & Lowry, 1966) has been superseded by unpublished WAPET reports, and by a short publication (Playford, 1976). This appendix describes the lithostratigraphic units, some not formally defined, that a number of workers have recently named. Many of the carbonate formations have been defined from an interpretation of their depositional environments. These interpretations and the consequent definitions of lithostratigraphic units have recently been challenged (Logan & Semeniuk, 1976).

LENNARD RIVER GROUP

Named from: Lennard River.

Defined by: WAPET.

Status of name: Not formally defined, and not apparently recognised by other workers.

Nature of group: The rocks of the Devonian carbonate complex of the Canning Basin.

Stratigraphic relations: The group overlies the Tandalgoo Red Beds or older rocks, and is overlain by the Fairfield Group.

Age: Givetian to Famennian.

FAIRFIELD GROUP

Named from: Fairfield Valley (17°35'S, 125°00'E).

Defined by: Druce & Radke (in press). The name was previously used by Kraus (1941), Guppy & others (1958) and Playford & Lowry (1966).

Nature of group: The post-carbonate complex mixed facies sequence of the Late Devonian-Early Carboniferous transgressive-regressive cycle.

Subdivision: The group comprises three formations:

Laurel Formation
Yellow Drum Sandstone
Gumhole Formation

Stratigraphic relations: The group rests conformably on the rocks of Bohemia Subgroup. The upper boundary is generally an unconformity overlain by Permian rocks. In the Fitzroy Trough the group may be conformably overlain by the Anderson Formation.

Age: Late Famennian to Tournaisian.

ANDERSON FORMATION

Named from: Mount Anderson.

Defined by: McWhae & others (1958).

Status of name: Formally defined.

Type section: Grant Range No. 1 (18°00'48"S, 124°00'22"E).

Modifications: Extended upward to include the St George Formation.

Outcrop: No outcrop section has been definitely assigned to the formation, but sands in the Bohemia Downs area (Playford & others, 1974) and Red Bluffs area (Druce & Radke, in press) may be correlated with the formation.

Distribution: Considered to be present in May River No. 1, Langoora No. 1, Meda Nos. 1 and 2, St George Range No. 1, Barlee No. 1, Yulleroo No. 1, AFO Nerrima No. 1, Grant Range No. 1, Point Moody No. 1, Lacepede No. 1A, Logue No. 1, and Fraser River No. 1. It is probably also present in Sisters No. 1 and Lake Betty No. 1. The known tract extends across the northwestern part of the Fitzroy Graben, and indications are that it continues along the graben offshore and onshore.

Thickness variation: None of the wells has penetrated a complete section. The thickest section is 2550 m in Yulleroo No. 1, in the southern part of the Fitzroy Graben. It thins northward to 37 m in Langoora No. 1, and to the south, where it does not extend south of the Fenton Fault.

Relations with other units: The base of the formation was not penetrated in Barlee No. 1, AFO Nerrima No. 1, Point Moody No. 1, Lacepede No. 1A, and Grant Range No. 1. Its top is everywhere truncated by unconformity. It underlies the Grant Formation in all wells except Barlee No. 1, and Lacepede No. 1A, where it underlies Jurassic sediments.

The lower part of the formation is the time equivalent of parts of the Fairfield Group. It rests conformably on the Fairfield Group in all the other wells except Logue No. 1, where it conformably overlies the Clanmeyer Siltstone.

Subdivision: None.

Lithology: The type section consists of an alternating sequence of sandstone, shale and siltstone, with thin beds of limestone dolomite and anhydrite, especially in the upper part. Considerable lithological variation occurs in other sections.

Age: At the type section a fauna including the conchostracan Leaia (Hemicyclokiua), and the bivalves Naiadites sp. cf. N. modiolaris and forms related to Anthracosia, were thought to indicate a lower Stephanian to Westphalian age. Bischoff (in Gewerkschaft Elwerath, 1968) dated rocks in Yulleroo No. 1 which are now equated with the Anderson Formation as follows:

unit A - Visean to Namurian E_1

unit B - No date

unit C - Tournaisian to Visean

BABRONGAN BEDS

Named from: Babrongan No. 1.

Defined by: Playford & others (1975).

Status of name: Formally defined.

Type section: Between 1736 m and 1949 m in Babrongan No. 1 (18°23'23"S, 123°35'37"E)

Previous names: None.

Modifications: None.

Outcrop: None recognised.

Distribution: Only in Logue No. 1 and Babrongan No. 1 - that is, only on the Jurgurra Terrace.

Thickness variations: 69 m in Logue No. 1 and 213 m in the type section, but neither well penetrated the basement.

Relations with other units: Its relations with underlying units are not known. It conformably underlies the Clanmeyer Siltstone in both wells. It probably has tine equivalents in some Famennian formations.

Lithology: Red-brown shale and siltstone interbedded with brown and grey dolomite and dolomitic limestone in the type section.

Age: In Logue No. 1 the contained assemblage may have resulted from caving, but did not indicate an age older than Late Devonian.

CLANMEYER SILTSTONE

Named from: Clanmeyer Pool (18°14'3"S, 123°44'8"E).

Status of name: Formally defined.

Type section: Between 713 m (2340 ft) and 1736 m (5697 ft) in Babrongan No. 1 (18°23'23"S, 123°35'37"E).

Modifications: None.

Outcrop: Not recognised in outcrop.

Distribution: Sisters No. 1, Laurel Downs No. 2, Babrongan No. 1, Frome Rocks No. 2, and Logue No. 1 - that is, only along the margins of the Fitzroy Graben.

Thickness variation: Only Laurel Downs No. 2 has penetrated a full section of the formation - 465 m. The incomplete sections range from 378 m (in Frome Rocks No. 2) to 1066 m (in Logue No. 1).

Relations with other units: The formation rests conformably on the Babrongan Beds in Logue No. 1 and Babrongan No. 1, and on the Gogo Formation in Laurel Downs No. 2. It conformably underlies the Luluigui Formation in Sisters No. 1, Laurel Downs No. 2, and Frome Rocks No. 2, and has a faulted or unconformable contact with the Luluigui Formation in Babrongan No. 1; in Logue No. 1 it unconformably underlies Luluigui Formation.

Subdivision: None.

Lithology: In the type section: grey-green siltstone with interbedded fine sands and fossiliferous calcarenites; nodules, lenses, and beds of limestone are present in the lower part.

Age: Microspores and the goniatite (?Platyclymenia sp.) indicate a middle to late Famennian age.

GOGO FORMATION

Named from: Gogo station.

Defined by: Guppy & others (1958).

Status of name: Formally defined.

Type section: Measured along the northern flank of the Pillara Range (18°36'S, 125°26'E).

Previous names: Part of the Wade's (1936) Gogo Stage, which included the redefined Gogo Formation and lower unfossiliferous part of the Virgin Hills Formation.

Modifications: Playford & Lowry (1966) introduced the interpretative concept of the Gogo Formation as an inter-reef facies equivalent of the Sadler Limestone. This hypothetical interpretation is not applied here.

Described outcrop: Restricted to the area south of the Fitzroy River in the Bugle Gap, Emanuel Range, and Pillara Range areas.

Distribution: Wells that have penetrated the formation are Matches Springs No. 1, Mowla No. 1, Barbwire No. 1, Noonkanbah No. 1, Laurel Downs No. 1 and Napier No. 1. The foomation is distributed about the margins of the trough.

Thickness variations: The maximum described thickness is 320 m from an unlocated poorly exposed outcrop. Napier No. 4 penetrated 366 m of the formation, whose thinnest development is 33 m in Barbwire No. 1.

Relations with other units: The formation lies conformably between Devonian carbonates, except in Napier No. 4, where the lower contact is with basement, and in Noonkanbah No. 1, the Laurel Downs No. 1. It is a time equivalent of the Sadler Limestone, with which it interfingers.

Subdivision: None.

Lithology: The lithology changes rapidly through siltstone, sandstone, and calcarenite. Quartz clastics increase towards the top, where zones of biohermal limestone occur. Concretions characterise the outcropping lithologies.

Age: Ammonoids - e.g., *Timanites angustus* - indicate a Frasnian age.

BEHN CONGLOMERATE

Named from: Mount Behn (17°29'S, 125°05'E).

Defined by: Guppy & others (1958).

Status of name: Never adequately defined.

Type section: Never proposed.

Previous names: None.

Modifications: Traditionally grouped with the Van Emmerick Conglomerate. Described as a facies variation of the Napier Formation by Guppy & others (1958).

Described outcrop: Mount Behn and vicinity.

Distribution: Not recorded outside area of outcrop.

Thickness: No measured thicknesses are reported. The formation is estimated to be about 300 m thick.

Relations with other units: Unconformably overlies basement and the Pillara Formation. It interfingers with and underlies the Napier Formation.

Age: Middle Famennian to middle Frasnian from bracketing and interfingering.

BUGLE GAP LIMESTONE

Named from: Bugle Gap.

Defined by: Guppy & others (1958).

Status of name: Formally defined.

Type section: Southwest end of Bugle Gap (18°42'S, 126°04'E).

Previous names: Part of the Mount Pierre Series of Wade (1936).

Modifications: None.

Described outcrop: Bugle Gap and Old Bohemia areas.

Distribution: Restricted to the area of outcrop.

Thickness variation: Guppy & others (1958) measured two sections as 290 m, which may have been a complete section, and 375 m. Playford & Lowry (1966) have indicated that the true thickness of the type section is about 150 m, or less if depositional dips of up to 30° exist within the formation.

Relations with other units: The Bugle Gap Limestone underlies the Fairfield Group with possible conformity, and is truncated in places by the pre-Grant Formation unconformity. It rests on the Virgin Hills Formation. It is laterally equivalent to the topmost Virgin Hills Formation, and to part of the Piker Hills Formation.

Subdivision: None proposed.

Lithology: Strongly jointed, bedded, and massive, light brown and white calcarenite and recrystallised calcarenite, partly biohermal (Guppy & others, 1958). Rolled limestone blocks are present in places (Playford & Lowry, 1966). A characteristic steep depositional dip is present.

Age: Conodonts indicate a late Famennian age. (Glenister & Klapper, 1966), which is compatible with coral and brachiopod dates (Veevers, 1959a; Hill & Jell, 1970). Some of the fossils may be derived.

GUMHOLE FORMATION

Named from: Gumhole Bore.

Defined by: Druce & Radke (in press).

Status of name: Proposed.

Type section: On the Great Northern Highway, 19 km west-northwest of Fitzroy Crossing and 1.5 km southeast of Gumhole Bore.

Previous names: Fairfield Formation (in part) of Playford & Lowry (1966).

Modifications: None.

Described outcrop. A linear belt from Red Bluffs 280 km northwestwards to the end of the Napier Range.

Distribution: The Lennard Shelf, the Fitzroy Graben, where it was penetrated in Yulleroo No. 1 well, and the Jurgurra Terrace, where it was penetrated in Frome Rocks No. 2.

Thickness variations: The type section is 71 m thick, but only 16 m are preserved at Red Bluffs. The maximum thickness penetrated is 369 m in Meda No. 1.

Relations with other units: It overlies the Nullara Limestone and the Luluigui Formation, and underlies the Yellow Drum Sandstone. It is a partial time equivalent of all these formations.

Subdivision: None.

Lithology: Limestone, siltstone and shale with minor dolomite and sandstone. The limestone is colour-laminated in places and varies from bioclastic through intraclastic to oolitic. It is interbedded with grey to grey-green siltstone and claystone. The basalt sequence may contain some poorly sorted orange-brown to pink sandstone. The formation is extremely fossiliferous.

Age: Late Famennian from spores, conodonts, ostracods, fish, solitary corals, and brachiopods.

KNOBBY SANDSTONE

Named from: Knobby Hills.

Defined by: Yeates & others (1975b). Name used informally by Veevers & others (1967).

Status of name: Formally defined.

Type section: Knobby Hills (19°24'24"S, 127°45'44"E), 2 km east of Stuart Creek and 7 km north of Skeen Hill.

Previous names: None.

Modifications: None.

Described outcrop: Outcrops are restricted to the Billiluna Shelf within a 40 km radius of the Knobby Hills.

Distribution: Not recorded outside the area of outcrop.

Thickness: Not known; believed to be over 200 m thick.

Relations with other units: It conformably overlies the Carranya Beds and the Precambrian, and unconformably underlain by the Grant Formation. It is the time equivalent of several Upper Devonian formations.

Subdivision: None.

Lithology: Red-brown, medium to coarse quartz sandstone interbedded with fine-grained sandstone, thin beds of multi-coloured siltstone and shale, and quartz pebble and granule conglomerate. Fish plates and fossil wood occur.

Age: Late Devonian from fish plates.

LAUREL FORMATION

Named from: Laurel Downs station.

Defined by: Thomas (1959).

Status of name: Formally defined.

Type section: Two sections proposed: one 3 km northwest of Twelve Mile bore, Brooking Springs station (17°55'S, 125°14'30"E); and the other 5 km south-southeast of the bore (17°58'S, 125°02'E).

Previous names: Laurel Beds (Thomas, 1957).

Modifications: Playford & Lowry (1966) amalgamated the Laurel Formation and the Fairfield beds into a single rock unit which they termed the Fairfield Formation. This has been challenged by Roberts (1971), who pointed out that there was no continuous exposure of the two formations. Druce & Radke (in press) use the term Laurel Formation to describe the Fairfield Formation of Playford & Lowry (1966). WAPET apparently uses the term in a similar way, but refers the equivalent sediments in the Fitzroy Graben to the Yulleroo Formation.

Described outcrop: Along the front of the Napier and Oscar Ranges from Alexander Creek to Oscar Hill, and also in the Horseshoe Range and Red Bluffs area (Playford & Lowry, 1966).

Distribution: May River No. 1, Langoora No. 1, Meda No. 1, Meda No. 2, Napier Nos. 1, 2, 4, and 5, Blackstone No. 1, The Sisters No. 1, Laurel Downs No. 2, St George Range No. 1, Frome Rocks No. 2, Doran No. 1, Yulleroo No. 1, Lake Betty No. 1, Mimosa No. 1, Noonkanbah No. 4, Lennard River Nos. 1 and 2, Mount Hardman No. 1, and Hawkstone Peak No. 1. It or its time equivalents were penetrated in Grant Range No. 1 and Fraser River No. 1. It is probably present over most of the Lennard Shelf and Fitzroy Graben.

Thickness: About 455 m at the type sections, although there is some question about the way in which the sections are related. True thicknesses have been penetrated in May River No. 1 (213 m) and Langoora No. 1 (571 m) respectively. Elsewhere penetrated thicknesses range from 50 m in Frome Rocks No. 2 to 2550 m in Yulleroo No. 1.

Relations with other units: The Grant Formation unconformity truncates the Laurel Formation in Meda Nos. 1 and 2, Napier No. 4, Blackstone No. 1, The Sisters No. 1, Laurel Downs No. 2, Babrongan No. 1, Frome Rocks No. 2, Doran No. 1, Yulleroo No. 1, Lake Betty No. 1, Mimosa No. 1, Mount Hardman No. 1, and Hawkstone Peak No. 1. The Anderson Formation overlies the Laurel

Formation in Grant Range No. 1, Fraser River No. 1, May River No. 1, Langoora No. 1, and St George Range No. 1. At all other well sites it is exposed at the surface.

It overlies other Fairfield Group sediments in all wells except Babrongan No. 1, where it overlies the Clanmeyer Siltstone; Yulleroo No. 1, Mimosa No. 1, and Mount Hardman No. 1, where it overlies the Luluigui Formation; and Fraser River No. 1, where it rests on basement. Grant Range No. 1, Doran No. 1, and St George Range No. 1 did not penetrate the base.

The formation has lateral equivalents in parts of the Anderson Formation, the Gumhole Formation, the Yellow Drum Sandstone and the Luluigui Formation.

Subdivision: Druce & Radke (in press) have proposed two unnamed members: the lower one consists of limestone; the upper one is dominated by calcareous shale.

Lithology: Fossiliferous calcarenite and siltstone. At the type sections, 215 m of grey to pale brown sandy calcarenite with thin sandstones at the base underlies 235 m of yellowish brown shelly calcarenite with a fish bed at 307 m.

Age: Tournaisian from several groups of the rich and varied biota.

LULUIGUI FORMATION

Named from: Luluigui station.

Status of name: Never adequately defined.

Type section: Between 1084 m (3557 ft) and 1909 m (6264 ft) in Frome Rocks No. 2 (18°15'15"S, 123°39'35"E).

Previous names: None.

Modifications: None.

Described outcrop: None.

Distribution: The Sisters No. 1, Laurel Downs No. 2, Frome Rocks No. 2, Yulleroo No. 1, Napier No. 4, Lake Betty No. 1, Mimosa No. 1, Noonkanbah No. 4, Lennard River No. 1, Mount Hardman No. 1, Doran No. 1, Palm Springs No. 1, and Babrongan No. 1.

Thickness variations: Penetrated true thicknesses range from 44 m (Laurel Downs No. 2) to 600 m (The Sisters No. 1). The thickest sequence penetrated is 1051 m in Mount Hardman No. 1. The type section (775 m) is truncated.

Relations with other units: The formation is conformable below the Laurel Formation in The Sisters No. 1, Yulleroo No. 1, Lake Betty No. 1, and Mimosa No. 1, and below the Gumhole Formation in Laurel Downs No. 2; in Frome Rocks No. 2 it is truncated by the Grant unconformity. It conformably overlies the Clanmeyer Siltstone in The Sisters No. 1, Frome Rocks No. 2, and Mimosa No. 1, and is in fault contact with the Poulton Formation in Lake Betty No. 1.

It is a time equivalent of the Nullara Limestone, and is partly a time equivalent of the Fairfield Group and Clanmeyer Siltstone.

Subdivision: None.

Lithology: Thinly bedded, interbedded sequence of siltstone, shale, limestone, and fine sandstone.

Age: Famennian from conodonts.

MELLINJERIE LIMESTONE

Named from: Mellinjerie Rock Hole, 11 km northwest of Sahara No. 1.

Defined by: Koop (in Singleton, 1965).

Status of name: Formally defined.

Type section: Between 931 m (3055 ft) and 1128 m (3700 ft) in Sahara No. 1.

Previous names: None.

Modifications: WAPET have suggested extending the formation downward to include the carbonate facies at the top of the Tandalgoo Red Beds.

Described outcrop: None.

Distribution: Kemp Field No. 1, Sahara No. 1, Kidson No. 1, Wilson Cliffs No. 1, and Contention Heights No. 1. It appears to be limited to the Kidson Sub-basin.

Thickness variation: Ranges from 18 m in Conention Heights No. 1, to 196 m in Sahara No. 1 and Kidson No. 1.

Relations with other units: At all observed localities the formation overlies the Tandalgoo Red Beds with apparent conformity and is truncated by the pre-Permian unconformity. It is a lateral equivalent of the Pillara Formation.

Subdivision: None.

Lithology: Limestone, dolomite, and minor black to dark green shale in the type section. Elsewhere the formation is anhydritic.

Age: Givetian to Frasnian on floral assemblages (E.M. Kemp, BMR, personal communication).

NAPIER FORMATION

Named from: Old Napier homestead.

Defined by: Guppy & others (1958).

Status of name: Formally defined.

Type section: Barker Gorge (17°16'S, 124°44'E).

Previous names: None.

Modifications: Playford & Lowry (1966) extended the use of the term to include the Oscar, Brooking, Copley, and Fossil Downs Formations of Guppy & others (1958). They redefined the 'Reef Facies' mentioned by Guppy & others (1958) as the Windjana Formation. Guppy & others (1958) referred to the Behn and Van Emmerick Conglomerates as local facies of the Napier Formation. Later usage is unclear with regard to these rocks.

Described outcrop: The Napier Range and part of the Oscar Plateau.

Distribution: In the subsurface the formation has been encountered along the northern margin of the Fitzroy Graben as far north as Tappers Inlet No. 1. It has not been recognised south of the graben.

Thickness variations: Guppy & others (1958) measured the type section as 311 m thick, a section near Old Napier homestead as 1021 m, and a section at Carpenters Gap as 213 m. Playford & Lowry (1966) claim that the formation has a depositional dip that precludes its true thickness from being measured.

Relations with other units: The lower boundary of the formation is unconformable on either basement or Poulton Formation. It interfingers with and passes conformably up into the Nullara Limestone, the Windjana Limestone, and the Piker Hills Formation. It is equivalent to parts of the Behn and Van Emmerick Conglomerates, and to the lower parts of the Bugle Gap Limestone and Piker Hills Formation.

Subdivision: None.

Lithology: Calcareous and quartzose clastic limestone interbedded with impure calcareous clastics. Repeated beds of calcareous siltstone and sandstone interbedded with silty and sandy calcarenites. The base often contains coarse clastic sediments, both of terrigenous material and from contemporaneous limestone sources. Lead occurs in the limestone at Barker Gorge.

Age: Late Frasnian to middle Famennian from conodonts.

NULLARA LIMESTONE

Named from: Nullara Spring (17°39'S, 124°57'E).

Defined by: WAPET.

Status of name: Informal WAPET name; published by Read (1973b).

Type section: 1 km southwest of Nullara Spring (17°40'S, 124°56'30"E).

Previous names: Part of the Napier Formation of Guppy & others (1958), of the Pillara Limestone of Playford & Lowry (1966), and of the Fairfield Formation of Guppy & others (1958).

Modifications: Parts of the formation are included in the Gumhole Formation of Druce & Radke (in press).

Described outcrop: Various outcrops in Napier Range and northwest Oscar Range.

Distribution: Lennard, Pender, and Margaret Shelves: the same formation may exist on the Jurgurra and Barbwire Terraces.

Thickness variation: The type section is 60 m thick. Over 300 m have been penetrated in the subsurface.

Relations with other units: It conformably overlies the Napier and Virgin Hills Formations, and interfingers with the former. It is conformably overlain by the Fairfield Group. It is a lateral equivalent of the Windjana Limestone.

Subdivision: None.

Lithology: Medium bedded biostromal limestone - containing ooids, corals, and fenstrate, laminated, and stromatolitic algae - and interbedded oolite grading down to a coarse calcarenite and quartz-pebble sandstone.

Age: Late Famennian from conodonts and foraminifera.

PIKER HILLS FORMATION

Named from: Piker Hills.

Defined by: Playford & Lowry (1966).

Status of name: Formally defined.

Type section: Piker Hills (18°4'30"E, 126°5'30"N).

Previous names: Contains part of the Fairfield Formation of Guppy & others (1958).

Modifications: None.

Described outcrop: Between Needle Eye rocks, Piker Hills, and Burrumundi Range.

Distribution: Restricted to the Lennard Shelf. Only Laurel Downs No. 2 encountered it in the subsurface.

Thickness variations: Only 24 m of section are exposed at the type locality; 134 m were encountered in the subsurface. The total thickness of the exposed formation is not known, but Playford & Lowry (1966) state that it may not exceed 300 m.

Relations with other units: It rests conformably on the Napier Formation and underlies the Fairfield Group conformably and the Grant Formation unconformably. It interdigitates with the Nullara Limestone, and is laterally equivalent to the Bugle Gap Limestone.

Subdivision: None.

Lithology: Interbedded sequence of shale, siltstone and limestone. The limestone is fine to medium-grained calcarenite and is commonly thinly bedded. May be cross-bedded at certain horizons. Depositional dips may be as high as 25°.

Age: Famennian from brachiopods and conodonts.

PILLARA FORMATION

Named from: Pillara Range.

Defined by: Guppy & others (1958).

Status of name: Formally defined.

Type Section: Menyous Gap (18°24'S, 125°25'E).

Previous names: Rough Range Formation of Wade (in part).

Modifications: Veevers & Wells (1961) restricted the name to Givetian and lower Frasnian rocks. Playford & Lowry (1966) followed earlier WAPET usage and termed the formation the Pillara Limestone. They extended the formation to include Famennian rocks of similar lithology. The present usage favours that of Guppy & others (1958).

Described outcrop: Widely distributed through the Oscar Range area and south-east of the Fitzroy and Margaret River system, it crops out in the Napier Range at several localities.

Distribution: Northern and southern margins of the Fitzroy Graben, from Tappers Inlet No. 1 to Lake Betty No. 1, including the Jurgurra and Barbwire Terraces and Lennard Shelf.

Thickness variation: The type section is 430 m thick. However it may attain a thickness of 1500 m.

Relations with other units: It unconformably overlies Ordovician, Precambrian, and Poulton Formation sediments with unconformity. On the southern side of the basin it overlies the Tandalgoo Red Beds. It unconformably or disconformably underlies the Napier Formation and its equivalents. It is a lateral equivalent of the Knobby Sandstone. The Mellinjerie Limestone is probably a severely truncated development of the Pillara Formation.

Lithology: Guppy & others (1958) described three main facies: an arkosic sandstone facies at the base, which in Windjana Gorge also contains stromatoporoidal limestones in cyclic succession; a calcarenite, calcilutite, biostrome facies; and a calcarenite, biostromal facies. Playford & Lowry (1966) described five facies of the formation: the stromatoporoid, coral, birdseye, oolitic, and oncolitic facies; they did not describe the terrigenous clastics of the formation as a separate facies. Read (1973b) described over 60 depositional cycles in the type section.

Subdivision: Read (1973a) proposed a subdivision of the formation into three members; from the bottom these are:-

1. Big Spring Member: thin-bedded arkose and thin lenses of micritic and detrital limestone.
2. Red Bull Member: thinly interbedded stromatoporoid biostromal limestone, birdseye limestone, and minor pelletal and skeletal biota.
3. Menyous Member: massive stromatoporoid biostromal limestone with a diverse biota.

Age: Late middle Givetian to early Frasian (though not in the sense of Playford & Lowry, 1966) from conodonts.

SADLER LIMESTONE

Named from: Sadler Ridge.

Defined by: Guppy & others (1958).

Status of name: Formally defined.

Type section: On Sadler Ridge (18°36'S, 125°56'E).

Previous names: Sadler Beds.

Modifications: Playford & Lowry (1966) removed the 'reef facies' of the Sadler Beds (which they retermed Sadler Limestone) to their Windjana Limestone. The separation of this facies is maintained here, although it is no longer assigned to the Windjana Limestone. This usage follows that of WAPET.

Described outcrop: Sadler Ridge, Pillara Range, Bugle Gap, Hull Range, Outcamp Yard, Pinbilly Hills, and a small area on the Oscar Plateau.

Distribution: Outside the area of outcrop it has probably been penetrated in Matches Springs No. 1.

Thickness variation: Measured complete sections range from 203 m (665 ft) to 375 m (1230 ft; Guppy & others, 1958).

Relations with other units: The formation rests unconformably on the Pillara Formation at some localities, and grades laterally into the Pillara Formation at others. It has similar varied relations with the Gogo Formation. It is overlain by the Napier and Gogo Formations, and interfingers with the Sparke Conglomerate and the Mount Elma Conglomerate.

Subdivision: Guppy & others (1958) recognised two lithofacies: the Clastic Limestone Lithofacies, and the Reef Lithofacies, which is now considered as a facies of the Pillara Formation. The Clastic Limestone Lithofacies has not been subdivided.

Lithology: Thinly bedded calcarenites with interbedded thin calcareous siltstones and marls. Megabreccias of derived Pillara Formation blocks occur locally. High sedimentary dips occur towards the margin of the shelf area.

Age: Givetian to early Frasnian from corals and conodonts.

STONY CREEK CONGLOMERATE

Named from: Stony Creek (17°57'S, 125°26'E).

Defined by: Guppy & others (1958).

Status of name: Never adequately defined.

Type section: Not formally designated.

Previous names: None.

Modifications: None.

Described outcrop: Stony Creek area.

Distribution: Not recognised in the subsurface.

Thickness variation: Total thickness not described. It presumably thickens to about 150 m (500 feet; Playford & Lowry, 1966).

Relations with other units: It interfingers with the Napier Formation, and overlies the Pillara Formation disconformably. It passes up into a grey conglomerate which Playford & Lowry (1966) assume to overlie the Stony Creek Conglomerate unconformably, and which they also assume to be of Permo-Carboniferous age, although this has yet to be established. It is probably the lateral equivalent of other Devonian Conglomerates.

Subdivision: The formation has not been subdivided.

Lithology: Boulders, cobbles, and pebbles of granite compose 80% of the clasts in the conglomerate; quartz, quartzite, and volcanic clasts constitute the rest. These are surrounded by an arkosic groundmass.

Age: It appears to be contemporaneous with Famennian Limestone. No direct dating of the formation has been made.

VIRGIN HILLS FORMATION

Named from: Virgin Hills (18°33'S, 125°55'E).

Defined by: Guppy & others (1958).

Status of name: Formally defined.

Type section: No. 5 Bore, Needle Eye Rocks area.

Previous names: Mount Pierre Series (in part) and No. 5 Formation.

Modifications: None.

Described outcrop: Restricted to the southeastern part of the Lennard Shelf Horseshoe Range, Virgin Hills, Bugle Gap, and Needle Eye Rocks/Mount Pierre areas.

Distribution: Encountered in Laurel Downs No. 1, and Napier Nos. 1, 2, and 5. Possible equivalent formations occur in Logue No. 1 and Babrongan No. 1 on the Jurgurra Terrace.

Thickness variation: 300 m (1000 feet) of section may be present in the type area (Guppy & others, 1958). 646 m were penetrated in Laurel Downs No. 1.

Relations with other units: Overlies the Gogo and Pillara Formations unconformably, and the Gogo Formation and Van Emmerick Conglomerate conformably. Interfingers with the Bobs Bore Conglomerate and conformably underlies by the Bugle Gap Limestone, the Windjana Limestone, the Nullara Limestone, and the Piker Hills Formation.

Subdivision: None proposed.

Lithology: Red brown to cream limestone with minor fine quartz sandstone. The limestone includes intraclastics, breccia, skeletal, and oolitic types. Bedding is thin in all but the breccia types. Depositional dips of up to 20° are present close to the abutment with other rocks. Huge allochthonous blocks and biohermal and biostromial structures are present.

Age: Late Frasnian to middle Famennian from conodonts.

WINDJANA LIMESTONE

Named from: Windjana Gorge (17°24'30"S, 124°57'30"E).

Defined by: Playford & Lowry (1966).

Status of name: Formally defined.

Type section: Type locality is Windjana Gorge.

Previous names: Guppy & others (1958) did not differentiate the Reef Facies of their Devonian Carbonate Complexes as a separate formation. The Windjana Limestone therefore supersedes parts of earlier named formations.

Modifications: WAPET have restricted the use of the name to deposits contemporaneous with the Nullara Limestone. These parts of the formation removed are not renamed but are regarded as a facies of the Pillara Limestone. Playford (1976) also follows this usage.

Described outcrop: Along Napier Range, northwest of Oscar Range, and west of Horseshoe Range.

Distribution: Not penetrated in the subsurface. Its known distribution is limited to the area of outcrop.

Thickness variation: Estimated to be between 90 and 150 m.

Relations with other units: Interfingers with the Nullara Limestone and the topmost beds of the Napier Formation. It conformably abuts Fairfield Group sediments; this contact may be a structural one.

Subdivision: None proposed.

Lithology: Massive to crudely bedded limestone with clustered algae in a micritic matrix, often dolomitised. The formation is distinct from that part removed from Playford & Lowry's (1966) definition by WAPET to the Pillara Formation. These older rocks contain stromatoporoid-brachiopod associations and rare coralline colonies along with the algae - such a fauna is absent in the Windjana Formation (sensu stricto).

Age: Late Famennian, by bracketing from the Napier Formation and the Fairfield Group.

YELLOW DRUM SANDSTONE

Named from: Yellow Drum Bore.

Defined by: Druce & Radke (in press).

Type section: 1 km northeast of Yellow Drum Bore.

Previous names: Part of the Fairfield Formation of Playford & Lowry (1966).

Modifications: None proposed.

Described outcrop: Southwest of Oscar Range, and northwest of the fault parallel to the front of Oscar Range.

Distribution: It extends from the Lennard Shelf into the Fitzroy Trough, where it was penetrated in Yulleroo No. 1.

Thickness variation: The type section is 70 m thick. 106 m in Noonkanbah No. 2.

Relations with other units: It overlies the Gumhole Formation, and is in faulted contact with the Luluigui Formation equivalent. In Hawkstone Peak No. 1 it directly overlies the Nullara Limestone. It passes up into the Laurel Formation.

Subdivision: None proposed.

Lithology: Sandstone,,dolomite, and siltstone, together with minor shale and limestone. Sandstones are white, yellow-brown, or grey, and the thicker units are cross-bedded; they are interbedded with the other deposits. The dolomites are brecciated at the base and become more calcareous up the section. The siltstones are bioturbated.

Age: Latest Devonian to earliest Carboniferous from conodonts and spores.

APPENDIX 4. STRATIGRAPHIC UNITS OF INTERVAL 4

Interval 4 defines a fairly complex phase of Permo-Carboniferous sedimentation, and includes sediments attaining a thickness of 2800 m (Pl. 10-4). The lower boundary of the interval is always marked by a strongly reflecting and easily traced horizon on the seismic sections.

Fifteen named formations are included in the interval. These are set out below. The Grant Formation is subdivided into three unnamed subunits, designated from bottom to top Grant Formation A, Grant Formation B, and Grant Formation C. These units are distinct and should perhaps be accorded formational status and the Grant Formation upgraded to Grant Group. The Paterson Formation, Buck Formation, and Braeside Tillite are equated with the youngest unit of the Grant Formation. A minor unconformity separates the Grant Formation from younger Permian rocks, but because of the similar lithologies of Grant Formation C and the sandstones of the Poole Sandstone it is only apparent when the Grant Formation is overlain by the discontinuous basal Nura Nura Member of the Poole Sandstone.

The Liveringa Formation is ugraded to Liveringa Group (after Yeates & others, 1975a) and its members are given formation status. The Balgo Member of Casey & Wells (1964) is included in the Lightjack Formation, after Playford & others (1975). The Triwhite Sandstone of the southern margins of the basin is a probable correlative of the Lightjack Formation, but the name is retained as there is no demonstrable continuity of outcrop.

A new unit, the Chirup Formation, is proposed for those rocks in the southwestern part of the basin which are contemporaneous with the Hardman Formation in the north. There is no continuity between the two formations.

Upper Permian basalts penetrated in Bedout No. 1 in the Bedout Sub-basin are given the informal name of Bedout Volcanics. The precise age and relationships of these basic rocks is unknown but they are thought to be contemporaneous with dolerite intrusions in the northwestern Fitzroy Graben. The offshore extent of the basalts (Pl. 8) has been inferred from magnetic intensity maps.

GRANT FORMATION

Named from: Grant Range.

Defined by: Guppy & others (1952).

Status of name: Formally defined.

Type section: No type section was designated; the type locality is Grant Range (18°02'00"S, 124°05'00"E).

Previous name: Talbot (in Blatchford, 1927) introduced the term Grant Range Beds. Teichert (1941d) later used the name Grant Range Series. The name was later amended to Grant Formation by Guppy & others (1952), who included the Kungangie, Willangie, and Grant Range Beds of Wade (1936) and the lower part of the Hawkstone Sandstone of Kraus (1942), Findlay (1942) and Reeves (1949).

Modifications: None proposed.

Outcrop: The unit crops out mainly on the Lennard Shelf, Margaret Terrace, Pender Terrace, Betty Terrace and Fitzroy Graben.

Distribution: The unit subcrops extensively over the Canning Basin (Pl. 10-4) and was penetrated by many wells. The offshore extension of the Grant Formation is unknown.

Thickness: The thickest drilled section is 1847 + metres in Grant Range No. 1. The unit thins over structural highs (Broome Arch), and onlaps the basin margins. These thinner sections are due to depositional thinning, bu: towards the west erosional thinning becomes increasingly dominant.

Relations with other units: The formation overlies progressively older units from the centre of the Fitzroy Graben outwards: in the central graben it rests unconformably on Carboniferous Anderson Formation, as in St George Range No. 1; then northwards the Lower Carboniferous Laurel Formation (Pl. 11-4), then rocks of the Devonian complex (as at Bugle Gap), Ordovician rocks (as in BMR Prices Creek No. 3), and Precambrian (Veevers & Wells, 1961). South of the central graben the Grant Formation oversteps progressively older formations onto the Broome Arch: Devonian rocks in Crossland No. 1 on the Barbwire Terrace and Ordovician rocks on the structurally higher Broome Arch (as in Thangoo No. 1A). Tilting of the Broome Arch down towards the southwest is evident as the Grant Formation progressively overlies younger lower Palaeozoic units in the Kidson-Willara Sub-basin.

These relations are shown in cross-sections (Pls. 11-3, 11-4, 11-6). South of the axis of the Kidson Sub-basin, the Grant Formation probably oversteps progressively older formations towards the margin of the Canning Basin, as correlative outlier formations - the Buck and Paterson Formations (see below) - rest unconformably on Precambrian rocks.

The Grant Formation disconformably to unconformably underlies the upper Sakmarian Nura Nura Member of the Poole Sandstone (Yeates & others, 1975b) except where erosion has removed the younger Permian rocks, so that Mesozoic, Tertiary, and/or Quaternary sediments overlie the Grant Formation. In the southwest, the Upper Permian Chirup Formation unconformably overlies the Grant Formation (e.g., in Chirup No. 1).

Subdivision: The formation is herein subdivided into three lithological units, designated:

Top: Grant Formation C
Grant Formation B
Grant Formation A

Lithology:

Grant Formation A. In St George Range No. 1 between 259 and 1518 m it consists mainly of sandstone: white to light grey, minor dark grey, minor dark grey, very fine to very coarse and conglomeratic, mainly fine to medium, subrounded to well rounded, poor to excellent sorting, in part feldspathic, in part micaceous, in part clayey, in part pyritic, silica-cemented or calcareous cement, massive, hard to occasionally friable, good porosity, with siltstone and shale, especially betwen 640 and 866 m; siltstone: white, light grey, medium grey, rare brown, well rounded, calcareous, often shaly, frequent carbonaceous partings, small amount of pyrite; shale: medium to dark grey, silty, micaceous, waxy, and lenses of bituminous shale; chocolate brown, silty waxy; conglomerate: orange, granule.

Other wells show variations on this lithology, with greater or lesser amounts of conglomerate, shale or siltstone and occasional thin beds of limestone.

Grant Formation B. In Mimosa No. 1 it consists of shale: grey, finely pyritic, rarely carbonaceous, subfissile to fissile, soft to firm, grading to claystone, minor interbeds and interlaminations of sandstone: very fine to silty, and siltstone: dark grey to black, argillaceous, sandy and kaolinitic in part, subfissile, soft to firm, grading down into sandstone and greywacke towards base; sandstone: as above, but very fine to coarse, poorly-sorted, rare granules of granite, and minor amounts of shale, siltstone, and claystone.

In Sahara No. 1 between 448 and 657 m, the unit consists of sandstone: light grey, fine to very fine and silty, clayey, micaceous, slightly pyritic; siltstone: medium to dark grey, sandy, calcareous, pyritic, slightly carbonaceous, with minor shale: dark, micaceous, traces of coal below 597 m, traces of limestone: light, fossiliferous.

Grant Formation C. Crowe & Towner (1976c) have described the unit in outcrop. In Mimosa No. 1 (675-863 m) the unit consists of three subunits correlatable with units delineated on the surface in the Noonkanbah Sheet area by Crowe & Towner (1976c).

Subunit 1 (675-722 m), correlated with Millajjeedee Member, consists of loose sand; clear, mainly medium to coarse, moderately sorted, subrounded, fine to very coarse and poorly sorted in places, interbedded, and traces of sandstone: off-white to light grey, very fine to silty though fine in places, micaceous and glauconitic in the lower parts, rare silica or pyrite cement and kaolinitic matrix, firm to friable. It grades down into subunit 2.

Subunit 2 (722-755 m), correlated with Wye Worry Member of Crowe & Towner (1976c), consists of upper siltstone: shaly, finely micaceous, subfissile, soft to firm; traces of claystone: light to medium grey, subfissile, to blocky, soft to firm, grading to shale: brownish grey, carbonaceous, grading down into subgreywacke: light brown, grey, carbonaceous traces, trace pyrite, glauconite, fine to coarse sandstone (as above), siltstone (as above), and fossil fragments, coarsens downwards into the lower subunit.

Subunit 3 (755-863 m), correlated with lower Grant Formation of Crowe & Towner (1976c), consists of sandstone: as in subunit 1, but with more siltstone: as above, calcareous and carbonaceous traces, pyrite, granite granules, and no glauconite.

Age: The bounding surfaces of the formation are unconformities, but the basal Grant Formation may be much younger than Namurian E1 (youngest Anderson Formation of Bischoff, 1968) and the uppermost beds older than the upper Sakmarian age of the overlying Nura Nura Member of the Poole Sandstone.

At present the Upper Carboniferous-Permian time scale relies heavily upon brachiopod zones, but brachiopods are rare in the Grant Formation. Plant fossils are present, though for the most part undescribed. Palynology is at present the only useful tool for age determination, although precise correlation with the standard Russian sequence is tentative.

The scheme used herein is that of Evans (1969), with modifications from later work by Norvick (1974) and Segroves (1970). Grant Formation A has a stage 1 microflora which is characteristic of glacial rocks (Kemp, 1975), but passes into a stage 2 assemblage near the top of the unit. The stage 1 assemblage is generally agreed to be pre-Permian in age, and stage 2 marks the base of the Permian (Evans, 1969). Thus Grant Formation A is Upper Carboniferous to basal Permian in age. B.E. Balme (in Johnson, 1968) reported a pre-stage 1 microflora in rocks previously thought to be basal Grant Formation in Blackstone No. 1; these beds are now correlated with the Anderson Formation. Balme thought that this microflora might be Moscovian in age: if substantiated this would be the youngest Anderson Formation so far penetrated. The oldest Grant Formation is then younger than Moscovian, possibly Stephanian.

Both Grant Formation B and C contain stage 2 microfloras assigned a Sakmarian and Lower Artinskian age by Evans (1969). Recent literature on the microfloras and the small numbers of Striatiti present suggest that only the Lower Stage zone (as defined by Norvick, 1974) may be present, and thus the upper part of the Sakmarian is absent. This is supported by the unconformable upper contact with the well-dated Nura Nura Member (upper Sakmarian). The Grant Formation thus ranges from Late Carboniferous (Stephanian) to Early Permian (early Sakmarian) in age.

Dickins & others (1975) dated macrofossils from Grant Formation C as late Sakmarian. Either the youngest Grant Formation may be as young as this or the macrofossils - which are genera, not species - are older than claimed. In the absence of other evidence the spore dating is accepted.

Macroflora from Grant Formation C in BMR Prices Creek No. 3 and from outcrops of the unit at Mount Mueller contain Lower Permian species (White, 1961; White & Yeates, 1976). Plants reported include Noeggarithriopsis hislopi, Glossopteris spp. and Gangamopteris sp.

PATERSON FORMATION

Named from: Paterson Range.

Defined by: Traves & others (1956).

Status of name: Formally defined.

Type section: None defined; type area Paterson Range (21°45'00"S, 122°10'00"E).

Previous name: Talbot (1920) called the formation Paterson Range Series, later revised by Traves & others (1956).

Modifications: None.

Described outcrop: South of Lake Waukarlycarly, east along the basin margin from the Yarrie Sheet area and southwards into the Officer Basin (Veevers & Wells, 1961; Lowry & others, 1972). The unit mapped as Paterson Formation (Towner & others, 1976) in the southeastern Canning Basin should be correlated with the Buck Formation of Wells & others (1970). The Paterson Formation also forms outliers on Precambrian rocks south of the basin margin.

Distribution: The unit is not recognised in the subsurface of the Canning Basin but is probably a correlative of Grant Formation C.

Thickness: The thickest measured section is 335 m at Woolnough Hills (Lowry & others, 1972), exposed in a probable salt dome. The section thins to 38 m at Cromer Cone and to less than 35 m in the Paterson Range at the headwaters of Cottom Creek (Veevers & Wells, 1961).

Relations with other units: Outliers of the formation unconformably overlie Precambrian rocks south of the margin of the Canning Basin. At Woolnough Hills the unit overlies a dolomite of possible late Precambrian age (Preiss, 1976). Northwards the formation probably oversteps Ordovician and then Devonian rocks (seismic correlation) and interfingers with Grant Formation C. Overlying units include Jurassic and Cretaceous rocks and surficial deposits (Veevers & Wells, 1961; Lowry & others, 1972; Towner & others, in prep.).

Subdivision: None attempted.

Lithology: Variable lithology of sandstone, claystone, and conglomerate forming glaciofluvial and glaciolacustrine deposits including tillite and varved shale. Sandstone: massive, coarse to conglomeratic, erratics of variable lithology, quartzite, quartz, metamorphics, granite, gneiss, basic igneous rocks, limestone, slumped and contorted locally (Veevers & Wells, 1961; Lowry & others, 1972). Claystone: with or without drop stones. Conglomerate: pebbles and boulders, lithology as for sandstone.

Age: Palynology indicates the unit contains a lower Sakmarian (Asselian) microflora (Balme, in Jackson, 1966; Kemp, 1976), suggesting correlation with the Grant Formation C. The only other fossils are unidentifiable trace fossils (Lowry & others, 1972).

BUCK FORMATION

Named from: Buck Hills.

Defined by: Wells & others (1964).

Status of name: Formally defined.

Type section: None given; type area is Buck Hills (23°08'00"S, 129°53'00"E).

Previous names: None known.

Modifications: None.

Described outcrop: On the southeastern margin of the Canning Basin and eastwards as outliers on Precambrian (Wells, 1968; Wells & others, 1970).

Distribution: As above.

Thickness variations: Usually more than 42 m thick on the Precambrian (Wells & others, 1970).

Relations with other units: Unconformable on Proterozoic sedimentary rocks and Precambrian rocks. At Dovers Hills, it lies on possible glacial pavement on Proterozoic Heavitree Quartzite (Wells & others, 1970). It probably overlies Ordovician and possibly Devonian rocks progressively into the Canning Basin where it interdigitates with Grant Formation C.

Subdivision: None.

Lithology: Sandstone: coarse, poorly sorted; conglomerate: tillitic texture, erratics of granite, schist, vein quartz, acid porphyry and white banded chert, striations, faceted; siltstone (Wells, 1968; Wells & others, 1970).

Age: Evans (in Wells & others, 1970) reported a Nuskoisporites assemblage from rocks similar to the Buck Formation. The Nuskoisporites assemblage of Balme (1964) is equivalent to stages 1 and 2 of Evans (1969). On palaeogeographic grounds the microflora is more likely to be stage 2 and the age early Sakmarian (?Asselian).

BRAESIDE TILLITE

Named from: Presumably Braeside homestead (21°10'00"S, 121°00'00"E).

Defined by: Clapp (1925).

Status of name: Formally defined.

Type section: None given; type locality is 3.2 km north northwest of the old Braeside homestead, Oakover River. A. Nott (personal communication) re-examined this outcrop and believes it is a silicified Tertiary conglomerate.

Previous name: None recorded.

Modifications: If in the type area, the Braeside Tillite does not exist, then the name should be dropped. Nearby glacial rocks would then be mapped as Paterson Formation, which outcrops to the north and east. Until this is resolved the name Braeside Tillite is retained.

Described outcrop: Confined to the Oakover River and Nullagine River valleys and to outliers on the surrounding Precambrian (Veevers & Wells, 1961).

Distribution: Penetrated by station bores (Warrawagine Bore), Western Australian Government water bores, and coal exploration bores. Probably extends north and interdigitates with or grades into the Paterson Formation or Grant Formation C.

Thickness variations: Outcrops measure about 30 m (McWhae & others, 1958) but up to 122 m were penetrated by a bore 8 km east of Warrawagine homestead, indicating northward thickening of the unit.

Relations with other units: Overlies glaciated pavements on Precambrian rocks at Ripon Hills (Forman, 1960) and 3.2 km north of Carawine Gorge. It presumably grades northwards into Grant Formation C and Paterson Formation. It underlies the Tertiary Oakover Beds in the valleys of the Nullagine and Oakover Rivers, and probably younger Permian units (i.e., Poole Sandstone) northwards.

Subdivision: None attempted.

Lithology: At the type area described by Traves & others (1956) as tillite: subrounded boulders, unsorted, unstratified and unwashed, boulders up to 1-2 m diameter. At Eel Creek the tillite is overlain by shale: banded red, brown, and white, some beds with rock fragments up to 91 mm diameter.

Age: No macrofossils have been described, but palaeogeographic evidence indicates an early Sakmarian age. Recent palynological examination of boreholes in the Oakover River area showed close similarities with the Nuskoisporites III Zone in Blackstone No. 1 (Backhouse, 1976), indicating a correlation with Grant Formation C.

POOLE SANDSTONE

Named from: Poole Range.

Type section: None given; type area is Poole Range (18°50'00"S, 125°45'00"E).

Previous names: Talbot (in Blatchford, 1927) originally described the unit as the Poole Range Beds, which Guppy & others (1952) redefined as the Poole Sandstone, incorporating parts of the 'Lower Ferruginous Series' of Wade (1938) and the 'Poole Range Sandstone (Lower Ferruginous)' of Reeves (1951).

Modifications: Although mainly a sandstone, drilling has shown that the lithology of the Poole Sandstone can vary, the proportion of fine-grained clastics increasing up to 40% (Pl. 12-8). In addition, the unit commonly has a basal limestone, shale, or siltstone member, the Nura Nura Member. For these reasons it is suggested that future workers consider dropping the descriptive term 'Sandstone' and use the term 'Formation' in its place.

Described outcrop: On the flanks of major folds in the Poole, St George, and Grant Ranges, Mount Wynne, Southesk Tableland, Stansmore Range, Balgo Hills, and north of Thorton Flat (Veevers & Wells, 1961; Yeates & others, 1975b; Crowe & Towner, 1976c).

Distribution: The unit was probably present in the Willara Sub-basin but has since been eroded. The offshore extent is unknown.

Thickness variations: The unit is thickest in the Fitzroy Graben (395 m at Nura Nura Ridge) and thins to about 100 m in the Kidson Sub-basin (Kidson No. 1 - 102 m; Wilson Cliffs No. 1 - 118 m). Erosional thinning occurs to the southwest and west.

Relations with other units: The Poole Sandstone is unconformable on the Grant Formation and gradational with the overlying Noonkanbah Formation. Where the basal Nura Nura Member is absent the Grant Formation and Poole Sandstone appear to be gradational (Yeates & others, 1975b), but lithological similaritiesmay obscure the contact; the time break between the units suggests at least a disconformable relation.

Subdivision: The formation has two components: the Poole Formation sensu stricto and a discontinuous basal Nura Nura Member. Crowe & Towner (in prep.) have further subdivided the unit, but this subdivision does not hold outside the Noonkanbah Sheet area and is not followed here.

Lithology: Most exposures consist of sandstone: white and brown, fine to coarse but mainly fine, partly kaolinitic, micaceous, quartzose, well sorted, well bedded, cross-bedded, ripple-marked, with tracks, jointed, ferruginised, less resistant than Grant Formation with planar and low-angle cross-bedding; minor shale (Veevers & Wells, 1961) and siltstone (Yeates & others, 1975b). Coal occurs locally (Lake Betty No. 1, Frome Rocks No. 2). Glauconite occurs in some wells (FKO Nerrima No. 1, Frome Rocks No. 2). Shale and siltstone occur on the Jurgurra Terrace, where they form the lower part of the unit (Dampier Downs No. 1, Thangoo No. 1A, Babrongan No. 1).

Age: Lower Permian fossil plants, including Glossopteris spp. and Gangamopteris spp. are common, particularly in the upper part of the unit (White, 1961; White & Yeates, 1976). Microflora of stage 3 (Evans, 1969) are characteristic and denote an Artinskian age.

In the Poole Range, marine faunas from the lower part of the Poole Sandstone are placed in faunal stage B of Dickins (1963) and are upper Sakmarian. The Nura Nura Member similarly has an upper Sakmarian fauna. The Poole Sandstone grades into the Upper Artinskian Noonkanbah Formation, which is characterised by stage D_1 faunas (Dickins, 1963).

CUNCUDGERIE SANDSTONE

Named from: Cuncudgerie Hill.

Defined by: Traves & others (1956).

Status of name: Formally defined.

Type section: The type area is 16 km east south east of Cuncudgerie Hill (21°02'00"E, 121°31'00"S; locality P1 of Traves & others, 1956).

Previous names: None.

Modifications: Towner & others (1976) have suggested that the name Cuncudgerie Sandstone be dropped, as it is stratigraphically continuous with the Poole Sandstone of the northern Canning Basin; both have similar faunas (Thomas & Dickins, unpublished) and lithologies.

Distribution: The unit has been mapped north of the type area near Lake Waukarlycarly and between Cronin and Helen Hills (Traves & others, 1956). Towner & others (1976) mapped the unit south of Lake Dora, which suggests it is continuous along the basin margin, to the northwest, with the type area. It is also continuous southwards along the basin margin.

Thickness variations: At the type section the unit is 33 m thick, and 40 m at Cuncudgerie Hill (Traves & others, 1956).

Relations with other units: The unit overlies the Paterson Formation conformably and Precambrian rocks unconformably (Veevers & Wells, 1961).

Lithology: At the type section (P1) the unit consists (Traves & others, 1956) of:

3 m sandstone: dark, coarse; and conglomerate: fine, pebbles up to 0.8 cm diameter, subrounded, ferruginous.
6 m sandstone and greywacke: medium to coarse, poorly sorted, ripple marks, swash marks, clay pellets, worm tracks, 15 cm bed of marine fossils at base, ferruginised.
3 m sandstone: yellow to white, fine to medium, micaceous, well bedded.
9 m sandstone: brown-white, medium, micaceous, massive, shell fossils, ferruginised.
9 m sandstone and claystone: violet, red, yellow, white, micaceous towards base, well bedded, bivalve fossils.

Age: Most species from the unit are in common with the Nura Nura Member and basal Poole Sandstone in the Poole Range (Dickins, 1963). Myonia subarbitrata occurs in sandstone at Helen Hill (Veevers & Wells, 1961), in the Dora Shale at Scott Bluff (Thomas & Dickins, unpublished), and in the Nura Nura Member and Concudgerie Sandstone. The range is upper Sakmarian (fauna B of Dickins, 1963).

DORA SHALE

Named from: Lake Dora.

Defined by: Traves & others (1956).

Status of name: Formally defined.

Type section: Type area (Playford & others, 1975) at northeast end of Lake Dora (21°52'30"S, 122°58'00"E).

Previous names: None.

Modifications: Towner & others (1976) have suggested that the term Dora Shale be abandoned because the unit is continuous with the Noonkanbah Formation of the northern Canning Basin; both are lithologically similar and have fossils in common (Crespin, in Traves & others, 1956).

Described outcrop: The unit is limited to the area around Lakes Dora, Blanche, Winifred, and George (Veevers & Wells, 1961).

Distribution: As above, and northwards into the Kidson Sub-basin as it correlates with the Noonkanbah Formation.

Thickness variation: 30 m measured at the type area (Traves & others, 1956), but Playford & others (1975) state that it is 13 m thick at Lake Dora.

Relations with other units: The unit was originally thought to overlie the Cuncudgerie Sandstone (Traves & others, 1956), but the presence of fossils similar to those in the Nura Nura Member (see Playford & others, 1975) clouded the issue. Mistaken correlation of the Dora Shale with a shaly unit (Grant Formation B in this report) near the top of the Grant Formation in Sahara No. 1 also led to considerable confusion in subsurface terminology. Towner & others (1976) have shown that the Dora Shale overlies the Cuncudgerie Sandstone at Lake Blanche with a distinct break, and the unit thus is correlated with the Noonkanbah Formation, with which it is lithologically similar.

Lithology: At the type area the units consist (Traves & others, 1956) of:
claystone: white, violet and yellowish, micaceous, well bedded, containing worm trails and ?wood, together with ferruginized beds, topmost beds of clay pellets and claystone breccia, and decalcified sandstone.

Age: The unit contains long-ranging foraminifera, which also occur in the Nura Nura Member and Noonkanbah Formation (Crespin, in Traves & others, 1956). Fossil shells from Scott Bluff, correlated with fauna B of Dickins (1970), are late Sakmarian in age.

NOONKANBAH FORMATION

Named from: Noonkanbah station.

Defined by: Guppy & others (1952).

Status of name: Formally defined.

Type section: Brutens Hill (18°43'00"S, 124°48'00"E).

Previous names: The term Noonkanbah Series was first introduced by Wade (1938) and later changed to Noonkanbah Shale after unpublished work (Guppy & others, 1950).

Modifications: None.

Described outcrop: The unit is distributed from the eastern shore of King Sound to the southeast of Thornton Flat.

Distribution: The distribution of the Noonkanbah Formation in wells is shown in Figure 5.4.6.

Thickness variations: The formation is 400 m thick in the central Fitzroy Graben and thins towards the basin margins; seismic interpretation suggests a thickness of 400 m in the Kidson Sub-basin. The formation is eroded towards the west and is not present in the southwestern area onshore and probably the adjoining offshore area. It may be present in deep synclinal areas offshore from the Fitzroy Graben, despite the presence of Mesozoic and Lower Carboniferous sediments in Wamac No. 1 and Lacepede No. 1A.

Relations to other units: The unit grades down into the Poole Sandstone and is overlain conformably by Liveringa Group rocks or unconformably by Mesozoic or younger rocks.

Lithology: The formation consists of siltstone, shale, calcilutite, calcarenite, sandy limestone, and coquinite (Veevers & Wells, 1961). The lithological variation is shown in Figure 5.4.6.

Gypsum and fontainbleau sandstone are exposed in outcrop (Guppy & others, 1958) and glauconite is reported from several wells (e.g., Sahara No. 1).

Age: The unit has probably the most diversified and abundant fauna of all the formations of interval 4. It contains the D_1 fauna of Dickins (1970), dated as late Artinskian, and the stage 4 microflora of Evans (1969).

LIVERINGA GROUP

Named from: Liveringa station.

Defined by: Yeates & others (1975a).

Status of name: Formally defined.

Type section: Liveringa Ridge (17°56'00"S, 124°06'00"E).

Previous names: Wade (1938) originally defined the unit as 'Upper Ferruginous or Liveringa Series', which Guppy & others (1950) called the 'Liveringa Sandstone' and Reeves (1951) the 'Liveringa beds'. Guppy & others (1952) then defined the 'Liveringa Group' to include the 'Liveringa Iron Sandstone, Belina Shale and Erskine Sandstone of Kraus (1942) and Findlay (1942)' and replace the 'Liveringa Beds' of Reeves (1949). In 1958 the name was again redefined to Liveringa Formation and subdivisions of the unit were given member status (Guppy & others, 1958). Yeates & others (1975a) have upgraded these members to formations and defined the Liveringa Group.

Modifications: None proposed.

Described outcrop: Northern Canning Basin from Derby area southeast to Balgo Hills and north of Thornton Flat.

Distribution: The continuity of the Liveringa Group and contemporaneous rocks in the Kidson Sub-basin has not been established. Correlative rocks, the Triwhite Sandstone, are present in the Kidson Sub-basin. Offshore, the group is probably absent owing to post-Triassic erosion but rocks of the same age as the upper part of the group were intersected directly beneath Triassic rocks in BMR Wallal No. 4A and Chirup No. 1, in the southwest Canning Basin. This suggests that Upper Permian rocks may be present in the southern Bedout Sub-basin.

Thickness variations: The thickest expression of the group is in the central Fitzroy Graben, where it reaches about 762 m (Playford & others, 1975). The group thins onto the Margaret and Betty Terraces and southwards to an inferred erosional limit approximating the Dummer Fault System.

Relations with other units: The group overlies the Noonkanbah Formation conformably.

Subdivision: The Liveringa Group is subdivided into three formations, one of which, the Hardman Formation, has three members:-

Hardman Formation - Cherrabun Member
Hicks Range Sandstone Member
Kirkby Range Member
Condren Sandstone
Lightjack Formation (including Balgo Member of Casey & Wells, 1964).

LIGHTJACK FORMATION

Named from: Lightjack Hill.

Defined by: Yeates & others (1975a).

Status of name: Formally defined.

Type section: Lightjack Hill (18°59'00"S, 125°50'00"E).

Previous names: Guppy & others (1958) named the lowest unit of the Liveringa Formation the Lightjack Member. In the Balgo Hills area a similar unit was called the Balgo Member (Casey & Wells, 1964). Recently Playford & others (1975) have placed the Balgo Member in synonymy with the Lightjack Member and this was mapped as the Lightjack Formation by Yeates & others (1975a, b).

Modifications: None.

Described outcrop: The formation crops out widely on flanks of anticlines in the Fitzroy Graben and extends southeast of Balgo Mission (Blake & Towner, 1974).

Distribution: The unit crops out in synclines in the Fitzroy Graben and Margaret Terrace. Because of erosion, the Lightjack Formation rarely onlaps the Broome Arch and is probably also absent offshore in the northwest.

Thickness: at PL 1, a faulted sand-covered section measured by WAPET (unpublished), the formation is 305 m thick. The thickest subsurface section is 185 m in Lake Betty No. 1, but the formation is generally thinner than 150 m in the central graben and about 60 m thick on the terrace.

Relations with other units: The formation rests conformably on the Noonkanbah Formation but oversteps Archaean rocks southeast of Balgo Mission (Blake & Towner, 1974). It is conformably overlain by the Condren Sandstone in the central depositional areas but the contact may be disconformable near the eastern margin (Yeates & others, 1975b). It underlies with angular unconformity the Jurassic Barbwire Sandstone at Barbwire Range (Yeates & others, 1975b), and it may be disconformable below the Godfrey Beds in the Lucas Sheet area. In the northeast, the Condren Sandstone is locally absent and the Hardman Formation rests disconformably on the Lightjack Formation (Crowe & Towner, 1976c).

Subdivision: None attempted.

Lithology: A characteristic of the Lightjack Formation is the basal, lensing, impersistent iron-rich sandstone: reddish and purple-brown, quartzose, poorly-sorted, commonly richly fossiliferous with lens-like pisolitic bodies

in ferruginous sandstone (Veevers & Wells, 1961; Yeates & others, 1975b). These bodies were analysed for iron content (Edwards, 1953; Yeates & others, 1975b) and contain up to 55% Fe_2O_3.

In the subsurface the formation consists of: siltstone: grey to black, carbonaceous laminae, interbedded with sandstone: grey, fine quartzose, micaceous, labile (Yeates & others, 1975b). In outcrop, structures include asymmetrical ripple marks, low-angle cross-bedding, clay pellet conglomerate (Yeates & others, 1975b). In the northern area sandstone predominates, with minor siltstone and shale (Fig. 5.4.7).

Age: A rich fauna, characterised by the bivalves Atomodesma exorata and Stuchburia muderongensis (Dickins & Jell, 1974) and the ammonites Pseudogastriceras goochi and ?Propinacoceras australe (Glenister & Furnish, 1961), indicates a Kungurian or slightly older (latest Artinskian) age (Glenister & Furnish, 1961; Banks, 1967).

Microfloras of upper stage 4b and lower stage 5c (Price, 1973a, b) give a late Artinskian to Kungurian age.

CONDREN SANDSTONE

Named from: Condren Pinnacles.

Defined by: Yeates & others (1975d).

Status of name: Formally defined.

Type section: Condren Pinnacles (20°06'00"S, 127°08'00"E).

Previous names: Previously mapped as 'middle plant bearing sandstone' of the Liveringa Formation (Guppy & others, 1958) and Condren Sandstone Member by Casey & Wells (1964).

Modifications: None.

Described outcrop: Southeastern Fitzroy Graben and north onto the Betty Terrace. The Condren Sandstone also crops out in ' · southwest of the Stansmore Sheet area (Yeates & others, 1975b).

Distribution: In wells along the graben and Margaret Terrace northwest to the erosional limit west of Derby. The unit is confined to the northern Canning Basin.

Thickness variations: The thickest section is 610 m in a probably fault repeated outcrop at WAPET section PL6 on the Liveringa-Noonkanbah boundary fence. The thickest subsurface section is 281 m in Myroodah No. 1, in the northern Fitzroy Graben; in the southern graben, Lake Betty No. 1 penetrated 185 m. The unit thins towards the basin margins.

Relations with other units: Grades down into the Lightjack Formation, but may be locally disconformable or unconformable. The upper boundary is conformable with the base of the Hardman Formation, but near Godfreys Tank the unit is unconformably overlain by the Godfrey Beds and, in the Mount Bannerman Sheet area, by Triassic rocks.

Subdivision: None.

Lithology: In the northwestern Fitzroy Graben the unit crops out as sandstone: fine to medium, micaceous, well sorted, thin-bedded, porous, with coal seams and minor claystone (Veevers & Wells, 1961). In Mimosa No. 1 (175-273 m) it consists of interbedded siltstone: dark grey, very micaceous, grading to shale: micaceous, commonly kaolinized; sandstone: clear to light grey, very fine to fine to silty; with sand: clear to light grey, rarely coloured, very fine to very coarse, mainly fine to medium, subrounded, loose, rare kaolin; and minor coal. The unit is cross-bedded and ripple-marked, and contains clay pellets, rare worm tracks, concretions, and conglomerate bands. Plant remains are common. The variation in lithology is shown in Figure 5.4.8.

In the southeastern graben the unit consists of a rhythmically bedded, fining-upward sequence of sandstone and siltstone. Sandstone: buff to white, fine to medium, some coarse, moderately sorted, detrital mica, quartzose, thin bedded, friable, with interbeds of siltstone, shale, and thin conglomerate. High-angle cross-bedding occurs in the basal sandstone, and small-scale cross-bedding in the siltstone at the top of the cycles. In BMR Mount Bannerman No. 1 the unit consists of siltstone: white to grey, micaceous; and shale: grey carbonaceous, interbedded with sandstone: grey, fine micaceous, well sorted, quartzose (Yeates & others, 1975b).

Age: Abundant plant fossils, including Gangamopteris sp. and Glossopteris spp. are dated as Permian (White, 1961). Microfloras of upper stage 5a (Price, 1973a, b) date the unit as late Permian, possibly Kazanian. The stratigraphic position of the Condren Sandstone - between the Lightjack Formation (Artinskian to lower Kungurian) and the Hardman Formation (Tatarian) - indicates a late Kungurian to Kazanian age.

HARDMAN FORMATION

Named from: Mount Hardman.

Defined by: Yeates & others (1975a).

Status of name: Formally defined.

Type section: Mount Hardman (124°39'00"E, 18°18'00"S).

Previous names: Guppy & others (1958) originally defined the unit as the Hardman Member of the Liveringa Formation.

Modifications: None proposed.

Described outcrop: The unit crops out only in the Fitzroy Graben.

Distribution: Confined to the Fitzroy Graben; its erosional limit is west of Derby.

Thickness variations: The thickest measured section is a possibly faulted section at the south flank of Grant Range (WAPET-measured section PL1). The next thickest section (possibly also faulted), 226 m, was measured on the Liveringa-Noonkanbah boundary fence (WAPET-masured section PL6). The thickest section penetrated in a well is 138 m in BMR Mount Bannerman No. 2, but elsewhere the unit averages 60 m. Thinner sections are the result of pre-Triassic and post-Late Triassic erosion.

Relations with other units: The unit overlies the Condren Sandstone conformably, except where the Condren Sandstone wedges out and it overlies the Lightjack Formation disconformably (Yeates & others, 1975b; Crowe & Towner, 1976c).

Subdivision: The formation has been divided into three members (Yeates & others, 1975a).

CHERRABUN MEMBER

HICKS RANGE SANDSTONE MEMBER

KIRKBY RANGE MEMBER

These units are not always distinguishable outside the Crossland and Noonkanbah Sheet areas.

Lithology: Lower unit (Kirkby Range Member) - from top to base - sandstone: mottled, silty, bioturbated, ferruginised worm tubes, overlying a marker bed of sandstone: calcareous, very fossiliferous, ferruginised, overlying sandstone: white to pale brown, fine, very micaceous, argillaceous, poorly sorted; laminated to interbedded subordinate siltstone: white, brown, grey, laminated, cross-bedded, ripple cross-lamination, small slumps and ripple-marked, overlying poorly exposed shale: grey and varicoloured, micaceous, ferruginised.

Middle unit (Hicks Range Sandstone Member) - mainly sandstone: light, fine to coarse but mainly medium, minor granule conglomerate, quartzose, very micaceous, well sorted, extensive cross-bedding in sets up to 1 m thick, thin to massive bedding, friable, medium to hard.

Upper unit (Cherrabun Member) - sandstone: brown, micaceous, glauconitic, argillaceous, calcareous near base, fine, poorly sorted, fossiliferous, cross-bedded, thin to medium bedded, interbedded with siltstone: laminated, micaceous; and shale: laminated, micaceous; thin lenses of conglomerate: pebble, clay pellet, especially towards the top. The unit is bioturbated.

The lithological variations within the Hardman Formation are shown in Figure 5.4.9.

Age: A rich fauna is present with a distinct hiatus from the older Lightjack Formation (Thomas, 1958b). Dickins (1963) assigned a Tatarian age to the formation and placed it in his faunal stage F. He suggested that the late Tatarian is absent.

Plant fossils described by White & Yeates (1976) were dated as Permian or transitional Permo-Triassic.

Microfloras from the Kirkby Range Member belong to upper stage 5 (Price, 1973a, b) and are dated as Late Permian (Yeates & others, 1975b).

PERMIAN ROCKS OF UNCERTAIN CORRELATION

TRIWHITE SANDSTONE

Named from: Triwhite Hills (123°30'00"E, 22°10'00"S).

Defined by: Traves & others (1956).

Status of name: Formally defined.

Type section: 1.6 km east of Dunn Soak (123°10'00"E, 22°04'00"S), locality T1 (210) of Wells (1960).

Previous names: None.

Modifications: None proposed.

Described outcrop: Southern margin around Lakes Dora, Blanche, Winnifred, Goerge, and Auld.

Distribution: Kidson Sub-basin: in Wilson Cliffs No. 1 and Kidson No. 1. As continuity has not been established with the Liveringa Group of the northern Canning Basin, the name Triwhite Sandstone is retained for rocks of the same age as the Lightjack Formation in the southern areas. The unit is confined to the Kidson Sub-basin and Lambert Shelf.

Thickness: Traves & others (1956) estimated the thickness as 61-92 m, though in Wilson Cliffs No. 1 it is 99 m thick and in Kidson No. 1 128 m.

Relations with other units: In Kidson No. 1 and Wilson Cliffs No. 1 the unit rests conformably on the Noonkanbah Formation. Along the southern margin of the basin it rests conformably on the Dora Shale (= Noonkanbah Formation) and is unconformably overlain by Mesozoic sediments (Veevers & Wells, 1961).

Subdivision: None proposed.

Lithology: At a locality 9.6 km east of Dunn Soak, Traves & others (1956) measured a section consisting of:

5 m sandstone and claystone: white, micaceous, quartzose, fine, well bedded
14 m sandstone: white, fine-medium, micaceous, well bedded
1.5 m greywacke: brownish, fine, micaceous, worm tracks, ripple marks, oolitic in part (Veevers & Wells, 1961), ironstone concretions, and indistinct fossils.

In the Kidson Sub-basin, Wilson Cliffs No. 1 penetrated sandstone: white, fine to coarse, argillaceous with depth, and interbedded near the base with ferruginous siltstone. Kidson No. 1 penetrated siltstone: medium grey, micaceous, pyritic, partly argillaceous, partly sandy, partly carbonaceous; and interbedded sandstone: white to pale grey, very fine to fine, micaceous, partly argillaceous and calcareous.

Age: The unit contains marine fossils similar to those from the upper Noonkanbah Formation or lower Liveringa Group (Dickins & Thomas, in Traves & others, 1956; Dickins, 1963), indicating an Early Permian age.

CHIRUP FORMATION

Named from: Chirup No. 1.

Defined by: New name proposed*.

Status of name: Defined herein.

Type section: Chirup No. 1 (449 to 537 m).

Previous name: None; referred to in Chirup No. 1 completion report as "Unit 'A' - Upper Permian" (Bird, 1969) and as 'Upper Permian' in BMR Wallal No. 4A (Henderson & others, 1963).

Modifications: Not applicable.

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* The name Chirup Formation has been submitted to the Stratigraphic Nomenclature Committee for approval.

Described outcrop: None.

Distribution: BMR Wallal No. 4A and Chirup No. 1, Wallal Embayment. Probably originally present in western Willara Sub-basin and probably present beneath Triassic rocks offshore in Bedout Sub-basin.

Thickness: 38 m in Chirup No. 1 and 31 m in BMR Wallal No. 4A.

Relations with other units: Overlies Grant Formation unconformably in both wells, and unconformably overlain by Jurassic Wallal Sandstone or Triassic Blina Shale.

Subdivision: None.

Lithology: In Chirup No. 1 - interbedded shale: light to dark grey-brown, grey-black to black, sandy, non-carbonaceous to very carbonaceous; lignite: brown black, partly pyritic, woody fossils; sandstone: light to medium grey, fine to conglomeratic, mainly subrounded, frosted, loose, some siliceous-cemented fine, hard layers, abundant chert fragments.

In BMR Wallal No. 4A - shale: carbonaceous, with laminae of sandstone: argillaceous, fine to medium.

Age: The unit contains a stage 5 microflora (Balme, in Bird, 1969). The presence of Indospora clara and Microreticulatisporites bitriangulatus suggests upper stage 5. The Hardman Formation of the Fitzroy Graben may be a correlative of the Chirup Formation. In BMR Wallal No. 4A the formation was dated as Late Permian (Balme, in Henderson & others, 1963), and similarities were noted with assemblages from the Liveringa Group.

GODFREY BEDS

Named from: Godfrey Tank, northwest Canning Basin.

Defined by: Elliot, Casey & Wells (in McWhae & others, 1958).

Type section: Section C3a of Casey & Wells (1964) at 20°12'35"S, 126°33'00"E.

Previous names: None.

Modifications: None proposed.

Described outcrop: Confined to the area around Godfrey Tank, Breadens Pool, and Crown Head (Yeates & others, 1975b), west of Micha Bore and in the Stretch Range.

Distribution: Described only from the outcrop area.

Thickness: The thickest section measured, 90 m, is at Crown Head (Veevers & Wells, 1961) but only 54.5 m crop out at the type section (Casey & Wells, 1964).

Relations with other units: The stratigraphic limits of the Godfrey Beds have long been equivocal since contacts with older or younger units were doubtfully assigned. Veevers & Wells (1961) state that the unit disconformably overlies probable Condren Sandstone at C59 (22 km north of Well 48), and that Rhizocorallium-bearing sandstone at C23 (about 56 km southeast of Minnie Range) overlies possible Lower Triassic Blina Shale. An outcrop near Culvida Soak was photo-interpreted as Godfrey Beds over Middle Triassic Culvida Sandstone (Casey & Wells, 1964). None of the units concerned were positively identified.

Detailed mapping in the type area revealed a possible disconformably contact with the underlying Condren Sandstone near Godfrey Tank and a faulted contact with the Millyit Sandstone (Yeates et al., 1975b). Elsewhere this upper contact is apparently conformable.

Subdivision: None.

Lithology: Yeates & others (1975b) described the basal beds as poorly sorted and overlain by interbedded sandstone: brown to grey, fine, slightly micaceous, argillaceous, quartzose, friable, and laminated; thin bedded siltstone: with rhizocorallid burrows, shell fragments, small-scale cross-bedding, clay-pellet conglomerates, and ripple marks.

Age: Rhizocorallium spp. burrows are common but undiagnostic as are other trace fossils in the unit. Plant fossils were dated as Permo-Triassic by White & Yeates (1976). Shell fragments found by Veevers & Wells (1961) were originally dated as Cretaceous by Dickins (in Veevers & Wells, 1961) but were only questionably assigned to the genus Etea.

Stratigraphic position above the Condren Sandstone and below the basal Lower Triassic Millyit Sandstone suggests a Tatarian age, similar to the Hardman Formation, of which it may be a facies equivalent.

BEDOUT VOLCANICS

Named from: Bedout No. 1

Defined by: New name proposed*.

Status of name: Informally defined.

Type section: Bedout No. 1, 3021 m to 3073 m (total depth).

Previous names: None.

Modifications: None.

Distribution: Known only in Bedout No. 1. It may be distributed northward along the Bedout High as suggested by magnetic interpretation (Pl. 8).

Thickness: 52 m in Bedout No. 1, but the total thickness is unknown.

Relations with other units: Underlie Lower Triassic rocks, presumably unconformably, because the volcanics near the top are altered. It may be related to ?Triassic dolerites in Barlee No. 1.

Subdivision: The unit consists of an upper volcanic conglomerate and a lower basalt.

Lithology: 3021 to 3046 m, conglomerate: light grey to dark greenish black; 60% altered basalt fragments, pebble to cobble size, average diameter 5-8 cm, poorly sorted, subangular to subrounded; 40% matrix, fine to pebble size, altered basalt fragments, mainly subangular; cemented by altered

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* The name Bedout Volcanics has been submitted to the Stratigraphic Nomenclature Committee for approval.

tuffaceous material; calcite and chlorite veins; moderately hard to very hard; no effective porosity.

3046 to 3073 m (total depth), basalt: fresh to highly altered, dark greenish grey to greenish black, or altered to reddish brown clay, 40% feldspar, 40% pyroxene, 20% accessory minerals, altered at top to clay minerals and chlorite, soft to very hard, no effective porosity.

Age: K-Ar dating of the volcanics has given an absolute age of 176 m.y. (BOCAL, 1971). However, as the rocks underlie Lower Triassic sediments and are extensively altered, this determination is probably incorrect. Dolerites in Wamac No. 1 well, to the northeast, have yielded a minimum K-Ar age of 228 m.y. (Early Triassic); Amax Petroleum (Australia) Inc. (1974) considered that argon loss is unlikely to have been more than 15% and so the intrusives in Wamac No. 1 are probably of Late Permian age. If the parent magmas were cogenetic, the age of the Bedout Volcanics is also Late Permian.

K-Ar dating on dolerite intrusives in Fraser River No. 1 yielded an age of 190 m.y., which is likely to be only a minimum age. The undated dolerite sills in Barlee No. 1 are probably also the result of this widespread Late Permian mafic igneous activity.

APPENDIX 5. STRATIGRAPHIC UNITS OF INTERVAL 5

This interval consists of the Millyit Sandstone, Blina Shale, Erskine Sandstone, Culvida Sandstone, and several unnamed units in the offshore area.

MILLYIT SANDSTONE

Named from: Millyit Range.

Defined by: Elliot (in McWhae & others, 1958, p. 90).

Status of name: Formally defined.

Type section: At the head of Spring Creek, Millyit Range (19°12'00"S, 125°35'30"E).

Previous name: Previously unnamed before Elliot.

Modifications: None.

Described outcrop: Millyit Range (station 117) and southeastern Fitzroy Graben.

Distribution: The Millyit Sandstone is confined to the Fitzroy Graben from Millyit Range to the southeast. It was encountered in BMR Lucas No. 13. It may extend as a thin wedge to northwest under the Blina Shale.

Thickness variations: The thickest section is 90 m in BMR Lucas No. 13. 14 m are preserved in the eroded type section and 25 m are exposed in another eroded section near Spring Creek (Yeates & others, 1975b).

Relations with other units: The Millyit Sandstone overlies the Liveringa Group with 1-2° unconformity at the type section (Elliot, in McWhae & others, 1958). In BMR Lucas No. 13 it overlies the Hardman Formation with apparent conformity (Yeates & others, 1975b). Its upper contact with the Blina Shale is transitional.

Subdivision: None.

Lithology: In BMR Lucas No. 13 - siltstone: grey and black, carbonaceous with thin-bedded fine-grained sandstone near the base; overlain by sandstone: clear, white, massive, medium to coarse-grained, quartzose high-angle cross-bedding, quartz pebbles. The transitional unit with the Blina Shale consists of sandstone: fine to medium-grained, quartzose, in medium to cross-bedded sets up to 30 cm thick; and interbedded siltstone: carbonaceous and micaceous.

In outcrop the medium to coarse-grained sandstone predominates, probably because the softer siltstones have been eroded. Cyclic sedimentation (5-m-thick cycles) and fining upwards sequences are known in outcrop.

Age: Fossil plant material indicates a Late Permian to Early Triassic age (White & Yeates, 1976). Forms identified from two localities include Vertebraria indica Glossopteris indica, and G. angustifolia. Palynology from BMR Lucas No. 13 indicates an Early Triassic age (basal stage Tr 1b of Evans, 1969; Yeates & others, 1975b).

BLINA SHALE

Named from: Blina station.

Defined by: Brunnschweiler (1954).

Status of name: Formally defined.

Type section: Not formally designated. Playford & others (1975) have suggested a section that McKenzie (1961) measured at Erskine Hill (17°51'25"S, 124°21'40"E), which we regard as the type section herein (station 61).

Previous names: Belina Shale (Kraus, 1941), Wongal Shale (Fairbridge, 1953b), and Wonjil Shale (Brunnschweiler, 1954).

Guppy & others (1950, p. 6) originally published the name Belina Shale, attributing it to unpublished reports by Kraus, (1941) and Reeves (1949). The name was corrected to Blina Shale by Brunnschweiler (1954), who placed the Wongal Shale of Fairbridge (1953) in synonomy.

Modifications: In this report the type section is taken as that measured by McKenzie (1961) and not that stated by Smith (1961), who misquoted Brunnschweiler (1957, p. 5). The section in Blackstone No. 1 is taken here as a reference section.

Described outcrop: Fitzroy Graben.

Distribution: Derby Town bore, Myalls bore, Bakers 2 bore, Wongil bore, BMR Wallal No. 4A, Brennans bore, May River No. 1, Langoora No. 1, Meda No. 1, Blackstone No. 1, BMR Lucas No. 13, No. 20 White Rocks Mill bore, No. 18 Mill bore, No. 34 Mill bore, Mimosa No. 1, Bannans bore, Egans bore, bore 6 (Noonkanbah), Thompsons bore, and other station bores.

The Blina Shale is confined to the Fitzroy Graben in all known occurrences except one: in the subsurface on the Lambert Shelf, in the southwest Canning Basin (BMR Wallal No. 4A). Offshore, rocks of similar lithology and age are known from the Bedout Sub-basin and are expected in the Rowley Sub-basin from seismic evidence.

Thickness variations: The original thicknesses are not commonly preserved. The thickest known complete section (311 m) is in Blackstone No. 1. BMR Lucas No. 13 penetrated a complete section of 84 m, suggesting that the unit thins to the southeast. BMR Wallal No. 4A penetrated 25 m of Blina Shale unconformably below Jurassic sediments. The thickest known outcrop section is in Dry Corner Syncline (244 m, Balme, 1969a) near Mount Anderson.

Relations with other units: In the northwestern Fitzroy Graben the Blina Shale rests unconformably on the Upper Permian Liveringa Group and grades into or is unconformable below the Erskine Sandstone. In the southwestern graben the contacts with the underlying Millyit Sandstone and overlying Erskine Sandstone are gradational or disconformable. Locally the Erskine Sandstone may overlie the Blina Shale disconformably or unconformably (Yeates & others, 1975b). The Blina Shale may locally overstep the Millyit Sandstone and rest disconformably on the Liveringa Group.

On the Lambert Shelf the Blina Shale may be conformable with the Chirup Formation and is unconformable beneath the Jurassic Wallal Sandstone.

Subdivision: No subdivision is proposed as detailed sections of the whole unit are not available. In the northwestern Fitzroy Graben a basal 40-m section can be subdivided from the total Blina Shale on lithology and wireline log characteristics.

Lithology: In the thickest section, in Blackstone No. 1, the lithologies are:

9-280 m - Siltstone: grey to whitish, finely micaceous, pyritic; finely interbedded with shale: grey and green; and minor sandstone: grey, fine-grained. Traces of glauconitic and calcareous material occur in the lower part.

280-320 m - Siltstone: glauconitic, micaceous, and pyritic, with minor sandstone interbeds.

The lower unit is sandier in other wells (Meda No. 1, Mimosa No. 1, and Langoora No. 1) and contains carbonaceous material, mica, glauconite, and marine fossils. The 31-m section at Mount Erskine (McKenzie, 1961) consists of blue, green, and grey, shale interbedded with siltstone in the lower part, and an upper half of interbedded siltstone and fine-grained sandstone. The fine-grained sediments are laminated, cross-laminated, and ripple-marked. Three marker horizons of conchostracan coquina are known, and vertebrate bone beds of up to 3 m thickness occur. Phosphatic intercalations are reported from the Wonjil bore area.

In the southeastern Fitzroy Graben the Blina Shale is sandier and consists of thin-bedded micaceous siltstone and interbedded very fine-grained, subangular, poorly to moderately sorted, micaceous quartzose sandstone with ripple marks.

Age: The age of the Blina Shale is Early Triassic (Scythian) and is well dated on spores and pollen (Balme, 1963) and vertebrate fossils (Cosgriff, 1965). R. Paten (cited in Yeates & others, 1975b) extends the age to Middle Triassic (Anisian). This is considered incorrect: rocks so identified may be Erskine Sandstone.

ERSKINE SANDSTONE

Named from: Erskine range.

Defined by: Wade (1938).

Status of name: Named formalised.

Type section: Erskine Range (17°50'S, 124°20'E).

Previous name: Erskine Series (Wade, 1938).

Modifications: Brunnschweiler (1954) revised the name to Erskine Sandstone.

Described outcrop: Throughout the Fitzroy Graben. Onlaps the Margaret Terrace east of Derby.

Distribution: Derby town bore, Myalls bore, Blackstone No. 1, and homestead water-bores in the northwest Fitzroy Graben. It is limited to the Fitzroy Graben at present, but the onlap to the Margaret Terrace in the northwest suggests that the original outcrop may have been more widespread.

Thickness variations: The thickest known section is 255 m in Derby town bore. The isopach suggests that, if the Blina Shale thickness is constant and the Jurassic does not occur in the subsurface, the Erskine Sandstone may reach 400 m in the Derby Syncline. On the northern scarp of the Sisters Plateau the unit is 35 m thick, and at Yarrada Hill 26 m. 40 m crop out at Point Alphonse, in the south-eastern Fizroy Graben, and 88 m in the Stretch Range.

Relations with other units: The Erskine Sandstone conformably to unconformably overlies the Blina Shale in the northwestern Fitzroy Graben and oversteps Permian rocks east of Derby. In the southeastern graben the contact with the Blina Shale is gradational, but is locally conformable and disconformable. The Erskine Sandstone is unconformably overlain by the Jurassic Meda Formation or Recent sands. The Culvida Sandstone may overlie the Erskine Sandstone conformably (Yeates & others, 1975b) at Culvida Soak, but the Erskine Sandstone is probably a lateral equivalent of the Culvida Sandstone.

Subdivision: No subdivision attempted.

Lithology: The Erskine Sandstone consists of sandstone: grey, silty, micaceous, carbonaceous, thinly to massively bedded, fine to medium-grained quartzose, commonly cross-bedded, with interbeds of quartz pebble conglomerate. Cut-and-fill structures contain clay-pellet conglomerate or conglomerate lag deposits, and ripple marks and mud-cracks sometimes occur in the interbedded siltstone. The only fossils present are trace fossils and plant remains.

Age: The Erskine Sandstone contains a macroflora of Triassic age (White & Yeates, 1976), and Balme (1969a), recorded late Scythian spores and pollen from Derby town bore and Myalls bore. The age is late Scythian to early Middle Triassic (Anisian).

CULVIDA SANDSTONE

Named from: Culvida Soak, in the Minnie Range (station 164).

Defined by: Casey & Wells (1960).

Status of name: Formalised and published by Veevers & Wells (1961) and Casey & Wells (1964).

Type section: Culvida Soak area (20°13'00"S, 126°55'00"E).

Distribution: Encountered in the subsurface only in BMR Cornish No. 2. The Culvida Sandstone is only known in a 20-km radius of the type area in the Minnie Range, Fitzroy Graben.

Thickness variations: The type section has a measured thickness of 18.3 m and the thickest section is 207 m, in BMR Cornish No. 2 (Yeates & others, 1975b).

Relations with other units: The Culvida Sandstone is a lateral equivalent of the Erskine Sandstone, and, as such, probably overlies the Blina Shale gradationally though may be disconformable to unconformable locally though

the unit conformably overlies a sandstone that may be the Erskine Sandstone. In BMR Cornish No. 2 (Yeates & others, 1975b); yet this lower unit may well be the Blina Shale.

Subdivision: None.

Lithology: In BMR Cornish No. 2 the unit consists of sandstone: white, some stained red, fine to coarse, poorly to well sorted, subangular, quartzose; conglomerate: red and yellow grain coatings, quartz granule; and subordinate siltstone; white, mauve, some multicoloured, carbonaceous, kaolinitic, with basal interbedded siltstone: grey green, earthy red, black, carbonaceous, laminated; and sandstone: green, fine, quartzose.

At the type locality the unit consists of sandstone: fine to coarse, micaceous, quartzose, with plant fossils, cross-bedding, ripple marks, mud-cracks, worm tracks, clay lenses and pellets, rhythmic bedding and fining-upward cycles (Casey & Wells, 1964; Yeates & others, 1975b).

Age: The contained macroflora is dated as Middle Triassic by White & Yeates (1976). Microflora from BMR Cornish No. 2 is assigned to stage 3 (Evans, 1966) by P.L. Price (see Paten & Price, Appendix C in Yeates & others, 1975b). Yeates (1975b) claimed that the unit is younger than the Erskine Sandstone, but the ages they quoted indicate that it overlaps with both the Erskine Sandstone and the upper part of the Blina Shale.

UNNAMED TRIASSIC SEDIMENTS IN THE BEDOUT SUB-BASIN (BEDOUT NO. 1 AND KERAUDREN NO. 1)

These rocks do not crop out and their distribution is unknown. They are considered to be the equivalent of all the onshore named Triassic formations and to occur in the Bedout and probably Rowley Sub-basins. The known thickness ranges from 110 m (Bedout No. 1) to 1384+ m in Keraudren No. 1, but may be much thicker.

The relations of the offshore Triassic are uncertain: Keraudren No. 1 did not fully penetrate the unit, and Bedout No. 1 bottomed in weathered volcanics of unknown age (Late Permian). The upper contact is disconformable with Lower Jurassic sediments.

Lithology: The thickest penetrated section in Keraudren No. 1 consists of predominantly clastic rocks:

(Top) 2460-2801 m:

Sandstone: argillaceous; very fine to medium-grained though coarse to granular locally; traces of mica, kaolinite, and pyrite; in part calcareous.

Claystone: multicoloured; traces of mica and carbonaceous matter.

Siltstone: minor.

Coal: minor thin seams.

2801-3630 m: As above but including Calcilutite: argillaceous and dolomitic in lower part with traces of pyrite.

3630-3844 m:

Claystone: partly silty; kaolinitic clay and mica in various amounts; traces of pyrite and carbonaceous matter.

Sandstone: argillaceous; fine to medium-grained; subangular to subrounded; poorly to moderately well sorted; traces of pyrite, biotite, and granular chlorite scattered throughout; kaolinite locally common; some carbonaceous matter; minor granule conglomerate.

Siltstone: dark, carbonaceous, occasionally argillaceous; traces of mica.

The much thinner Bedout No. 1 section consists of:

(Top) 2911-3012 m:

Claystone: olive grey to multicoloured; silty in part; 80-90% clay minerals; very fine to medium quartz grains, grading to siltstone in places; with interbedded light grey to greenish grey sandstone: very fine-grained to granular (mainly medium to coarse); moderately to moderately well sorted; angular to subrounded; some carbonaceous material.

Sandstone: white to dark greenish-grey; argillaceous; very fine to medium-grained; grainsize decreasing with depth; moderately to moderately well sorted; subangular; with minor argillaceous light grey siltstone: very well sorted, subangular; and claystone: medium dark grey, arenaceous, trace mica, fissile.

3012-3021 m:

Claystone: as above.

Sandstone: white to dark greenish grey; very fine to fine-grained; moderately to moderately well sorted; subangular.

Siltstone: minor as above.

Acritarchs occurring in this lower section distinguish it from the upper section, which contains only spores and pollen.

Age: Bedout No. 1 contains spores and pollen of Early to Middle Triassic age (W. Witt, personal communication). BOCAL (1971) previously dated this section as Late Triassic.

In Keraudren No. 1 the upper part (2462-2625 m) contains long-ranging Triassic miospores but the presence of Taeniaesporites australis and Aratrisporites sp. cf. A. strigosus indicates an age no younger than early Late Triassic (Hematite Petroleum Pty Ltd, 1974). The section from 2810-3565 m contains spores and pollen of Ladinian age (Hematite Petroleum Pty Ltd, 1974) and has forms in common with the Mungaroo Beds of the Carnarvon Basin (Balme, 1969a). The well bottomed in sediments dated as early Ladinian to Anisian (Middle Triassic).

APPENDIX 6. STRATIGRAPHIC UNITS OF INTERVAL 6

Interval 6 contains the Wallal Sandstone, Alexander Formation, Jarlemai Siltstone, Jowlaenga Formation, Barbwire Sandstone, Jurgurra Sandstone, Callawa Formation, Cronin Sandstone, Meda Formation, James Sandstone, Mudjalla Sandstone, Mowla Sandstone, and an unnamed Jurassic clastic rock.

WALLAL SANDSTONE

Named from: Wallal station, in the Mandora 1:250 000 Sheet area.

Defined by: J.R.H. McWhae (Appendix C in Johnstone, 1961).

Type section: 915-1927 feet (279-598 m) in Wallal No. 4A (19°44'12"S, 120°44'25"E). Station 234.

Previous name: None.

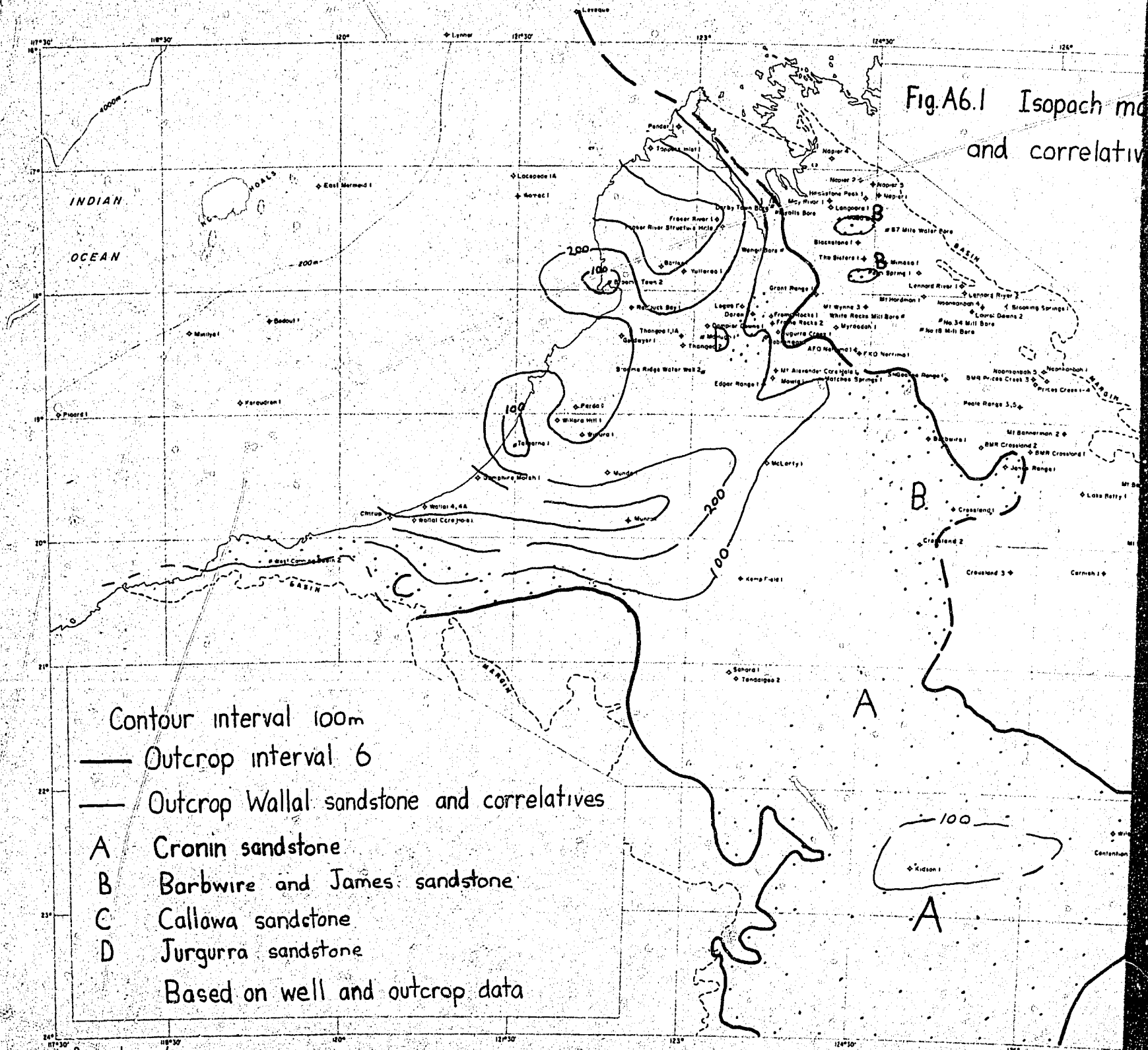
Modifications: None.

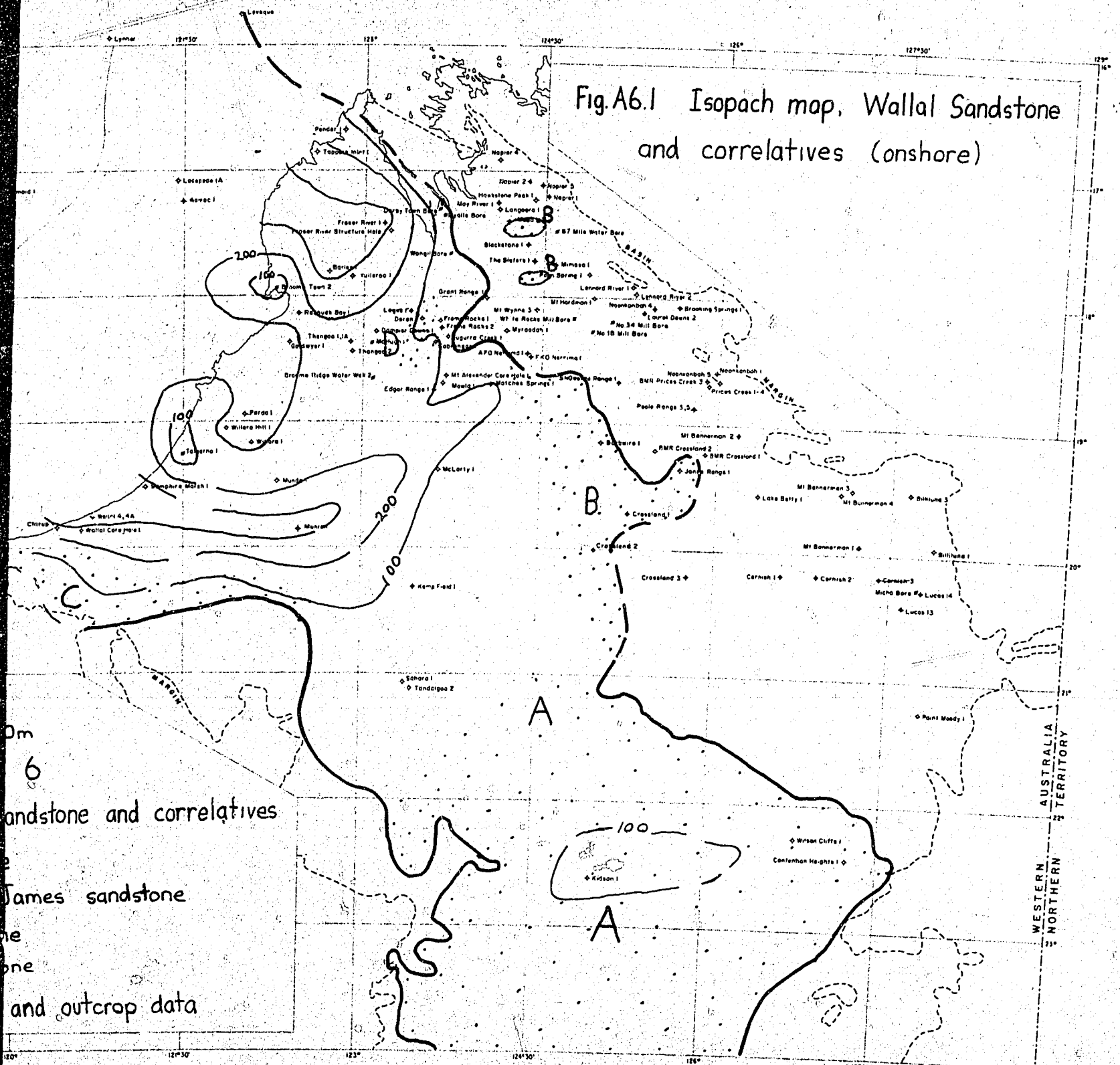
Outcrop: None described.

Distribution: The Wallal Sandstone is recognised over the western third of the onshore Canning Basin. The wells that intersected this information and the approximate limit of the unit are shown in Figure A6.1.

Thickness variation: The formation reaches a known maximum thickness of 369 m in Munro No. 1. Isopach mapping of the Wallal Sandstone (Fig. A6.1) shows that it thickens in the Fitzroy Graben area and the area south of the Willara Sub-basin (the Wallal Embayment and its eastern extension), and appears to thin not only eastward out to less than 100 m over the western Broome Arch and the northern Willara Sub-basin. Conformable units overlying the Wallal Sandstone in the areas of thinning suggest that this thinning is depositional not erosional.

Relations with other units: It unconformably overlies Triassic, Permian, and Carboniferous rocks with an angular discordance evident on seismic sections. Near the edge of the basin it may unconformably rest on older Palaeozoic or


Fig. A6.1 Isopach ma
and correlativ
INDIAN
OCEAN
BASIN
MARGIN
Contour interval 100m
Outcrop interval 6
Outcrop Wallal sandstone and correlatives
A Cronin sandstone
B Barbwire and James sandstone
C Callawa sandstone
D Jurgurra sandstone
Based on well and outcrop data
Record 1979/32



Om

6

andstone and correlatives

e

James sandstone

ne

one

and outcrop data

XAUS-4-139

87%

Precambrian rocks. The top of the formation is unconformable with the Alexander Formation. East of the limit of the Alexander Formation the Wallal Sandstone is eroded and covered with Recent sand or Cretaceous rocks (i.e., Broome Sandstone, Anketell Formation).

The Wallal Sandstone is a lithological and possibly time equivalent of most of the non-marine formation in interval 6 (Pl. 12-5). Lack of precise age dating for many of these units makes their relation to the Wallal Sandstone questionable, but as they appear to be lithological correlatives they are correlated with the Wallal Sandstone. (For a discussion of these correlations see the Cronin Sandstone, Callawa Formation, Meda Formation, James Sandstone, Barbwire Sandstone, Jurgurra Sandstone).

Subdivision: None.

Lithology: Mainly quartz sandstone with minor lenses of conglomerate, siltstone, and coal. The lithology at the type sections is:

52 m	Sandstone: quartzose, argillaceous matrix, poorly sorted, fine to coarse-grained, very porous and friable, glauconitic, cross laminated; interbedded with pebble conglomerate and minor coarse siltstone; contains carbonised and pyritised wood fragments.
40 m	Sandstone: as above but mostly fine and medium-grained.
102 m	Sandstone: as above but mostly medium and coarse-grained, silty, with pebble conglomerate, pyrite nodules, and coal fragments.
30 m	Sandstone: as above but generally better sorted, and a zone of abundant pyritic matrix.
46 m	Sandstone: brownish-grey, medium-grained, moderately well sorted, very porous and friable, and containing minor siltstone.
38 m	Siltstone, claystone, and shale: quartzose, laminae of fine-grained argillaceous sandstone; carbonaceous matter associated with the shale.

The abundance of the minor constituents varies over the basin but the formation remains mainly quartz sandstone (Pls. 11-3, 11-4).

Age: Toarcian to Oxfordian (Early to Late Jurassic). The widespread extent of numerous wells intersecting the Wallal Sandstone have provided abundant microfauna and microflora for dating this formation.

ALEXANDER FORMATION

Named from: Mount Alexander in the Mount Anderson 1:250 000 Sheet area, where the type section is exposed.

Defined by: Brunnschweiler (1954).

Status of name: Formally defined.

Type section: 134 feet (41 m) cropping out at Mount Alexander (18°41'S, 123°39'E). Station 30.

Previous name: The formation was included in Reeves (1949) Fraser River Beds.

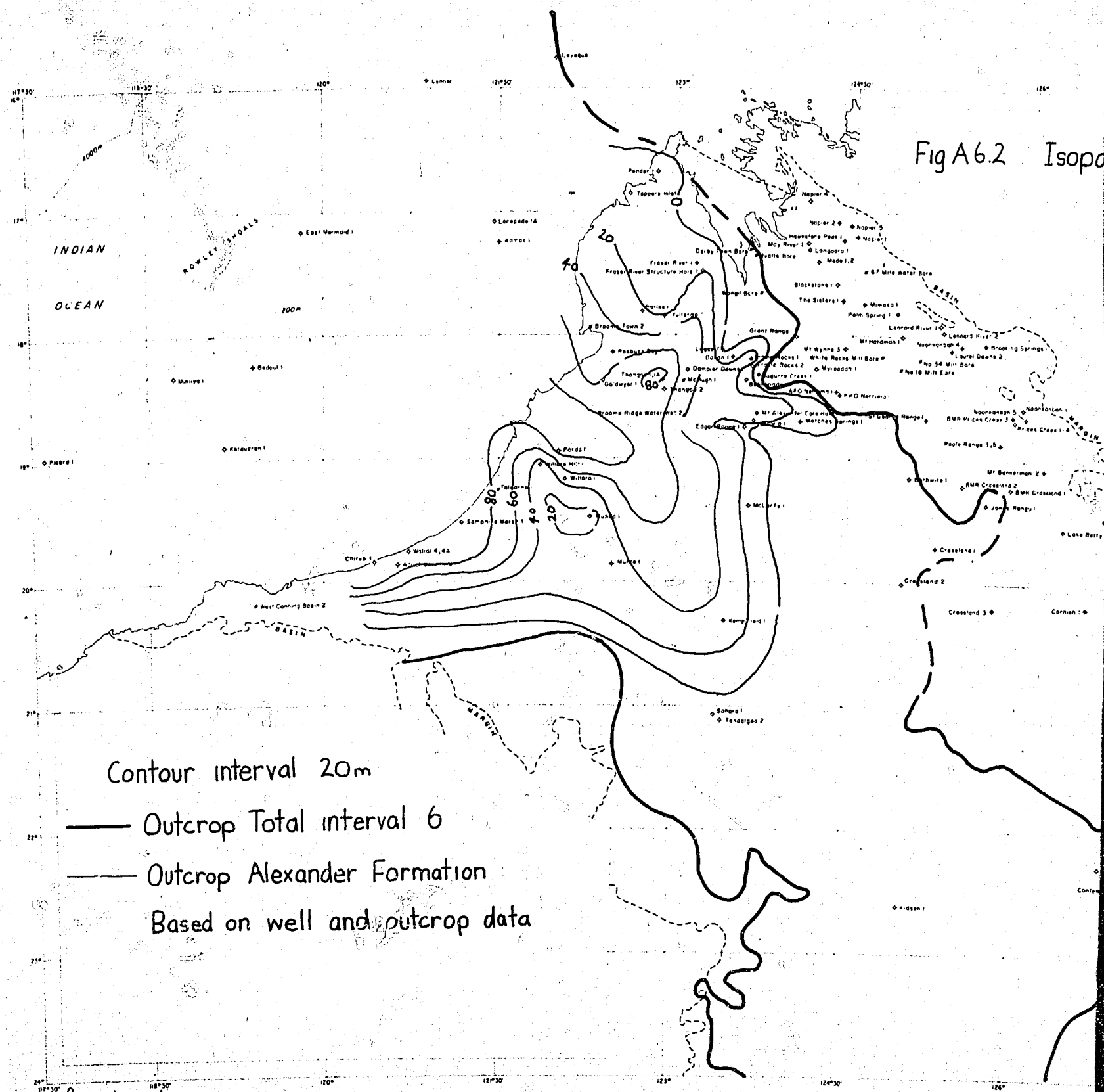
Modifications: None.

Outcrop: Exposed in the Edgar Ranges at Langey Crossing, and in the southeast corner of the Noonkanbah 1:250 000 Sheet area in dissected mesas and buttes, and in the Mount Anderson and McLarty Hills 1:250 000 Sheet areas as small conical hills which rise above a sand plain. The beds are subhorizontal with shallow dips.

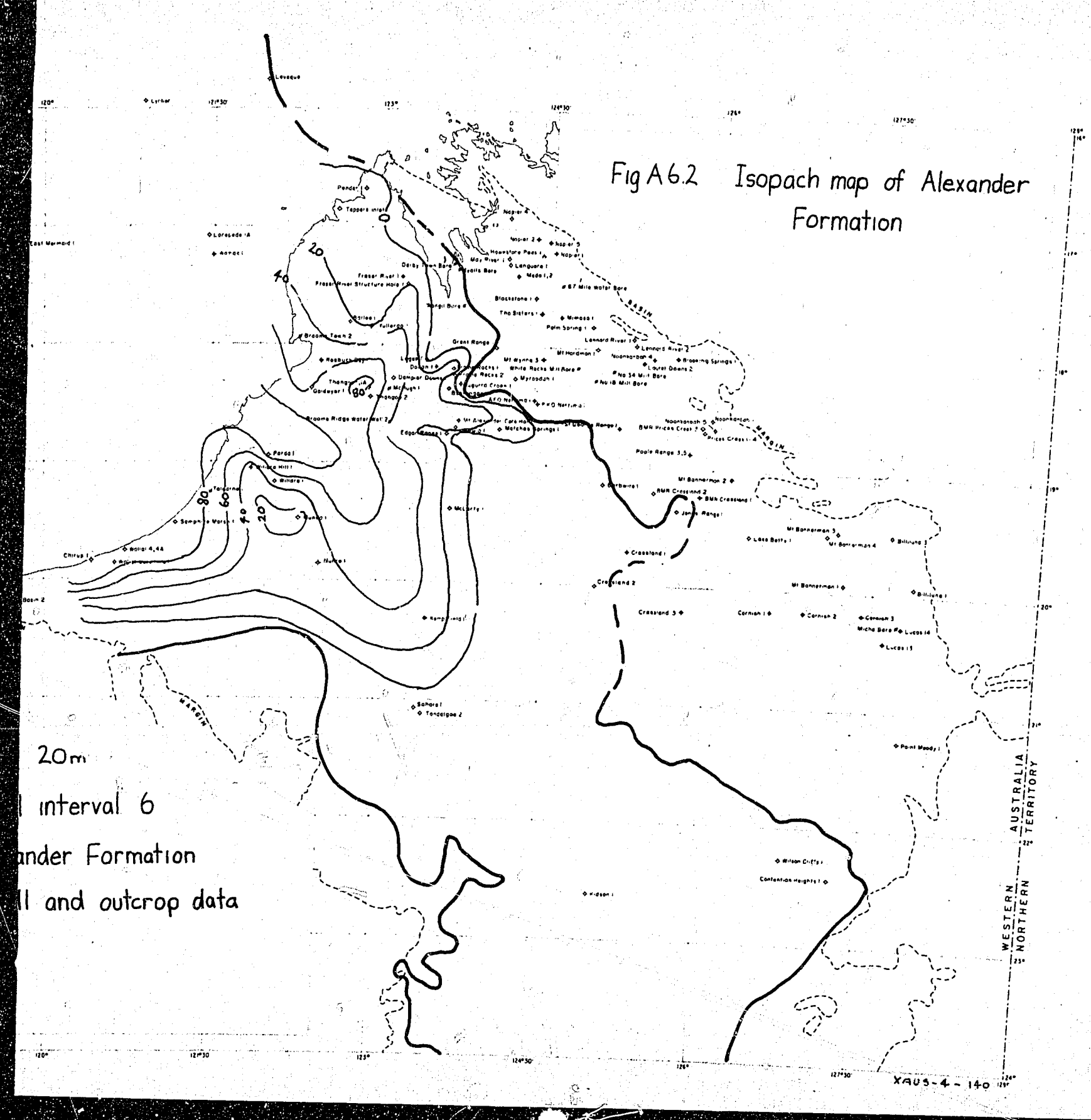
Distribution: Western third of the onshore Canning Basin in both outcrop and wells: Pender No. 1; Tappers Inlet No. 1; Yulleroo No. 1; Barlee No. 1; Babrongan No. 1; Fraser River No. 1; Fraser River Structure Hole No. 1; Roebuck Bay No. 1; Goldwyer No. 1; Frome Rocks No. 1; Thangoo Nos. 1, 1A, and 2; Broome Ridge water well No. 2; McHugh No. 1; Dampier Downs No. 1; Edgar Range No. 1; Mount Alexander Core Hole No. 1; Matches Springs No. 1: Parda No. 1; Willara No. 1; Munda No. 1; McLarty No. 1; Kemp Field No. 1; Munro No. 1; Talgarno No. 1; Samphire Marsh No. 1; BMR Wallal Nos. 4, 4A; Willara Hill No. 1; Wallal Core Hole No. 1; Broome Town No. 2; Chirup No. 1. The limits of the Alexander Formation are shown in Figure A6.2.

Thickness variation: The maximum thickness was recorded in Samphire Marsh No. 1, where 92 m of Alexander Formation was intersected. A belt of thick sediment extends southeast across the western Broome Arch towards Kemp Field No. 1. This belt is separated from the thick sediments in Samphire Marsh No. 1 by an area of thinner sediment in the area covered by the Willara Sub-basin, centering around Munda 1 where only 15 m of the Alexander Formation is present (Fig. A6-2).

Fig A6.2 Isopa



Record 1979/32


Fig A6.2 Isopach map of Alexander Formation
20m
l interval 6
ander Formation
ll and outcrop data
AUSTRALIA
TERRITORY
WESTERN
NORTHERN
MARGIN
BASIN
XAUS-4-140
87%

Relations with other units: The Alexander Formation conformably overlies the Wallal Sandstone over most of its known extent. At the eastern edge on the Mount Anderson 1:250 000 Sheet area it unconformably overlies the Jurgurra Sandstone (Casey, 1958a). The contact with the Jurgurra Sandstone at the type section is obscured, but is exposed at other outcrops in the same area. The formation is conformably overlain by the Jarlemai Siltstone. Along its eastern limit where the Jarlemai Siltstone is not present the Alexander Formation is eroded and either exposed or covered with Recent sand.

There are no direct correlatives of the Alexander Formation in the onshore Canning Basin. Playford & others (1975) equated the base of the formation with the upper part of the Mudjalla Sandstone. Veevers & Wells (1961) suggested the Mudjulla Sandstone is a landward facies of the Alexander Formation. This relation is discussed under the Mudjalla Sandstone in this Appendix. Other formations suggested as landward equivalents are the Meda Formation and the James Sandstone. These correlations are also discussed in this Appendix under the various formation names. The unnamed Upper Jurassic marine sandstone recorded in several offshore wells is tentatively correlated with the onshore Alexander Formation on both lithology and age (Pl. 12-5). In Bedout No. 1, no marine sediments were recorded but a deltaic sandstone of similar age is present and probably represents a facies equivalent of the Alexander Formation to the east (Figs. 5, 6, 7).

Subdivision: None.

Lithology: Mainly fine to coarse sandstone interbedded with siltstone. Locally the formation grades into mainly siltstone. At the type section the following lithology was recorded:

16 m Sandstone: white to brown, quartzitic, fine to medium-grained; interbedded with siltstone: white to red-blue, fine-grained, massive to well bedded, partly silicified.

18 m Sandstone: white to brown, quartzitic, fine and medium-grained, ripple-marked, thin-bedded; interbedded with siltstone: white, thin-bedded.

4 m Sandstone: grey-brown to yellow-brown, weathers reddish-brown, medium-grained, porous, current-bedded, weathers slightly massive, irregularly jointed.

3 m No outcrop.

The lithology of the Alexander Formation in the subsurface is similar to that at the type section although locally variable both laterally and vertically. Mainly sandstone, the colour ranges from grey or white to varicoloured and the grainsize from very fine to rarely very coarse. As in outcrop, the subsurface sandstone is interbedded with siltstone, which are grey, white and brown, and less commonly shale or mudstone, which are grey to black. The sandstone is commonly silty, pyritic, glauconitic, and fossiliferous. Sorting varies locally and ranges from well sorted to poorly sorted. The formation is calcareous locally, and rarely contains limestone as in Thangoo No. 1. It commonly contains wood fragments and less often lignite. Tracks, trails, and ripple marks described from outcrop sections have not been recorded in subsurface descriptions.

The Alexander Formation is distinguished from the underlying Wallal Formation by its marine fauna, finer-grained clastics, decreased amount of lignite, and absence of coal seams.

Age: Late Oxfordian to early Kimmeridgian. The formation is well dated in outcrop by ammonoids, pelecypods, brachiopods, and ophiuroids, and by microflora, microplankton, forams, radiolaria, belemnites, pelecypods, and ostracods from subsurface sections. The Alexander Formation is richly fossiliferous and several genera are known.

Brunnschweiler (1954, 1960) recorded ammonites Virgatosphinctes cf. communis and Kossmatia; bivalves Inoceramus cf. everesti, Meleagrinella maccoyelloides cf. Quenstedtia, and Maccoyella cf. corbiensis; brachiopod Lingula; and ophiuroids. He originally suggested a Kimmeridgian to early Tithonian age for the formation (Brunnschweiler, 1954), but later lowered the age to Oxfordian (Brunnschweiler, 1960). McWhae & others (1958) also suggested an Oxfordian age for the formation.

JARLEMAI SILTSTONE

Named from: Mount Jarlemai in the Edgar Ranges.

Defined by: Brunnschweiler (1954) as Jarlemai Siltstone, amended by Guppy & others (1958) to Jarlemai Formation.

Status of name: Formally defined.

Type section: 171 feet (52 m) outcropping at Mount Jarlemai (18°43'00"S, 123°48'30"E). Station 103.

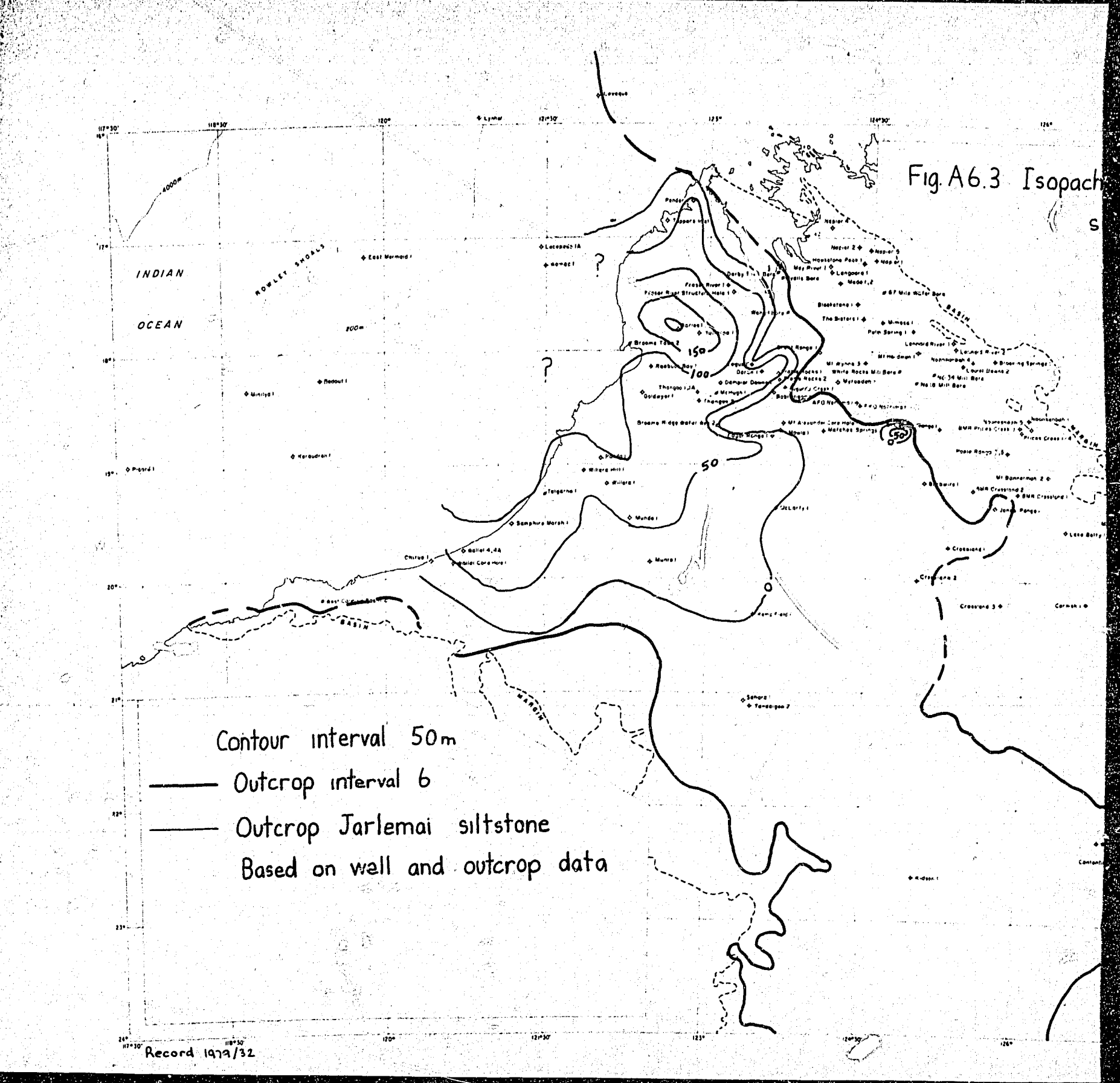
Previous name: Originally named Jarlemai Siltstone by Brunnschweiler (1954) and was included in Reeves (1951) Edgar Range Beds. Guppy & others (1958) amended the name to Jarlemai Formation because of the amount of sandstone present with the siltstone. The name Jarlemai Siltstone is retained in this study.

Redundant Synonyms: 'Buchia Beds', 'Broome Buchia Beds', Buchia Sandstone', Langey Shale.

Modifications: Veevers & Wells (1961) and Playford & others (1975) have retained the name Jarlemai Siltstone.

Outcrop: Outcrops of the Jarlemai Siltstone are mainly restricted to the area in and near the Edgar Ranges in the Mount Anderson 1:250 000 Sheet area. The formation is exposed in sheer, rugged cuestas in the western part of the Edgar Ranges and in numerous mesas in the eastern part. At Mount Jarlemai the exposure is finely jointed and cut by drainage. On some of the mesas such as those north of Goorda Tower, the Jarlemai Siltstone forms small flat-topped residuals.

Distribution: The Jarlemai Siltstone covers the western third of the onshore Canning Basin. Isolated outcrops in the Edgar Ranges and an isolated well section (Frome Rocks No. 1) suggest that it extended farther east than its present preserved limit. It is recognised in both well sections and outcrops. Wells in which the formation was penetrated are: Pender No. 1, Tappers Inlet No. 1; Fraser River No. 1; Fraser River Structure Hole No. 1; Barlee No. 1; Yulleroo No. 1; Roebuck Bay No. 1; Goldwyer No. 1; Thangoo Nos. 1, 1A, 2; McHugh No. 1; Dampier Downs No. 1; Frome Rocks No. 1; Parda No. 1; Talgarno No. 1; Willara No. 1; Willara Hill No. 1; Munda No. 1; Munro No. 1; Samphire Marsh No. 1; Wallal Nos. 4, 4A; Wallal Core Hole; Chirup No. 1; Broome town bores. The limits of the formation are illustrated in Figure A6-3.


Fig. A6.3 Isopach
INDIAN
OCEAN
ROWLEY SHOALS
4000m
200m
150
100
50
0
?
?
BASIN
MARGIN
Contour interval 50m
Outcrop interval 6
Outcrop Jarlemai siltstone
Based on well and outcrop data
Record 1979/32

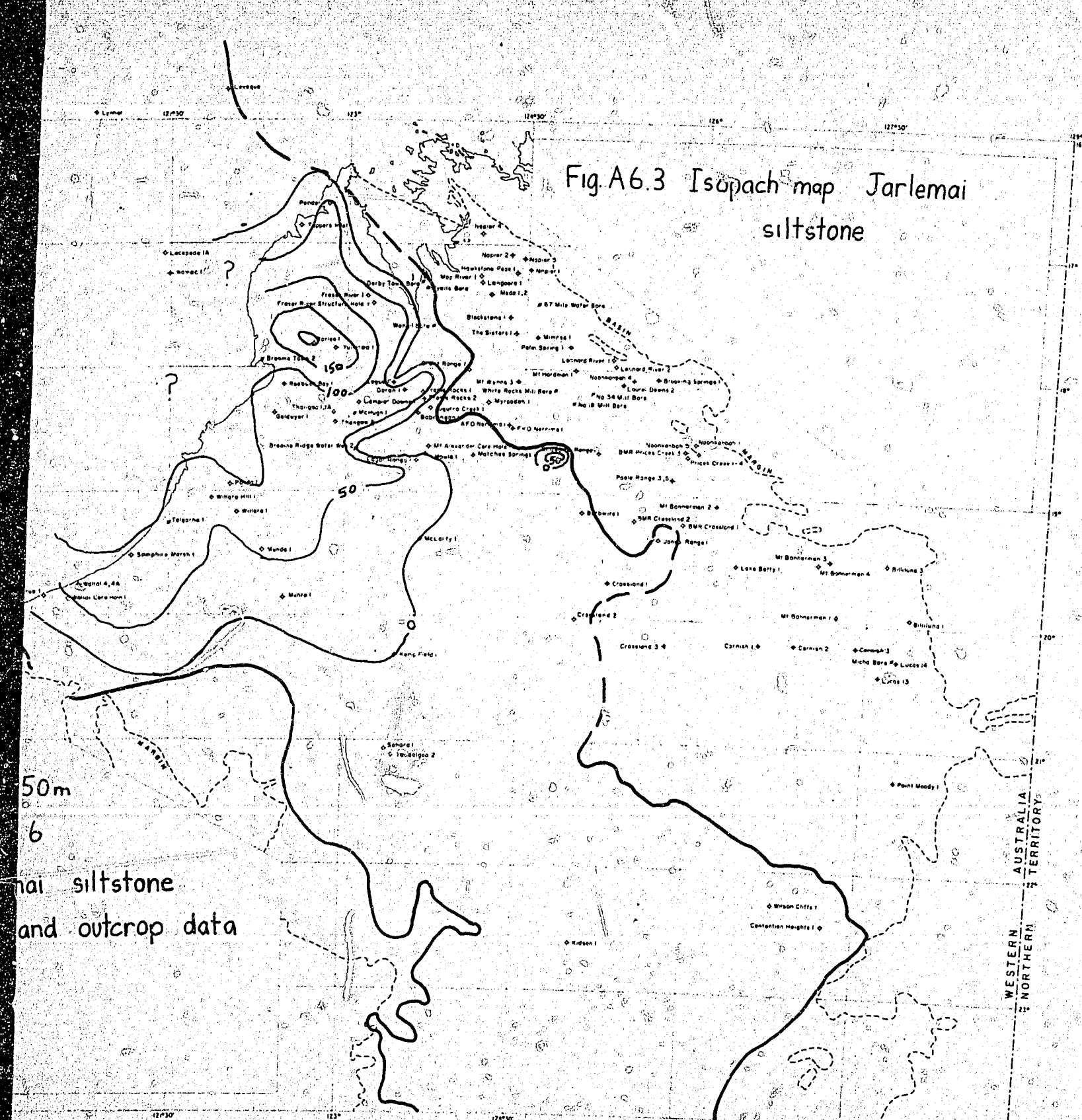


Fig. A6.3 Isopach map Jarlemai siltstone

50m

6

nai siltstone

and outcrop data

XAUS-4-141

87

Thickness variation: The thickest section is in the southwestern onshore Fitzroy Graben where the formation reaches a maximum thickness of 210 m in Barlee No. 1. The Jarlemai Siltstone thins rapidly to the east, but remnant exposures and the isolated section in Frome Rocks No. 1 indicate that the thinning is due to erosion rather than depositional limits (Fig. A6.3).

Relations with other units: The Jarlemai Siltstone conformably overlies the Alexander Formation and is conformably overlain by the Jowlaenga Formation. Beyond the limit of the Jowlaenga Formation, the Jarlemai Siltstone is unconformably overlain by the Broome Sandstone in the subsurface (Pl. 11.3) and by the Mowla Sandstone in the Edgar Ranges; elsewhere it is eroded and exposed or covered by Recent sand.

Both the 'Broome Buchia Beds' and Langey Shale have a similar lithology and are of equivalent age to the Jarlemai Siltstone, and should be considered as part of this formation and the name 'Broome Buchia Beds' be dropped. The Langey Shale appears to be a local development within the lower part of the Jarlemai Siltstone and is best regarded as a member of the formation.

Playford & others (1975) correlated the upper part of the Jarlemai Siltstone with the whole of the Jowlaenga Formation. Subsurface well correlation and dating support Skwarko's (1974a) interpretation that the Jarlemai Siltstone is overlain by the Jowlaenga Formation not equivalent to it. Challinor (1970) correlated the formation with the Dingo Claystone equivalent in the Dampier Sub-basin of the Carnarvon Basin.

Subdivision: None proposed except in the Langey Crossing area, where the Langey Shale is recognized as a subdivision of the Jarlemai Siltstone (see Langey Shale for a discussion of this unit).

Lithology: Mainly siltstone and claystone: light to dark grey, with minor sandstone and sandy siltstone. The type section at Mount Jarlemai consists of 52 m of siltstone: varicoloured, locally tending to claystone, some scattered quartz grains, and generally poorly bedded. This section as the type section for this formation is unfortunate. Although it is characteristic of the exposures in the Edgar Ranges it is not representative of the formation in the subsurface where most wells intersected complete sections.

The lithology in Samphire Marsh No. 1, which has a thicker Jarlemai section, indicates a more varied and unweathered sequence:

47 m Siltstone: brown-grey, coarse, micaceous, sandy, glauconitic in part with pyrite nodules.

17 m Sandstone: brownish grey, silty, fine to medium-grained, well rounded, pyritic, fossiliferous, with some calcareous cement and glauconitic lenses.

15 m Siltstone: brown, coarse-grained, sandy, glauconitic, pyritic.

13 m Siltstone: very sandy, very glauconitic.

The lithology of the Jarlemai Siltstone varies across the basin, though it is mainly fine-grained siltstone or claystone. Glauconite is present in many of the sections, particularly those on the Broome Arch. Fragments of wood have been recorded in a few wells, and lignite particles were described from Yulleroo No. 1. The sandstone zone in Samphire Marsh No. 1 is absent in many of the well sections, though minor beds of sandstone have been recorded at different intervals in the majority of wells.

Age: Late Oxfordian to early Tithonian. The Jarlemai Siltstone is well dated by abundant microfauna and macrofauna. Brunnschweiler (1954) described the bivalves Buchia cf. spitiensis, B. cf. extensa, Meleagrinella, and ?Lima from the type section, and assigned the formation to the middle Tithonian. He amended the age of the lower part of the formation to the late Oxfordian based on the ammonoid Perisphinctes (Brunnschweiler, 1960). Teichert (1940b) described other species of Buchia and the belemnite Belemnopsis from the Broome water wells, and dated the formation as Oxfordian to early Kimmeridgian, an age supported by Cookson & Eisenack (1960), who examined the microplankton from the same bores. Stevens (1965), however, placed the Broome Buchia species in the early to middle Tithonian, and the beds containing Belemnopsis, stratigraphically below the Buchia beds, in the middle Kimmeridgian. Balme (1964) on microfloral evidence put the Jarlemai Siltstone from middle Oxfordian to early Tithonian.

JOWLAENGA FORMATION

Named from: Mount Jowlaenga in the Broome 1:250 000 Sheet area.

Defined by: Brunnschweiler (1957), amended by McWhae & others (1958). Guppy & others (1952) first used the name Jowlaenga Sandstone, but did not define it.

Type section: Outcrop at Mount Jowlaenga (17°22'S, 122°55'E). Station 11.

Previous name: Defined as Jowlaeng Sandstone by Brunnschweiler (1957) and was the oldest formation of his Dampier Group.

Modifications: McWhae & others (1958) amended the name to Jowlaenga Formation.

Outcrop: The Jowlaenga Formation crops out on the Dampier Peninsula at several localities including Mount Jowlaenga, Mount Clarkeson, North Cliffs, where it forms mesas and buttes capped by Melligo Quartzite, along the west coast, and on Valentine Island. The formation is exposed in low rises or cliffs and is cut by widely space east-trending faults.

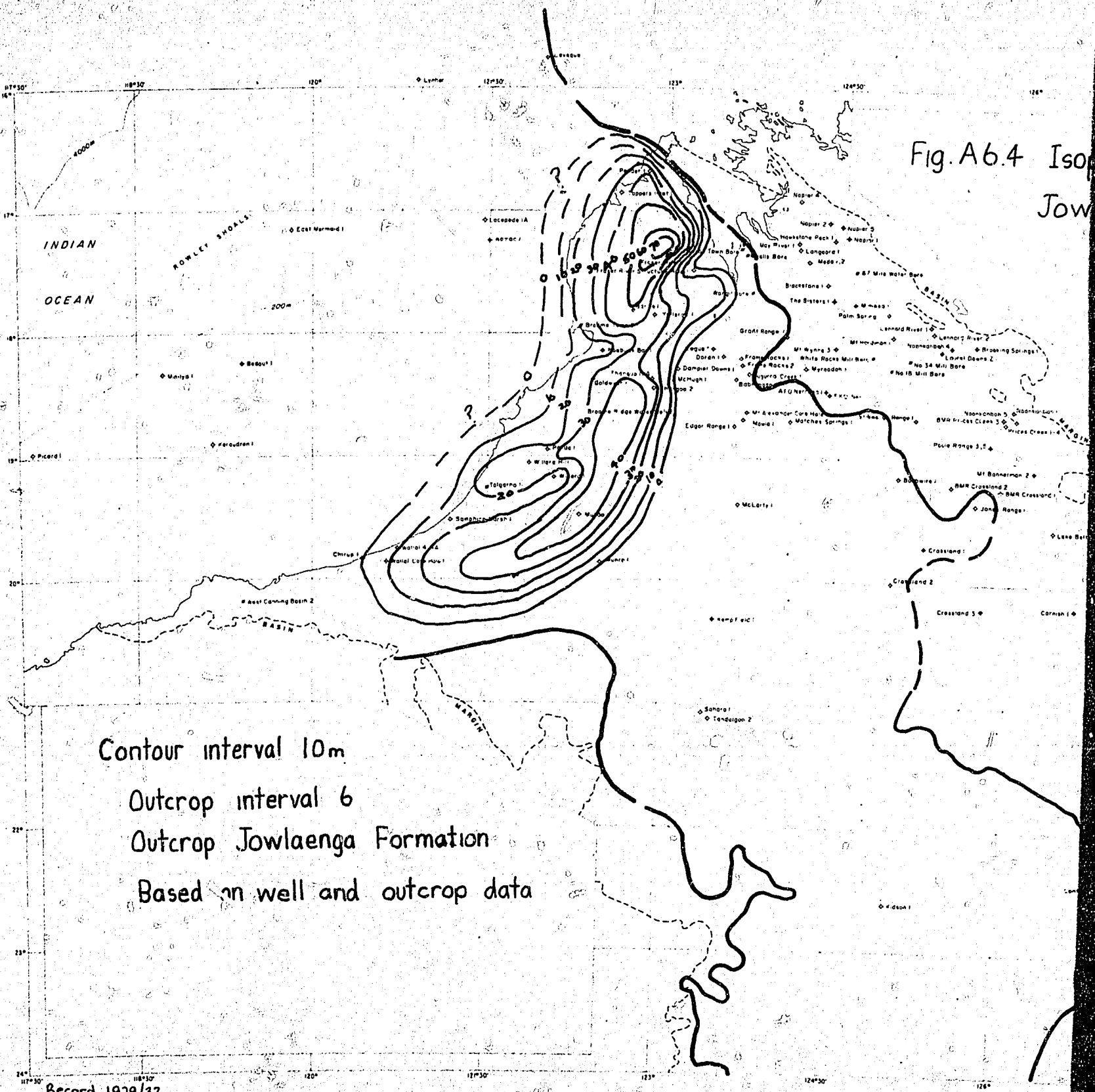
Distribution: Recognised on the western quarter of the onshore Canning Basin in both outcrop and wells. Wells intersecting the formation are: Pender No. 1, Tappers Inlet No. 1; Yulleroo No. 1; Barlee No. 1; Roebuck Bay No. 1; Goldwyer No. 1; Thangoo Nos. 1, 1A, 2; Parda No. 1; Willara Hill No. 1; Willara No. 1; Munda No. 1; Talgarno No. 1; Samphire Marsh No. 1; BMR Wallal Nos. 4, 4A; Wallal Core Hole No. 1; Broome Town No. 2. The limits of the formation are shown in Figure A6-4.

Thickness variations: The maximum thickness, 76 m, is in the Fraser River area (Brunnschweiler, 1957). The formation thins rapidly to the east and probably represents an erosional limit; west and south it is more gradual. A second centre of accumulation developed farther south in the area of Munda No. 1 and immediately north; in Munda No. 1 the formation is up to 40 m thick (Fig. A6-4). The formation is not recognised offshore.

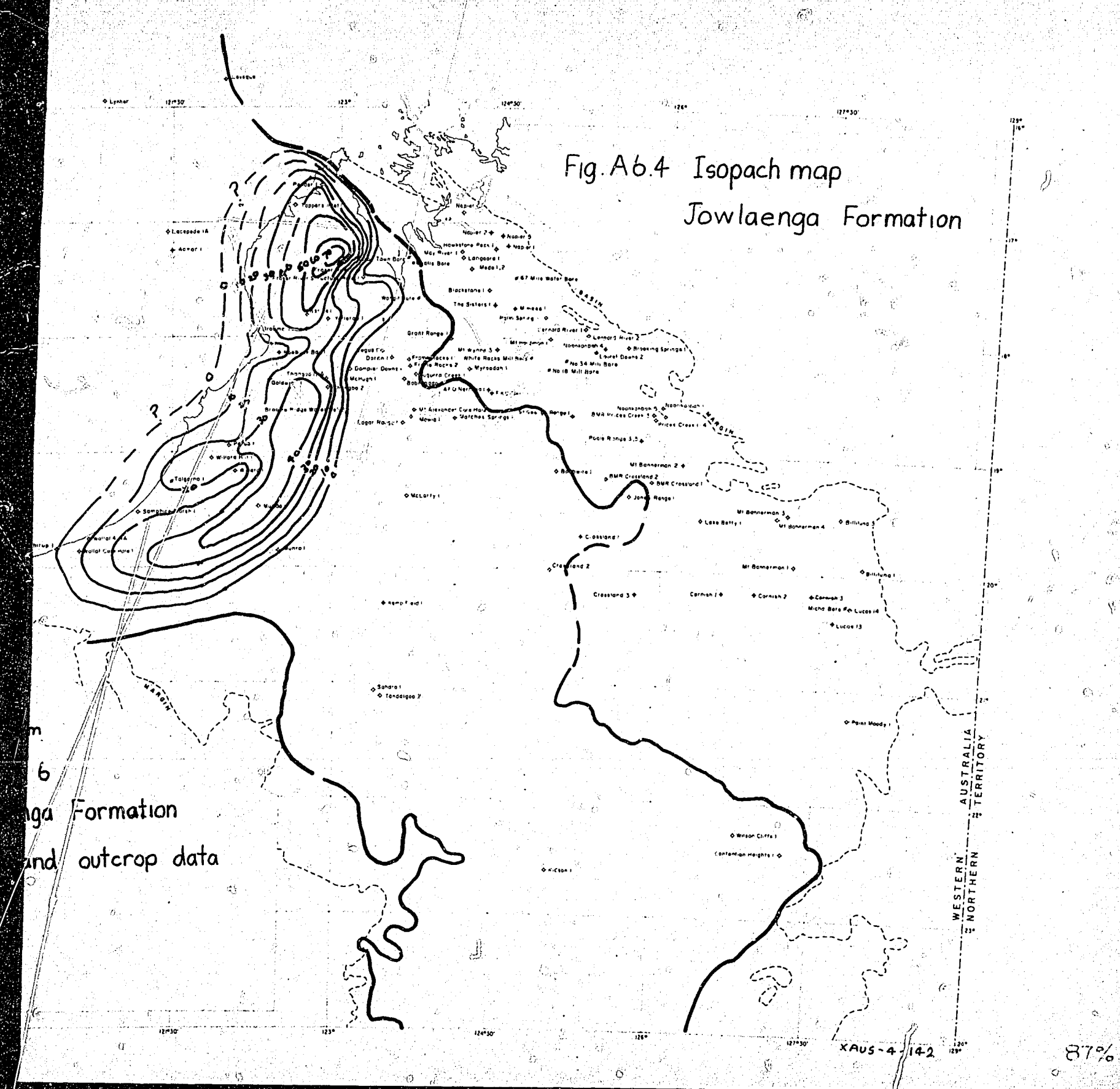
Relations with other units: The Jowlaenga Formation overlies the Jarlemai Siltstone and is unconformably overlain by the Broome Sandstone in the subsurface and the Melligo Sandstone in outcrop where the top is not eroded and exposed.

No correlatives are known in the offshore Canning Basin and no lithological equivalent are recognised onshore. Playford & others (1975) equated all the Jowlaenga Formation with the upper part of the Jarlemai Siltstone; McWhae & others (1958) equated it with the Broome Sandstone. Well data show these correlation to be invalid. Brunnschweiler (1957) and Skwarko (1974a) placed the Jowlaenga Formation stratigraphically above the

Fig. A6.4 Isop
Jow



Record 1979/32



6

nga Formation

and outcrop data

87%

Jarlemai Siltstone. This correlation is supported by well data and is accepted as the correct one, although the formation is probably diachronous and the base of the Jowlaenga Formation may be a time equivalent of the top of the Jarlemai Siltstone in places (Pl. 12-5).

Subdivision: None recommended.

Lithology: Sandstone ranging in colour from clear or milky white to varicoloured: red-brown pink, yellow, purple, and brown to grey; and minor siltstone and claystone beds. The sandstone varies from very fine to very coarse-grained but is commonly fine to medium-grained, mainly unconsolidated, subangular to subrounded, moderately sorted, although locally it may be well sorted or poorly sorted. In outcrop the formation is commonly ferruginised, well bedded, and partly cross-bedded. The missle and lower part may be interbedded with varicoloured claystone as in Barlee No. 1, or grey claystone as in Pender No. 1; the claystone predominates locally. Pyrite, mica, and glauconite were reported from many well sections. A clayey matrix and calcareous cement is present in some subsurface sections; in others the sandstone is unconsolidated. Lignite fragments and wood are recorded in Yulleroo No. 1 but are rare in the Jowlaenga Formation. Generally the formation is porous, its porosity varies locally depending on the amount of claystone and consolidation.

Age: Tithonian (probably early Tithonian). The fauna of the Jowlaenga Formation is characterised by the belemnite Hibolites cf. subfusiformis, and the pelecypods Meleagrinella sp. nov. aff. curta, M. cf. superstes, Questedtia sp. nov. aff. rodborensis, and indeterminate bivalves. Brunnschweiler (1957) also included Apiotrigonia in his faunal collection from the type section, and assigned the Jowlaenga Formation to the early Neocomian. Skwarko (1967) made a new collection from the same locality and found Apiotrigonia occurring in the overlying formation not associated with any of the other forms described from the Jowlaenga Formation. The removal of Apiotrigonia from the faunal list restricts the rest of the pelecypods to the Late Jurassic. Stevens (1965) also preferred a Tithonian age for the fauna of the Jowlaenga Formation.

BARBWIRE SANDSTONE

Named from: Barbwire Range in the Noonkanbah and Crossland 1:250 000 Sheet areas.

Defined by: Guppy & others (1958).

Status of name: Formally defined.

Type section: 71 feet (22 m) cropping out in the Barbwire Range (18°59'00"S, 125°00'00"E). Station 110.

Previous name: None.

Modifications: None.

Outcrop: Crops out as flat-lying beds in buttes and mesas of the Barbwire and Worrel Ranges. Veevers & Wells (1961) suggested that it also fills the valley formed by the underlying Permian Liveringa Formation in the south and the Fenton Fault scarp in the north.

Distribution: The Barbwire Sandstone crops out in the Noonkanbah and Crossland 1:250 000 Sheet areas and is tentatively recognised in the subsurface in Barbwire No. 1 and Crossland Nos. 1 and 2. The subsurface limits are unknown but the formation is probably limited to the eastern edge of the Jurassic rocks (Pl. 10-6).

Thickness variation: The thickest known section is the type section in the Barbwire Range. The top is eroded at both outcrop and well localities thus the total thickness is unknown.

Relations with other units: The Barbwire Sandstone unconformably overlies the Permian Liveringa Group with an angular discordance of up to 5° in outcrop. In the subsurface the Liveringa Group is missing and the Barbwire Sandstone unconformably overlies the older Permian Grant Formation (Pl. 11-8). The top of the formation is eroded and exposed or covered by Recent sand. Along the Fenton Fault the formation is faulted against the Liveringa Formation.

Lithological similarity and proximity to the James Sandstone imply that the Barbwire Sandstone is a close correlative and may even be the same formation. (See James Sandstone for a discussion of their relations). Correlation with the Wallal Sandstone, Meda Formation, and Jurgurra Sandstone is suggested by environmental and lithological similarity, but the Barbwire Sandstone lies east of the limit of the Alexander Formation and may represent a non-marine facies of this formation (Pl. 12-5).

Subdivision: None

Lithology: The Barbwire Sandstone is a quartz sandstone with thin interbeds of siltstone and conglomeratic lenses. The sandstone, which is generally white or brown, ranges from fine to coarse-grained and is poorly sorted, strongly cross-bedded, and thickly bedded. Both the conglomerate pebbles and sand grains are subangular to rounded but poorly sorted, and porosity is variable. The siltstone is mainly white, weathering to reddish-brown, laminated to thin-bedded, and partly micaceous.

In the subsurface the Barbwire Sandstone is weathered, often red, yellow, and orange, and interbedded with minor siltstone or claystone. Conglomeratic lenses are less common than described in outcrops. The sandstone is often better sorted and grains are frosted. The well sections are south and east of the outcrops of Barbwire Sandstone and differences in lithology are probably the result of the distance from the source area and local variations in environment.

Age: Late Jurassic. The only fossils are poorly preserved plant remains, including Otozomites feistmanteli and Pagiophyllum peregrinum, which restrict the formation to the Jurassic or Early Cretaceous (Yeates & others, 1975b). Guppy & others (1958) tentatively assigned a Late Jurassic age. Lithological correlations support Guppy's Late Jurassic age, which is therefore retained in this study.

JURGURRA SANDSTONE

Named from: Jurgurra Creek (also called Geegully Creek) the main drainage of the Edgar Ranges to the north.

Defined by: Brunnschweiler (1954).

Status of name: Formally defined.

Type section: 4 m exposure on the south bank of Jurgurra Creek less than 1 km south of Mount Alexander. Station 30.

Previous name: None.

Modifications: None.

Outcrop: Restricted to the Jurgurra Creek bed and its tributaries and to the basal section of nearby hills. Outcrops are generally small and isolated.

Distribution: Recognised only in the Mount Anderson 1:250 000 Sheet area between Roebuck Downs and the north flank of the Edgar Ranges. The subsurface limits are unknown. Only one well, Mount Alexander Corehole, intersected a sandstone that is tentatively identified as Jurgurra Sandstone.

Total Exploration Australia in Edgar Range No. 1 identified the shallow sandstone overlying Permian rocks as Jurgurra Sandstone. Correlation with surrounding wells indicate that it is the Wallal Sandstone not the Jurgurra Sandstone. Veevers & Wells (1961) extended the limits of the Jurgurra Sandstone over much of the western Canning Basin. They considered that the post-Permian sandstone in Frome Rocks Nos. 1 and 2, Roebuck Bay No. 1, and Broome Town No. 2 is Jurgurra Sandstone and that it extends south to interfinger with the Callawa Formation. WAPET identified the Wallal Sandstone but not the Jurgurra Sandstone in these wells. The company interpretation is accepted as the correct one and the Jurgurra Sandstone is restricted to those limits defined by outcrop.

Thickness variation: The thickest section is 184 m, intersected in the Mount Alexander Corehole. The base of the formation was not reached, thus the total thickness could be much greater. Surface exposures have a maximum thickness of 20 m (Guppy & others, 1958), but their bases are concealed.

Relations with other units: The base of the Jurgurra Sandstone is concealed in outcrop and has not been reached in drillholes. Playford & others (1975) and McWhae & others (1958) suggested that it rests unconformably on the Noonkanbah Formation. It is unconformably overlain by the Jurassic

Alexander Formation. Brunnschweiler (1954) regarded this contact as a submarine erosional break of short duration.

Similar lithologies and stratigraphic positions suggest that the Jurgurra Sandstone and the Wallal Formation are correlatives. The proximity and close lithological resemblance suggest that the Jurgurra Sandstone might be included in the Wallal Sandstone and the name Jurgurra Sandstone dropped. If the Meda Formation and Mudjalla Sandstone are pre-Alexander Formation units, the Jurgurra Sandstone is probably also a marine facies of these formations.

Subdivisions: None.

Lithology: The Jurgurra Sandstone is a massive medium-grained buff to red, slightly micaceous quartz sandstone with thin beds of siltstone and clay pellets. It is current-bedded and well sorted. Poorly preserved fossil wood and small marine pelecypods are present.

Age: Middle to early Late Jurassic. The age of the formation is determined by lithological correlation and superposition. The fossil wood and pelecypods are indeterminate. Brunnschweiler (1954) regarded it as Jurassic but did not further restrict its age. Guppy & others (1958) limited it to the post-Triassic to pre-Late Jurassic, and McWhae & others (1958) to the Middle Jurassic. Playford & others (1975) tentatively confined the formation to the Late Jurassic (Callovian). Skwarko (1974a) suggested that its age ranges from Middle Jurassic to early Late Jurassic. On the basis of correlation with the Wallal Sandstone the age proposed by Skwarko for the Jurgurra Sandstone has been accepted as correct.

CALLAWA FORMATION

Named from: Callawa Hills, northwest of Callawa Station in the Yarrie 1:250 000 Sheet area.

Defined by: Defined as Callawa Boulder Beds by Reeves (1951). The unit was redefined as Callawa Formation by Traves & others (1956).

Status of name: Formally defined.

Type section: 52 m (170 feet) section cropping out in the Callawa Hills near the head of Eel Creek in the Yarrie 1:250 000 Sheet area.

Previous name: Callawa Boulder Beds (Reeves, 1951), Callawa Beds (Fairbridge, 1953b).

Modifications: Veevers & Wells (1961) amended the description to 'conglomerate, conglomeratic sandstone, sandstone, and claystone'.

Outcrop: The Callawa Formation is subhorizontal with a northerly dip of less than one-half degree. The sandstone often crops out as soft smooth forms, or is exposed in incised dendritic watercourses in which the overlying conglomerate forms residual exposures above. The formation also occurs as groups of isolated conical hills and as mesas incised at the edges.

Distribution: The limits of the formation are uncertain but are probably restricted to the southwestern edge of the onshore Canning Basin, between the west coast and the Anketell Hills and possibly as far east as the Grabowsky Range. The formation has been mapped in the Port Hedland (Low, 1965), Yarrie (Wells, 1959d), Anketell (Casey, 1957) 1:250 000 Sheet areas and on the southern edge of the Mandora and Munro 1:250 000 Sheet areas (Veevers & Wells, 1961). A.T. Wells recorded undifferentiated Mesozoic which includes the Callawa Formation in both the Paterson Range (Wells, 1959e) and Tabletop (Wells, 1960a) 1:250 000 Sheet area. Towner, Crowe & Yeates (1976) also identified these rocks as the Callawa Formation, and suggest that they extend as far east as the Ural and Percival 1:250 000 Sheet areas.

The Callawa Formation is not present in any exploration wells but was identified in the West Canning Basin No. 2 water bore drilled by the Geological Survey of West Australia. Bastian (1962) called the Jurassic sandstone present in Wallal Nos. 4 and 4A Callawa Sandstone. J.R.H. McWhae (Appendix C in Johnstone, 1961) chose this unit in Wallal No. 4A as the type section for the Wallal Sandstone.

Thickness variation: The thickest known section is 103 m intersected in the West Canning Basin No. 2 water bore (Rowston, 1973). J.H. Lord (personal communication) has suggested that the formation has a maximum thickness of 167 m in this area. The type section is only 52 m thick. Traves & others

(1956) determined a maximum thickness for the outcrop of 76 m from a composite section of three exposures, including the type section.

Relations with other units: The Callawa Formation unconformably overlies Permian rocks - which Traves & others (1956) described as glacial sediments, and Wells (1959d) identified as Braeside Tillite - and Precambrian metamorphics (Veevers & Wells, 1961) and Archaean sediments, (Rowston, 1973). Where not eroded and exposed, the formation is unconformably overlain by the Cretaceous Anketell Formation. Veevers & Wells (1961) described the upper contact as conformable; Towner, Crowe & Yeates (1976) considered it to be gradational and in places to interfinger with the Anketell Formation. But a hiatus exists between the two formations. The age of the formation in the West Canning Basin No. 2 water bore is no older than Kimmeridgian. Although the top in the well is eroded, correlation with Wallal Sandstone support a Kimmeridgian age for the top of the formation. The Anketell Formation is dated Neocomian, thus the whole Tithonian is missing and the contact is unconformable.

The Callawa Formation is both a lithological and time equivalent of the Wallal Sandstone and a lithological correlative of the Cronin Sandstone. Because of the close lithological similarity to the Wallal Sandstone and the confusion in identification between the two formations, it is recommended that the name Callawa Formation be dropped or that it be restricted to the area where coarse conglomerate beds are present and the type section for the Wallal Sandstone be changed.

Subdivisions: None proposed.

Lithology: Interbedded sandstone conglomerate, conglomerate sandstone, and shale.

The type section consists of the following lithology:

21 m Conglomerate, red-brown, coarse, containing rounded and subrounded boulders and pebbles of quartz, jasper, slate, basalt, and porphyry. The beds are unsorted and have lenses of claystone containing plant stems. Sandstone, red-brown, is interbedded. The sandstone is coarse to medium-grained, cross-bedded to the north or northeast.

31 m Interbedded claystone and sandstone. The sandstone is varicoloured and contains plant stems, leaves, and seeds.

The boulder beds are restricted to the type area. The composite section has the conglomerate beds overlain by:

14 m Sandstone, dark ferruginised, coarse-grained, with angular fragments. Clay pellets, large, are present in the top 2 m and contain plant stems.

This section in turn is overlain by another section which consists of:

10 m Shale, violet and white, micaceous. The top is lateritised.

No description was given for the well section other than sandstone, claystone, and siltstone with a basal conglomerate of coarse sandstone (J. Lord, personal communication).

Age: Late Jurassic. The Callawa Formation has yielded only plant fossils. Brunnschweiler in Traves & others (1956) identified several genera and assigned a Late Triassic or Early Jurassic age. M. White (in Veevers & Wells, 1961) re-examined this collection but determined that they represent a Late Jurassic or Early Cretaceous age.

CRONIN SANDSTONE

Named from: Cronin Hills, in the Runton 1:250 000 Sheet area.

Defined by: Veevers & Wells (1961).

Status of name: Formally defined.

Type section: 23 m (77 feet) outcrop in the eastern end of the Cronin Hills (23°15'00"S, 123°20'00"E). Station 207.

Previous name: None.

Modifications: None.

Outcrop: Crops out as isolated hillocks and rounded hills above mulga-covered rubble outwash. Some of the exposures are founded by low scarps.

Distribution: Probably restricted to the southeastern part of the basin. The limits of the formation are uncertain. Near the basin margins it is bounded by either Permian or Precambrian rocks. Veevers & Wells (1961) restricted

the Cronin Sandstone to the type locality in Cronin Hills. Towner, Crowe & Yeates (1976) extended the Cronin Sandstone over most of the Runton 1:250 000 Sheet area.

The formation is tentatively recognised in Kidson No. 1, Contention Heights No. 1, and Wilson Cliffs No. 1 on lithological similarity to described outcrop. It was not recognised in either Sahara No. 1 or Tandalgoo No. 2. The Jurassic sandstone in these wells is assigned to the Wallal Sandstone, a correlative of the Cronin Sandstone. Using this correlation, the northern limit is probably in the southern part of the Sahara and possibly the western part of the Percival 1:250 000 Sheet areas.

Thickness variations: Veevers & Wells (1961) recorded the thickness of only three outcrops of the Cronin Sandstone. Only two of these exposures are complete sections; the thickest, 23 m, is the type section. The maximum known thickness is 119 m, in Kidson No. 1. Both Wilson Cliffs No. 1 (70 m) and Contention Heights No. 1 (74 m) to the northeast intersected thinner sections. Well data suggest that the formation thickens towards the centre of the area previously covered by the Kidson Sub-basin.

Relations with other units: The Cronin Sandstone unconformably overlies the Permian Liveringa Group and Noonkanbah Formation in well sections and the Permian Paterson Formation in outcrop (A. Yeates, personal communication). Veevers & Wells (1961) have also mapped the formation unconformably resting on Precambrian sediments. The upper contact is less well defined. The formation is overlain by Cretaceous Anketall Formation and by Cretaceous Samuel Formation, and Recent sand near the basin margins. At many of the outcrops near the basin margin the top is eroded and exposed. Towner, Crowe, and Yeates (1976) considered the contact with the Anketell Formation to be gradational and possibly diachronous based on lithological similarity. However, available age dates suggest a disconformity between the two formations.

Both the Callawa Formation and the Wallal Sandstone are lithological and possible time correlatives. The Cronin Sandstone may also be a landward facies of the Wallal Sandstone, although the age dating from the formation is not restricted enough to establish any time equivalents with certainty.

Subdivisions: None.

Lithology: The lithology at the type sections consists of:

12 m	Sandstone, coarse, massive, cross-bedded; interbedded with conglomerate, fine-grained, and sandstone, fine-grained and angular.
9 m	Sandstone, fine-grained, cross-bedded, thinly bedded, coarsening toward the top.
0.6 m	Conglomerate.
0.6 m	Sandstone, fine-grained, fossiliferous.
1 m	Shale.

No information was published on colour or sorting of the rock at the type section. In well sections the sandstone is usually white, micaceous, poorly to moderately sorted, and less conglomeratic. It is interbedded with a grey or rare ochre to red siltstone that is argillaceous, micaceous, and in places pyritic. No siltstone is described from the type section, but the fine-grained sandstone may be a facies equivalent. A white clay is described in Kidson No. 1 and traces of grey and black carbonaceous shale are present in Contention Heights No. 1. The multicoloured siltstone is most common towards the base of the well sections where it is interbedded with very fine to fine-grained white sandstone.

Age: Middle to Late Jurassic. Plants and worm tracks were collected from the outcrop sections. M. White (in Veevers & Wells, 1961) described the fern Stenopteris tripinniata, leaves of Linguifolium denmeadi, fragments of the coniferous plant Elactoctodus planus, fronds of Ptilophyllum pecten, leaves of Hausmannia sp., casts of small round seeds of the Carpolithus circularis type, portions of the leaves of Taeniopteris sp. cf. T. elongata, and bennettitalean flower bracts and squamae of Cycadolepsis sp. She assigned an age to this flora ranged from Late Triassic to Jurassic. Lithological correlations suggest the age be restricted to the Middle to Late Jurassic. Spores and pollen from Wilson Cliffs No. 1 were indeterminate.

MEDA FORMATION

Named from: Meda Station, 38 km east of Derby.

Defined by: Guppy & others (1958).

Status of name: Formally defined.

Type section: None formally designated. Guppy & others (1958) did not name a type section when defining the formation. McWhae & others (1958) placed the type section in the Erskine Range at 17°51'S, 124°22'E, but gave no description of the section. Veevers & Wells (1961) considered that the type section should be in the type locality, the Meda area, but did not propose a new type section in that area.

Previous name: Wade (1936) and Findlay (1942) included this unit in the Erskine Series; Reeves (1949) put it in his Derby Beds; and Brunnschweiler (1954) assigned it to the Erskine Sandstone.

Outcrop: The formation is exposed in a gravel pit near Derby. Elsewhere it crops out as a capping on the Erskine Sandstone on small isolated hills and in the Erskine Range.

Distribution: Known only in the Derby 1:250 000 Sheet area. The subsurface limits are unknown but may not extend much beyond the outcrop area. It is not recognised in any well sections.

Thickness: Little is published on the thickness of the Meda Formation. The thickest exposure described is 9 m at Trig H 81 (Guppy & others, 1958).

Relations with other units: The Meda Formation unconformably overlies the Triassic Erskine Sandstone and the Permian Liveringa Group (Casey, 1958b) which McWhae & others (1958) described as a low-angle unconformity. The top is unconformable under Quaternary sediments, or eroded and exposed.

The formation is undated therefore no time eqivalence can be established. It has a lithological resemblance to the Wallal Sandstone and Jurgurra Sandstone south and west of it, and is probably a lithological correlative. It also lies east of the Upper Jurassic marine formations and may be a landward facies of the Alexander Formation or even the Jarlemai Siltstone. McWhae & others (1958) correlated the Meda Formation with the Cretaceous Melligo Sandstone.

Subdivisions: None.

Lithology: Sandstone, quartz, red-brown, medium and coarse-grained, with beds and lenses of pebble conglomerate. The sandstone is thickly bedded to massive, cross-bedded, and ripple-marked. The conglomerate pebbles are well-rounded quartz, quartzite, and material from the Erskine Sandstone.

Age: Unknown owing to absence of fossils. A Late Jurassic age is postulated because of the lithological resemblance to rocks of that age in the basin. McWhae & others (1958) and Balme (1969) have suggested an Early Cretaceous age.

JAMES SANDSTONE

Named from: Mount James, near the eastern edge of the Mount Anderson 1:250 000 Sheet area.

Defined by: Guppy & others (1958).

Status of name: Formally defined.

Type section: Measured section 32 m (107') thick at Mount James (18°41'S, 124°28'E). Station 72.

Previous name: Wade (1936) included this sequence in his Erskine Series.

Modifications: None.

Outcrop: Crops out near the Fenton Fault in the Mount Anderson and Noonkanbah 1:250 000 Sheet areas. The outcrops are generally small, low, scattered hills.

Distribution: Recognised only in outcrop near the Fenton Fault. The James Sandstone is mapped between Moulamen Hill South in the Mount Anderson Sheet area to 8 km southeast of Mount Fenton.

Thickness variation: The thickness of most outcrop sections is not recorded. 32 m was measured at Mount James. Thomas (1953) stated the formation thickness was less than 24 m (80 feet) in the Noonkanbah 1:250 000 Sheet area. Recent mapping of this Sheet area indicates the formation is as thin as 5 m (R. Towner, personal communication).

Relations with other units: The James Sandstone unconformably overlies the Poole Sandstone, Noonkanbah Formation, and Liveringa Group (Guppy & others, 1958). The top is eroded and exposed everywhere in outcrop.

The formation is lithologically similar to the Barbwire Sandstone. Because of its lithological similarity and proximity to the Barbwire Sandstone it could be included in this formation and the name James Sandstone dropped. Guppy & others (1958) correlated the James Sandstone with the basal ferruginous beds of the Alexander Formation on lithology. The formation lies east of the limit of the marine Alexander Formation and may represent a non-marine facies of that formation. It conversely may be a pre-Alexander Formation sequence as it has environmental and lithological similarities to older Jurassic formations: Wallal Sandstone, Meda Formation, Jurgurra Sandstone, and Mudjalla Sandstone.

Subdivisions: None.

Lithology: It is a quartz sandstone interbedded with quartz conglomerate and rare siltstone lenses. The type section is typical of the formation and consists of dark blue-black ferruginous massive sandstone, fine to coarse-grained, and poorly sorted. It is underlain by a ferruginous basal quartz pebble conglomerate in a sandstone matrix which grades upward into the overlying sandstone. The sandstone is angular to subrounded and contains layers of quartz pebbles up to 25 mm that are concentrated along bedding planes or form conglomerate lenses up to 30 cm thick. Cross-bedding is evident at the top of the outcrop. Rare siltstone lenses up to 8 cm thick occur in the top of the section.

Age: Unknown due to the absence of fossils. A Late Jurassic age is postulated because of the lithological resemblance to rocks of that age in the basin.

MUDJALLA SANDSTONE

Named from: Mudjalla Yard on Luluigui station, near the Fitzroy River.

Defined by: Guppy & others (1958).

Status of name: Formally defined.

Type section: An outcrop 41 m (135 feet) thick northwest of Mudjalla Yard on the south bank of the Fitzroy River (18°02'40"S, 123°46'20"E). Locality 37.

Previous name: None.

Modifications: None.

Outcrop: Crops out along the south bank of the Fitzroy River and along Jurgurra Creek (Geegully Creek in the Derby and Mount Anderson 1:250 000 Sheet areas. Most of the outcrops are low, scattered, and poorly exposed areas. The best exposure is in the type area northwest of Mudjalla Yard where stream action has dissected the outcrop into 'badlands' topography.

Distribution: Recognised in outcrop principally along the Fitzroy River between Willara Bridge in the northwest and 2 km west of Mudjalla Yard in the south-east. Scattered outcrops are recognised to the south within 5 km south of Sandfly Yard on Jurgurra Creek. Little information is available on the subsurface limits of the formation. Shallow boreholes up to 17 km west and 6 km north of Langey Crossing bottomed in the Mudjalla Sandstone. No other well in the basin penetrated the formation.

Thickness variation: The maximum thickness is unknown. Mines Exploration Pty Ltd drilled 95 m into the Mudjalla Sandstone without reaching its base near Langey Crossing (Russell, 1966a). The thickest exposed section is 41 m, the type section. No minimum thicknesses have been published.

Relations with other units: The Mudjalla Sandstone unconformably rests on the Upper Permian Liveringa Group. It is overlain by the Upper Jurassic Alexander Formation (Pl. 12-5) in boreholes (D. Gibson, personal communication). Playford & others (1975) identified the sandstone in the boreholes as wholly Mudjalla, and suggested that the contact with the Langey Shale is disconformable. All exposures of the Mudjalla Sandstone have an eroded and exposed top or are covered by Recent sand.

McWhae & others (1958) and Guppy & others (1958) correlated the Mudjalla Sandstone with the Jurgurra Sandstone on lithology. Guppy & others (1958) also considered that the formation is a possible non-marine facies of the Alexander Formation and Jarlemai Siltstone. Veevers & Wells (1961) agreed that the Mudjalla Sandstone equates with the Alexander Formation.

The disconformity at the top of the Mudjalla Sandstone and its lithological similarity and proximity to the Jurgurra Sandstone support correlation with the Jurgurra Sandstone. However, the early Late Jurassic age of the formation indicates a possible time equivalence to the lower part of the Alexander Formation. Playford & others (1975) correlated the Mudjalla Sandstone with both the Lower part of the Alexander Formation and the upper part of the Wallal and Jurgurra Sandstone.

Subdivisions: None.

Lithology: The formation is mainly a quartzose sandstone interbedded with rare siltstone and conglomeratic lenses. The type section, described below, is the thickest esposure and is typical of the formation.

10 m Brown, silty, quartz sandstone, slightly micaceous and medium-grained; interbedded with fine-grained, very micaceous, clayey quartz sandstone and red-brown coarse to medium-grained, poorly sorted, cross-bedded sandstone. Clay pellets are common in the coarser sandstone. Plant fossils are restricted to a few levels.

5 m Fine-grained grey to yellow, banded to mottled sandstone. Thickly bedded, changing laterally at the top where it is interbedded with quartz sandstone. Rare cobble lenses and plant fragments.

4 m Poorly sorted medium-grained sandstone. Bedding ranges up to thick-bedded and is both flat and cross-bedded. Mica flakes and clay pellets are common. The sandstone is interbedded with white thin sandy siltstone containing plant fragments.

23 m The basal part of this sequence is interbedded medium-grained, well sorted cross-bedded porous sandstone and sandy, clay-pellet, thin-bedded siltstone. It is overlain by interbedded red-brown fine-grained sandstone and white micaceous laminated siltstone.

Bore L1 (Russell, 1966a) near Langey Crossing recorded a similar sequence of mainly sandstone interbedded with siltstone, but apparently without clay pellets. The sandstone is massive, well sorted white and medium-grained, and contains some pyrite nodules, micaceous shale beds, and wood, and thin black carbonaceous shale beds near the base.

Age: Early Late Jurassic. The only fossils are conifer fragments, spores, and microplankton. B.S. Ingram (personal communication in Playford & others, 1975) suggested an early Late Jurassic age for the spores and microplankton. D. Gibson (personal communication) suggests these microfossils are from the Alexander Formation and not the Mudjalla Sandstone.

LANGEY SHALE

Named from: Langey Crossing on the Fitzroy River 40 km south of Derby.

Defined by: Formally defined as 'Glauconitic Siltstone' by R.A. Brunnschweiler (1957); amended to Langey Beds by Veevers & Wells (1961); amended to Langey Shale by Playford & others (1975).

Status of name: Formally defined.

Type section: An isolated outcrop on the west bank of the Fitzroy River at Langey Crossing. No thickness is published.

Previous names: 'Langey Crossing Marl', 'Langey Marl', 'Langey Siltstone', 'Glauconitic Siltstone', Langey Beds, Langey Shale. The name 'Langey Crossing Marl' was first used in a table by Guppy & others (1952), but was not described. Fairbridge (1953b) altered the name to 'Langey Marl' and described the unit but did not specify a type section or discuss its age. Brunnschweiler (1954) changed the name to 'Langey Siltstone' but did not describe the unit; he later defined the unit (Brunnschweiler, 1957) though referred to it by the informal name of 'Glauconitic Siltstone', and subsequently (Brunnschweiler, 1960) informally named it the 'Langey Beds' when describing fossils from it. Veevers & Wells (1961) formally amended the name to Langey Beds, and Playford & others (1975) amended it to Langey Shale.

Modifications: It is recommended that future workers consider making the Langey Shale a member of the Jarlemai Siltstone as drilling in the Langey Crossing area shows the lithology above the zone of phosphatic nodules is the same as that of the Jarlemai Siltstone. The name Langey Member is preferred rather than the Langey Shale of Playford & others (1975) because the unit as defined here is mainly siltstone, not shale.

Outcrop: Only two small isolated outcrops are known at Langey Crossing. They are exposed in gravel sites on either side of the Great Northern Highway. After recent field mapping, Crowe, Towner & Gibson (1978) report that these pits are now filled in.

Distribution: Phosphatic exploration drilling by Mines Exploration Pty Ltd (Russell, 1966a, b) has demonstrated that the Langey Shale extends west of type type area in the subsurface. Shallow drilling has defined its eastern limit in the Langey Crossing area, but the western limit is uncertain. The unit is not recognised in any petroleum wells and is probably restricted to the western part of the Derby Sheet area west of the Fitzroy River.

Thickness variation: The Langey Shale range between 1.2 and 5.6 m in the bores drilled by Mines Exploration, and it averages about 2.5 m. The greatest thickness variation is in the upper part of the unit, the glauconitic siltstone. The lower part, the phosphate nodule bed, where present, generally ranges between 0.3 and 1.2 m.

Relations with other units: The top of the unit is eroded in outcrop but grades into the Jarlemai Siltstone in the subsurface. It probably disconformably overlies the Alexander Formation (D. Gibson, personal communication). Mines Exploration identified this sandstone as the Mudjulla Sandstone (Russell, 1966a, b), but regional relations suggest it is the Alexander Formation. The Langey Shale is a lateral equivalent of the basal Jarlemai Siltstone based on its stratigraphic position, age and lithology. Because it is indistinguishable from the Jarlemai Siltstone where the phosphatic nodule bed is not present it is best considered a local development within the Jarlemai Siltstone.

Subdivision: Informally subdivided into an upper unit of glauconitic siltstone and a lower unit of phosphatic nodules in a matrix of glauconitic siltstone.

Lithology: Mainly glauconitic siltstone with a basal bed of phosphatic nodules in a siltstone matrix. The published type section is an incomplete section whose top is eroded and whose basal phosphatic zone is not exposed; the lithology is better described from borehole L25 drilled by Mines Exploration. This borehole, which contains the thickest complete section of the Langey Shale, is representative of the unit, which consists of:

5 m Siltstone, green to white, glauconitic, sandy, moderately sorted, medium-grained, angular to subangular quartz in a white clay matrix.

0.6 m Siltstone, as above, containing broken fragments of phosphorite. The phosphorite nodules are white, hard, rounded, and glauconitic.

Age: Kimmeridgian. This unit contains a rich invertebrate fauna at the Langey Crossing outcrop. Brunnschweiler (1957, 1960) described Belemnopsis cf. aucklandica, B. cf. alfurica, Kossmatia cf. tenuicostata, Buchia malayomaerica, Calpionella, Nucula, Cucullae, Modiolus, Exogyra, Opis, and Astarte from this section and assigned the unit to the late Tithonian. Stevens (1965), however, considered this fauna to be similar to that of the New Zealand Ohauan Stage, which places it in the Middle Kimmeridgian. Palynomorph assemblages from nearby exploration bores support a pre-Tithonian age from the Langey Shale (Playford & others, 1975).

MOWLA SANDSTONE

Named from: Mowla Bluff in the Edgar Ranges.

Defined by: Brunnschweiler (1954).

Status of name: Formally defined.

Type section: Near Mowla Bluff (station 28) in the Edgar Ranges (18°45'S, 123°45'E).

Previous names: Mowla Conglomerate (Brunnschweiler, 1954); amended by Guppy & others (1958).

Modifications: None proposed.

Described outcrop: In synclinal areas near Mowla Bluff.

Distribution: Type area and environs.

Thickness variations: The thickest measured section is 17 m (Brunnschweiler, 1954; Guppy & others, 1958).

Relations with other units: Overlies the Jurassic Jarlemai Siltstone (Brunnschweiler, 1954) gradationally with local channeling. Overlain by surficial sand.

Subdivision: None proposed.

Lithology: The unit consists of sandstone, strongly cross-bedded, friable, unsorted, conglomeratic passing upwards into micaceous sandstone with minor shale interbeds (Brunnschweiler, 1954; Guppy & others, 1958).

Age: The unit contains fossil plants and is correlated with the Upper Jurassic Jowlaenga Formation of similar lithology and stratigraphic position above the Jarlemai Siltstone.

UNNAMED JURASSIC CLASTICS

Named from: Not applicable.

Defined by: Undefined. Described in well completion reports.

Status of name: Informal.

Type section: None proposed.

Previous name: None formally defined.

Modifications: None.

Outcrop: None.

Distribution: Covers all the present offshore Canning Basin and is encountered in all the offshore wells.

Thickness variation: Isopach mapping (Pl. 10-6) shows that the sequence varies from a thickness of less than 300 m to over 2500 m. The unit thickens from east to west; the greatest accumulation is preserved in the Bedout Sub-basin.

Relations with other units: An angular unconformity separates the Jurassic clastics from the underlying Triassic sediments in the offshore Fitzroy Graben; elsewhere in the basin this contact is disconformable. The top of this unit is disconformably overlain by the Baleine Formation. The lower part of the Jurassic clastics have no correlatives in the Canning Basin. The upper part of the deltaic clastics (see section 5.6) is a time and lithological equivalent of the Wallal Sandstone. The marine clastics are a lithological correlative of the Alexander Formation but a time correlative of most of the Upper Jurassic sediments preserved onshore (Pl. 12-5).

Subdivisions: Informally subdivided into two members on microfaunal type. Lithologically the upper part of the deltaic member cannot be distinguished from the marine member. Using microfauna the upper or marine member, which contains microfauna indicating deposition in a marine environment, can be separated from the lower or deltaic member, whose microfauna suggest a terrestrial to deltaic depositional environment.

Lithology: Mainly quartzose sandstone with interbedded claystone, siltstone, and coal. The sandstone composing 75-90% of the unit is grey, coarse to fine-grained, subrounded to angular, poorly to well sorted. The sand beds are interbedded with claystone, siltstone, and coal beds. Some of the sandstone beds are over 50 m thick, are pyritic, and may fine upward. Near the top of the unit the sand becomes finer-grained and better sorted.

The claystone interbeds are grey to black, silty, and compose up to 20% of the sequence. In the eastern Bedout Sub-basin a multi-coloured claystone forms a basal unit missing in the rest of the basin (Pl. 11-1). Thin seams of brown to black coal consisting of up to 50% clay are interbedded with the sandstone and claystone beds. These coal beds are most common in the middle of the unit. They are less common towards the base and are absent from the top of the sequence.

Age: Early to Late Jurassic. Detailed studies of the microflora and fauna by the companies yield an age ranging from Liassic (earliest Jurassic) to Kimmeridgian or possibly Tithonian (Late Jurassic). Age dating from Lynher No. 1, in the Browse Basin, of very late Triassic for the base of this unit suggests that in the northwest of the Canning Basin the base of this unit may also extend into the uppermost Triassic. The top of the unit is more variable in age: its apparent age range from Middle Jurassic in Wamac No. 1 to early Tithonian in Bedout No. 1 is probably the result of post depositional erosion rather than diachronism.

APPENDIX 7. STRATIGRAPHIC UNITS OF INTERVAL 7

The Baleine Formation is the only formation in interval 7 and comprises all the rocks within the interval.

BALEINE FORMATION (new name proposed)

Named from: Baleine Bank, 61 km west of Beagle Bay and 63 km northeast of Lacepede No. 1A in the Pender 1:250 000 Sheet area.

Definition: The Baleine Formation is proposed from the Tithonian to Lower Neocomian claystone and interbedded sandstone and siltstone, comprising all of interval 7. It rests disconformably on an unnamed Upper Jurassic sandstone and is disconformable overlain by an unnamed Lower Cretaceous claystone or sandstone. In the western Bedout Sub-basin the upper contact is conformable and lacks the change in lithology observed to the east.

Status of name: Submitted for formal approval to the Stratigraphic Nomenclature Committee.

Type section: 904-1273 m (2966-4175 feet) in Lacepede No. 1A (17°5'8"S, 121°26'41"E). Station 3.

Previous name: None.

Modifications: None.

Outcrop: None recognised.

Distribution: Lacepede No. 1A, Wamac No. 1, Bedcut No. 1, Keraudren No. 1, East Mermaid No. 1, and Minilya No. 1 in the Canning Basin.

The Baleine Formation is present only in the subsurface of the offshore Canning and Browse Basins. Its limit to the east is uncertain, but the absence of the formation in either coastal wells or outcrop suggest that it is west of the present shoreline.

Thickness variations: All offshore wells in the basin intersected complete sections. The thinnest accumulation is over the Bedout High where Bedout No. 1 encountered only 151 m. It is 369 m in the type section, Lacepede No. 1A; 381 m in Wamac No. 1; 323 m in Keraudren No. 1; and about 500 m in East Mermaid No. 1. (Pl. 10-7). The formation thickens to about 1000 m in the western Bedout Sub-basin.

Relations with other units: Detailed palynological dating has established the disconformable contact of the base of the Baleine Formation on Kimmeridgian to Oxfordian or older rocks. On well logs the base of the interval is easily picked, as the lower member of the Baleine Formation is underlain by sandstone. The upper contact is less well defined. Palynological dating indicates that the upper contact is disconformable in the east and conformable in the west. Where the upper member of the Baleine Formation is not present or the disconformity does not exist the top cannot be reliably picked on well logs. The upper and lower members of the formation are conformable and in places gradational.

The Baleine Formation has no onshore correlative in the Canning Basin. Previously this sequence of rocks was either included in or correlated with the Jarlemai Siltstone and Jowlaenga Formation (Mollan & others, 1969; Challinor, 1970). Although the lithology of the Baleine Formation is similar to that of the Jarlemai Siltstone and Jowlaenga Formation the entire sequence is younger than either formation (Pl. 12-5). No disconformity exists at the base of the Jarlemai Siltstone similar to that at the base of the Baleine Formation although the Late Jurassic transgression was to the east. Therefore correlation with these onshore units is invalid. It can be correlated to an unnamed rock sequence of similar age in the Dampier Sub-basin (Playford & others, 1975). The Barrow Formation in the Carnarvon Basin to the south is a time equivalent.

Subdivision: The Baleine Formation can be divided into two members. The lower member is a grey claystone present in all the wells. The upper member consists of interbedded light grey sandstone and siltstone; it is present only in the eastern part of the offshore Canning Basin and is absent in Bedout No. 1 and the Rowley Sub-basin. Laterally the upper member probably interfingers to the west and northwest with a claystone or siltstone indistinguishable from the lower member and therefore is considered part of that member.

Lithology: The lithology is chiefly grey claystone, silty to arenaceous and commonly has traces of glauconite, pyrite, and mica. Towards the east the upper part of the formation is usually interbedded with sandstone and siltstone (Pl. 11-1).

At the type section both the upper and lower members are present. The lower member is wholly claystone, slightly silty and medium grey except for the base, which is black, laminated, moderately hard, with no effective porosity. Traces of glauconite as high as 10%, mica, and pyrite are present. The upper member consists of interbedded sandstone and siltstone. The sandstone is light grey, and ranges in size from very fine to granule. In the upper part it is mainly medium to coarse-grained, poorly sorted, and subangular, but grades downward to an argillaceous sandstone, mainly very fine-grained, well sorted, and subrounded. Clay matrix up to 10% and traces of glauconite are present in both sandstones. The coarser sandstone is unconsolidated; the finer sandstone ranges from unconsolidated to moderately hard and is cemented with carbonate cement which makes up 10% of its composition. Both sandstones have very good granular porosity. The top of the member consists of siltstone which lower in the section is interbedded with the sandstones described above. This siltstone is medium grey, sandy, and argillaceous. Grainsize ranges from clay to silt but is chiefly silt size with clay matrix. No effective porosity is present.

The lithology of the lower member differs in some of the other offshore wells. The percentage of silt in the composition varies from well to well: in Wamac No. 1 the upper part and base is silty; Bedout 1 consists wholly of clay-size sediment. Glauconite percentages are also variable; they approach 30% in Bedout No. 1. In both Wamac No. 1 and Keraudren No. 1 the lower member is arenaceous in part. In Keraudren No. 1 well logs indicate a 4-m bed of sandstone 30 m from the base.

The upper member is much more variable lithologically than the lower member. Claystone is interbedded with sandstone and siltstone in both Wamac No. 1 and Keraudren No. 1, and becomes more common towards the base of the member. Both wells also contain rock fragments, usually chert and jasper in trace quantities. The siltstone at the top of the type section is missing in Keraudren No. 1. The entire member is absent in Bedout No. 1 and in the Rowley Sub-basin.

The age of the Baleine Formation ranges from late Tithonian to mainly early Neocomian. The top of the interval is diachronous from east to west with the youngest rocks in the west.

Dating is based mainly on palynology. Arenaceous forams were recovered from well sidewall cores but are mostly indeterminate. Spores, pollen, and microplankton were recovered in all wells from sidewall cores and ditch cuttings. Except in Wamac No. 1, all age determinations are from sidewall cores.

Lister (BOCAL, 1970d) identified microplankton and spores and pollen from the type section that include:

Microplankton

- Cannosphaeridium mirabilis
- Scriniodinium attadalense
- Dingodinium jurassicum
- Wanea cf. spectabilis
- Belodinium dysulum
- Fromea amphorea
- Nannoceratopsis pellucida
- Cyclonophelium areolatum
- Komewaia glabra

Spores and Pollen

- Murospora florida
- Foveotriletes parviretes
- Microcachryadites antarcticus
- Aquaetriradites hispidus
- A. sp. cf. verrucosis
- Cicatricosisporites rudbrooki
- C. australensis
- Klukisporites scaberis
- Velosporites triquetrus
- Densiosporites velalus
- Reticulatisporites pudens
- Lycopodiumsporites circolumensis
- Trilobosporites pervurulentus

Dinophyte cysts including Belodinium dysculum and Scriniodinium luridum were also identified in Bedout No. 1 by Lister (BOC, 1971).

From Keraudren No. 1, B.S. Ingram (Hematite Petroleum Pty Ltd, 1974) identified dinoflagellates that included: Leptodinium eumorphum, Cannosphaeropsis mirabilis, Palaeostromocystis sp. aff. P. cylindrica, Dingodinium jurassicum, Scriniodinium luridum.

APPENDIX 8. STRATIGRAPHIC UNITS OF INTERVAL 8

This interval comprises the following formations: the Broome Sandstone, Melligo Sandstone, Frezier Sandstone, Leveque Sandstone, Parda Formation, Anketell Formation, Bejah Claystone, Samuel Formation, Kidson Beds, and offshore unnamed Upper Neocomian to Lower Cenomanian rocks.

BROOME SANDSTONE

Named from: The town of Broome.

Defined by: Reeves (1951, p. 2491).

Status of name: Formally defined.

Type section: Gantheaume Point, southwest of Broome; station 18 (17°58'30"S, 122°10'30"E).

Modifications: None.

Described outcrop: On the western coast of Dampier Peninsula from Cape Leveque in the north to as far south as Gourdon Bay.

Distribution: Barlee No. 1, Yulleroo No. 1, Thangoo Nos. 1, 1A, and 2, Roebuck Bay No. 1, Broome water bores 1-5, Goldwyer No. 1, Parda No. 1, Willara No. 1, Willara Hill No. 1, Talgarno Weapons Research Establishment bore 1, Samphire Marsh No. 1, Samphire Marsh water well, BMR (Wallal) Nos. 4 and 4A, Wallal core hole No. 1, Munda No. 1, Munro No. 1, Tappers Inlet No. 1, Pender No. 1, and Chirup No. 1.

The onshore distribution of the Broome Sandstone is confined to a narrow coastal strip in the Dampier Peninsula, and occurs in the western Willara Sub-basin, and Pilbara Shelf. Probable correlatives of the Broome Sandstone have been found in the Bedout and Rowley Sub-basins and on the westerly extension of the Broome Arch: in Lacepede No. 1A, Wamac No. 1, Bedout No. 1, and Keraudren No. 1.

Thickness variations: At the type section the measured thickness is 12 m (Brunnschweiler, 1957), but the thickest known section onshore is 274 m in Tappers Inlet No. 1. The section in Broome Water-bores 1-5 may be 280 m

thick, but details of these rocks are not available. From its type section the formation thins eastwards to 56 m in Munro No. 1 and thickens westwards to Wamac No. 1 (202 m).

Relations with other units: The Broome Sandstone is unconformable on the Jurassic Jarlemai Siltstone or Jowlaenga Formation in all onshore wells. In Wamac No. 1 and Lacepede No. 1A the Broome correlative disconformably overlies Tithonian to lower Neocomian Baleine Formation. The upper beds, which are conformably overlain by Aptian claystone offshore and onshore, grade upwards through passage beds into the Leveque Sandstone, and are disconformably overlain by the Parda Formation or unconformably overlain by Recent sand.

Subdivision: No subdivision is proposed.

Lithology: The Broome Sandstone is mainly sandstone with minor beds of grey siltstone and claystone. Grainsize ranges from very fine to very coarse (generally coarse) with minor thin pebble conglomerate bands. The fine-grained beds are better sorted than the coarser beds. Quartz grains are angular to rounded and may have secondary quartz overgrowths. Mica is present and the sandstone may have a clay matrix, which is often ferruginised and weathered near the present land surface. Cross bedding is noted at the type section (Brunnschweiler, 1957).

Age: The Broome Sandstone contains the Neocomian Microcachryidites assemblage (Balme, 1964) and it conformably underlies the Aptian Leveque Sandstone (Skwarko, 1970). In the offshore wells palynology indicates a Late Neocomian age. Plant macrofossils are not inconsistent with this age determination (White, in Veevers & Wells, 1961).

MELLIGO SANDSTONE

Named from: Melligo Creek on the eastern side of Dampier Peninsula.

Defined by: Brunnschweiler (1957, p. 9).

Status of name: Formally defined.

Type section: Melligo Creek (16°34'S, 122°56'E).

Previous name: Melligo Quartzite (Brunnschweiler, in Guppy & others, 1952, p. 112); amended to Melligo Sandstone by Rattigan & Elliot (in McWhae & others, 1958, p. 107).

Modifications: None proposed.

Described outcrop: Eastern side of Dampier Peninsula from south of the Great Northern Highway north to Apex Island.

Distribution: The unit is not encountered in any petroleum exploration wells. The area of distribution is essentially the same as outcrop.

Thickness variation: Brunnschweiler (1957) cites thicknesses of 12 to 21 m.

Relations with other units: The Melligo Sandstone possibly gradationally overlies the Jowlaenga Formation at Dampier Hill (Crowe, Towner & Gibson, in prep.) but elsewhere is unconformable and overlaps Precambrian rocks on Apex Island. The unit is overlain by Recent sand.

Subdivision: None proposed.

Lithology: In outcrop the unit consists of about 95% orthoquartzite, white to grey, well rounded, medium to coarse-grained completely silicified to opaline silica. The highest beds in the Stony Ridge area are conglomerative with layers of small well-rounded pebbles of vein quartz and chert (Brunnschweiler, 1957). The unit is poorly to well bedded and cross-bedded. Large-scale cross-bedding occurs locally (Gellatly & Sofoulis, 1973).

Age: The macrofossils Fissilunula clarkei and Apiotrigonia dampierensis recovered from the Melligo Sandstone indicate an Aptian age (Brunnschweiler, 1957; 1960). Skwarko (1970) recognised Melligo Sandstone at Mount Clarkeson (cf. Brunnschweiler, 1957) and assigned an Aptian age.

FREZIER SANDSTONE

Named from: Cape Frezier, southwest of Cape Bossut.

Defined by: Lindner & Drew (in McWhae & others, 1958, p. 108).

Status of name: Formally defined.

Type section: Cape Frezier (18°53'S, 121°37'E).

Modifications: None proposed.

Described outcrop: Along the coast from Cape Villaret to south of Cape Frezier.

Distribution: The Frezier Sandstone is distributed only in the outcrop area, but is recognized to the east of Cape Villaret in Goldwyer No. 1, suggesting that the unit crops out eastwards under surficial sand.

Thickness variations: At the type section the Frezier Sandstone is 6 m thick, and 17 m thick at Gourdon Bay (McWhae & others, 1958, p. 108). The thickest measured section is 46 m in Goldwyer No. 1.

Relations with other units: The unit disconformably overlies the Parda Formation both in the exposed section and in Goldwyer No. 1 and is overlain by Recent sand.

Subdivision: None proposed.

Lithology: At the type area the unit consists of cross-bedded sandstone, conglomeratic sandstone, and minor siltstone. In Goldwyer No. 1 it occurs as a sandstone: very fine to very coarse-grained, poorly sorted, slightly micaceous, angular with occasional conglomerate beds.

Age: Aptian from Pseudavicula papyracea (Dickins, in Veevers & Wells, 1961).

LEVEQUE SANDSTONE

Named from: Cape Leveque, in the extreme north of Dampier Peninsula.

Defined by: Brunnschweiler (1957, p. 9).

Status of name: Formally defined.

Type section: Cape Leveque (16°24'S, 122°56'E); station 9.

Previous name: Cape Leveque Sandstone (Guppy & others, 1952, p. 112).

Modification: None proposed.

Described outcrop: Known from only the Cape Leveque area.

Distribution: As above.

Thickness: The only thickness recorded is 10 m (Brunnschweiler, 1957).

Relations with other units: The unit grades down into the Broome Sandstone through passage beds which may be up to 3 m thick (Brunnschweiler, 1957) and is overlain by surficial sand, Quaternary freshwater limestone, and red soils.

Subdivision: None proposed.

Lithology: The Leveque Sandstone is a sandstone: light red-brown hard, well bedded, almost platy, coarse-grained, rare mica. It is distinguished from the Broome Sandstone by lack of worm tubes (Brunnschweiler, 1957; Veevers & Wells, 1961).

Age: The unit contains macrofossils (Inoceramus spp.), trace fossils (Rhizocorallium spp.), and plant fossils (Ptilophyllum sp. and Elatocladus (Taxites) sp.) regarded as Aptian in age (Guppy & Lindner, 1949; Brunnschweiler, 1957; Veevers & Wells, 1961; Skwarko, 1970).

PARDA FORMATION

Named from: Parda Hill.

Defined by: Lindner & Drew (in McWhae & others, 1958, p. 107).

Status of name: Formally named.

Type section: Parda Hill, south of Broome (18°53'S, 121°59'E); station 230.

Previous name: None.

Modifications: None proposed.

Described outcrop: An area bounded to the east by Parda Hill and Willara Hill, and by the coast to the west. Northern outcrop extent is as far as Cape Villaret; southern extent is east of Anna Plains homestead.

Distribution: The Parda Formation occurs in both Parda No. 1 and Tappers Inlet No. 1 far to the north of the area of outcrop.

Thickness variations: The type section is 27 m thick and the section in Parda No. 1 is 13 m thick. The correlative in Tappers Inlet No. 1 is 21 m thick.

Relations with other units: The Parda Formation disconformably overlies the Broome Sandstone (McWhae & others, 1958), and interfingers with the Anketell Formation (Veevers & Wells, 1961). Travers & others (1956) considered that it is conformable beneath the Callawa Formation but this is doubtful as the ages of the two units are separated by a long hiatus. The Parda Formation is overlain disconformably by the Frezier Sandstone (McWhae & others, 1958).

The Parda Formation unconformably overlies Permian rocks in the Paterson Sheet area.

In Tappers Inlet No. 1 the unit is conformable on the Broome Sandstone and probably disconformable to unconformable below the Tertiary Emeriau Sandstone.

Subdivision: None proposed.

Lithology: In the type area the unit consists of interbedded siltstone and fine-grained sandstone (McWhae & others, 1958). In Parda No. 1 it comprises claystone, grading to finely micaceous, argillaceous siltstone. Lateritisation has affected the sediments.

Age: The Parda Formation is unfossiliferous but Crespin (in Traves & others, 1956) identified foraminifera of Early Cretaceous age from the Anketell Formation, which interfingers with the Parda Formation. The Anketell Formation is regarded as Aptian in age and the Parda Formation is therefore considered to be this age.

ANKETELL FORMATION

Named from: Anketell 1:250 000 Sheet area.

Defined by: Traves & others (1956).

Status of name: Formally defined.

Type section: Hill T7, at 22°08'S, 124°20'E (Traves & others, 1956 p. 28). Veevers & Wells (1961, p. 157) redefined the unit and selected Hill 11 (station 221) as the new type section (20°26'30"S, 122°32'30"E) of the Anketell Formation. Veevers & Wells (1961) considered that the Hill T7 exposure is part of the Kidson Beds.

Previous name: Anketell Sandstone (Traves & others, 1956, p. 28); amended by Veevers & Wells (1961, p. 157).

Modifications: None proposed.

Distribution: Covers a large part of the southwest Canning Basin from Percival Lakes northwest to the coast. The northern extent is south of Anna Plains homestead, where the Anketell Formation prob[illegible] interfingers with the Parda Formation.

In the subsurface, the Anketell Formation has been recognised in Sahara No. 1 and Tandalgoo Nos. 1-3.

Thickness variations: At Hill 11 the unit has a maximum thickness of 25 m (Veevers & Wells, 1961) and is generally thinner. Sahara No. 1 penetrated 6 m of rock assigned to the Anketell Formation. Precise thickness is not always apparent owing to difficulties of separating the unit from the underlying Callawa Formation in weathered sections. The thickest section is 40 m in Tandalgoo No. 3 (214).

Relations with other units: In much of the area of outcrop the Anketell Formation overlies with probable disconformity either the Jurassic Callawa Formation or undifferentiated Jurassic rocks. It also overlies undifferentiated Mesozoic and Permian rocks in various areas (Veevers & Wells, 1961). The Parda Formation interfingers with the Anketell Formation (Veevers & Wells, 1961).

At A11 the Anketell Formation is capped by a 2-m-thick coarse sandstone which may be the base of a younger formation (Traves & others, 1956) extending northeastwards into the basin. This may be equated with either the Lampe Beds, which crop out to the southeast, or unnamed Tertiary formation. Veevers & Wells (1961) suggest that at A11 the overlying unit is Frezier Sandstone.

Subdivision: None proposed.

Lithology: The unit consists of claystone, shale, and siltstone with thin lenses of conglomerate (Traves & others, 1956; Veevers & Wells, 1961). While its lithology is variable the formation is characterised by an alternation of fine-grained clastics and sandstone. At the type section it consists of sandstone: medium-grained, interbedded with pebbly grit, well-rounded northwest of A11 (Veevers & Wells, 1961).

In Sahara No. 1 the unit consists of claystone: sandy, with interbedded sandstone: fine to medium-grained with some intergranular clay.

Tandalgoo Nos. 1-3 penetrated sandstone: fine to medium-grained, moderately sorted; siltstone: and claystone: micaceous. The sections generally coarsen up from siltstone or claystone to sandstone at the top.

Age: Early Cretaceous (Crespin in Traves & others, 1956). The formation interfingers with the unfossiliferous Parda Formation, which is overlain by the Aptian Frezier Sandstone (Veevers & Wells, 1961); so its age is no younger than Aptian. If the Anketell Formation is the equivalent of the Samuel Formation (see below) its age is Aptian also. Note the questionable Frezier Sandstone overlies the Anketell Formation at Hill A11.

KIDSON BEDS

Named from: Kidson Bluff.

Defined by: Veevers & Wells (1961, p. 136).

Status of name: Formally defined.

Type section: Kidson Bluff (22°16'S, 125°03'E).

Previous name: Anketell Sandstone in Tabletop Sheet area (Traves & others, 1956).

Modifications: Playford & others (1975) dropped the name Kidson Beds in favour of Anketell Formation.

Described outcrop: Kidson Sub-basin.

Distribution: In the subsurface the Kidson Beds are identified in Kidson No. 1. From surface mapping the unit is confined to the Kidson Sub-basin but probably is a lateral equivalent of the lithologically similar Anketell Formation and Samuel Formation.

Thickness variations: The Kidson Beds are 31 m thick at the type section (Veevers & Wells, 1961), and 13 m at Reeves Knoll (Traves & others, 1956).

Relations with other units: The Kidson Beds overlie undifferentiated Mesozoic rocks, and possibly Lower Permian rocks where Jurassic rocks are eroded. The beds probably interfinger with both the Anketell Formation and Samuel Formation. The upper contact is unconformable with surficial sand.

Subdivision: None proposed.

Lithology: The unit consists of sandstone: well-sorted medium to coarse-grained, quartzose, with grit bands, scour-and-fill structures, ripple marks, undulate bedding and cross-bedding (Veevers & Wells, 1961). In Kidson No. 1 the unit consists of sandstone: very fine to coarse-grained with minor siltstone: argillaceous and micaceous. At Dowling Hills (201)

the Kidson Beds consist of sandstone: fine to coarse-grained, quartzose, massive to flaggy beds, with thin beds of claystone and shale. Clay pellets and rare pebbles are more common in the upper part; angular quartz grains and large mica flakes occur throughout.

Age: Aptian, based on interfingering with the Anketell Formation to the northwest and the Samuel Formation to the south. The fossils recorded are trace fossils (Rhizocorallium spp.) and shells dated by Skwarko (1967a) as Aptian.

SAMUEL FORMATION

Named from: Mount Samuel, Officer Basin.

Defined by: Lowry & others (1972, p. 54).

Status of name: Formally defined.

Type section: Mount Charles, Officer Basin (25°45'S, 126°11'E).

Previous name: 'Undifferentiated/Cretaceous' of Wells (1963, p. 24).

Modifications: None.

Described outcrop: Southeastern Desert south of 23°S and northern Officer Basin.

Distribution: The Samuel Formation has not been drilled in the Canning Basin. It is considered to be a facies equivalent of the Kidson Beds and as such is part of an extensive Aptian sedimentary section extending southeast from the coastline into the northern Officer Basin via the Willara-Kidson Sub-basin.

Thickness variations: 15 m is exposed at the type section at Mount Charles, and a combined thickness of 300 m for the Samuel Formation and Bejah Claystone along the Gunbarrel Highway (Officer Basin) is suggested by Lowry & others (1972). In the Canning Basin the formation is less than 25 m thick (Yeates & others, 1975b).

Relations with other units: The Samuel Formation is disconformable on the Permian Paterson Formation (Lowry & others, 1972) at Browne Diapir (Officer Basin) and is probably disconformable on Jurassic sandstone (Cronin Sandstone) in the Canning Basin. The Samuel Formation probably interfingers to the north with the Kidson Beds and is gradational with the overlying Bejah Claystone (Lowry & others, 1972).



Subdivision: None proposed.

Lithology: The unit consists of sandstone: laminated to thin-bedded, moderately well sorted, moderately rounded, indistinctly cross-bedded, fine to medium-grained, with minor siltstone and claystone. Bioturbation and trace fossils are common (Lowry & others, 1972). Medium-scale low-angle cross-bedding occurs in some of the sandstone beds and glauconite-rich sandstone is widespread (van de Graaf, 1974).

Age: Skwarko (1967a) placed an Aptian age on molluscan faunas collected from the Samuel Formation. Kemp (1976) assigned a late Aptian age (Dingodidium cerviculum zone of Evans, 1967) to the unit in the Officer Basin on spores and pollen.

BEJAH CLAYSTONE

Named from: Bajah Hill.

Defined by: Veevers & Wells (1961, p. 166).

Status of name: Formally defined.

Type section: Bejah Hill (23°46'S, 124°09'E); station 205.

Previous names: Bejah Beds (Veevers & Wells, 1961, p. 166); amended to Bejah Claystone by Lowry & others (1972, p. 54).

Modifications: None proposed.

Described outcrop: Southeastern Desert south of 23°S and northern Officer Basin.

Distribution: Not penetrated by any wells in the Canning Basin. Outcrop limits are effectively the distribution limits.

Thickness distribution: 14 m at Bejah Hill, increasing to 30 m in the Officer Basin (Lowry & others, 1972).

Relations with other units: The Bejah Claystone overlies the Samuel Formation with a gradational contact in the eastern area but overlies the Permian Paterson Formation disconformably in the western Officer Basin. In the Canning Basin it is gradational with the underlying Samuel Formation. The upper limit is erosional, or disconformable to unconformable under the Tertiary Lampe Beds (Lowry & others, 1972).

Subdivision: None proposed.

Lithology: The unit consists of claystone: white, siliceous; shale: well-bedded; and minor sandstone: thin to medium-bedded, coarse-grained (Veevers & Wells, 1961; Lowry & others, 1972). The claystone is often bioturbated and contains up to 90% silica. Radiolarite is reported (Veevers & Wells, 1961, p. 170).

A ferruginised sandstone, probably the Lampe Beds, often caps the Bejah Claystone in mesas.

Aptian shelly faunas were described by Skwarko (1967a) from the Bejah Claystone.

UNNAMED LOWER CRETACEOUS ROCKS IN THE OFFSHORE CANNING BASIN

Distribution: Lower Cretaceous (upper Neccomian to lower Cenomanian) rocks were penetrated by Keraudren No. 1, Wamac No. 1, Bedout No. 1, East Mermaid No. 1, Lacepede No. 1A, and Minilya No. 1. These rocks thin towards an interpreted zero isopach on the north Turtle Arch, suggesting that they are restricted to the Bedout and Rowley Sub-basins as well as to the offshore extensions of the Broome Arch and Fitzroy Graben.

Thickness variations: The thickest drilled section is 614 m in East Mermaid No. 1. The thickest interpreted section (seismic) mapped is 1300 m in the Rowley Sub-basin/Browse Basin area (Pl. 10-8).

Relations with other units: Offshore, Lower Cretaceous (upper Neocomian to Cenomanian) rocks are disconformable on lower Neocomian claystones in Lacepede No. 1A and conformable in Minilya No. 1 and East Mermaid No. 1.

A hiatus is present between lower Albian and Cenomanian rocks offshore where Cenomanian claystones rest on lower Albian claystones.

Subdivision: See Lithology

Lithology: In the Bedout Sub-basin basal rocks of interval 8 are claystones, in contrast with the ubiquitous sandstones found in other wells and outcrops. Between 1368 and 1400 m in Keraudren No. 1 this basal unit consists of claystone: medium dark grey to olive-grey, silty, with rare micrite, traces of glauconite, and in places, common quartz silt; minor sandstone and sandy claystone are interbedded. In Bedout No. 1 the section is thicker (1512-1648 m) and consists of claystone: dark, silty, and sandy, with fine-grained sandstone in thin laminae; and sandstone: very fine to very coarse-grained, poorly sorted, subangular to subrounded, quartzose.

The lower rocks of interval 8 in Lacepede No. 1A and Wamac No. 1 and the sandstone interval above the basal claystone in Bedout No. 1 and Keraudren No. 1 are lithologically similar to the Broome Sandstone. In Bedout No. 1 (1464-1664 m) the unit consists of sandstone: fine to coarse, but mainly medium, moderately well sorted, subrounded, quartzose with minor clay in the matrix. The section between 1215 and 1368 m Keraudren No. 1 contains sandstone: light grey to medium grey, very fine to very coarse, but mainly medium to coarse-grained with minor amounts of granule conglomerate, moderately sorted subrounded to rounded grains, quartz abundant, traces of quartz silt, clay minerals, glauconite, pyrite, feldspar, and rock fragments. In the finer-grained sandstone calcite or siderite forms cement.

The section between 702 and 904 m in Lacepede No. 1A consists of sandstone: very fine to very coarse, mainly medium to coarse-grained, with some granule conglomerate, poorly sorted, subrounded, 95% quartz, traces of glauconite and pyrite, to 5% clay minerals. Claystone interbeds are minor. The Broome Sandstone equivalent in Wamac No. 1 occurs between 707 and 944 m; lithologically it is similar to that in Lacepede No. 1A, but is more argillaceous in the upper part (707-742 m). Traces of coal occur at 740 m and 926 m. Kaolinite and silica may form cements in the lower part.

Above the Broome Sandstone equivalent the lithologies in all wells are generally finer-grained. In the Bedout Sub-basin, Bedout No. 1 penetrated

claystone between 1125 and 1464 m. The interval is divided into three subunits. The upper subunit, between 1125-1259 m, consists of claystone: olive-grey, 80% clay minerals, up to 20% micrite. The middle subunit, between 1259-1423 m is made up of claystone: olive-black, clay minerals 90-100%, quartz grains (5-10%), mica flakes (5%) and glauconite grains (up to 10%) concentrated near the base. The lower subunit, between 1423-1464 m, consists of sandstone: greenish-black, medium to very coarse, mainly medium, up to 50% glauconite grains, quartz grains (10%), and clay matrix (40%), with scattered patches of calcite; interbedded with claystone: olive-black, clay minerals (70-90%), quartz grains (5-10%), silt-size quartz (20%), glauconite grains (up to 5%), and scattered mica flakes.

The section penetrated between 838 and 1215 m in Keraudren No. 1 consists mainly of claystone: medium dark grey to olive-grey, usually silty, in part calcareous. Between 838 and 1065 m micrite may be up to 20% and clauconite, pyrite, mica, Inoceramus prisms, pelecypod fragments and foraminifera also occur in trace amounts. Below 1065 m to 1215 m micrite only occurs in traces, but glauconite may form up to 30% of the rock. The claystone grades to thin beds of argillaceous sandstone between 870-90 m. Below 1155 m, the section consists of sandstone: very fine to very coarse, mainly fine to medium, occasionally granular, moderately to moderately well sorted, angular to rounded, abundant quartz silt, traces of clay, calcite cement up to 15%, sideritic and pyritic cements in trace amounts, traces to 30% of glauconite, traces of mica, fish and pelecypod fragments scattered throughout.

The Broome Sandstone equivalent in Lacepede No. 1A comprises two distinctive lithologies. Between 375-541 m the section consists of interbedded and interlaminated claystone and siltstone; claystone: 100% clay minerals, traces of glauconite and mica, grades to 80% clay minerals with 20% quartz silt; siltstone: brownish grey, argillaceous, up to 80% quartz silt, 20% clay, traces of glauconite and mica; grading to siltstone: pinkish brown, sandy, with 50% quartz silt, 30% quartz sand, 10% glauconite and 10% sideritic cement. From 702 to 904 m the lithology consists of interbedded siltstone and silty sandstone: siltstone: dark greenish grey, sandy 50% quartz silt, 40% quartz sand, 10% glauconite; grading to siltstone: sandy argillaceous, 10% clay minerals, up to 10% sideritic cement; and sandstone: generally silty very fine to fine, well sorted, subrounded, 75% quartz sand, 20% quartz silt, 5% glauconite.

The unit above the thick sandstone in Wamax No. 1 (410-707 m) consists of claystone: medium grey, glauconitic, micaceous, jasper, becoming more silty below 556 m; interbedded with green sand: yellow to grey, very fine to very coarse, moderately sorted to poorly sorted, glauconitic, minor amounts of micrite; and marl: medium grey, glauconitic throughout the claystone section.

Age: From a survey of data supplied by the companies (BOCAL, 1970d, 1971; Amax Petroleum (Australia) Inc. 1974; Hematite Petroleum Pty Ltd, 1974) the age of interval 8 ranges from late Neocomian to early Cenomanian. An unconformity exists between the Aptian and Albian in Keraudren No. 1 (1084 m) and Bedout No. 1 (1259 m). The age of this unconformity coincides with the age of the top of interval 8 in Lacepede No. 1A and Wamac No. 1. Albian-early Cenomanian rocks are not preserved in the Lacepede-Wamac area, but have been eroded.

The Broome Sandstone equivalent in the offshore wells contains microfloras which indicate the following ages:

Keraudren No. 1 (1215-1365 m) late Neocomian (?Hauterivian)

Bedout No. 1 (1464-1512 m) late Neocomian to early Aptian

Wamac No. 1 (742-944 m) late Neocomian (Barremian) to Aptian

Lacepede No. 1A (702-904 m) late Neocomian (Barremian) to basal Aptian.

APPENDIX 9. STRATIGRAPHIC UNITS OF INTERVAL 9

Introduction

Rocks of interval 9 are present only offshore and have been penetrated by six wells (Pl. 10-9), of which four are subsidised. Of the two unsubsidised wells in the study area (East Mermaid No. 1 and Minilya No. 1) stratigraphic data from only East Mermaid No. 1 had been released when this report was being written.

Although some of the rocks in interval 9 are clearly correlatable with named units in the Carnarvon Basin (Condon, 1968), no formal names have been given to them in this study.

Distribution

Interval 9 thickens to 1000 m to the northwest from an arbitrary boundary parallel to and about 65 km northwest of the coastline (Pl. 10-9). It has an average thickness of about 400 m over the shelf, and the rate of thickening increases sharply near the shelf edge.

Lithology

Five units are recognised in Bedout No. 1. In descending order, these are:

(a) glauconitic sandstone and claystone
(b) siltstone, claystone, and minor marl (best developed in Lynher No. 1)
(c) claystone and fine-grained sandstone (Lynher No. 1, Minilya No. 1)
(d) calcilutite with minor marl and calcareous siltstone near palaeoshore line (Lacepede No. 1A)
(e) marl, claystone, and minor basal glauconitic sandstone (Leveque No. 1).

Unit (a) - between 716 and 794 m in Bedout No. 1. It consists of sandstone: olive-grey to dark greenish grey, arenaceous in part, argillaceous, very fine to

granule, mainly medium, 45-50% glauconite, 10-30% clay minerals, 10% quartz silt, trace to 15% quartz grains, 0-30% fine to coarse dolomite rhombs, trace calcite cement, soft to moderately hard, no effective porosity; with thin beds of claystone: olive-black, 85-90% clay minerals, 10-15% glauconite, trace to 5% micrite, moderately hard, no effective porosity.

Unit (b) - between 794 and 1000 m in Bedout No. 1. It consists of claystone: yellowish brown to olive-black, silty, 50-80% clay minerals, 5-10% micrite, 15-30% quartz silt, trace to 10% Inoceramus prisms below 914 m, trace shell fragments, moderately hard, no effective porosity; with minor siltstone: yellowish brown, argillaceous, arenaceous, 45-50% quartz silt, 10-15% very fine to fine quartz grains, 20-30% clay minerals 5% micrite, trace to 10% glauconite, trace mica, moderately hard, no effective porosity; with (942-966 m), very thin beds of calcilutite: yellowish grey, 85% micrite, 10% clay minerals, 5% skeletal fragments, moderately hard, no effective porosity.

Unit (c) - between 1000 and 1042 m in Bedout No. 1. It consists of claystone: yellowish brown, calcareous, 45-80% clay minerals, 10-15% micrite, 0-40% Inoceramus prisms, 5% quartz silt, trace to 5% shell fragments, trace quartz grains, trace calcite silt, moderately hard, no effective porosity.

Unit (d) - between 1064 and 1112 m in Bedout No. 1. It consists of calcilutite: yellowish grey, argillaceous, 60-70% micrite, 20% calcite silt, 10-20% clay minerals, soft, no effective porosity. Between 1042 and 1064 m the calcilutite unit is overlain by claystone: as above, and marl: very light grey to light olive-grey, 50% micrite, trace to 10% calcite silt, 30-40% clay minerals, 0-20% Inoceramus prisms, soft to moderately hard, no effective porosity.

Unit (e) - between 1112 and 1125 m in Bedout No. 1. It consists of marl: greenish grey to olive-grey, 40-60% calcite, 40-60% clay minerals, moderately hard, no effective porosity, with thin interbeds of claystone: as above.

Facies distribution

Not all five units delineated in Bedout No. 1 are distinguishable in other wells. The correlation discussed below is based on wireline-log characters and illustrated in Figure A9-1 and lithological maps (Figs. A9-2, A9-3, A9-4, A9-5, A9-6).

The basal unit (e) thins northwest of Lynher No. 1 and east towards the zero isopach and becomes progressively calcareous northwards (Fig. A9-6). The calcilutite unit (d) is present in all wells except those close to the palaeoshoreline (Lacepede No. 1A) where the equivalent unit consists of siltstone and claystone (Fig. A9-5).

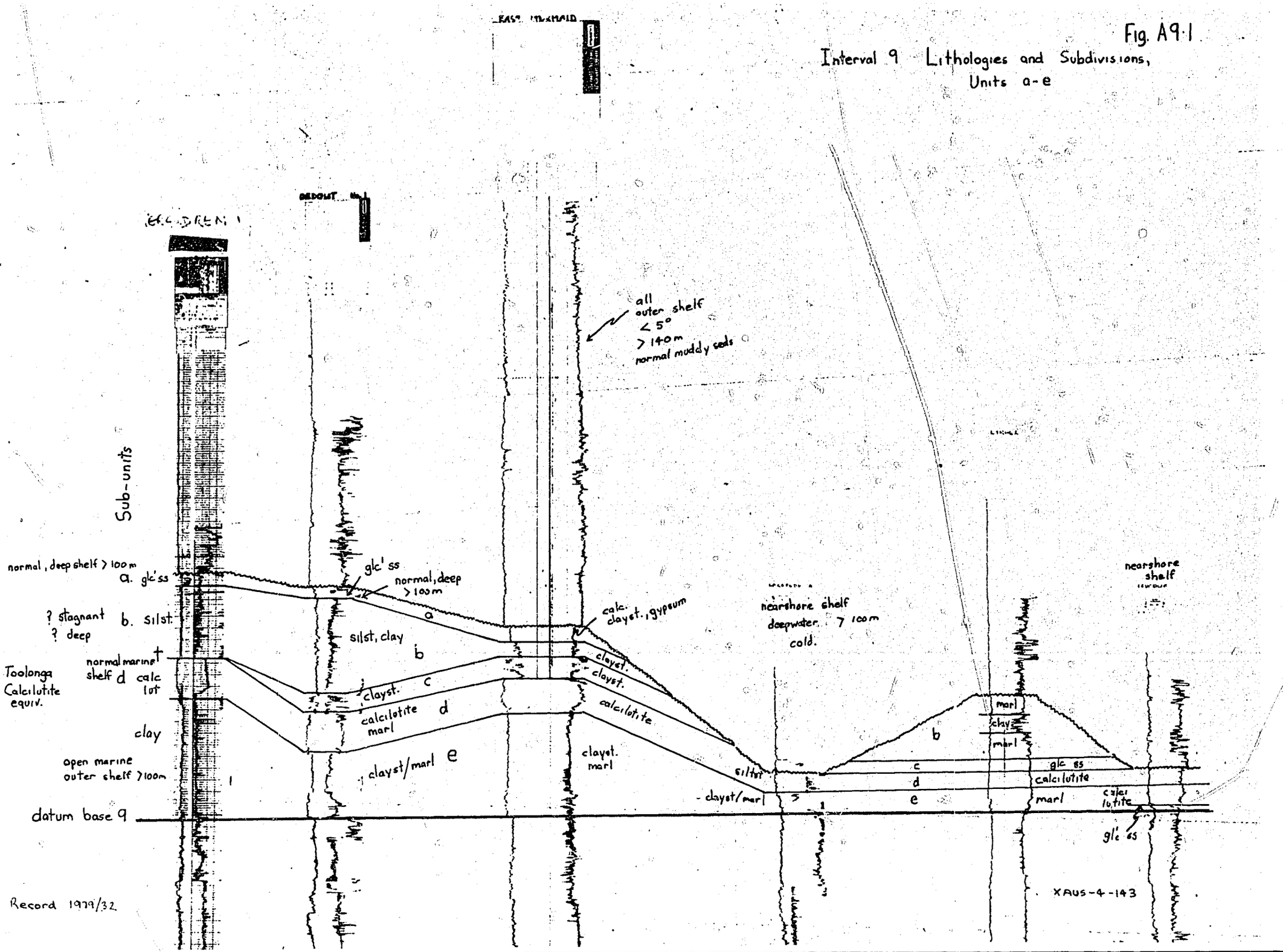
The overlying claystone unit (c) is also present in East Mermaid No. 1 to the northwest, Lynher No. 1 in the Browse Basin, and, as fine-grained sandstone, also in Minilya No. 1, but does not occur in wells near the palaeoshoreline or to the southwest in Picard No. 1 or Keraudren No. 1 (Fig. A9-4). This may represent non-deposition or erosion of the unit towards the southwest, but relations are unclear; there appear to be no missing foraminiferal zones to the southwest, suggesting erosion did not occur. The siltstone and claystone unit (b) oversteps the claystone unit (c) to the southwest (Fig. A9-1) and all five units are truncated by the Paleocene unconformity progressively shorewards (Wamac No. 1, Lacepede No. 1A, and Leveque No. 1). The unit becomes more calcareous towards the north, and marl occurs in Lynher No. 1 (Fig. A9-3) The uppermost unit (a) is preserved only in Keraudren No. 1, Bedout No. 1, and East Mermaid No. 1. The glauconite sandstone and claystone of the southern Bedout Sub-basin is represented by calcareous claystone in more northern wells (East Mermaid No. 1) and possibly by claystone and marl in Minilya No. 1 (Fig. A9-2).

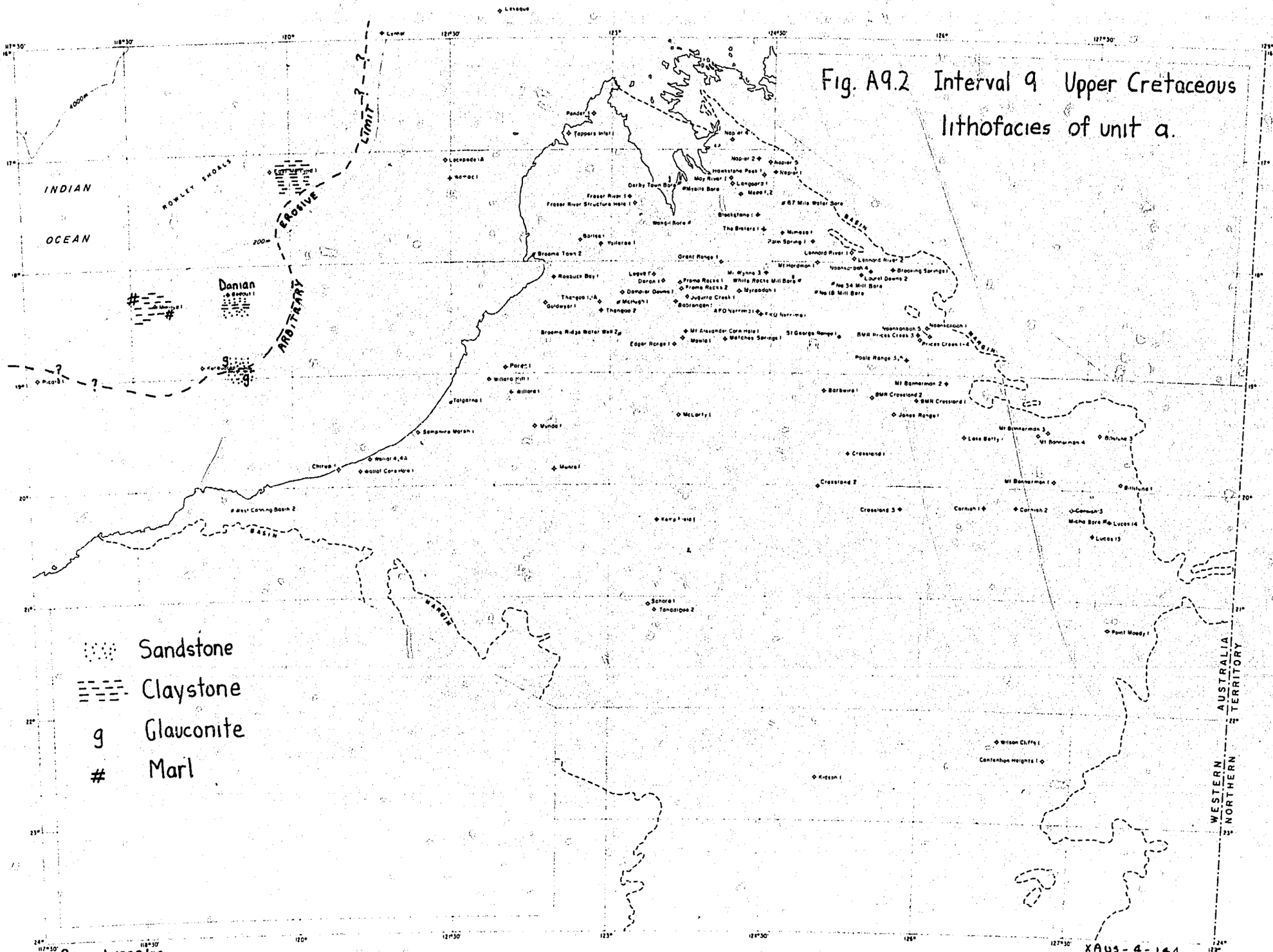
Age

The determination of ages is based on published data from forams and palynology and is summarised below. The age dating was clarified by comparing published foraminiferal lists with the zonation schemes of Bolli (1966) and Postuma (1971).

Fig. A9·1

Interval 9 Lithologies and Subdivisions, Units a-e





Record 1979/32

XAUS-4-144

87%

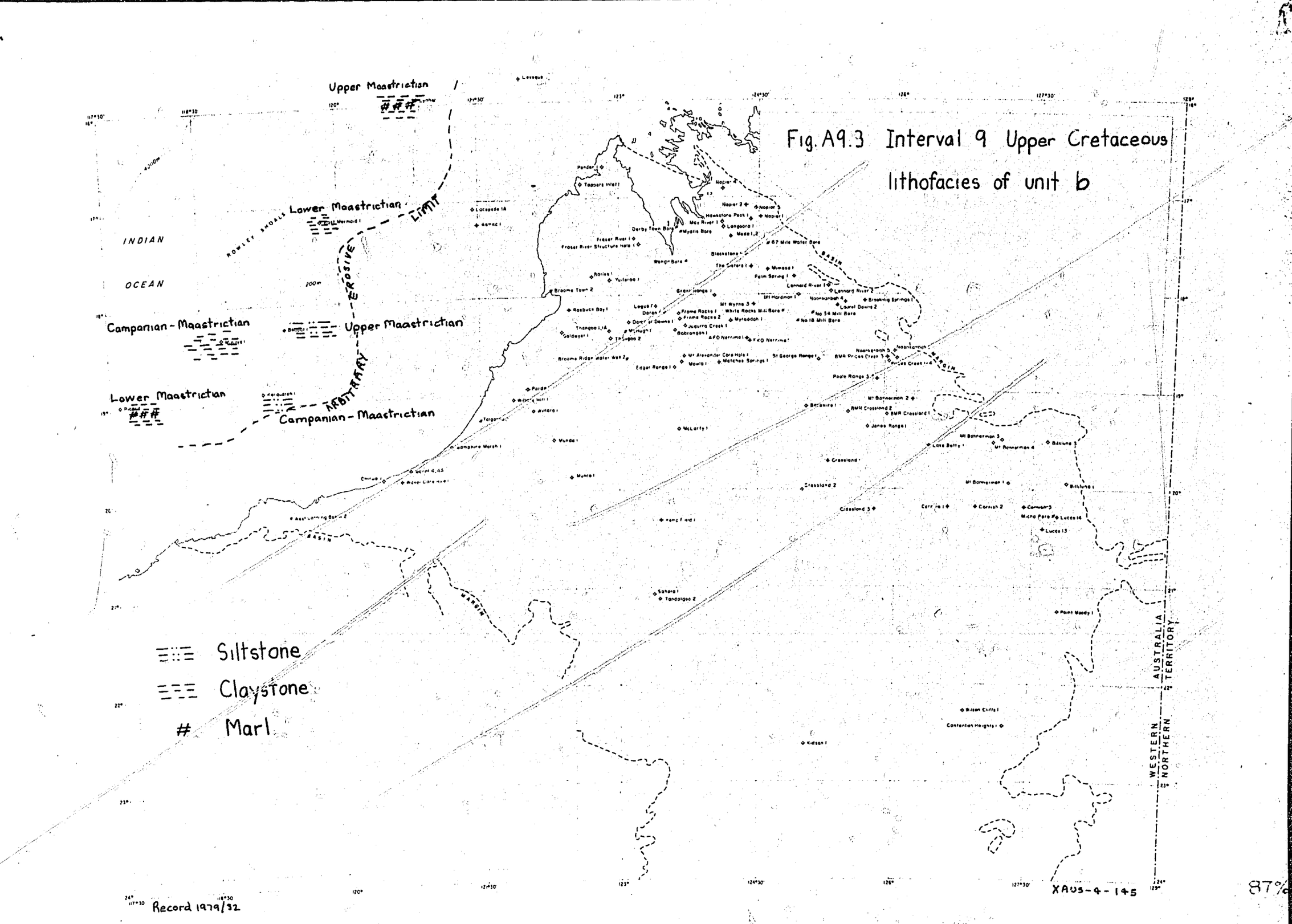


Fig. A9.3 Interval 9 Upper Cretaceous lithofacies of unit b

XAUS-4-145

Record 1979/32

87%

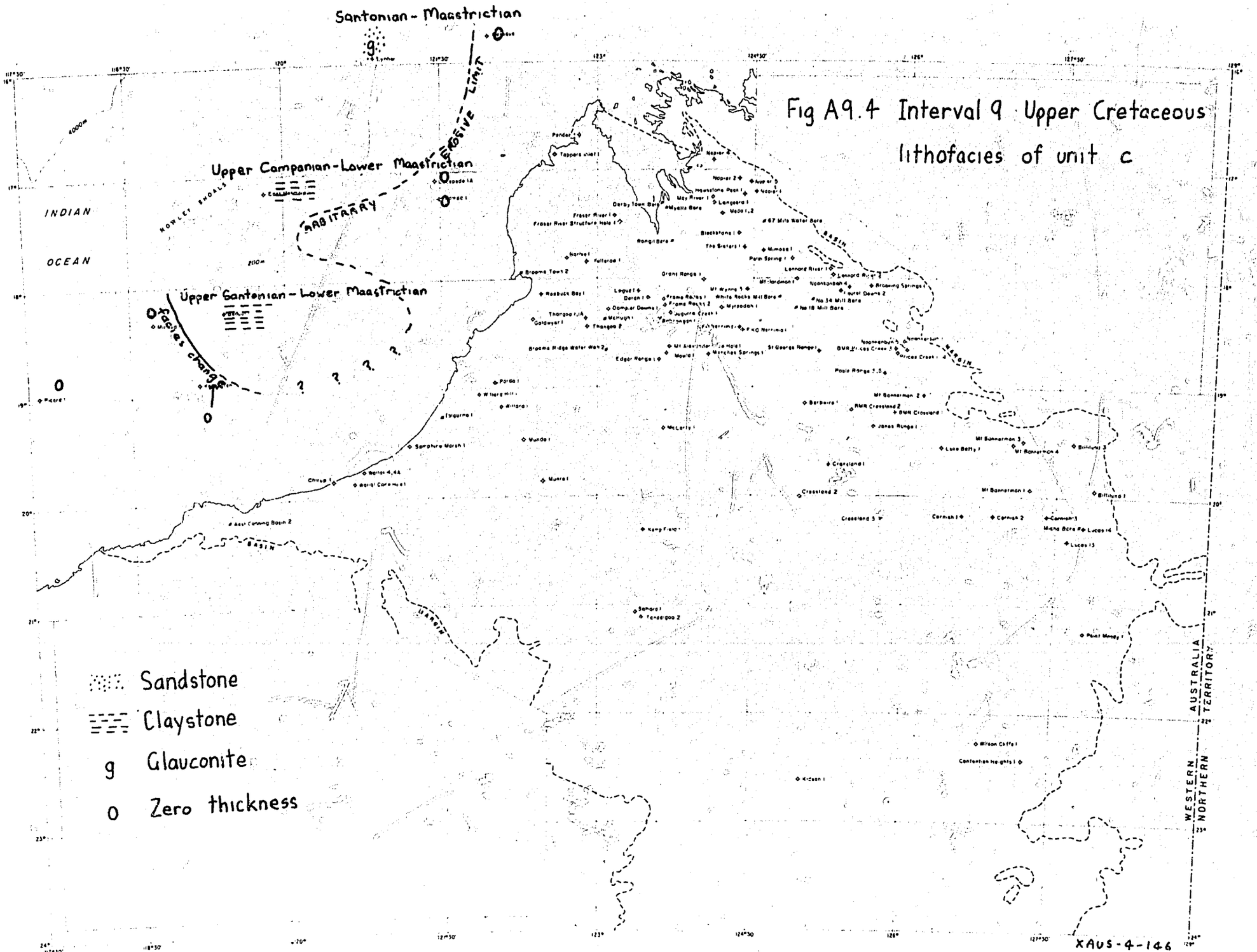


Fig A9.4 Interval 9 Upper Cretaceous lithofacies of unit c

XAUS-4-146

Record 1979/32

87%

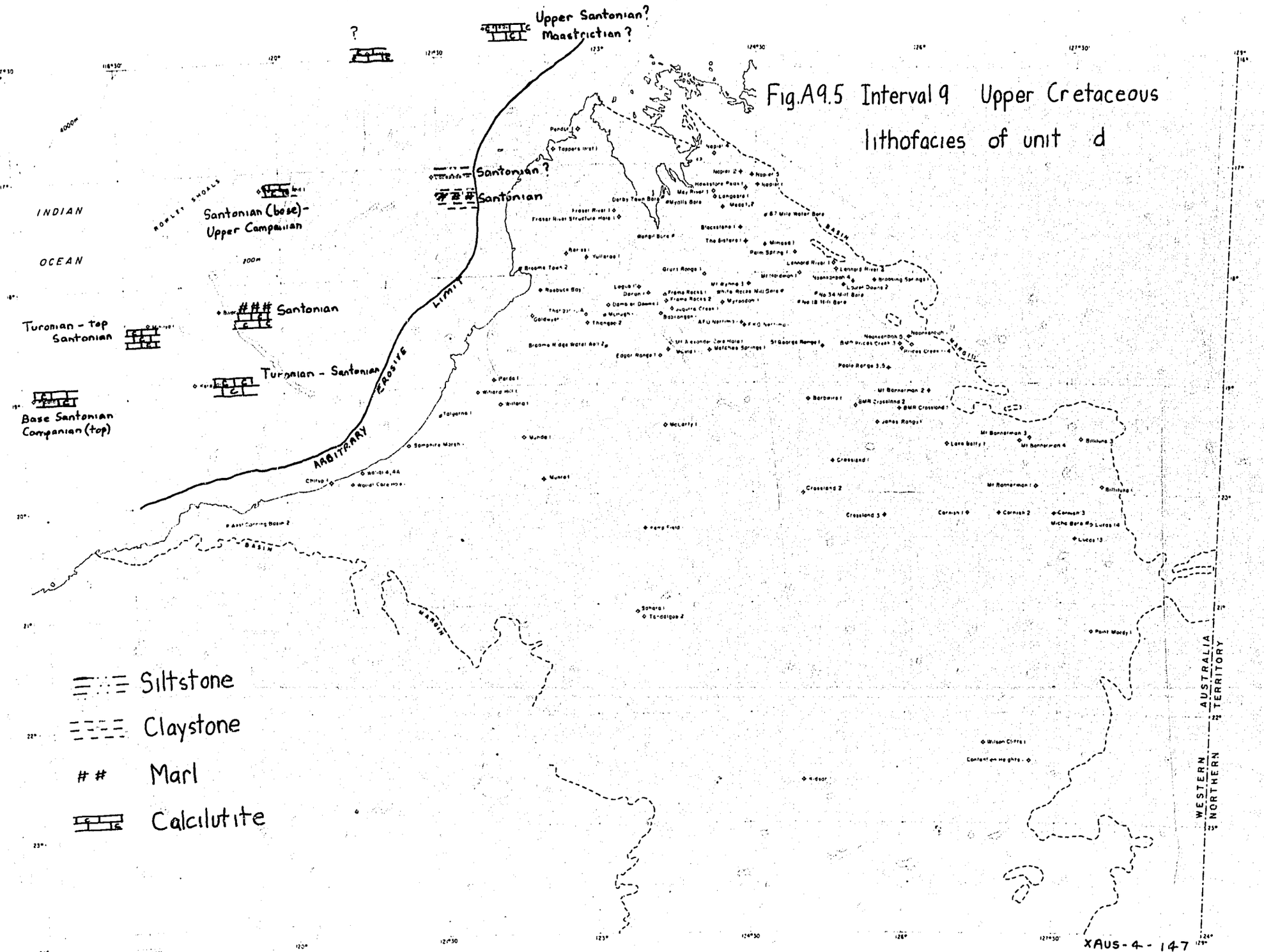
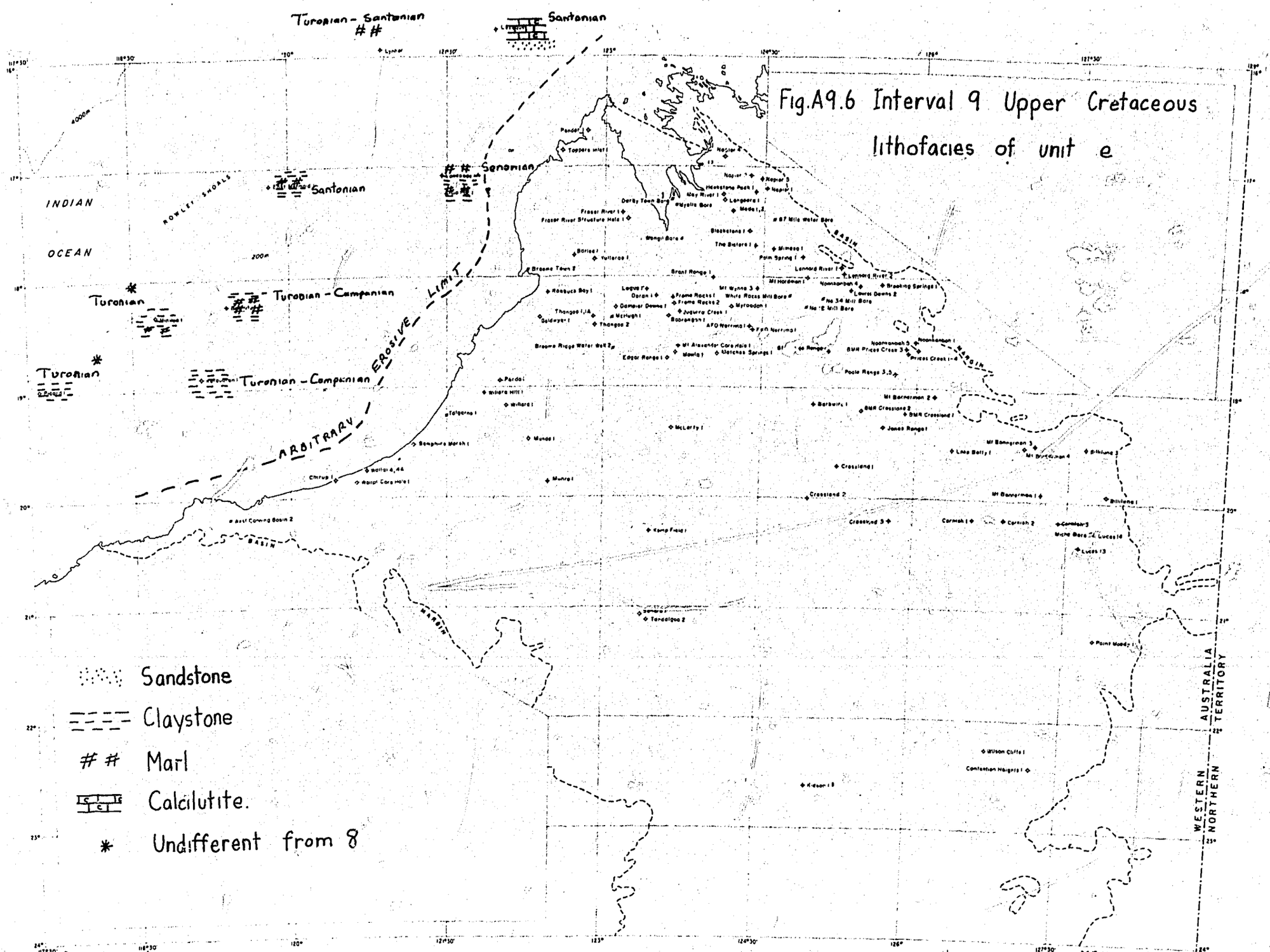


Fig. A9.5 Interval 9 Upper Cretaceous lithofacies of unit d

Record 1979/32

XAUS-4-147

87%



Record 1979/32

XAUS - 4 - 148

Unit (a) - Danian

Well name	Stage	Palynozone	Foram zone	Lithology
MINILYA 1	Danian?	1	T6-T1	Claystone and marl
KERAUDREN 1	Lower Tertiary	Indeterminate Tertiary/ Cretaceous	?Upper Cretaceous or Tertiary	Glauconitic sandstone and claystone
BEDOUT 1	Danian			Glauconitic sandstone and claystone
EAST MERMAID 1	upper Paleocene	upper Paleocene	T5-T4	Claystone and minor marl
LYNHER 1	not present			
LEVEQUE 1	not present			
WAMAC 1	not present			
LACEPEDE 1A	not present			

The age of the glauconite unit from the table is Paleocene. The presence of older rocks (Danian) in the southeast (Minilya No. 1, Bedout No. 1) suggests that the transgression moved northwards and reached the East Mermaid No. 1 and Lynher No. 1 area by middle Paleocene. The absence of the unit nearshore (Leveque No. 1, Lacepede No. 1A) is probably due to pre-Miocene erosion.

Unit (b) - Campanian to late Maastrichtian

Well name	Stage	Palynozone	Foram zone	Lithology
MINILYA 1	Campanian to Maastrichtian		C10-C13	Claystone
KERAUDREN 1	Campanian	Campanian	Campanian-Santonian	Siltstone
BEDOUT 1	Upper Maastrichtian	lower part KM16		Siltstone and claystone
EAST MERMAID 1	?lower Maastrichtian	KM16-15	?C11 *Inoceramus*	Claystone
LYNHER 1	upper Maastrichtian	KM16		Claystone and marl
LEVEQUE 1	not present			
WAMAC 1	not present			
LACEPEDE 1A	not present			

The table suggests that the siltstone and claystone unit (facies b) transgressed to the north: the older rocks deposited in the southwest are of Campanian age, and the basal rocks of the unit to the north (in the East Mermaid No. 1 and Lynher No. 1) are of Maastrichtian age. The absence of the unit in the nearshore wells is due to pre-Miocene erosion.

Unit (c) - Campanian to early Maastrichtian

Well name	Stage	Palynozone	Foram zone	Lithology
MINILYA 1	lower Campanian			Sandstone and claystone
KERAUDREN 1	not present			
BEDOUT 1	upper Santonian lower Maastrichtian	KM15		Claystone
EAST MERMAID 1	upper Campanian to lower Maastrichtian	KM15 (Campanian)	?C11-C10	Claystone
LYNHER 1	Santonian-Campanian-Maastrichtian	KM15-16		Glauconitic sandstone
LEVEQUE 1	not present			
WAMAC 1	not present			
LACEPEDE 1A	not present			

The age of the claystone unit (c) where present is late Campanian to early Maastrichtian and therefore equivalent in age to the older rocks of the overlying unit of the wells in the southwest (Minilya No. 1, Keraudren No. 1) in which the claystone unit is absent. The implication is that the absence of the unit is due to facies changes rather than erosion and that the top of the unit is a lithological rather than an erosional surface. It is also significant that no palaeontological zones are absent.

Unit (d) - Turonian to early Campanian

Well name	Stage	Palynozone	Foram zone	Lithology
MINILYA 1	Turonian to top Santonian	Turonian to top Santonian	C6-C10	Calcilutite
KERAUDREN 1	Turonian to Santonian	Indet. Upper Cretaceous Coniacian-Turonian	lower Santonian to Santonian	Calcilutite
BEDOUT 1	Santonian to upper Santonian. ?Lower stages not sampled	KM15-KM13		Calcilutite
EAST MERMAID 1	basal Santonian and Coniacian to upper Campanian	KM15 at top (Campanian)	C8, 9 and C7-C6	Calcilutite
LYNHER 1	not sampled			Calcilutite
LEVEQUE 1	u. Sant-Maast ?	KM15 at top KM10 at base		Calcilutite
WAMAC 1	Santonian	KM14		Claystone and marl
LACEPEDE 1A	?Santonian (not calcilutite)	KM14		Siltstone

The calcilutite unit is older in the southwest (Turonian) and younger northwards and nearshore (Leveque No. 1, Lacepede No. 1A, Wamac No. 1), suggesting an easterly transgression.

Unit (e) - Turonian to Santonian

Well name	Stage	Palynozone	Foram zone	Lithology
MINILYA 1	not differentiated from interval 8			Claystone and marl
KERAUDREN 1	Turonian-Coniacian			Claystone
BEDOUT 1	Turonian-Coniacian			Marl and claystone
EAST MERMAID 1	Santonian			Marl and claystone
LYNHER 1	Turonian-Santonian	K10b-14 Turonian		Marl
LEVEQUE 1	Santonian			Calcilutite and basal sandstone
LACEPEDE 1A	Senonian (Coniacian-Campanian)			Claystone and marl
WAMAC 1	no data			Claystone and marl

The marl and claystone unit is the basal unit of the interval 9 transgression. The unit thins northwards and eastwards, and becomes more calcareous northwards. The age is not well defined but is Turonian at the base in Lynher No. 1 under overlying lower Cenomanian rocks. Rocks of equivalent age are present in Minilya No. 1, but it has not been possible to subdivide the unit in this well.

Several schemes of stratigraphic subdivision of the Upper Cretaceous of the North West Shelf have been published (Challinor, 1970; Kaye, Edmond, & Challinor, 1972). These schemes are correlated with the unit in the present study, although no formal names are suggested.

Fossils

Fossils recovered from interval 9 include forams, microplankton (dinoflagellates), spores and pollen, Inoceramus sp., bivalves, sponge spicules, and radiolaria.

APPENDIX 10. STRATIGRAPHIC UNITS OF INTERVAL 10

Introduction

Interval 10 occurs in Minilya No. 1, Keraudren No. 1, Bedout No. 1, and East Mermaid No. 1 in the Canning Basin offshore, and in Lynher No. 1 in the Browse Basin. To the south, in the Dampier Sub-basin, interval 10 is present in Picard No. 1 and rocks of equivalent age, the Cardabia Group and Lower Giralia Group (Condon, 1968), are known from the Carnarvon Basin.

As with interval 9, no formal names have been given to interval 10 rocks offshore. Four onshore units, the Emeriau Sandstone, Pender Bay conglomerate, Lake George Beds and Lampe Beds, are included in the interval.

Distribution

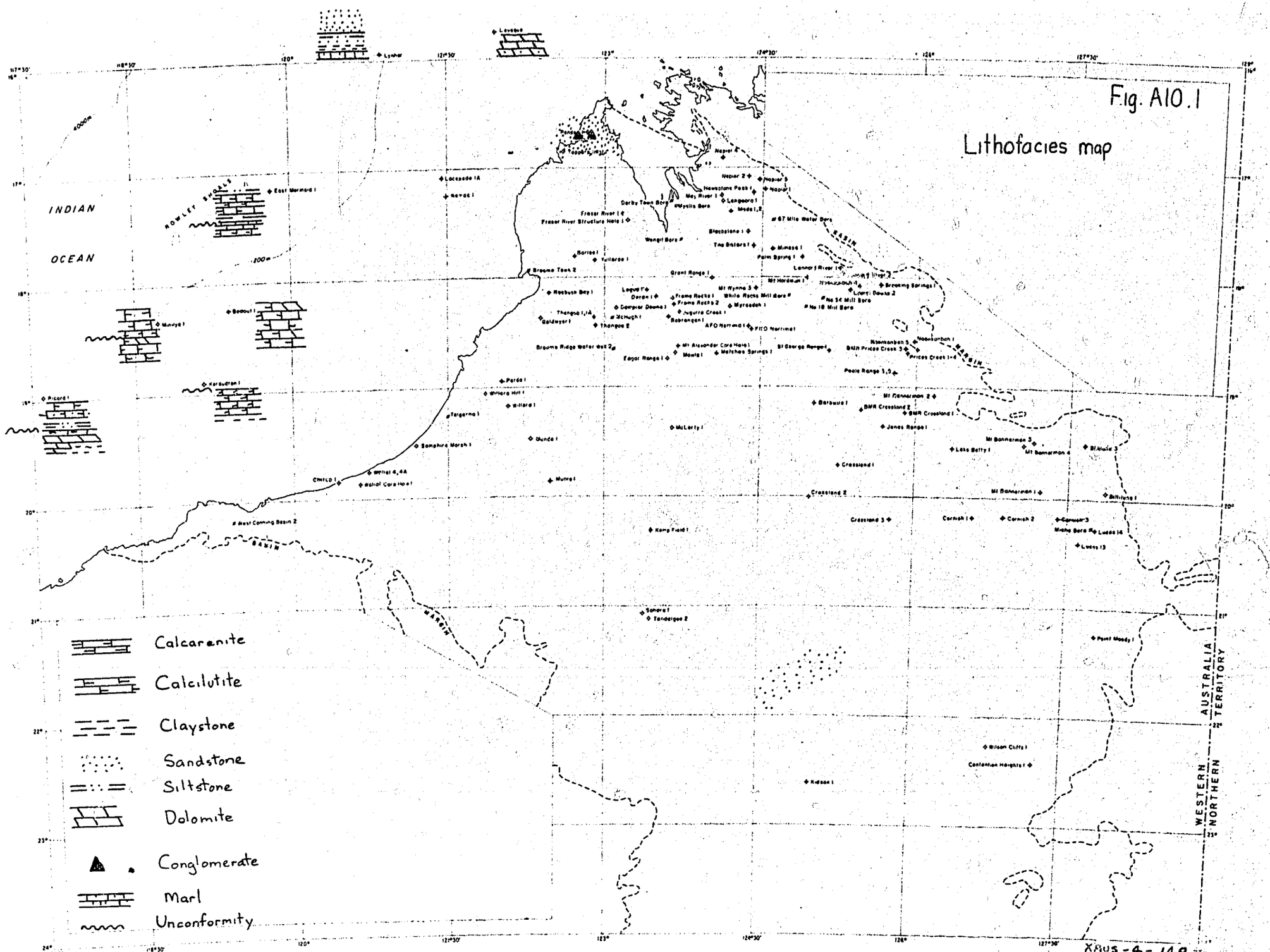
Interval 10 is thickly developed only offshore (Pl. 10-10), where it reaches a mapped maximum thickness of 900 m west of the shelf break. On the shelf the thickness ranges from an approximate zero isopach parallel to the present shore to about 250 m near the shelf break. On the Dampier Peninsula and in the southeastern Canning Basin (Lampe Beds), interval 10 rocks seldom exceed 50 m thick.

Lithology

The thickest section penetrated in Minilya No. 1, consists of calcilutite and minor dolomite beds near the top. All other wells (with the exception of Lynher No. 1, which contains sandstone) are mainly calcarenite with minor dolomite and claystone interbeds. Lithofacies is shown in Figure A 10-1, A 10-2 and Plate 10-10.

In Bedout No. 1, interval 10 rocks have been divided into two smaller units.

Upper unit, 629-643 m, consists of dolomite, claystone, and calcarenite. Dolomite: top of interval 10 in Bedout No. 1, sucrosic, moderately hard, and underlain by claystone: mottled greyish blue-green and dark yellowish orange, silty, with 85% clay minerals, 10% very fine quartz grains, 5% quartz silt, soft, no effective porosity. Basal calcarenite: yellowish grey, 85% skeletal fragments, silt size to very coarse but mainly medium, 10% micrite, 5% calcite cement, trace clay minerals, moderately hard, no effective porosity.

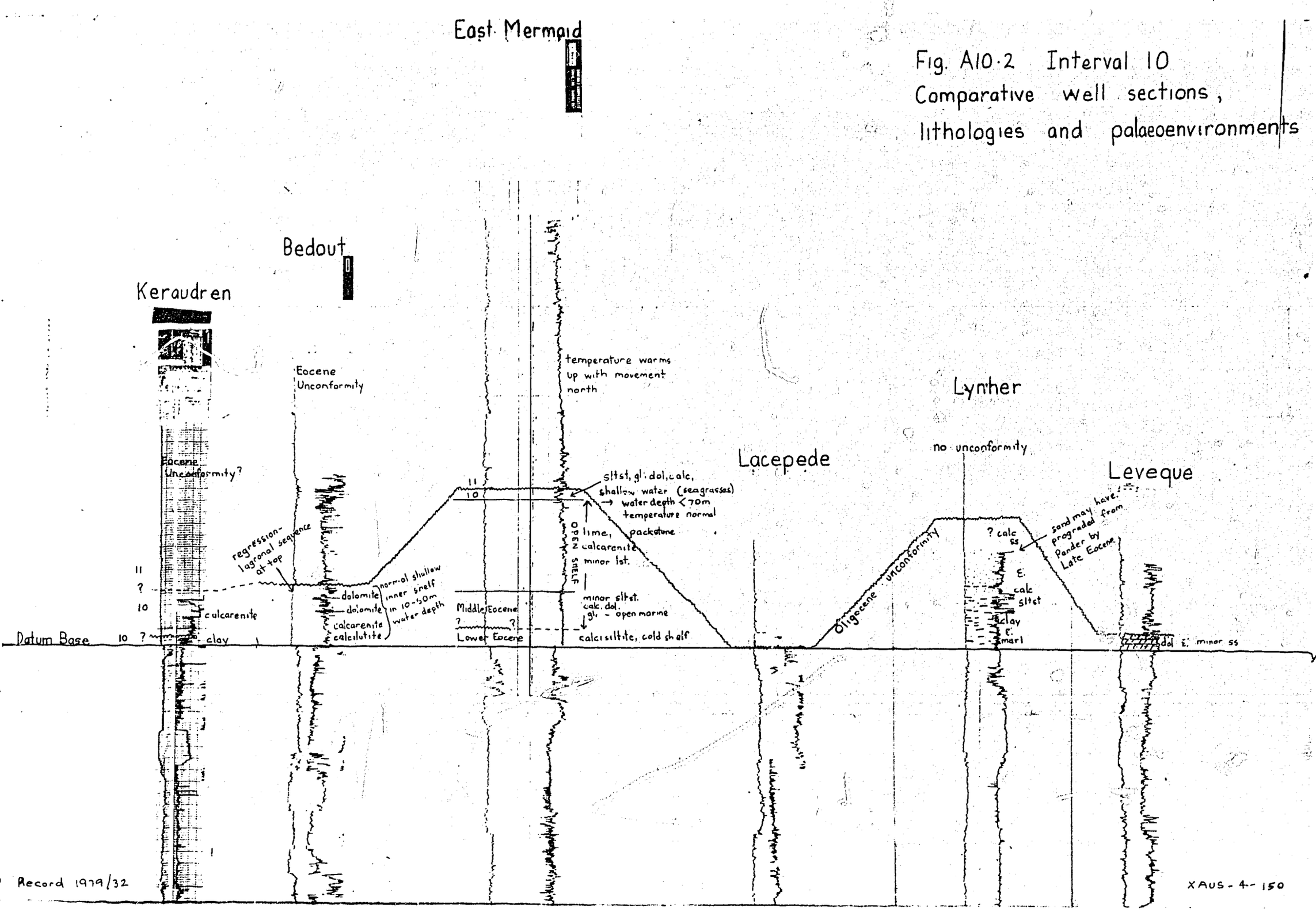


Record 1979/32

XRUS-4-149

87%

Fig. A10·2 Interval 10 Comparative well sections, lithologies and palaeoenvironments



Lower unit, 643-771 m, comprises mainly calcilutite: very light grey to dusky yellowish brown, dolomitic, 35-90% micrite, 5-40% skeletal fragments, fine to granule but mainly coarse, trace to 5% clay minerals, trace quartz grains in upper part, trace pyrite below 495 m, 5-30% fine to coarse, dolomite rhombs moderately hard, no effective porosity, up to 50% recrystallised to cryptocrystalline calcite, up to 20% dolomitised to microcrystalline dolomite, recrystallization decreasing with depth, with thin beds of dolomite: light brown to dark grey, calcareous in part, argillaceous in part, 70-100% dolomite, microcrystalline to sucrosic, 0-20% clay minerals, 0-20% micrite, trace skeletal fragments, moderately hard, no effective porosity, with minor calcarenite: yellowish grey, 85% skeletal fragments, silt size to very coarse but mainly medium, 10% micrite, 5% calcite cement, trace clay minerals, moderately hard, no effective porosity, up to 10% dolomitised.

These units cannot be traced beyond Bedout No. 1.

Relations with other units

Interval 10 offshore overlies lower Paleocene rocks with a distinct but short time break.

Age

Foraminiferal zonations of Blow (1969) and Berggren (1969) were used to establish the age of interval 10 in offshore wells. The interval spans the P4 to probably P17 zones and is thus late Paleocene to late Eocene. The existence of the mid-Eocene unconformity in the Beagle Sub-basin, south of the Canning Basin, cannot be proved on the scanty evidence available, although some foram. zones are absent. Whether this is due to sampling bias or a break in the sequences is unknown.

ONSHORE UNITS

EMERIAU SANDSTONE

Named from: Emeriau Point, Dampier Peninsula.

Defined by: Brunnschweiller (1957).

Status of name: Formally defined.

Type section: Emeriau Point.

Previous name: None recorded.

Modifications: None.

Described outcrop: Along the coast of Dampier Peninsula mainly south of Pender Bay (Brunnschweiler, 1957).

Distribution: Tappers Inlet No. 1, Pender No. 1. The unit is known only from Dampier Peninsula, but probably extended westwards.

Thickness: 4 m at the type section, but about 30 m at Carnot Peak and Kings Peak. Pender No. 1 penetrated 62 m.

Relations with other units: Overlies an eroded surface of Jurassic Jowlaenga Formation and Cretaceous Broome Sandstone (Veevers & Wells, 1961) with unconformity (Brunnschweiler, 1957). The unit is overlain by Pleistocene Chimney Rock Oolite (Brunnschweiler, 1957) or Recent sand and alluvium.

Subdivision: None attempted.

Lithology: At the type area the unit consists of sandstone: black, ferruginous, medium-grained, angular and rounded quartz grains, and poorly graded (Brunnschweiler, 1957; Veevers & Wells, 1961). Large worm tracks may be common (Brunnschweiler, 1957).

In Pender No. 1 the unit consists of a basal (39 m) sandstone: clear, rarely coloured, medium to coarse grained, subrounded, moderately sorted, very porous, overlain by 3 m of sandstone: clear to white, slightly silty in part, fine to medium quartz grains, subrounded to rounded, moderately sorted, silica cemented, hard, tight, overlain by 21 m of sandstone: colourless to white, yellow, or brown, fine-grained quartz, subrounded with yellow, white, or brown clay matrix, grading to siltstone: slightly micaceous.

Age: The only organic traces are trails (Brunnschweiler, 1957). The unit unconformably overlies Neocomian-Aptian Broome Sandstone and is overlain by Pleistocene rocks, indicating a Late Cretaceous to Late Tertiary age. The unit is lateritised and therefore deposited before the mid-Tertiary lateritisation. A Late Cretaceous to Early Tertiary age is assumed.

PENDER BAY CONGLOMERATE

Named from: Pender Bay, Dampier Peninsula.

Defined by: Brunnschweiler, (1957).

Status of name: Formally defined.

Type section: None defined - type locality at Pender Bay (16°45'00"S, 122°35'00"E).

Previous name: None.

Modifications: None proposed.

Described outcrop: Both shores of Pender Bay only. The unit is probably a coarse facies of the Emeriau Sandstone. Conglomerates on Valentine Island and King Sound may be correlatives.

Distribution: As above.

Thickness variations: At Pender Bay the unit never exceeds 4 m (Brunnschweiler, 1957). At Valentine Island, it is 8 m.

Relations with other units: The unit overlies eroded Jurassic Jowlaenga Formation and Lower Cretaceous Broome Sandstone. The Valentine Island outcrop overlies Jowlaenga Formation. The unit is overlain disconformably by Recent sediments and the Late Tertiary Borda Sandstone at Pender Bay (Veevers & Wells, 1961).

Subdivision: None attempted.

Lithology: At Pender Bay the unit consists of Conglomerate: dark, graded upwards, rounded and subrounded, quartz sandstone and pebbles, matrix of medium-grained quartz sandstone, indurated (Brunnschweiler, 1957).

Age: The Pender Bay Conglomerate antedates the extensive mid-Tertiary lateritisation; it is lateritised and overlain by the unferruginised Borda Sandstone on a duricrusted surface. The age is thus thought to be Early Tertiary.

LAMPE BEDS

Named from: Mount Lampe, Officer Basin.

Defined by: Lowry & others (1972).

Status of name: Formally defined.

Type section: Mount Johnson, Officer Basin.

Previous name: None recorded.

Modifications: None.

Described outcrop: Southeastern margin of Canning Basin and northern Officer Basin.

Distribution: As above.

Thickness variations: Unknown, but outcrops rarely attain 3 m in height (Lowry & others, 1972).

Relations with other units: Overlie Proterozoic, Permian, and Lower Cretaceous rocks unconformably to disconformably and always have an upper erosional surface (Lowry & others, 1972).

Subdivision: None attempted.

Lithology: The unit consists of sandstone: light grey, occasionally white or earthy red, medium to very coarse, conglomeratic, poorly sorted, medium to thick-bedded, much silicified (Lowry & others, 1972).

Age: The unit is unfossiliferous but is lateritised. Laterite in the Officer Basin is pre-Miocene (Lowry & others, 1972) and thus the Lampe Beds are probably pre-Miocene. The unconformable relation with Lower Cretaceous rocks suggests that the unit is Late Cretaceous to Early Tertiary in age. The age is here thought to be Early Tertiary.

LAKE GEORGE BEDS

Named from: Lake George, Percival 1:250 000 sheet.

Defined by: Towner, Crowe, & Yeates (1976).

Status of name: Defined (Crowe & Towner, 1976d).

Type section: Not defined.

Previous name: None.

Modifications: None.

Described outcrop: South of Percival Lakes in the Percival 1:250 000 sheet area.

Distribution: Southwest of Percival Lakes.

Thickness variations: Unknown, but 5 m measured.

Relations with other units: Overlies Lower Cretaceous and older rocks.

Subdivision: None.

Lithology: Sandstone: quartzose, silicified, ferruginised, massive (Towner, Crowe, & Yeates, 1976).

Age: The unit contains undiagnostic 'pipe rock' and ?root structures, but underlies laterite (Towner, Crowe, & Yeates, 1976) and is itself ferruginised. The unit overlies Lower Cretaceous rocks (the Aptian Anketell Formation) unconformably. From the arguments advanced above the age is thought to be Early Tertiary.

APPENDIX 11. STRATIGRAPHIC UNITS OF INTERVAL 11

Introduction

Rocks assigned to interval 11 are known from both the present onshore and offshore areas. Several units have been named in the onshore area. These include the Oakover Beds, Lawson Beds, Chimney Rock Oolite, North Head Limestone, Bossut Formation, Borda Sandstone, Wolf Gravel, Warrimbah Conglomerate, and Lake Gregory Beds. Also recognised onshore are pisolitic ironstone, ferricrete, silcrete, calcrete, limonite, hardpan, laterite, sand, and alluvium. Offshore, rocks of interval 11 age are unnamed at present.

Distribution of offshore interval 11

The interval gradually thickens seaward from a thin veneer in the coastal area to about 1000 m at the shelf break (Pl. 10-11). Reef development on the Rowley Shoals increases the thickness to 1200 m.

Lithology

In Bedout No. 1 the sampled section has been divided lithologically into three units, but no samples were collected from the sea bed (170 m) to the base of casing (442 m). These units, in descending order, are:

- Dolomite unit
- Calcilutite unit
- Sandstone unit

The gamma-ray response pattern above the dolomite unit is similar to that of the calcilutite unit, suggesting the non-sampled part of the unit is also calcilutite. The dolomite unit may represent diagenetic changes during subareal exposure, and may correlate with the Pliocene R_1 unconformity (Veevers, 1973a), also present at 640 m in East Mermaid No. 1 where the calcareous section is also capped by dolomite. This break may occur at 549 m in Minilya No. 1.

Dolomite unit

In Bedout No. 1 (442-492 m) the unit consists of dolomite: very light orange to light brown, 90-100% dolomite, microcrystalline to sucrosic, trace to 10% clay minerals, trace to 5% foraminifera, trace skeletal fragments, trace quartz grains, moderately hard, trace to good vugular porosity.

Calcilutite unit

In Bedout No. 1 (492-616 m) the unit consists of calcilutite: light orange to light olive-grey, dolomitic, 50-100% micrite, 5-40% skeletal fragments, fine to granule but mainly coarse, 0-5% clay minerals, 0-5% quartz silt, trace to 10% gypsum, moderately hard, nil to trace vugular porosity, up to 50% recrystallised, up to 40% dolomitised; calcarenite: light olive-grey, 50-60% skeletal fragments, as above, 20-40% micrite, 0-10% calcite cement, 5% clay minerals, 0-5% quartz silt, trace to 5% gypsum, moderately hard, poor to good vugular and intergranular porosity, up to 20% recrystallised, up to 10% dolomitised; with minor thin beds of dolomite: very light orange to light brown, 90-100% dolomite, microcrystalline to sucrosic, trace to 10% clay minerals, trace to 5% skeletal fragments, moderately hard, trace to poor vugular porosity.

Sandstone unit

In Bedout 1 (616-629 m) the unit consists of sandstone: light grey to brownish grey, in part calcareous, in part dolomitic, 50-75% quartz grains, very fine to very coarse but mainly medium, poorly sorted, subangular, 5-30% micrite, 5-10% clay minerals, 0-10% skeletal fragments, trace quartz silt, 0-5% dolomite rhombs, fine to medium, trace glauconite, soft, trace to poor intergranual porosity, up to 15% dolomitised.

Other wells

Lacepede 1 and 1A. No samples were recovered from the sea bed to 300 m in Lacepede 1A. Between this depth and the base of interval 11, at 303 m, the sequence is unknown except for the basal sampled interval which consists of dolomite: white to tan, sandy, microcrystalline to medium-grained but mainly microcrystalline, 90% dolomite, 10% quartz sand, trace nodular chert, moderately hard, no effective porosity. The lithology of the unsampled section of Lacepede 1A is illustrated in Lacepede 1, which penetrated a 235 m thick sequence of fossiliferous calcirudite with minor marl horizons and a thin basal dolomite unit.

Wamac 1. No samples were recovered to 375 m, but cavings consisted of glauconitic sandstone and fossiliferous dolomite. The dolomite is white to yellow and the sandstone light to dark brown. The gamma-ray log confirms the presence of sandstone in the sequence.

Age

In Bedout No. 1 Miogypsina spp. (mainly Miogypsina polymorpha). Gypsina globula and rare Lepidocyclina indicate a middle Miocene to Burdigalian age (Wall in BOCAL, 1971) for the lower part. Samples from above 536 m contain Pliocene to Miocene benthic foraminifera. As no samples were recovered above 422 m the age is unknown, but is probably Pliocene to Recent.

Interval 11 fossils from Lacepede 1 show little vertical variation. The yield is dominated by small calcareous benthonic foraminifera and rare planktic forms. From 97.5 to 219.5 m these range from late Miocene to Pliocene. A sample at about 274 m in Lacepede 1A yielded unreliable ages, but samples below this depth contained no faunas older than late Miocene. A sample collected from 0.2 to 0.7 m below the sea floor contained Recent to early Miocene foraminifera. It is therefore suggested that the sections encountered in the Lacepede wells range from late Miocene to Recent (BOCAL, 1970d). Other fossils from Lacepede 1 include bivalves, gastropods, coral fragments, and echinoid spines between 97.5 and 104 m, rare ostracods, and bivalves between 140 and 146 m, and 152 m and 158 m. A divers sample at 207 m also contained bivalves and echinoid spines.

Faunas recovered from East Mermaid No. 1 indicate an Aquitanian age for the oldest rocks of interval 11 (Shell, 1973).

No flora or fauna were recovered from either Keraudren No. 1 or Wamac No. 1, although fossiliferous dolomite was reported from batches of caved cuttings in Wamac No. 1 well (Amax Petroleum (Australia) Inc., 1974).

Fossil evidence from three wells, Bedout No. 1 and Lacepede Nos. 1 and 1A, suggest that interval 11 transgresses to the east. Wells west of Bedout No. 1 can therefore be expected to contain sections older than Burdigalian (e.g., Minilya No. 1, as they do on the Rankin Trend, to the southwest (e.g., Depuch No. 1; BOCAL, 1973). The basal sediments of interval 11 in Leveque No. 1 are upper Miocene (BOCAL, 1970e), but to the west in Lynher No. 1 they contain specimens of Nephrolepidina, which indicates that Middle and/or Lower Miocene rocks are present in the well above interval 10 (Wall, in BOCAL, 1970f) and confirms the west to east transgression.

Onshore formations of interval 11

OAKOVER BEDS

Named from: Presumably Oakover River.

Defined by: Maitland, 1904.

Status of name: Formally defined.

Type section: None defined - type area is Oakover River valley (station 225).

Previous name: Braeside Limestone, an unpublished term used by Reeves, cited by Traves & others (1956).

Modifications: None.

Described outcrop: Oakover River valley, Pilbara Goldfield.

Distribution: Same area as outcrop, but may correlate with travertine deposits south of Lake Waukarlycarly (Wells, 1959a).

Thickness: Roughly 33 m (McWhae & others, 1958; de la Hunty, 1964).

Relations with other units: Overlies Upper Proterozoic dolomitic limestone near Carrawine Pool (Traves & others, 1956), metamorphics, and granite. They are nowhere overlain by other formations (Wells, 1959b).

Subdivision: None attempted.

Lithology: Limestone: white to brown, silicified to chalcedony and common opal at the top, overlying calcareous sediments containing limestone breccia and silica nodules, basal unit containing numerous ferruginous concretions and pisolitic ironstone (Traves & others, 1956; McWhae & others, 1958).

Age: Undiagnostic ostracods were recorded from the formation (Veevers & Wells, 1961). The presence of reworked pisolitic ironstone indicates a post-lateritisation - i.e., Late Tertiary or Pleistocene. A skull of the extinct giant marsupial Diprotodon was collected from the area of Warrawagine station (Anon., 1942) presumably from the Oakover Beds. This fossil supports a late Pleistocene age of the unit.

LAWFORD BEDS

Named from: Lawford Creek.

Defined by: Casey & Wells (1964); first published by Veevers & Wells (1961).

Status of name: Formally defined.

Type section: M41 at Lawford Creek (station 151; Casey & Wells, 1964).

Previous name: None recorded.

Modifications: None.

Described outcrop: Northwest Canning Basin in 'mesas and buttes on the banks of Christmas Creek, Lawford Creek and Wolf Creek' (Veevers & Wells, 1961, p. 199). Smith & others (1964) traced the unit northwards into the Gordon Downs Sheet area.

Distribution: As above.

Thickness: Casey & Wells (1964) measured 24 m and Smith & others (1964) 10 m.

Relations with other units: Overlies Permian formations unconformably (Yeates & others, 1975b). Overlain by alluvium or sand, or has eroded top.

Subdivision: Casey & Wells (1964) recognised two subunits at the type section, as described below.

Lithology: 6 m of chalcedony: bedded, massive, vuggy in places, hard. 18 m of marl and limestone: mottled, earthy, pallid, lateritic, pisolitic, some conglomerate.

Age: Postdates laterite formation and contains Quaternary macroflora (Yeates & others, 1975b).

CHIMNEY ROCK OOLITE

Named from: Chimney Rock, near Emeriau Point, western Dampier Peninsula (station 7).

Defined by: Brunnschweiler (1957).

Status of name: Formally defined.

Type section: Type area is near Emeriau Point. As defined by Brunnschweiler (1957) the location of the type section is 12 m above low-water level on the headland called Chimney Rock. As Brunnschweiler's co-ordinates (16°45'S, 122°35'E) plot 1.8 km north-northeast of Chimney Rock in 11 m of water, we have replotted the type locality on the Chimney Rock headland according to Brunnschweiller's geological map (with no grid). The new location is 16°46'33"S, 122°36'00"E.

Previous name: None recorded, but may be synonym of 'Coastal Limestone' of Fairbridge (1953b).

Modifications: None.

Described outcrop: Between Perpendicular Point and Emeriau Point, Dampier Peninsula.

Distribution: Type area only, as above.

Thickness variations: Not recorded.

Relations with other units: Overlies the Emeriau Sandstone disconformably (Brunnschweiler, 1957).

Subdivision: None attempted.

Lithology: Oolite: light brown, calcareous, oolitic, average diameter 1 mm, some with quartz nuclei, apparently well bedded, well indurated (Brunnschweiler, 1957).

Age: Calcareous foraminifera present but undescribed. Postdates laterite formation and is probably Late Tertiary or Pleistocene.

NORTH HEAD LIMESTONE

Named from: North Head, Beagle Bay, Dampier Peninsula (station 6).

Defined by: Brunnschweiler (1957).

Status of name: Formally defined.

Type section: Brunnschweiler (1957) placed the type locality at North Head on the northern shore of Beagle Bay (16°48'S, 122°33"E). These co-ordinates plot on topographic maps in 6 m of water off the northern shore of Tappers Inlet. We have replotted the type section near North Head, according to Brunnschweiler's geologic map at 16°50'20"S, 122°32'20"E.

Previous name: None recorded.

Modifications: None.

Described outcrop: Northern shore of Beagle Bay, Dampier Peninsula.

Distribution: As above.

Thickness variations: Brunnschweiler (1957) measured a 5-m section.

Relations with other units: Brunnschweiler (1957) did not state the unit's stratigraphic relations, but it probably overlies Cretaceous or Lower Tertiary rocks unconformably.

Subdivision: None attempted.

Lithology: Limestone: brown, sandy, fine-grained, unbedded, almost unfossiliferous, soft (Brunnschweiler, 1957).

Age: No fossils have been described. Brunnschweiler (1957) equated the unit with a 3-m bench above present sea level and a mid-Holocene eustatic rise.

BOSSUT FORMATION

Named from: Cape Bossut.

Defined by: The formation was first named informally in WAPET's 1954 annual report. Defined by A.W. Lindner (in Johnstone, 1961), though Traves & others (1956) had previously referred to it.

Status of name: Formally defined.

Type section: Coastal area near Wallal station (Traves & others, 1956).

Previous name: Probably included in 'Coastal Limestone' of Fairbridge (1953b).

Modifications: None.

Described outcrop: The unit crops out discontinuously along the coast from Cape Villaret south to Port Hedland (Veevers & Wells, 1961).

Distribution: Present in Samphire Marsh No. 1, Samphire Marsh water well 1, BMR Wallal No. 4, and Chirup No. 1. The unit probably extends seawards.

Thickness: Maximum measured thickness is 33 m in Samphire Marsh No. 1. Thicknesses in other wells are 32 m in Samphire Marsh water well 1, 10 m in BMR Wallal No. 4, and 3 m in Chirup No. 1.

Relations with other units: In Chirup No. 1 the formation overlies pisolitic ironstone; in BMR Wallal No. 4 and Samphire Marsh No. 1 it overlies the ferruginised cap of the Aptian Frezier Sandstone; and it disconformably overlies the Aptian Parda Formation in outcrop (Veevers & Wells, 1961). The unit is overlain by Quaternary sands and surficial deposits.

Subdivision: None attempted.

Lithology: A.W. Lindner (in Johnstone, 1961) described the Bossut Formation as quartzose calcarenite, calcarenite, and oolite. In Samphire Marsh No. 1 it consists of calcarenite: brown-grey, fossiliferous, fine to coarse, lenses of calcilutite: greenish-white. In Chirup No. 1 the unit is calcilutite and calcirudite: grey-white to cream, fossiliferous, cross-bedded, with varying amounts of quartz grains, very fine to very coarse, occasionally pebbly, partly oolitic.

Age: The formation contains a varied fauna of fragmented and complete forams, and molluscs which at times are so plentiful as to form coquinite (Veevers & Wells, 1961; Henderson & others, 1963). No age determinations have been made on these faunas. Since it overlies lateritised Aptian sediments and is itself unlateritised, its age is postlateritisation, or Late Tertiary-Quaternary.

BORDA SANDSTONE

Named from: Cape Borda, Dampier Peninsula.

Defined by: Brunnschweiler (1957).

Status of name: Formally defined.

Type section: Cape Borda, west side of Dampier Peninsula (16°41'00"S, 122°45'00"E).

Previous name: None.

Modifications: None.

Described outcrop: Only from the Cape Borda area.

Distribution: As above, but probable correlatives occur on the east side of Dampier Peninsula at Cunningham Point (Brunnschweiler, 1957), indicating that the Formation may once have spanned the Peninsula.

Thickness: 5 m thick at the type area (Brunnschweiler, 1957) and 3 m thick at Cunningham Point.

Relations with other units: At Cape Borda it disconformably overlies the Lower Tertiary Pender Bay Conglomerate (Brunnschweiler, 1957). At Cunningham Point the correlative of the Borda Sandstone lies disconformably on the Upper Jurassic Jowlaenga Formation.

Subdivision: None attempted.

Lithology: At Cape Borda, the Borda Sandstone consists of basal thin layers of conglomerate: cobbles and pebbles of black sandstone; overlain by sandstone: light, mottled, fine, unfossiliferous, soft (Brunnschweiler, 1957).

Age: Although unfossiliferous, the formation overlies a ferruginised surface. The Borda Formation is itself unlateritised, showing that its age must post-date laterite formation; it is here regarded as Late Tertiary.

WOLF GRAVEL

Named from: Wolf Creek.

Defined by: Casey & Wells (1964).

Status of name: Introduced by Casey & Wells (1964) but not formally defined.

Type section: None given.

Previous name: None recorded.

Modifications: None.

Described outcrop: In the area around Wolf Creek and Christmas Creek, northeast Canning Basin.

Distribution: As above.

Thickness: 5 m in the Christmas Creek area (Casey & Wells, 1964).

Relations with other units: Unknown, but presumably overlies Permian rocks unconformably.

Subdivision: None attempted.

Lithology: Unconsolidated gravel, conglomerate, and sand (Casey & Wells, 1964).

Age: Unknown, but similarities and relations with gravels of the present Wolf Creek indicate a latest Tertiary or Quaternary age.

WARRIMBAH CONGLOMERATE

Named from: Warrimbah homestead, on the Fitzroy River.

Defined by: Guppy & others (1958).

Status of name: Formally defined.

Type section: None given.

Previous names: None recorded.

Modification: None.

Described outcrop: Scattered localities along the Fitzroy area near Myroodah and Warrimbah homesteads (Guppy & others, 1958).

Distribution: As above, but probably once more extensive and confined to ancestral Fitzroy River coarse.

Thickness variations: Unknown.

Relations with other units: Unknown, but infills dissected laterite profile and probably unconformably overlies Permian or Triassic units (Guppy & others, 1958). Also overlies Devonian rocks in Windjana Gorge area ('high-level gravels' of Guppy & others, 1958).

Subdivision: None attempted.

Lithology: Conglomerate: well-rounded pebbles and boulders, massive, unconsolidated (Guppy & others, 1958; Veevers & Wells, 1961).

Age: No fossils have been found directly associated with the conglomerate. A femur of the late Pleistocene diprotodontid Diprotodon australia (= D. optatum) was found in the Lennard River below Windjana Gorge (Hardman, 1884). High-level gravels similar to the Warrimbah Conglomerate occur in the area (Guppy & others, 1958) and if these gravels are correlatives then a late Pleistocene age can be ascribed to the unit. Crocodilian and chelonian remains collected from indurated high-level gravels in Winjana Gorge (Gorter & Nicoll, 1978) suggest a Late Tertiary age.

LAKE GREGORY BEDS

Named from: Lake Gregory, northeastern Canning Basin.

Defined by: Yeates & others (1975b).

Status of name: Formally defined.

Type section: BMR Cornish No. 3 (station 174) at Lera Yard (20°11'00"S, 127°24'00"E).

Previous name: None recorded.

Modifications: None.

Described outcrop: Crops out along the shores of Lake Gregory, and on the eastern side of Bulbi Plain and at Gilwah Waterhole (Yeates & others, 1975b).

Distribution: As above and drilled by BMR Cornish No. 3, and Mount Bannerman No. 1, extending the area south beneath surficial cover to Sturt Creek (Yeates & others, 1975b).

Thickness: 100 m thick in BMR Cornish No. 3, 64 m in Mount Bannerman No. 1, and up to 2 m thick in outcrop (Yeates & others, 1975b).

Relations with other units: Lies on a ferruginised surface and is therefore unconformable on older rocks. Upper surface is covered by surficial deposits and is contemporaneous with present lake sediments (Yeates & others, 1975b).

Subdivision: None attempted.

Lithology: In BMR Cornish No. 3 the unit consists of interbedded clay and silt: green, brown, red, calcareous to non calcareous, laminated to thin-bedded, minor gypsum, with sand: white, thin-bedded, cross-bedded; and rare gravel: of limonite pisolites.

Age: Surface outcrops contain gastropod coquinas, and fish bones were recorded in BMR Cornish No. 3 (Yeates & others, 1975b) but were not described. Stratigraphic position above the laterite profile and contemporaneous present-day deposition indicate that the unit is no older than Late Tertiary and is still being deposited at the present time.

UNNAMED STRATIGRAPHIC UNITS

These consist of calcrete and associated deposits, alluvial sediments, dune sands, and sand sheets. Fossils are present but generally undescribed. At Jubilee Dam (Alligator Dam of Guppy & others, 1958) a soil containing vertebrate bones and gypsum crystals was excavated (Glauert, 1921, 1926; Guppy & others, 1958). Vertebrates included crocodilians, the extinct giant wombat Phascolonus gigas and the extinct wallaby Protemnodon anak. These fossils represent a Late Pleistocene age.

Appendix 12

Stratigraphic control points

APPENDIX 12. STRATIGRAPHIC CONTROL POINTS

Stations shown on plate 3

Legend

- exploration well and bore hole
- water well
- outcrop
- shot hole
- composite section
- generalised section
- * denotes subsidised well

Station Number	Symbol	Station Name	Coordinates	Sheet Area	Datum feet (metres)	Thickness feet (metres)	Interval feet (metres) Basement	1	2	3	4	5	Top feet (metres) 6	7	8	9	10	11	Source	Reference
1		East Mermaid 1	17°10'01.00"S 119°49'21.20"E	Offshore SE 50/8	R.T. 37 (11)	13345 (4068)							9460 (2883)	7805 (2379)	6555 (1998)	5240 (1597)	4140 (1262)	1309 (399)	Shell Development (Australia) Pty Ltd	P(SL)A 73/1002
2		Wamac 1*	17°14'25.86"S 121°29'29.63"E	Offshore SE 51/5	R.T. 33 (10)	9068 (2764)				6444 (1964)			4347 (1325)	3097 (944)	345 (410)	1171 (357)		279 (85)	Amax Petroleum (Australia) Inc	BMR File 73/246
3		Lacepede 1A*	17°05'18.47"S 121°26'41.94"E	Offshore SE 51/5	R.T.(31) (9)	7500 (2286)				6555 (1998)			4175 (1273)	2966 (904)	1230 (375)	993 (303)		223 (68)	B.O.C. of Australia Ltd	BMR File 70/426
4		Carnot Peaks/Kings Peaks	17°04'00"S 122°26'00"E	Broome SE 51/6	Base of section	100 (30)											Present No data		Bureau of Mineral Resources	BMR Bull. 60; BMR Rep. 13
5		Tappers Inlet 1*	16°51'38"S 122°35'22"E	Pender SE 51/2	R.T.(73) (22)	9371 (2856)	9300 (2835)	6614 (2016)	6400 (1951)	5030 (1533)	2110 (643)		1360 (415)		1120 (341)		11 (3)		West Australian Petroleum Pty Ltd	BMR File 71/301
6		Beagle Bay	16°50'20"S 122°32'20"E	Pender SE 51/2	Base of section	15 (5)												Present No data	Bureau of Mineral Resources	BMR Rep. 13
7		South Pender Bay	16°46'33"S 122°36'00"E	Pender SE 51/2	Base of section	No data											Present No data	Present No data	Bureau of Mineral Resources	BMR Rep. 13
8		Pender 1*	16°40'48"S 122°50'06"E	Pender SE 51/2	R.T. 79 (24)	2991 (912)	2967 (904)				1448 (441)		596 (182)	204 (62)			10 (3)		West Australian Petroleum Pty Ltd	BMR File 72/2000
9		Northern Dampier Peninsula	16°34'30"S 122°55'00"E	Pender SE 51/2	Base of section	70 (21)								Present No data					Bureau of Mineral Resources	BMR Bull. 60; BMR Rep. 13
10		Fraser River/North Cliffs	17°16'00"S 123°05'00"E	Derby SE 51/7	Base of section	320 (98)							250 (76)	320 (98)					West Australian Petroleum Pty Ltd	Wapet Section KJ
11		Mt Jowlaenga area	17°24'00"S 122°54'00"E	Broome SE 51/6	Base of section	250 (76)							Present No data						Bureau of Mineral Resources	BMR Bull. 60 BMR Rep. 13
12		Fraser River 1	17°25'04"S 123°09'39"E	Derby SE 51/7	D.F. 189 (58)	10144 (3092)				4530 (1381)	1390 (424)		40 (12)					14 (4)	West Australian Petroleum Pty Ltd	Well log
13		Fraser River Structure Hole 1	17°28'50"S 123°12'30"E	Derby SE 51/7	D.F. 144 (44)	1202 (366)							25 (8)					4 (1)	West Australian Petroleum Pty Ltd	BMR Bull. 60; Well Index Sheet
14		Mt Clarkson	17°34'44"S 123°19'16"E	Derby SE 51/7	Base of section	50 (15)							Present No data	Present No data					Bureau of Mineral Resources	BMR Bull. 108
15		Yulleroo 1*	17°51'16"S 122°54'25"E	Broome SE 51/6	G.L. 164 (50)	15001 (4572)				2815 (858)	1840 (561)		216 (66)	50 (15)				0 (0)	Gewerkschaft-Elwerath Inc.	BMR File 67/4249

STRATIGRAPHIC CONTROL POINTS

Station Number	Symbol	Station Name	Coordinates	Sheet Area	Datum feet (metres)	Thickness feet (metres)	Interval: Basement	1	2	3	4	5	Top feet (metres): 6	7	8	9	10	11	Source	Reference
16		Barlee 1*	17°48'25"S 122°42'40"E	Broome SE 51/6	D.F. 74 (23)	8101 (2469)				2257 (688)			143 (44)		32 (10)			12 (4)	West Australian Petroleum Pty Ltd	BMR File 62/1057; P.S.S.A. Publ. 16
17		Broome Town 2	17°57'31"S 122°14'19.8"E	Broome SE 51/6	G.L. 43 (13)	1775 (541)							920 (280)		0 (0)				Geological Survey of Western Australia	Well Index Sheet; BMR Bull. 60
18		Gantheaume Point, W. of Broome	17°58'30"S 122°10'30"E	Broome SE 51/6	Base of section	40 (12)									Present No data				Bureau of Mineral Resources	BMR Bull. 60
19		Roebuck Bay 1	18°09'33.9"S 122°27'27.8"E	La Grange SE 51/10	D.F. 138 (42)	4000 (1219)		3940 (1201)	3355 (1023)		1567 (478)		500 (152)		30 (9)			5 (2)	West Australian Petroleum Pty Ltd	Well Log
20		Goldwyer 1	18°22'47"S 122°22'58"E	La Grange SE 51/10	D.F. 268 (82)	4720 (1439)	4660 (1420)	2783 (848)			1750 (533)		530 (162)		40 (12)			9 (3)	West Australian Petroleum Pty Ltd	Well Log
21		Thangoo 1*	18°22'06"S 122°53'22"E	La Grange SE 51/10	D.F. 566 (173)	3475 (1059)		2797 (853)			1380 (421)		224 (68)		39 (12)			9 (3)	West Australian Petroleum Pty Ltd	P.S.S.A. Publ. 16; BMR File 62/1054
21		Thangoo 1A*	18°21'52"S 122°53'09"E	La Grange SE 51/10	D.F. 568 (173)	5429 (1655)	5100 (1555)	2782 (848)			1405 (428)		235 (72)		39 (12)			9 (3)	West Australian Petroleum Pty Ltd	P.S.S.A. Publ. 16; BMR File 62/1054
22		Thangoo 2*	18°26'32.26"S 122°54'32.54"E	La Grange SE 51/10	R.T. 633 (193)	4830 (1472)	4718 (1438)	2585 (788)			1385 (422)		253 (77)		39 (12)			16 (5)	West Australian Petroleum Pty Ltd	BMR File 73/218
23		Broome Ridge Water Well 2	18°39'08"S 123°05'30"E	Mt Anderson SE 51/11	G.L. 717 (219)	706 (215)							21 (6)					0 (0)	West Australian Petroleum Pty Ltd	Well Index Sheet
24		McHugh 1	18°22'40"S 123°03'15"E	Mt Anderson SE 51/11	G.L. 510 (155)	140 (43)							80 (24)		18 (5)			0 (0)	West Australian Petroleum Pty Ltd	Well Index Sheet
25		Dampier Downs 1	18°18'00"S 123°06'00"E	Mt Anderson SE 51/11	D.F. 463 (141)	3038 (923)		2625 (800)			1037 (316)		15 (5)					5 (2)	West Australian Petroleum Pty Ltd	Well log & completion report
26		Edgar Range 1*	18°45'26"S 123°35'33"E	Mt Anderson SE 51/11	K.B. 447 (136)	6457 (1968)	6286 (1916)	2462 (750)	1875 (572)		370 (113)		14 (4)						Total Exploration Australia	BMR File 68/2041
27		Edgar Range, 18 km SW of Mt Alexander	18°48'00"S 123°32'00"E	Mt Anderson SE 51/11	Base of section	250 (76)							250 (76)						West Australian Petroleum Pty Ltd	Wapet Section JA2; BMR Bull. 60
28		Mowla Bluff (Edgar Range)	18°49'00"S 123°43'25"E	Mt Anderson SE 51/11	Base of section	60 (18)							Present No data						Bureau of Mineral Resources	BMR Bull. 60
29		Mowla 1*	18°43'50"S 123°42'35"E	Mt Anderson SE 51/11	K.B. 418 (127)	2500 (762)				1553 (473)	85 (26)		16 (5)					14 (4)	Total Exploration Australia Pty Ltd	BMR File 69/2039
30		Mt Alexander Corehole 1	18°41'27"S 123°40'04"E	Mt Anderson SE 51/11	D.F. 383 (117)	204 62							3 (1)						West Australian Petroleum Pty Ltd	Well Index Sheet
30		Mt Alexander	18°41'00"S 123°39'00"E	Mt Anderson SE 51/11	Base of section	158 (48)							158 (48)						West Australian Petroleum Pty Ltd	Wapet Section JA1; BMR Bull. 36
31		Babrongan 1*	18°23'23"S 123°35'37"E	Mt Anderson SE 51/11	D.F. 360 (110)	6395 (1949)				2195 (669)	407 (143)		30 9					10 (3)	West Australian Petroleum Pty Ltd	P.S.S.A. Publ. 48; BMR File 62/1090
32		BMR Jurgurra Creek 1	18°20'04"S 123°43'05"E	Mt Anderson SE 51/11	R.T. 232 (71)	1680 (512)					8 (2)							5 (2)	Bureau of Mineral Resources	BMR Rep. 60
33		Frome Rocks 2*	18°15'15"S 123°39'35"E	Mt Anderson SE 51/11	D.F. 296 (90)	7504 (2287)				3557 (1084)	206 (63)		30 (9)					9 (3)	West Australian Petroleum Pty Ltd	P.S.S.A. Publ. 8; BMR File 62/1033
34		Frome Rocks 1*	18°11'45"S 123°38'42"E	Mt Anderson SE 51/11	D.F. 230 (70)	4003 (1220)			2256 (688)	734 (224)			40 (12)					9 (3)	West Australian Petroleum Pty Ltd	P.S.S.A. Publ. 8; BMR File 62/1029

STRATIGRAPHIC CONTROL POINTS

Station Number	Symbol	Station Name	Coordinates	Sheet Area	Datum feet (metres)	Thickness feet (metres)	Interval feet (metres) Basement	1	2	3	4	5	Top feet (metres) 6	7	8	9	10	11	Source	Reference
35		Doran 1*	18°10'56"S 123°29'06"E	Mt Anderson SE 51/11	R.T. 214 (65)	2504 (763)				2432 (741)	595 (181)		20 (6)					5 (2)	West Australian Petroleum Pty Ltd	BMR File 68/2031
36		Logue 1*	18°07'33"S 123°23'24"E	Mt Anderson SE 51/11	R.T. 192 (59)	8854 (2699)				4460 (1359)	540 (165)		35 (11)					15 (5)	West Australian Petroleum Pty Ltd	BMR File 71/479
37		NW of Mudjalla Yard	18°02'40"S 122°46'20"E	Mt Anderson SE 51/11	Base of section	135 (41)							135 (41)						West Australian Petroleum Pty Ltd	Wapet Section JN BMR Bull. 36
38		Langey Crossing	17°40'00"S 123°33'00"E	Derby SE 51/7	No data	100 (30)							Present No data						Bureau of Mineral Resources	BMR Bull. 60 BMR Rep. 13
39		Wongil Bore	17°40'00"S 123°43'00"E	Derby SE 51/7	G.L.	767 (234)						0 (0)							Bureau of Mineral Resources	BMR Bull. 36
39		Wongil Ridge	17°38'10"S 123°45'00"E	Derby SE 51/7	Base of section	5 (2)						5 (2)							Bureau of Mineral Resources	BMR Rep. 13
40		Myalls Bore	17°21'00"S 123°40'00"E	Derby SE 51/7	G.L.	1056 (322)						0 (0)							West Australian Petroleum Pty Ltd/ Bureau of Mineral Resources	Well Report; BMR Bull. 36
41		Derby Town Bore	17°19'00"S 123°37'00"E	Derby SE 51/7	G.L.	2371 (723)					1760 (536)	16 (5)						0 (0)	West Australian Petroleum Pty Ltd/ Bureau of Mineral Resources	Well Report; BMR Bull. 60
42		3 km E of One Tree Well	17°14'00"S 123°47'30"E	Derby SE 51/7	No data	No data							Present No data						Bureau of Mineral Resources	BMR Bulls. 36, 60
43		Napier 4*	16°55'00"S 124°05'35"E	Yampi SE 51/3	K.B. 300 (91)	3166 (965)	3090 (942)		2000 (610)	223 (68)	10 (3)								Lennard Oil N.L.	BMR File 70/589
44		May River 1*	17°14'50"S 124°05'01"E	Derby SE 51/7	R.T. 67 (20)	5505 (1678)	5388 (1642)			3180 (969)	120 (37)	65 (20)						11 (3)	West Australian Petroleum Pty Ltd	BMR File 67/4252
45		Langoora 1*	17°18'07"S 124°06'48"E	Derby SE 51/7	D.F. 78 (24)	5299 (1615)	5240 (1597)			4170 (1271)	418 (127)	104 (32)						9 (3)	West Australian Petroleum Pty Ltd	P.S.S.A. Publ. 48 BMR File 62/1094
46		Meda 1*	17°24'00"S 124°11'32"E	Derby SE 51/7	D.F. 100 (30)	8809 (2685)	8663 (2640)			4200 (1280)	714 (218)	60 (18)						12 (4)	West Australian Petroleum Pty Ltd	P.S.S.A. Publ. 7 BMR File 62/1022
46		Meda 2	17°24'36"S 124°11'23"E	Derby SE 51/7	D.F. 100 (21)	7628 (2325)				4322 (1317)	832 (254)	70 (21)							West Australian Petroleum Pty Ltd	Well Index Sheet
47		Napier 2*	17°04'55"S 124°21'20"E	Derby SE 51/7	K.B. 283 (86)	5272 (1607)	5209 (1588)		3950 (1204)	30 (9)								13 (4)	Lennard Oil N.L.	BMR File 69/2031
48		Napier 5*	17°06'30"S 124°28'06"E	Derby SE 51/7	K.B. 244 (74)	5437 (1607)	5411 (1649)		3870 (1180)	12 (4)									Lennard Oil N.L.	BMR File 70/750
49		Van Emmerick Range	17°03'30"S 124°37'00"E	Lennard River SE 51/8	Base of section	1000 (305)				Present No data									Geological Survey of Western Australia	GSWA Bull. 118 BMR Bull. 36
50		Barker Gorge and 'Napier Downs' Section	17°16'00"S 124°43'50"E	Lennard River SE 51/8	Base of section	1019 (311)				1019 (311)									West Australian Petroleum Pty Ltd	Wapet Section DN1 BMR Bull. 36
51		Wagon Pass, 'Old Napier Downs'	17°10'30"S 124°37'20"E	Lennard River SE 51/8	Base of section	3350 (1021)				3350 (1021)									West Australian Petroleum Pty Ltd	Wapet Section DN5 BMR Bull. 36
51		Wagon Pass, 'Old Napier Downs'	17°11'00"S 124°38'40"E	Lennard River SE 51/8	Base of section	406 (124)				406 (124)									West Australian Petroleum Pty Ltd	Wapet Section DMP5 BMR Bull. 36

STRATIGRAPHIC CONTROL POINTS

Station Number	Symbol	Station Name	Coordinates	Sheet Area	Datum feet (metres)	Thickness feet (metres)	Interval					Top feet (metres)						Source	Reference
							Basement	1	2	3	4	5	6	7	8	9	10	11		
52		Napier 1*	17°12'20"S 124°31'36"E	Lennard River SE 51/8	K.B. 244 (74)	5910 (1801)	5816 (1773)		4253 (1296)	13 (4)									Lennard Oil N.L.	BMR File 69/2015
53		Hawkstone Peak 1*	17°14'45"S 124°24'26"E	Derby SE 51/7	D.F. 170 (52)	3897 (1188)	3855 (1175)		3521 (1073)	610 (186)	50 (15)							9 (3)	West Australian Petroleum Pty Ltd	P.S.S.A. Publ. 48; BMR File 62/1093
54		Kimberley Downs	17°23'20"S 124°21'00"E	Derby SE 51/7	Base of section	162 (49)					162 (49)								West Australian Petroleum Pty Ltd	Wapet Section PL10
55		Trig. H81	17°27'00"S 124°17'00"E	Derby SE 51/7	Base of section	30 (9)						Present No data	Present No data						Bureau of Mineral Resources	BMR Bull. 36, 60
56		67 Mile Water Bore	17°29'42"S 124°36'23"E	Lennard River SE 51/8	G.L. 191 (58)	3012 (918)	2528 (770)			1055 (322)	0 (0)								West Australian Petroleum Pty Ltd	Wapet Section; Well Index Sheet
57		The Sisters Plateau	17°35'00"S 124°24'30"E	Derby SE 51/7	Base of section	80 (24)						80 (24)							West Australian Petroleum Pty Ltd	Wapet Section TRE2; BMR Bull. 36
58		Blackstone 1*	17°35'14"S 124°21'01"E	Derby SE 51/7	R.T. 213 (65)	10005 (3050)		7285 (2220)	6280 (1914)	4875 (1486)	1050 (320)	16 (5)						11 (3)	West Australian Petroleum Pty Ltd	BMR File 67/4262
59		The Sisters 1	17°43'31"S 124°25'09"E	Derby SE 51/7	R.T. 305 (93)	9828 (2996)				5185 (1580)	10 (3)								Associated Freney Oilfields N.L.	Well log; BMR Bull. 60
60		Mimosa 1*	17°44'58"S 124°35'00"E	Lennard River SE 51/8	190 (58)	13704 (4177)				3524 (1074)	387 (118)	49 (15)						13 (4)	West Australian Petroleum Pty Ltd	BMR File 73/233
61		Erskine Hill and Erskine Range	17°51'00"S 124°21'00"E	Derby SE 51/7	Base of section	203 (62)						183 (56)	203 (62)							
62		Grant Range 1	18°01'00"S 124°00'30"E	Mt Anderson SE 51/11	D.F. 237 (72)	12915 (3936)				6090 (1856)	30 (9)								West Australian Petroleum Pty Ltd	Wapet Section TRE1; BMR Bull. 36
63		South Flank Grant Range	18°05'20"S 124°02'00"E	Mt Anderson SE 51/11	Base of section	1850 (564)					1850 (564)							12 (4)	West Australian Petroleum Pty Ltd	Well log
64		Eastern end of Grant Range	18°02'30"S 124°09'30"E	Mt Anderson SE 51/11	Base of section	136 (41)					136 (41)								West Australian Petroleum Pty Ltd	Wapet Section PL1; BMR Bull. 36
64		Liveringa Homestead, Eastern end of Grant Range	18°02'30"S 124°10'00"E	Mt Anderson SE 51/11	Base of section	677 (206)					677 (206)								West Australian Petroleum Pty Ltd	Wapet Section PG3
65		Myroodah 1	18°16'30"S 124°11'27"E	Mt Anderson SE 51/11	D.F. 410 (125)	6001 (1829)					10 (3)								West Australian Petroleum Pty Ltd	Wapet Section PP1; BMR Bull. 36
66		Mt Arthur	18°29'00"S 124°12'00"E	Mt Anderson SE 51/11	Base of section	285 (87)					285 (87)								Associated Freney Oilfields N.L.	Well Index Sheet, log; BMR Bull. 60
67		Matches Springs 1*	18°41'28"S 124°03'11"E	Mt Anderson SE 51/11	K.B. 487 (148)	9300 (2835)	6625 (2019)	5598 (1706)	1795 (547)	405 (123)		16 (5)						14 (4)	West Australian Petroleum Pty Ltd	Wapet Section PP2
68		Nerrima 1	18°26'55"S 124°22'17"E	Mt Anderson SE 51/11	D.F. 390 (119)	9072 (2765)				8010 (2441)	10 (3)								Total Exploration Australia Pty Ltd	BMR File 69/2023
69		Nerrima 1	18°28'16"S 124°24'02"E	Mt Anderson SE 51/11	D.F. 382 (116)	4271 (1302)					15 (5)								Associated Freney Oilfields N.L.	BMR Bull. 60; Well log
70		7 km ESE of Little Flow	18°29'30"S 124°17'30"E	Mt Anderson SE 51/11	Base of section	333 (101)					333 (101)							10 (3)	Freney Kimberley Oil Co. N.L.	BMR Bull. 60; Well data
71		4 km N of Mt James	18°41'40"S 124°31'20"E	Noonkanbah SE 51/12	Base of section	331 (101)					331 (101)								West Australian Petroleum Pty Ltd	Wapet Section PL3
																			West Australian Petroleum Pty Ltd	Wapet Section PL2

STRATIGRAPHIC CONTROL POINTS

Station Number	Symbol	Station Name	Coordinates	Sheet Area	Datum feet (metres)	Thickness feet (metres)	Interval					Top feet (metres)						Source	Reference
							Basement	1	2	3	4	5	6	7	8	9	10	11	
72		Mt James	18°42'00"S 124°28'00"E	Mt Anderson SE 51/11	Base of section	179 (55)					72 (22)		179 (55)						West Australian Petroleum Pty Ltd	Wapet Section MJ1; BMR Bull. 36
73		Nura Nura Ridge	18°04'40"S 124°24'00"E	Mt Anderson SE 51/11	Base of section	1302 (397)					1302 (397)								West Australian Petroleum Pty Ltd	Wapet Section PP3
74		Mt Wynne 3	18°06'00"S 124°27'00"E	Mt Anderson SE 51/11	G.L. 206 (63)	2154 (657)					16 (5)							0 (0)	Freney Kimberley Oil Co.	Well Index Sheet, data; BMR Bull. 60
75		Duchess Ridge	18°09'30"S 124°34'00"E	Noonkanbah SE 51/12	Base of section	203 (62)					203 (62)								West Australian Petroleum Pty Ltd	Wapet Section PL4
76		Mt Hardman	18°19'00"S 124°39'00"E	Noonkanbah SE 51/12	Base of section	208 (63)					208 (63)								West Australian Petroleum Pty Ltd	Wapet Section PL5
77		Noonkanbah/Liveringa Boundary Fence	18°23'00"S 124°42'00"E	Noonkanbah SE 51/12	Base of section	3025 (922)					3025 (922)								West Australian Petroleum Pty Ltd	Wapet Section PL6
78		White Rocks Mill Bore	18°11'00"S 124°46'30"E	Noonkanbah SE 51/12	G.L.	780 (238)						0 (0)							Bureau of Mineral Resources	BMR Bull. 36
79		Mt Hardman 1*	18°00'38"S 124°54'48.4"E	Noonkanbah SE 51/12	R.T. 385 (117)	11023 (3360)				3504 (1068)	16 (5)								West Australian Petroleum Pty Ltd	BMR File 73/259
80		Palm Spring 1*	17°48'56"S 124°53'07"E	Lennard River SE 51/8	R.T. 397 (121)	3500 (1067)				1520 (463)	20 (6)						10 (3)		West Australian Petroleum Pty Ltd	BMR File 72/2002
81		Morown Springs; Morown Cliffs	17°38'30"S 124°57'10"E	Lennard River SE 51/8	Base of section	1128 (344)					1128 (344)								West Australian Petroleum Pty Ltd	Wapet Section DN3
82		Windjana Gorge	17°24'30"S 124°57'40"E	Lennard River SE 51/8	Base of section	577 (176)					577 (176)								West Australian Petroleum Pty Ltd	Wapet Section DMP4
82		Windjana Gorge	17°25'20"S 124°58'00"E	Lennard River SE 51/8	Base of section	2780 (847)					2780 (847)								West Australian Petroleum Pty Ltd	Wapet Section DN12
83		Carpenter Gap	17°28'00"S 125°00'00"E	Lennard River SE 51/8	Base of section	706 (215)					706 (215)								West Australian Petroleum Pty Ltd	Wapet Section DN4
84		Mt Behn	17°30'00"S 125°04'00"E	Lennard River SE 51/8	Base of section	1000 (305)					Present No data								Geological Survey of Western Australia	GSWA Bull. 118; BMR Bull. 36
85		Fairfield Homestead, McSperrys Gap	17°32'30"S 125°04'10"E	Lennard River SE 51/8	Base of section	300 (91)					300 (91)								West Australian Petroleum Pty Ltd	Wapet Section DF8
85		Fairfield Homestead, McSperrys Gap	17°34'10"S 125°06'00"E	Lennard River SE 51/8	Base of section	1091 (333)					1091 (333)								West Australian Petroleum Pty Ltd	Wapet Section DN2
86		Wire Springs	17°41'50"S 125°07'30"E	Lennard River SE 51/8	Base of section	1209 (369)					1209 (369)								West Australian Petroleum Pty Ltd	Wapet Section DN10
87		NW Oscar Plateau, new Dingo Gap	17°41'00"S 125°11'10"E	Lennard River SE 51/8	Base of section	574 (175)					574 (175)								West Australian Petroleum Pty Ltd	Wapet Section DMP10
87		NW Oscar Plateau, near Dingo Gap	17°40'20"S 125°10'40"E	Lennard River SE 51/8	Base of section	1600 (488)					1600 (488)								West Australian Petroleum Pty Ltd	Wapet Section DN11
88		Linesman Creek Oscar Range	17°51'00"S 125°11'00"E	Lennard River SE 51/8	Base of section	2284 (696)					2284 (696)								West Australian Petroleum Pty Ltd	Wapet Section DN1; BMR Bull. 36
89		BMR Lennard River 1	17°55'00"S 125°14'30"E	Lennard River SE 51/8	G.L.	208 (63)					0 (0)								Bureau of Mineral Resources	BMR Record 1973/26

STRATIGRAPHIC CONTROL POINTS

Station Number	Symbol	Station Name	Coordinates	Sheet Area	Datum feet (metres)	Thickness feet (metres)	Interval						Top feet (metres)					Source	Reference
							Basement	1	2	3	4	5	6	7	8	9	10	11	
90		3.5 km SE of Leopold Range Pass, Oscar Range	17°55'50"S 125°18'30"E	Lennard River SE 51/8	Base of section	2337 (712)				2337 (712)									West Australian Petroleum Pty Ltd	Wapet Section DS2
91		12-mile bore area Type section Laurel Formation	17°56'00"S 125°15'30"E	Lennard River SE 51/8	Base of section	550 (167)				550 (167)									West Australian Petroleum Pty Ltd	Thomas, 1957; BMR Rep. 60; Wapet Section DF10
92		BMR Lennard River 2	17°57'45"S 125°16'30"E	Lennard River SE 51/8	G.L.	226 (69)				46 (14)	0 (0)								Bureau of Mineral Resources	BMR Record 1973/26
93		Stoney Creek	17°57'00"S 125°26'00"E	Lennard River SE 51/8	Base of section	200 (61)				200 (61)									Bureau of Mineral Resources	BMR Bull. 36
94		Brooking Gap, old Leopold Downs Road	17°55'30"S 125°33'00"E	Lennard River SE 51/8	Base of section	1885 (575)				1885 (575)									West Australian Petroleum Pty Ltd	Wapet Section DMP3
94		Brooking Gap, old Leopold Downs Road	17°59'00"S 125°33'00"E	Lennard River SE 51/8	Base of section	3147 (959)				3147 (959)									West Australian Petroleum Pty Ltd	Wapet Section DK1; BMR Bull. 36
95		Brooking Springs 1, W Geikie Range	18°04'00"S 125°39'00"E	Noonkanbah SE 51/12	G.L.	530 (161)				0 (0)									West Australian Petroleum Pty Ltd	Well Index Sheet
95		Brooking Springs, W Geikie Range	18°04'00"S 125°39'00"E	Noonkanbah SE 51/12	Base of section	1338 (408)				1338 (408)									West Australian Petroleum Pty Ltd	Wapet Section DS1; BMR Bull. 36
96		Geikie Gorge, Copley Valley	18°04'50"S 125°41'00"E	Noonkanbah SE 51/12	Base of section	2649 (808)				2649 (808)									West Australian Petroleum Pty Ltd	Wapet Section DH1; BMR Bull. 36
97		Geikie Range	18°05'30"S 125°46'00"E	Noonkanbah SE 51/12	Base of section	1562 (476)				1562 (476)									West Australian Petroleum Pty Ltd	Wapet Section DL3; BMR Bull. 36
98		5 km E of Brooking Springs HS	18°06'30"S 125°40'30"E	Noonkanbah SF 51/12	Base of section	770 (235)				770 (235)									West Australian Petroleum Pty Ltd	Wapet Section DS2
99		BMR Noonkanbah 4	18°04'30"S 125°25'00"E	Noonkanbah SE 51/12	G.L.	226 (69)				0 (0)									Bureau of Mineral Resources	BMR Record 1973/26
100		BMR Laurel Downs 2	18°07'24"S 125°19'58"E	Noonkanbah SE 51/12	R.T. 564 (172)	4000 (1219)				140 (43)	30 (9)							4 (1)	Bureau of Mineral Resources	BMR Records 1956/49, 95; BMR Rep. 60
101		34 Mill Bore	18°12'00"S 125°04'00"E	Noonkanbah SE 51/12	G.L.	350 (107)					318 (97)	0 (0)							Bureau of Mineral Resources	BMR Bull. 36
102		18 Mill Bore	18°17'00"S 124°56'00"E	Noonkanbah SE 51/12	G.L.	800 (244)						0 (0)							Bureau of Mineral Resources	BMR Bull. 36
103		Mt Jarlemai	18°43'00"S 123°48'30"E	Mt Anderson SE 51/11	Base of section	171 (52)							171 (52)						West Australian Petroleum Pty Ltd	Wapet Section JJ1; BMR Bull. 36
104		Mt Tuckfield	18°42'20"S 124°53'00"E	Noonkanbah SE 51/12	Base of section	1117 (341)					1117 (341)								West Australian Petroleum Pty Ltd	Wapet Section PP4
104		Mt Tuckfield	18°41'40"S 124°53'30"E	Noonkanbah SE 51/12	Base of section	545 (166)					545 (166)								West Australian Petroleum Pty Ltd	Wapet Section PG2
104		Mt Tuckfield	18°42'12"S 124°53'18"E	Noonkanbah SE 51/12	Base of section	1017 (310)					1017 (310)								Bureau of Mineral Resources	BMR Rec. 1976/24 Section 13
105		Carolyn Valley (St George Range)	18°41'00"S 124°58'30"E	Noonkanbah SE 51/12	Base of section														Continental Oil Company of Australia Limited	Company Report 1965

STRATIGRAPHIC CONTROL POINTS

Station Number	Symbol	Station Name	Coordinates	Sheet Area	Datum feet (metres)	Thickness feet (metres)	Interval						Top feet (metres)					Source	Reference
							Basement	1	2	3	4	5	6	7	8	9	10	11	
105		Carolyn Valley (St George Range)	18°42'30"S 124°54'21"E	Noonkanbah SE 51/12	Base of section	236 (72)					236 (72)								Bureau of Mineral Resources	BMR Rec. 1976/24 Section 17
106		Millajidee	18°48'06"S 124°57'15"E	Noonkanbah SE 51/12	Base of section	249 (76)					249 (76)								Bureau of Mineral Resources	BMR Rec. 1976/24 Section 14
106		6.5 km S of Millajidee Homestead	18°51'00"S 124°56'00"E	Noonkanbah SE 51/12	Base of section														Continental Oil Company of Australia Limited	Company Report 1965
107		North of St George Range	18°37'20"S 125°07'00"E	Noonkanbah SE 51/12	Base of section	603 (184)					603 (184)								West Australian Petroleum Pty Ltd	Wapet Section PP5
107		Mid St George Range	18°42'56"S 125°08'09"E	Noonkanbah SE 51/12	Base of section	499 (152)					499 (152)								Bureau of Mineral Resources	BMR Rec. 1961 Section 10
108		St George Range 1*	18°41'30"S 125°08'11"E	Noonkanbah SE 51/12	K.B. 584 (178)	14558 (4437)				8160 (2487)	18 (5)								Continental Oil Company of Australia Limited	BMR File 65/4170
109		Wye-Worry Valley	18°42'30"S 125°14'00"E	Noonkanbah SE 51/12	Base of section														Continental Oil Company of Australia Limited	Company Report 1965
110		Barbwire Range	18°59'00"S 125°00'00"E	Noonkanbah SE 51/12	Base of section	429 (131)					358 (109)		429 (131)						West Australian Petroleum Pty Ltd	Wapet Section M55 BMR Bull. 60
111		Barbwire 1*	19°10'38"S 125°00'58"E	Crosslands SE 51/16	R.T. 717 (219)	3515 (1071)		3411 (735)	1193 (364)	470 (143)	220 (67)		10 (3)						West Australian Petroleum Pty Ltd	BMR File 72/2001
112		Kirkby Range (NW corner)	19°06'00"S 125°07'00"E	Crosslands SE 51/16	Base of section	343 (105)					343 (105)								West Australian Petroleum Pty Ltd	Wapet Section M59
113		Hall Range (south side of Kirby Range)	19°11'00"S 125°10'00"E	Crosslands SE 51/16	Base of section	100 (30)						5 (2)						100 (30)	West Australian Petroleum Pty Ltd	Wapet Section M64
114		Shore Range	18°58'20"S 125°29'00"E	Noonkanbah SE 51/12	Base of section	645 (197)					645 (197)								West Australian Petroleum Pty Ltd	Wapet Section PL8
114		Shore Range	18°57'54"S 125°13'12"E	Noonkanbah SE 51/12	Base of section	394 (120)					394 (120)								Bureau of Mineral Resources	BMR Rec. 1976/24 Section 21
115		BMR Crosslands 2	19°12'16"S 125°28'03"E	Crossland SE 51/16	G.L.	455 (139)					0 (0)								Bureau of Mineral Resources	BMR Rec. 1975/99
116		Millyit Range (N side)	19°09'00"S 125°37'00"E	Crossland SE 51/16	Base of section	349 (106)					349 (106)								West Australian Petroleum Pty Ltd	Wapet Section M1
117		Millyit Range (S side)	19°12'30"S 125°30'00"E	Crossland SE 51/16	Base of section	773 (236)					726 (221)	773 (236)							West Australian Petroleum Pty Ltd	Wapet Section M2; BMR Bull. 60
118		Jones Range 1	19°21'40"S 125°40'13"E	Crossland SE 51/16	R.T. 761 (232)	8233 (2509)				3136 (956)	73 (22)		0 (0)						West Australian Petroleum Pty Ltd	Well log, report
119		Lightjack Hill	18°59'00"S 125°50'30"E	Noonkanbah SE 51/12	Base of section	220 (67)					220 (67)								West Australian Petroleum Pty Ltd	Wapet Section N557; BMR Bull. 36
119		Lightjack Hill	18°59'18"S 125°50'36"E	Noonkanbah SE 51/12	Base of section	318 (97)					318 (97)								Bureau of Mineral Resources	BMR Rec. 1976/24 Section 22
120		Mt Piper	18°54'00"S 125°46'00"E	Noonkanbah SE 51/12	Base of section	222 (68)					222 (68)								West Australian Petroleum Pty Ltd	Wapet Section FP6

STRATIGRAPHIC CONTROL POINTS

Station Number	Symbol	Station Name	Coordinates	Sheet Area	Datum feet (metres)	Thickness feet (metres)	Interval: Basement	1	2	3	4	5	Top feet (metres): 6	7	8	9	10	11	Source	Reference
120		Mt Millard	18°52'10"S 125°46'30"E	Noonkanbah SE 51/12	Base of section	186 (57)					186 (57)								West Australian Petroleum Pty Ltd	Wapet Section PG4
121		Poole Range 3	18°53'06"S 125°47'20"E	Noonkanbah SE 51/12	G.L. 615 (187)	3264 (995)					0 (0)								Freney Kimberley Oil Co. Ltd	BMR Bull. 60; Rep. 41A; Waterford, 1941
121		Poole Range 5	18°52'27"S 125°49'02"E	Noonkanbah SE 51/12	G.L.	1545 (471)					0 (0)								Frency Kimberley Oil Co. Ltd	BMR Bull. 60, Rep. 41A;
121		Poole Range	18°52'18"S 125°48'30"E	Noonkanbah SE 51/12	Base of section	210 (64)					210 (64)								Bureau of Mineral Resources	BMR Rec. 1976/? Section 2
121		Poole Range	18°53'54"S 125°47'33"E	Noonkanbah SE 51/12	Base of section	423 (129)					423 (129)								Bureau of Mineral Resources	BMR Rec. 1976/? Section 1
122		Brutens Yard, Christmas Creek Station	18°43'00"S 125°37'00"E	Noonkanbah SE 51/12	Base of section	1331 (406)					1331 (406)								West Australian Petroleum Pty Ltd	Wapet Section PN1; BMR Bull. 36
123		BMR Prices Creek 3	18°39'44"S 125°54'00"E	Noonkanbah SE 51/12	R.T. 522 (159)	694 (212)	593 (181)	4 (1)											Bureau of Mineral Resources	BMR Rep. 60
123		Emanuel Creek	18°39'44"S 125°55'00"E	Noonkanbah SE 51/12	Base of section	1946 (593)		1946 (593)											Bureau of Mineral Resources	Wapet Section OE1; BMR Bull. 36
123		Gap Creek	18°38'00"S 125°55'00"E	Noonkanbah SE 51/12	Base of section	612 (187)		612 (187)		Present No data									Bureau of Mineral Resources	Wapet Section OG1; BMR Bull. 36
124		Prices Creek 1	18°40'30"S 125°55'00"E	Noonkanbah SE 51/12	G.L. 570 (174)	1008 (307)		0 (0)											Freney Kimberley Oil Co. Ltd	BMR Bull. 60; Waterford, 1941
124		Prices Creek 2	18°40'45"S 125°55'00"E	Noonkanbah SE 51/12	G.L. 610 (186)	340 (104)		0 (0)											Freney Kimberley Oil Co. Ltd	BMR Bull. 60; Waterford, 1941
124		Prices Creek 3	18°41'25"S 125°55'15"E	Noonkanbah SE 51/12	G.L. 565 (172)	809 (247)		0 (0)											Freney Kimberley Oil Co. Ltd	BMR Bull. 60; Waterford, 1941
124		Prices Creek 4	18°41'00"S 125°53'30"E	Noonkanbah SE 51/12	G.L. 487 (148)	444 (135)				442 (135)	0 (0)								Freney Kimberley Oil Co Ltd	BMR Bull. 60; Waterford, 1941
125		BMR Noonkanbah 5	18°40'00"S 125°59'40"E	Noonkanbah SE 51/12	G.L.	225 (69)				0 (0)									Bureau of Mineral Resources	BMR Re. 1973/26
126		Sadler Ridge, Emanual Range	18°37'33"S 125°58'00"E	Noonkanbah SE 51/12	Base of section	756 (230)				756 (230)									West Australian Petroleum Pty Ltd	Wapet Section DD2
126		Longs well, Sadler Ridge	18°36'00"S 125°59'20"E	Noonkanbah SE 51/12	Base of section	460 (140)				460 (140)									West Australian Petroleum Pty Ltd	Wapet Section D No. 10-2
127		BMR Noonkanbah 1	18°34'13"S 125°58'16"E	Noonkanbah SE 51/12	G.L.	510 (155)				0 (0)									Bureau of Mineral Resources	BMR Rec. 1973/26
128		Emanuel Range	18°36'00"S 125°54'00"E	Noonkanbah SE 51/12	Base of section	500 (152)				500 (152)									West Australian Petroleum Pty Ltd	Wapet Section DMP2
128		Sadler Ridge, Emanuel Range	18°36'00"S 125°55'10"E	Noonkanbah SE 51/12	Base of section	1229 (375)				1229 (375)									West Australian Petroleum Pty Ltd	Wapet Section DD1; BMR Bull. 36
129		Virgin Hills (Home Range)	18°32'00"S 125°51'30"E	Noonkanbah SE 51/12	Base of section	59 (18)				59 (18)									West Australian Petroleum Pty Ltd	Wapet Section DP4
129		Virgin Hills (Home Range)	18°32'00"S 125°54'00"E	Noonkanbah SE 51/12	Base of section	566 (173)				566 (173)									West Australian Petroleum Pty Ltd	Wapet Section DP6
129		Virgin Hills (Home Range)	18°30'40"S 125°54'40"E	Noonkanbah SE 51/12	Base of section	213 (65)				213 (65)									West Australian Petroleum Pty Ltd	Wapet Section DP6; BMR Bull. 36

Station Number	Symbol	Station Name	Coordinates	Sheet Area	Datum feet (metres)	Thickness feet (metres)	Interval						Top feet (metres)					Source	Reference
							Basement	1	2	3	4	5	6	7	8	9	10	11	
130		Menyous Gap Area	18°24'00"S 125°50'30"E	Noonkanbah SE 51/12	Base of section	1596 (486)				1596 (486)									West Australian Petroleum Pty Ltd	Wapet Section DMP1; BMR Bull. 36
130		Manyous Gap Area	18°24'00"S 125°51'00"E	Noonkanbah SE 51/12	Base of section	825 (251)				825 (251)									West Australian Petroleum Pty Ltd	Wapet Section DD3
130		Menyous Gap Area	18°24'30"S 125°51'00"E	Noonkanbah SE 51/12	Base of section	1235 (376)				1235 (376)									West Australian Petroleum Pty Ltd	Wapet Section DP5; BMR Bull. 36
131		Hills W of Needle Eye Rocks	18°16'20"S 125°49'00"E	Noonkanbah SE 51/12	Base of section	143 (44)				143 (44)									West Australian Petroleum Pty Ltd	Wapet Section DF6
132		Needle Eye Rocks	18°16'10"S 125°51'20"E	Noonkanbah SE 51/12	Base of section	90 (27)				90 (27)									West Australian Petroleum Pty Ltd	Wapet Section DF7
132		Needle Eye Rocks	18°15'00"S 125°51'20"E	Noonkanbah SE 51/12	Base of section	543 (166)				543 (166)									West Australian Petroleum Pty Ltd	Wapet Section DP2; BMR Bull. 36
133		10 km E of Bullock Paddock Bore, Fossil Downs	18°08'00"S 126°04'00"E	Mt Ramsey SE 52/9	Base of section	267 (81)				267 (81)									West Australian Petroleum Pty Ltd	Wapet Section DF4
133		10 km E of Bullock Paddock Bore, Fossil Downs	18°08'30"S 126°04'30"E	Mt Ramsey SE 52/9	Base of section	122 (37)				122 (37)									West Australian Petroleum Pty Ltd	Wapet Section DF5
134		2 km E of Piker Hills	18°03'00"S 126°05'40"E	Mt Ramsey SE 52/9	Base of section	63 (19)				63 (19)									West Australian Petroleum Pty Ltd	Wapet Section DF3
135		S of Barramundi Range	18°05'40"S 126°09'00"E	Mt Ramsey SE 52/9	Base of section	992 (302)				992 (302)									West Australian Petroleum Pty Ltd	Wapet Section DL2
135		S of Barramundi Range	18°07'00"S 126°10'20"E	Mt Ramsey SE 52/9	Base of section	579 (176)				579 (176)									West Australian Petroleum Pty Ltd	Wapet Section DF2; BMR Bull. 36
136		Barramundi Range	18°14'00"S 126°14'00"E	Mt Ramsey SE 52/9	Base of section	450 (137)				450 (137)									Bureau of Mineral Resources	BMR Bull. 36; Lexique Stratigraphique International Vol VI
137		Mt Elma, Horseshoe Range	18°13'00"S 126°13'00"E	Mt Ramsey SE 52/9	Base of section	1952 (595)				1952 (595)									West Australian Petroleum Pty Ltd	Wapet Section DL1
138		Jubilee Dam, Quanbun Station	18°18'30"S 125°14'00"E	Noonkanbah SE 51/12	No data	No data												Present No data	Bureau of Mineral Resources	J. Roy. West Soc. 44(3)
139		Sparke range area	18°35'00"S 126°11'00"E	Mt Ramsey SE 52/9	No data	1000 (305)				1000 (305)									Bureau of Mineral Resources	BMR Bull. 36
140		Old Bohemia Downs	18°42'20"S 126°06'20"E	Mt Ramsey SE 52/9	Base of section	2687 (819)				2687 (819)									West Australian Petroleum Pty Ltd	Wapet Section DP2
140		Old Bohemia Downs	18°41'40"S 126°06'00"E	Mt Ramsey SE 52/9	Base of section	307 (94)				307 (94)									West Australian Petroleum Pty Ltd	Wapet Section DP3
141		Bugle Gap	18°45'13"S 126°02'13"E	Mt Ramsey SE 52/9	No data	950 (290)				950 (290)									Bureau of Mineral Resources	BMR Bull. 36
141		Bugle Gap	18°44'30"S 126°04'30"E	Mt Ramsey SE 52/9	Base of section	1233 (376)				1233 (376)									West Australian Petroleum Pty Ltd	Wapet Section DB1; BMR Bull. 36
141		4 km E of Pinnacle Springs, Bugle Gap	18°45'00"E 126°04'40"S	Mt Ramsey SE 52/9	Base of section	224 (68)					244 (68)								West Australian Petroleum Pty Ltd	Wapet Section PG5

STRATIGRAPHIC CONTROL POINTS

Station Number	Symbol	Station Name	Coordinates	Sheet Area	Datum feet (metres)	Thickness feet (metres)	Interval feet (metres) Basement	1	2	3	4	5	Top feet (metres) 6	7	8	9	10	11	Source	Reference
142		9 km E of Christmas Creek	18°51'40"S 125°56'50"E	Noonkanbah SE 51/12	Base of section	1219 (372)					1219 (372)								West Australian Petroleum Pty Ltd	Wapet Section PN2 Section M56
143		Christmas Creek	19°02'00"S 126°04'00"E	Mt Ramsey SE 52/9	Base of section	70 (21)					70 (21)								Bureau of Mineral Resources	BMR Report 49 Section M56
144		BMR Mt Bannerman 2	19°04'03"S 126°10'21"E	Mt Bannerman SE 52/13	G.L.	455 (139)					3 (1)							0 (0)	Bureau of Mineral Resources	BMR Rec. 1975/77
145		Hicks Range	19°14'00"S 125°53'30"E	Crossland SE 51/16	Base of section	143 (44)					143 (44)								West Australian Petroleum Pty Ltd	Wapet Section M7
145		Hicks Range	19°13'30"S 125°54'06"E	Crossland SE 51/16	Base of section	81 (25)					81 (25)								Bureau of Mineral Resources	BMR Rec. 1975/77 Measured section A24
145		BMR Crossland 1	19°13'03"S 125°53'30"E	Crossland SE 51/16	G.L.	860 (262)					10 (3)							0 (0)	Bureau of Mineral Resources	BMR Rec. 1975/77
146		Cadjabut Yard	19°16'30"S 126°05'30"E	Mt Bannerman SE 52/13	Base of section	60 (18)					60 (18)								Bureau of Mineral Resources	BMR Bull. 60, Section M48
147		Lake Jones	19°26'30"S 126°07'18"E	Mt Bannerman SE 52/13	Base of section	No data						Present No data							Bureau of Mineral Resources	BMR Report 49, Section 52
148		Boundary Hill	19°21'00"S 126°12'00"E	Mt Bannerman SE 52/13	Base of section	60 (18)					60 (18)								Bureau of Mineral Resources	BM[illegible] plan. notes 1[illegible] Section M50; Bull. 60
149		McDonald Spring area	19°12'24"S 126°08'42"E	Mt Bannerman SE 52/13	No data	No data												Present No data	Bureau of Mineral Resources	BMR Rec. 1975/77
150		Red Bluffs area	18°52'00"S 126°26'30"E	Mt Ramsey SE 52/9	No data	No data				Present No data									Bureau of Mineral Resources	Veevers et al., 1967; GSWA Bull. 118
151		Lawford Creek	18°57'00"S 126°38'00"E	Mt Ramsay SE 52/9	Base of section	80 (24)												80 (24)	Bureau of Mineral Resources	BMR Report 49, Section M41
152		S of Kai Ki Yard	19°03'18"S 126°48'12"E	Mt Bannerman SE 52/13	No data	No data					Present No data							Present No data	Bureau of Mineral Resources	BMR 1973 E Canning Field Party (L. Wyborn).
153		Lawford Creek/headwaters Christmas Creek	19°04'36"S 126°51'06"E	Mt Bannerman SE 52/13	Base of section	33 (10)					33 (10)								Bureau of Mineral Resources	BMR 1973 E Canning Field Party (L. Wyborn)
153		Lawford Creek/headwaters Christmas Creek	19°04'30"S 126°49'03"E	Mt Bannerman SE 52/13	Base of section	49 (15)					49 (15)								Bureau of Mineral Resources	BMR 1973 E Canning Field Party (L. Wyborn)
154		Lake Betty 1	19°34'08"S 126°19'45"E	Mt Bannerman SE 52/13	R.T. 913 (278)	10321 (3146)	10100 (3079)	5436 (1657)	15 (5)										West Australian Petroleum Pty Ltd	BMR File 71/441
155		Crossland 1	19°43'10"S 125°14'50"E	Crossland SE 51/16	R.T. 603 (184)	2996 (913)		990 (302)	210 (64)	30 (9)								9 (3)	West Australian Petroleum Pty Ltd	BMR File 71/465
156		Crossland 2*	20°00'45"S 124°59'36"E	Dummer SF 51/4	R.T. 582 (178)	3000 (914)	2164 (660)		210 (64)	22 (7)								9 (3)	West Australian Petroleum Pty Ltd	BMR File 71/465
157		Crossland 3*	20°12'12"S 125°45'39"E	Dummer SF 51/4	R.T. 766 (233)	3003 (915)		1560 (475)	20 (6)									9 (3)	West Australian Petroleum Pty Ltd	BMR File 71/465

STRATIGRAPHIC CONTROL POINTS

Station Number	Symbol	Station Name	Coordinates	Sheet Area	Datum feet (metres)	Thickness feet (metres)	Interval feet (metres) Basement	1	2	3	Top feet (metres) 4	5	6	7	8	9	10	11	Source	Reference
158		Shothole 648, Line A, Wapet E Canning Seismic 1972. 15 km N of Dummer Range	20°04'30"S 125°54'24"E	Dummer SF 51/4	G.L.	No data					0 (0)								Bureau of Mineral Resources/Mines Administration Pty Ltd.	BMR Rec. 1975/77 D 1238
159		Shothole 36, Line E, Wapet E Canning Seismic 1972. 35 km WNW of Mt Cornish	20°12'00"S 126°06'06"E	Cornish SF 52/1	G.L.	No data					0 (0)								Bureau of Mineral Resources/Mines Administration Pty Ltd	BMR Rec. 1975/77 CO 1232, 1234, 1235
160		Shothole 311, Line F, Wapet E Canning Seismic 1972. 9 km WNW of Mt Cornish	20°16'12"S 126°18'30"E	Cornish SF 52/1	G.L.	No data					0 (0)								Bureau of Mineral Resources/Mines Administration Pty Ltd	BMR Rec. 1975/55 CO 1268
161		Godfrey Tank	20°12'35"S 126°33'00"E	Cornish SF 52/1	Base of section	179 (55)					179 (55)								Bureau of Mineral Resources	BMR Rep. 49 Section C3a; Rec. 1975/77; Bull. 60
162		BMR Cornish 1	20°10'03"S 126°33'54"E	Cornish SF 52/1	G.L.	538 (164)					5 (2)							0 (0)	Bureau of Mineral Resources	BMR Rec. 1975/77
163		BMR Cornish 2	20°11'09"S 126°52'30"E	Cornish SF 52/1	G.L.	745 (227)						20 (6)						0 (0)	Bureau of Mineral Resources	BMR Rec. 1975/77
164		Culvida Soak	20°13'00"S 126°55'00"E	Cornish SF 52/1	Base of section	60 (18)						60 (18)							Bureau of Mineral Resources	BMR Rep. 49 Rec. 1975/77
165		BMR Mt Bannerman 1	19°56'06"S 127°13'42"E	Mt Bannerman SE 52/13	G.L.	666 (203)					64 (20)							0 (0)	Bureau of Mineral Resources	BMR Rec. 1975/77
166		BMR Mt Bannerman 4	19°30'03"S 127°03'03"E	Mt Bannerman SE 52/13	G.L.	495 (151)					18 (6)							0 (0)	Bureau of Mineral Resources	BMR Rec. 1975/55
167		BMR Mt Bannerman 3	19°29'18"S 127°09'33"E	Mt Bannerman SE 52/13	G.L.	308 (94)					49 (15)							0 (0)	Bureau of Mineral Resources	BMR Rec. 1975/77
168		14 km W of Wolf Creek Meteorite Crater	19°11'00"S 127°40'00"E	Billiluna SE 52/14	Base of section	351 (107)	351 (107)												Bureau of Mineral Resources	BMR Rec. 1975/77. Section A1; Rep. 49, Locality B3
169		Knobby Hills	19°24'24"S 127°45'44"E	Billiluna SE 52/14	Base of section	43 (13)			43 (13)										Bureau of Mineral Resources	BMR Rec. 1975/77, Section A3; Rep. 49
170		BMR Billiluna 3	19°30'30"S 127°38'18"E	Billiluna SE 52/14	G.L.	528 (161)			0 (0)										Bureau of Mineral Resources	BMR Rec. 1975/77
171		Mt Mueller	19°53'00"S 127°48'30"E	Billiluna SE 52/14	Base of section	150 (46)					150 (46)								Bureau of Mineral Resources	BMR Rep. 49, Section B24; Bull. 60
172		BMR Billiluna 1	19°56'33"S 127°51'55"E	Billiluna SE 52/14	G.L.	405 (123)					0 (0)								Geological Survey of Western Australia	GSWA Rec. 1973/13; BMR Rec. 1975/77
173		Condren Pinnacles	20°06'00"S 127°38'00"E	Lucas SF 52/2	Base of section	85 (26)					85 (26)								Bureau of Mineral Resources	BMR Rep. 49; Bull. 60; Rec. 1975/77
174		BMR Cornish 3	20°10'51"S 127°24'12"E	Cornish SF 52/1	G.L.	325 (99)					325 (99)							0 (0)	Bureau of Mineral Resources	BMR Rec. 1975/77

STRATIGRAPHIC CONTROL POINTS

Station Number	Symbol	Station Name	Coordinates	Sheet Area	Datum feet (metres)	Thickness feet (metres)	Interval	Top feet (metres)										Source	Reference
							Basement	1	2	3	4	5	6	7	8	9	10	11	
175		Dooma Dora Well	20°12'30"S 127°53'00"E	Lucas SF 52/2	No data	50 (15)					Present No data								Bureau of Mineral Resources	BMR Rep. 49, L4
176		BMR Lucas 14	20°16'39"S 127°46'33"E	Lucas SF 52/2	G.L.	335 (105)					0 (0)								Bureau of Mineral Resources	BMR Rec. 1975/77
177		Micha Bore, Balgo Mission	20°16'00"S 127°44'00"E	Lucas SF 52/2	G.L.	230 (70)					0 (0)								Mines Administration Pty Ltd	Minad Field Report 1972
178		BMR Lucas 13	20°24'06"S 127°36'09"E	Lucas SF 52/2	G.L.	620 (189)						0 (0)							Bureau of Mineral Resources	BMR Rec. 1975/77
178		Point Alphonse	20°23'30"S 127°36'30"E	Lucas SF 52/2	Base of section	144 (44)						144 (44)							Bureau of Mineral Resources	BMR Rec. 1975/77
179		5 km NNW of Lady Edith Lagoon	20°39'40"S 127°13'36"E	Cornish SF 52/1	Base of section	68 (21)						68 (21)							Mines Administration Pty Ltd	Section A93, Minad Field Report 1972
180		10 km N [illegible] nge	20°30'56"S 127°22'56"E	Cornish SF 52/1	Base of section	42 (13)						42 (13)							Mines Administration Pty Ltd	Section A86, Minad Field Report 1972
181		7 km NE of L[illegible] nge	20°35'16"SZ 127°26'00"E	Cornish SF 52/1	Base of section	40 (12)						34 (10)						40 (12)	Mines Administration Pty Ltd	Section A111, Minad Field Report 1972
182		East side Lake Dennis	20°53'30"S 128°56'00"E	Lucas SF 52/6	Base of section	47 (14)	Paleozoic age - no interval determined												Bureau of Mineral Resources	BMR Rec. 1973/171, Rep. 49
183		Yam Hill	20°51'00"S 128°43'00"E	Lucas SF 52/6	Base of section	40 (12)	Paleozoic age - no interval determined												Bureau of Mineral Resources	BMR Rec. 1973/17, Rep. 49
184		S of Mt Hughes	20°45'00"S 128°18'00"E	Lucas SF 52/6	No data	3 (1)	Possible Mesozoic - no interval determined												Bureau of Mineral Resources	BMR Rec. 1973/171
185		Thomas Peak	20°58'00"S 128°05'00"E	Lucas SF 52/6	Base of section	65 (20)					65 (20)								Bureau of Mineral Resources	BMR Bull. 60, Section L30; BMR Rep. 49
186		Stretch Range	20°57'42"S 127°42'30"E	Lucas SF 52/6	Base of section	299 (91)						299 (91)							Bureau of Mineral Resources	BMR Rec. 1975/77, Section A32
187		Thornton Flat	21°05'24"S 127°05'54"E	Helena SF 52/5	Base of section	65 (20)					65 (20)								Mines Administration Pty Ltd	Section A53, Minad Field Report 1972
187		Thornton Flat	21°05'24"S 127°08'54"E	Helena SF 52/5	Base of section	No data					Present No data								Bureau of Mineral Resources	BMR Bull. 60, Locality He9
188		8 km E of Thornton Flat	21°06'06"S 127°14'48"E	Helena SF 52/5	Base of section	16 (5)					16 (5)								Mines Administration Pty Ltd	Section A48, Minad Field Report 1972
188		8 km E of Thornton Flat	21°06'30"S 127°15'12"E	Helena SF 52/5	Base of section	38 (12)					38 (12)								Mines Administration Pty Ltd	Section A49, Minad Field Report 1972
189		Point Moody 1*	21°15'34"S 127°48'22"E	Stansmore SF 52/6	R.T. 1403 (428)	8009 (2441)		6472 (1973)			40 (12)							13 (4)	Australian Aquitaine Petroleum Pty Ltd	BMR File 65/4174 BMR Rec. 1975/77
190		Stansmore Range (north)	21°15'00"S 128°01'30"E	Stansmore SF 52/6	Base of section	1132 (345)					1132 (345)								Bureau of Mineral Resources	BMR Rec. 1975/77, Section A12
190		Stansmore Range (north)	21°15'00"S 128°01'00"E	Stansmore SF 52/6	Base of section	164 (50)					164 (50)								Bureau of Mineral Resources	BMR Rec. 1975/77, Section A18

STRATIGRAPHIC CONTROL POINTS

Station Number	Symbol	Station Name	Coordinates	Sheet Area	Datum feet (metres)	Thickness feet (metres)	Interval: Basement	1	2	3	Top: 4	5	6	7	8	9	10	11	Source	Reference
191		Stansmore Range (south)	21°27'40"S 128°05'30"E	Stansmore SF 52/6	Base of section	427 (130)					427 (130)								Bureau of Mineral Resources	BMR Bull. 60; BMR Rec. 1975/77, Section A17.
191		Stansmore Range (south)	21°30'00"S 128°08'00"E	Stansmore SF 52/6	Base of section	689 (210)					689 (210)								Bureau of Mineral Resources	BMR Rec. 1975/77, Section A6
192		Stansmore Sheet S60	21°39'30"S 128°44'00"E	Stansmore SF 52/6	Base of section	25 (8)									25 (8)				Bureau of Mineral Resources	BMR Bull. 60. Rec. 1973/171
193		Stansmore Sheet S70	21°56'30"S 127°48'40"E	Stansmore SF 52/6	Base of section	100 (30)					100 (30)								Bureau of Mineral Resources	BMR Bull. 60
194		Wilson Cliffs	22°02'00"S 127°03'00"E	Wilson SF 52/9	Base of section	12 (4)												12 (4)	Bureau of Mineral Resources	BMR Bull. 60
195		Wilson Cliffs 1*	22°16'39"S 126°46'55"E	Wilson SF 52/9	R.T. 1460 (445)	12212 (3722)	11494 (3503)	8310 (2533)	3650 (1113)	3172 (967)	270 (82)		40 (12)					16 (5)	Australian Aquitaine Petroleum Pty Ltd	BMR File 68/2011
196		Contention Heights 1*	22°25'36"S 127°13'34"E	Wilson SF 52/9	R.T. 1392 (424)	5876 (1791)		4405 (1343)	2730 (832)		288 (88)		45 (14)					15 (5)	Australian Aquitaine Petroleum Pty Ltd	BMR File 73/230
197		Contention Heights	22°56'30"S 126°43'30"E	Wilson SF 52/9	Base of section	70 (21)									60 (18)			70 (21)	Bureau of Mineral Resources	BMR Bull. 60, Towner (pers. comm.)
198		Angas Hills area	22°51'00"S 128°12'30"E	Webb SF 52/10	Base of section	118 (36)	Probably Paleozoic - no interval determined												Bureau of Mineral Resources	BMR Rec. 1974/53
199		Dovers Hills (M38)	28°06'00"S 128°41'35"E	McDonald SF 52/14	Base of section	137 (42)					137 (42)								Bureau of Mineral Resources	BMR Rep. 65 BMR Bull. 100
200		50 km SSW of Angas Hills	23°15'00"S 127°40'00"E	McDonald SF 52/14	No data	No data					Present No data								Bureau of Mineral Resources	BMR Rep. 65 BMR Bull. 100
201		Ryan Buttes	23°55'00"S 126°35'00"E	Ryan SF 52/13	Base of section	120 (37)					120 (37)								Bureau of Mineral Resources	BMR Bull. 60, Section Ry8
202		Dowling Hills	23°45'00"S 126°12'00"E	Ryan SF 52/13	Base of section	44 (13)									44 (13)				Bureau of Mineral Resources	BMR Bull. 60, Section Ry4
203		Kidson Bluff	22°16'00"S 125°03'00"E	Ural SF 51/12	Base of section	102 (31)									102 (31)				Bureau of Mineral Resources	BMR Bull. 60
204		Kidson 1*	22°37'00"S 125°00'22"E	Ural SF 51/12	R.T. 1181 (360)	14539 (4431)	14040 (4279)	5800 (1768)	5153 (1571)		530 (162)		140 (43)		60 (18)			16 (5)	West Australian Petroleum Pty Ltd	BMR File 65/4177
205		Bejah Hill	23°46'00"S 124°09'00"E	Runton SF 51/15	Base of section	45 (14)									45 (14)				Bureau of Mineral Resources	BMR Bull. 60, Section Rn 38
206		Cromer Cone, Runton Sheet RN45	23°35'00"S 123°20'00"E	Runton SF 51/15	Base of section	125 (38)					125 (38)								Bureau of Mineral Resources	BMR Bull. 60, Section Rn45
207		Cronin Hills	23°15'00"S 123°20'00"E	Runton SF 51/15	Base of section	80 (24)					3 (1)		80 (24)						Bureau of Mineral Resources	BMR Bull. 60, Section Rn65
208		Cotton Creek	22°54'00"S 122°38'00"E	Rudall SF 51/10	Base of section	116 (35)					116 (35)								Bureau of Mineral Resources	BMR Bull. 60, Section Rn18
209		9 km NE of Well 26	22°53'00"S 123°35'00"E	Tabletop SF 51/11	Base of section	120 (37)					120 (37)								Bureau of Mineral Resources	BMR Bull. 60, Section T14

STRATIGRAPHIC CONTROL POINTS

Station Number	Symbol	Station Name	Coordinates	Sheet Area	Datum feet (metres)	Thickness feet (metres)	Interval: Basement	1	2	3	4	5	Top feet (metres): 6	7	8	9	10	11	Source	Reference
210		Triwhite Hills, NE of Lake Dora	22°05'00"S 123°13'00"E	Tabletop SF 51/11	Base of section	65 (20)					65 (20)								Bureau of Mineral Resources	BMR Rep. 29, Section T2
211		10 km NE of Bremner Peak	21°20'00"S 124°27'45"E	Sahara SF 51/7	Base of section	50 (15)									50 (15)				Bureau of Mineral Resources	BMR Bull. 60, Section A131
212		Lake Dora	21°59'30"S 122°59'00"E	Paterson Range SF 51/6	Base of section	40 (12)					40 (12)								Bureau of Mineral Resources	BMR Rep. 29, Bull. 60
213		Paterson Range	21°48'00"S 122°09'00"E	Paterson Range SF 51/6	Base of section	100 (30)					100 (30)								Bureau of Mineral Resources	BMR Rep. 29
214		Tandalgoo 2	21°07'00"S 123°27'00"E	Sahara SF 51/7	D.F. 869 (265)	500 (152)					180 (55)		80 (24)		28 (9)			4 (1)	West Australian Petroleum Pty Ltd	Well Report
215		Sahara 1*	21°04'40"S 123°23'30"E	Sahara SF 51/7	R.T. 884 (269)	6956 (2120)			3700 (1128)	3055 (931)	195 (59)		60 (18)		40 (12)			[illegible]	West Australian Petroleum Pty Ltd	P.S.S.A. Publ. 80 BMR File 64/4129
216		Kemp Field 1*	20°19'10"S 123°27'58"E	Joanna Springs SF 51/3	K.B. 782 (238)	3875 (1181)			2364 (721)	1847 (563)	339 (103)		55 (17)					14 (4)	Total Exploration Australia Pty Ltd	BMR File 68/2048
217		McLarty Hills	19°30'30"S 123°30'00"E	McLarty Hills SE 51/15	No data	No data							May be present No data						Bureau of Mineral Resources	BMR Bull. 60
218		McLarty 1*	19°23'45"S 123°39'30"E	McLarty Hills SE 51/15	K.B. 572 (174)	8500 (2591)			5350 (1631)	1483 (452)	412 (126)		77 (24)					14 (4)	Total Exploration Australia Pty Ltd	BMR File 68/2009
219		Munda 1*	19°28'27"S 122°17'32"E	Munro SE 51/14	R.T. 319 (97)	3500 (1067)				2626 (800)	1348 (411)		480 (146)		9 (3)				West Australian Petroleum Pty Ltd	BMR File 71/475
220		Munro 1*	19°51'47"S 122°28'28"E	Munro SE 51/14	R.T. 196 (60)	6941 (2116)	6909 (2106)		4925 (1501)	3844 (1172)	1610 (491)		200 (61)		15 (5)				West Australian Petroleum Pty Ltd	BMR File 72/846
221		N of Anketell Hills	20°26'30"S 122°32'30"E	Anketell SF 51/2	Base of section	111 (34)							20 (6)		111 (34)				Bureau of Mineral Resources	BMR Bull. 60, Section A11
222		5 km E of Section A3, W of Anketell Hills	20°17'00"S 121°49'30"E	Anketell SF 51/2	Base of section	40 (12)							40 (12)						Bureau of Mineral Resources	BMR Bull. 60
223		16 km ESE of Cuncudgerie Hill	21°01'30"S 121°40'00"E	Patterson Range SF 51/6	Top of section	100 (30)					0 (0)								Bureau of Mineral Resources	BMR Rep. 29
224		3 km NNW of the Old Braeside Homestead, Oakover River	21°10'00"S 121°00'00"E	Nullagine SF 51/5	Base of section	No data					Present No data								Bureau of Mineral Resources	BMR Rep. 29
225		Oakover River Valley	20°45'00"S 120°56'30"E	Yarrie SF 51/1	Base of section	100 (30)												100 (30)	Bureau of Mineral Resources	BMR Rep. 29; Bull. 60
226		13 km NE of Callawa Homestead	20°32'30"S 120°35'15"E	Yarrie SF 51/1	Base of section	200 (61)							200 (61)						Bureau of Mineral Resources	BMR Bull. 60, Section Y38
227		Willara 1*	19°10'48"S 122°04'14"E	Munro SE 51/14	R.T. 265 (81)	12806 (3903)			5697 (1736)	4148 (1264)	1615 (492)		440 (134)		70 (21)			16 (5)	West Australian Petroleum Pty Ltd	BMR File 65/4158
228		Willara Hill 1*	19°03'31"S 121°52'45"E	Munro SE 51/14	R.T. 252 (77)	2815 (858)					2068 (630)		930 (283)		59 (18)			5 (2)	West Australian Petroleum Pty Ltd	BMR File 68/2044

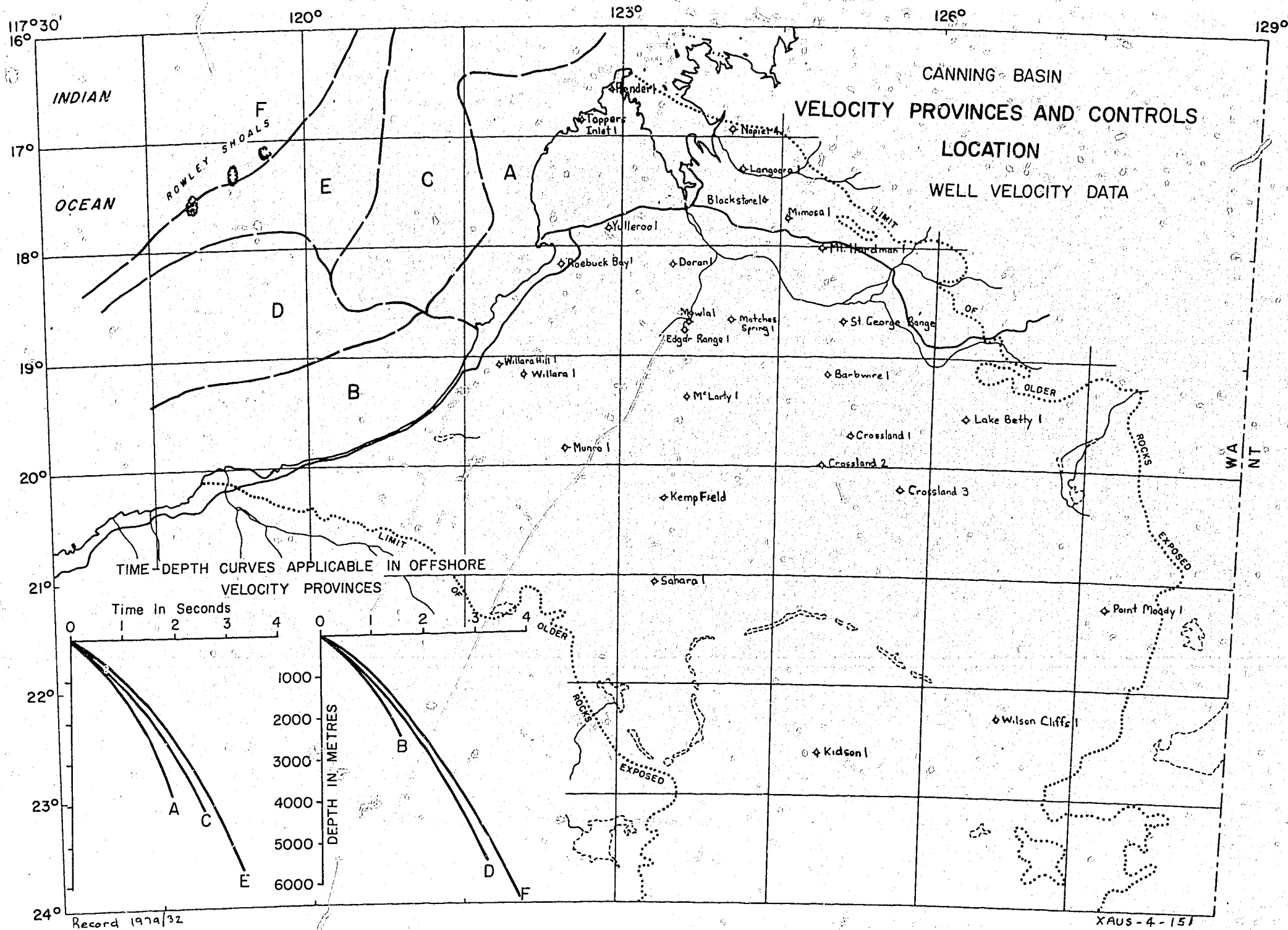
STRATIGRAPHIC CONTROL POINTS

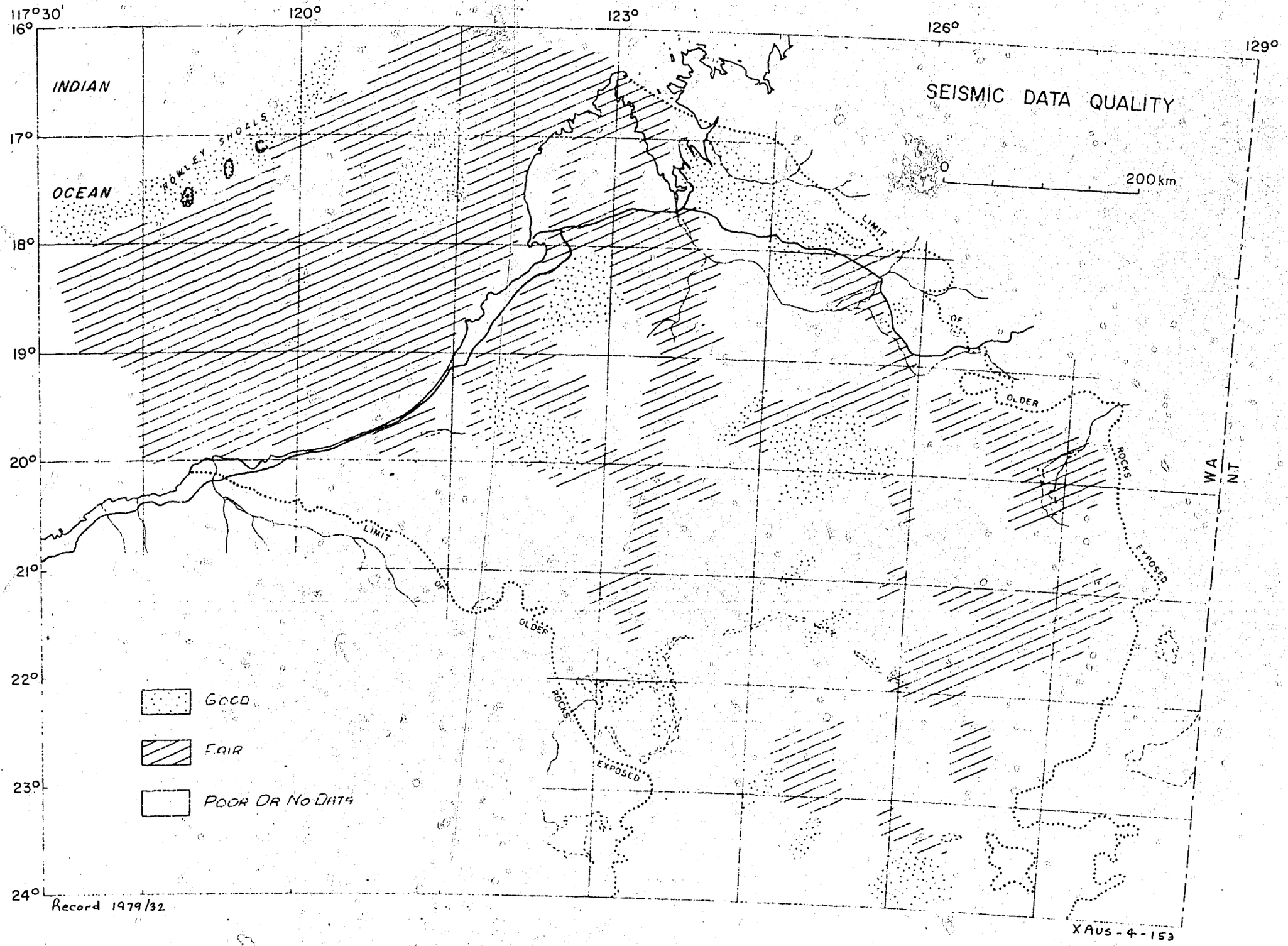
Station Number	Symbol	Station Name	Coordinates	Sheet Area	Datum feet (metres)	Thickness feet (metres)	Interval						Top		feet (metres)				Source	Reference
							Basement	1	2	3	4	5	6	7	8	9	10	11		
229		Parda 1*	18°56'08"S 122°00'34"E	La Grange SE 51/10	R.T. 351 (107)	6256 (1907)	5830 (1777)	3821 (1165)	3216 (980)		2007 (612)		620 (189)		16 (5)				West Australian Petroleum Pty Ltd	BMR File 65/4137
230		Parda Hill	18°56'00"S 121°59'00"E	La Grange SE 51/10	Base of section	90 (27)									90 (27)				Bureau of Mineral Resources	BMR Bull. 60, 36
231		Cape Frezier	18°53'00"S 121°37'00"E	La Grange SE 51/10	Base of section	20 (6)									20 (6)				Bureau of Mineral Resources	BMR Bull. 60, 36
232		Talgarno 1	19°15'00"S 121°30'00"E	Mandora SE 51/13	G.L. 55 (17)	1324 (404)							505 (154)		10 (3)			0 (0)	Commonwealth Dept of Works	Well Index Sheet
233		Samphire Marsh 1*	19°31'08"S 121°10'51"E	Mandora SE 51/13	D.F. 28 (9)	6664 (2031)	6610 (2015)	4069 (1240)			2258 (688)		505 (154)		134 (41)			12 (4)	West Australian Petroleum Pty Ltd	P.S.S.A. Publ. 5; BMR File 62/1002
234		BMR Wallal 4	19°44'12"S 120°44'25"E	Mandora SE 51/13	R.T. 34 (10)	1410 (430)							344 (105)		75 (23)			2 (1)	Bureau of Mineral Resources	BMR Rep. 60
234		BMR Wallal 4A	19°44'12"S 120°44'25"E	Mandora SE 51/13	R.T. 32 (10)	2224 (678)	2224 (678)				2010 (613)	1927 (587)	344 (105)		75 (23)			2 (1)	Bureau of Mineral Resources	BMR Rep. 60
235		Wallal Core Hole 1	19°51'46"S 120°37'58"E	Mandora SE 51/13	R.T. 84 (26)	1014 (309)							280 (85)		40 (12)			4 (1)	West Australian Petroleum Ltd	Well report, log
236		Chirup 1	19°50'54"S 120°25'57"E	Mandora SE 51/13	R.T. 15 (5)	2502 (763)					1637 (499)		457 (139)		21 (6)			5 (3)	West Australian Petroleum Ltd	Well report, log
237		West Canning Basin 2	20°10'25"S 119°24'45"E	Port Hedland SF 50/4	G.L.	237 (72)	103 (31)						0 (0)						Geological Survey of Western Australia	GSWA Rec. 1973/7
238		Keraudren 1*	18°54'27"S 119°09'15"E	Offshore SE 50/12	R.T. 98 (30)	12612 (3844)						8071 (2460)	5049 (1539)	3986 (1215)	3543 (1080)	1841 (561)	Present	410 (125)	Hematite Petroleum Pty Ltd	BMR File 73/240
239		Bedout 1*	18°14'40"S 119°23'23"E	Offshore SE 50/12	S.B. 559 (170)	10082 (3073)	Palaeozoic - age unknown	9911 (3021)				9550 (2911)	5900 (1798)	5406 (1648)	4130 (1259)	2570 (783)	2065 (629)	559 (170)	BOC of Australia Ltd	BMR File 71/435
C240		Minilya 1	18°19'28"S 118°43'57"E	Offshore SE 50/12	K.B. 30 (9)	7874 (2400)													BOC of Australia Ltd	BMR File 74/116
		Lynher 1	15°56'24.36"S 121°04'59"E	Offshore SE 49/13	R.T. 31 (9)	8940 (2725)					8650 (2637)		4390 (1338)	4072 (1241)	2386 (727)	1730 (527)	600 (183)	252 (77)	BOC of Australia Ltd	BMR File 70/948
		Leveque 1	15°45'11.9"S 122°00'17.7"E	Offshore SE 49/14	R.T. 31 (9)	2951 (899)	2939 (896)							2400 (732)	1380 (421)	1098 (335)	990 (302)	286 (87)	BOC of Australia Ltd	BMR File 70/670

C - data confidential

Appendix 13

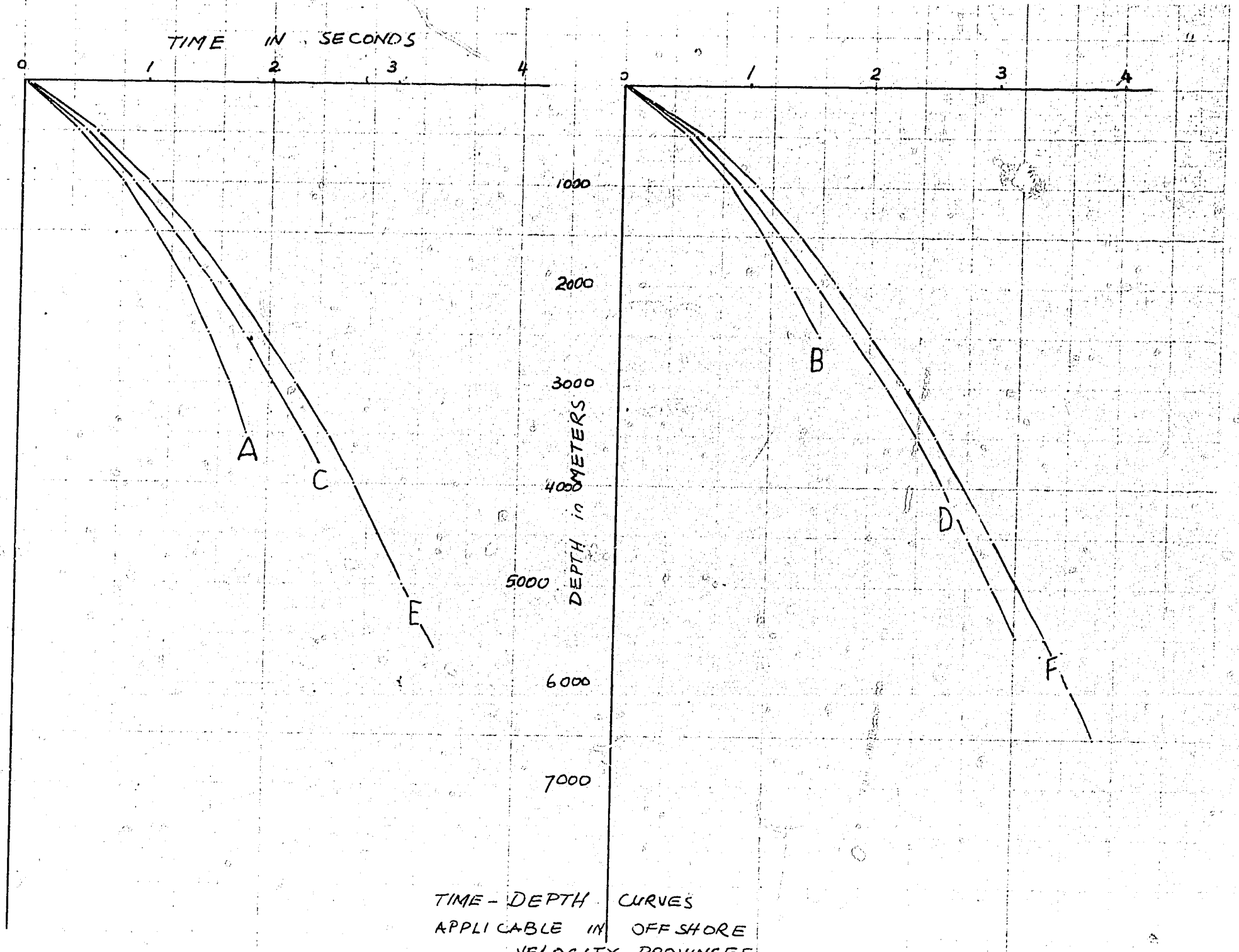
Well velocity profiles


CANNING BASIN
VELOCITY PROVINCES AND CONTROLS
LOCATION
WELL VELOCITY DATA
INDIAN OCEAN
ROWLEY SHOALS
F
E
C
A
D
B
LIMIT OF OLDER ROCKS EXPOSED
WA
NT
Handert 1
Toppers Inlet 1
Napier 4
Langoora 1
Blackstone 1
Mimosa 1
Yulleroo 1
Mt. Hardman 1
Roebuck Bay 1
Doran 1
Mowla 1
Matches Spring 1
Edgar Range 1
St George Range
Willara Hill 1
Willara 1
Barbwire 1
McLarty 1
Lake Betty 1
Crossland 1
Munro 1
Crossland 2
Crossland 3
Kemp Field
Sahara 1
Point Moody 1
Wilson Cliffs 1
Kidson 1
TIME-DEPTH CURVES APPLICABLE IN OFFSHORE VELOCITY PROVINCES
Time In Seconds
0 1 2 3 4
DEPTH IN METRES
1000 2000 3000 4000 5000 6000
A C E
B D F
117°30'
120°
123°
126°
129°
16° 17° 18° 19° 20° 21° 22° 23° 24°
Record 1979/32
XAUS-4-151



Record 1979/32

XAus-4-153



TIME - DEPTH CURVES
APPLICABLE IN OFFSHORE
VELOCITY PROVINCES

Record 1979/32

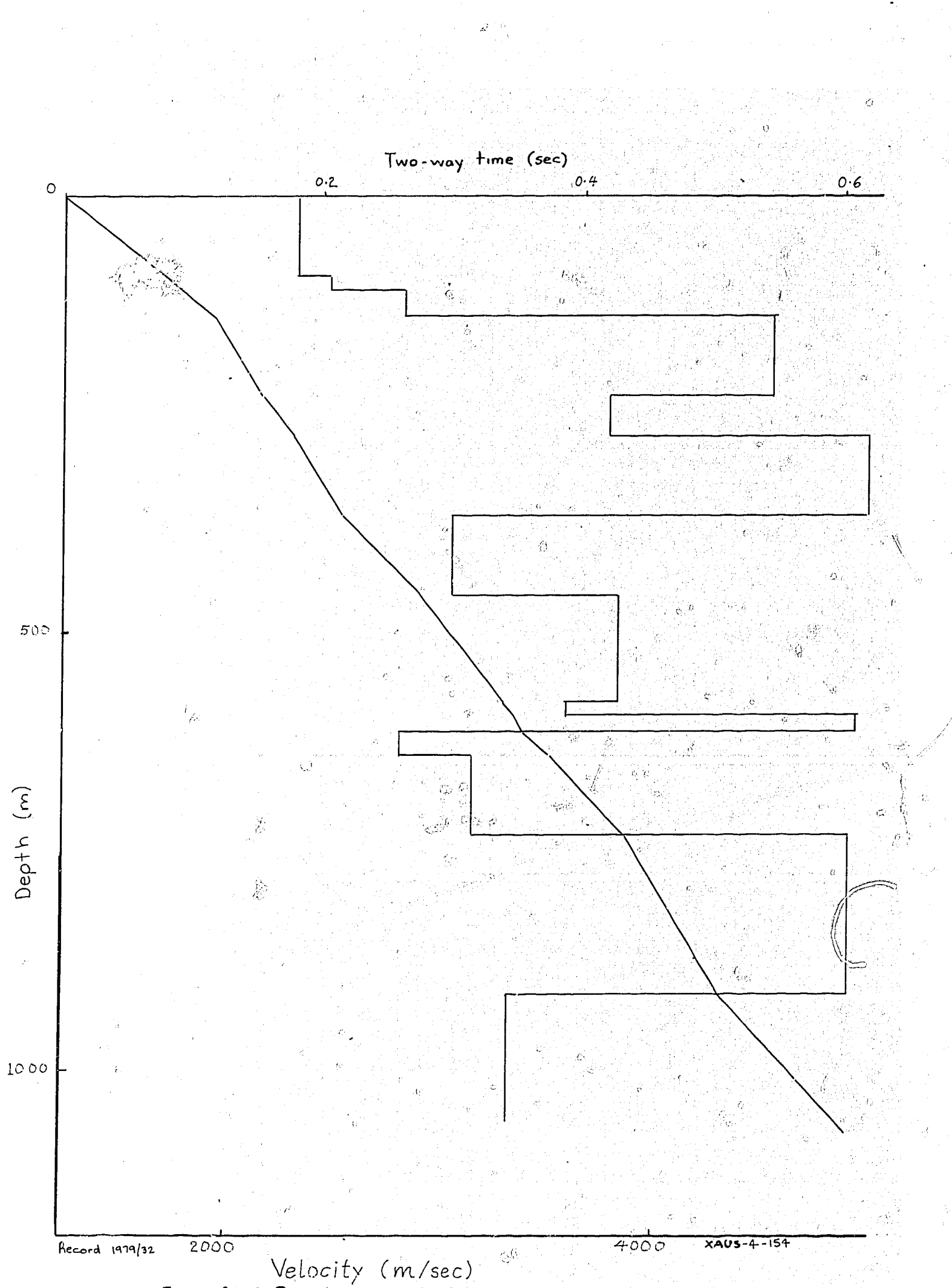
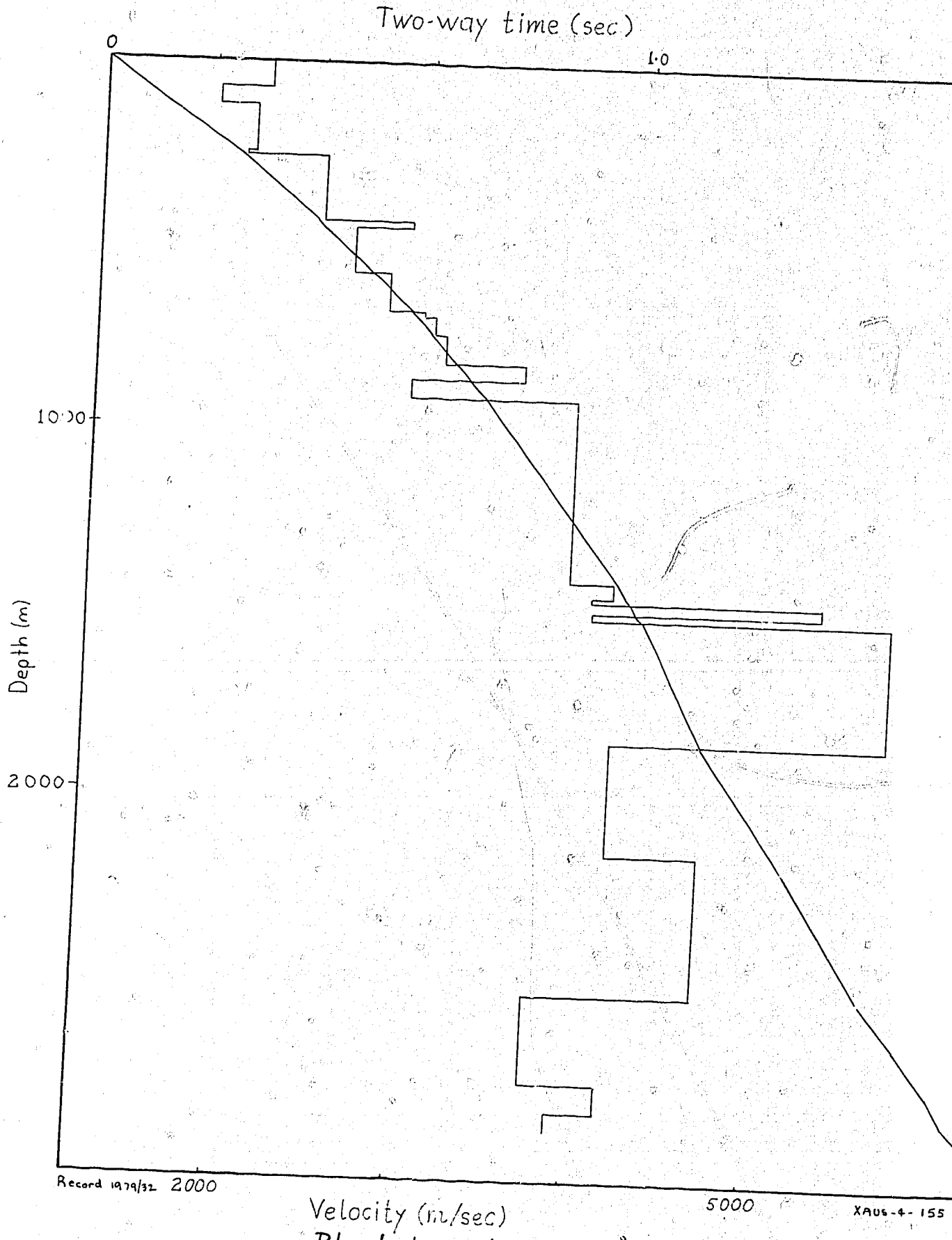
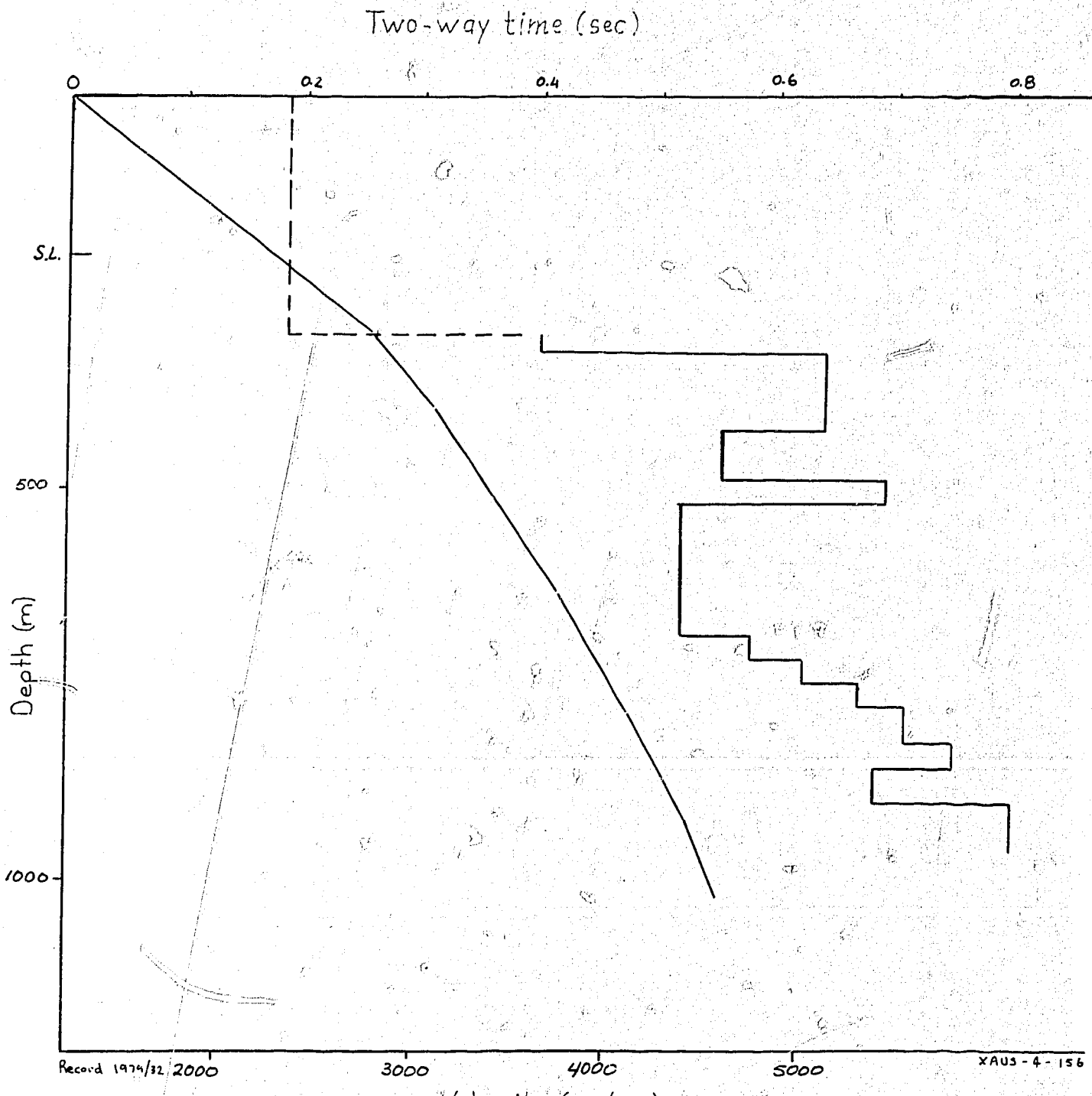


Figure A13.3 Barbwire No.1



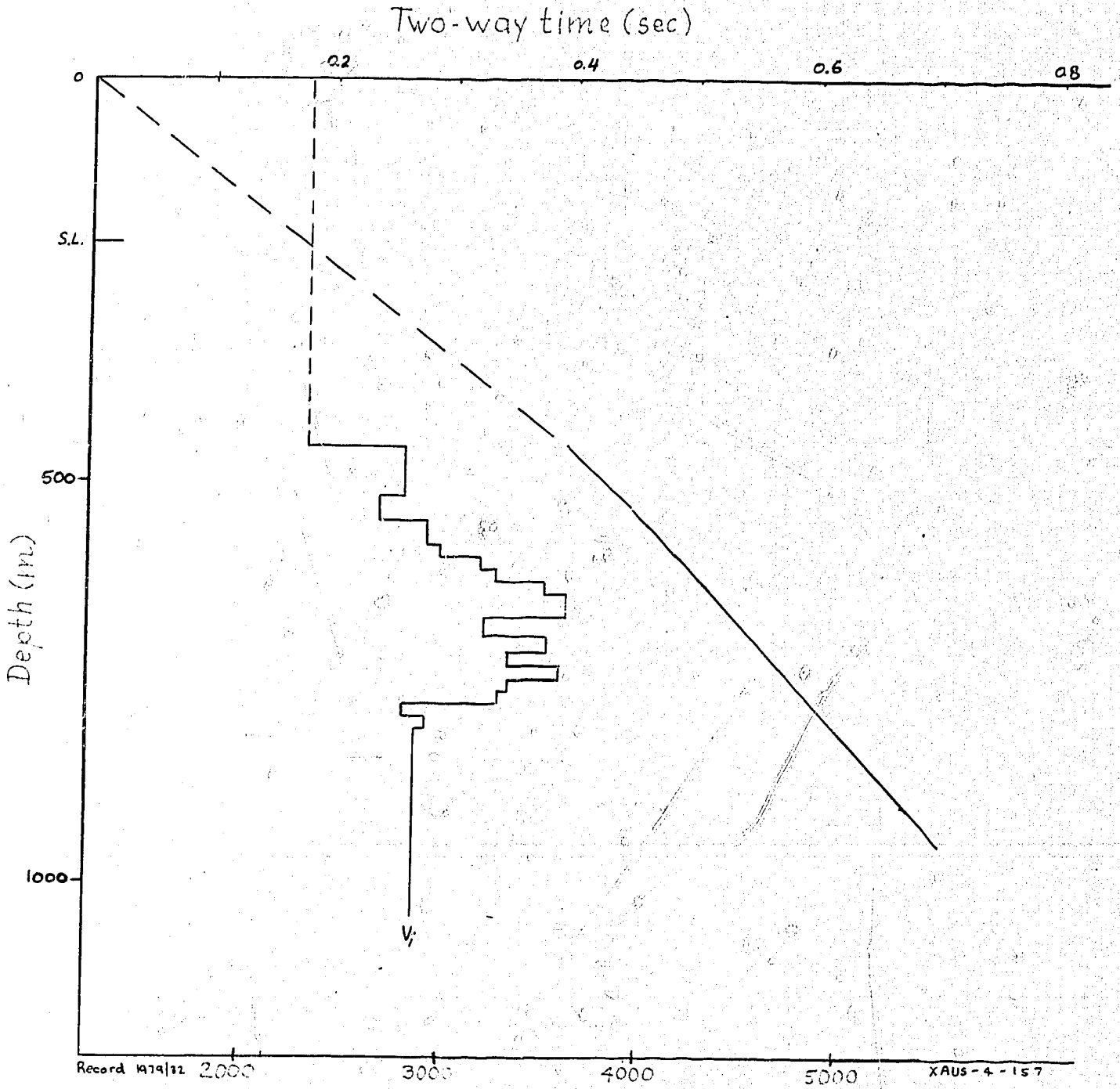
Blackstone No.1

Figure A13.4



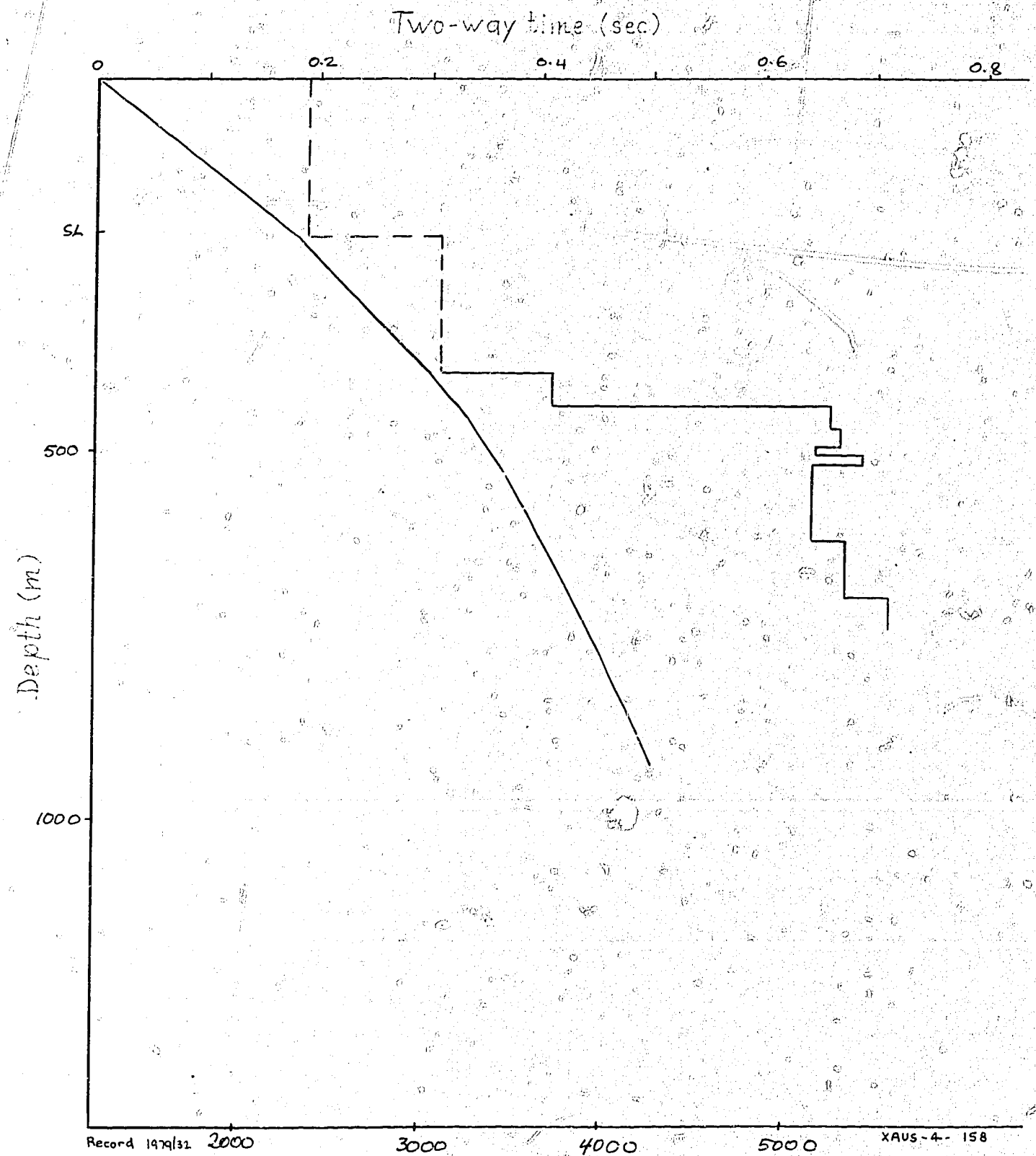
Crossland No.1

Figure A 13.5



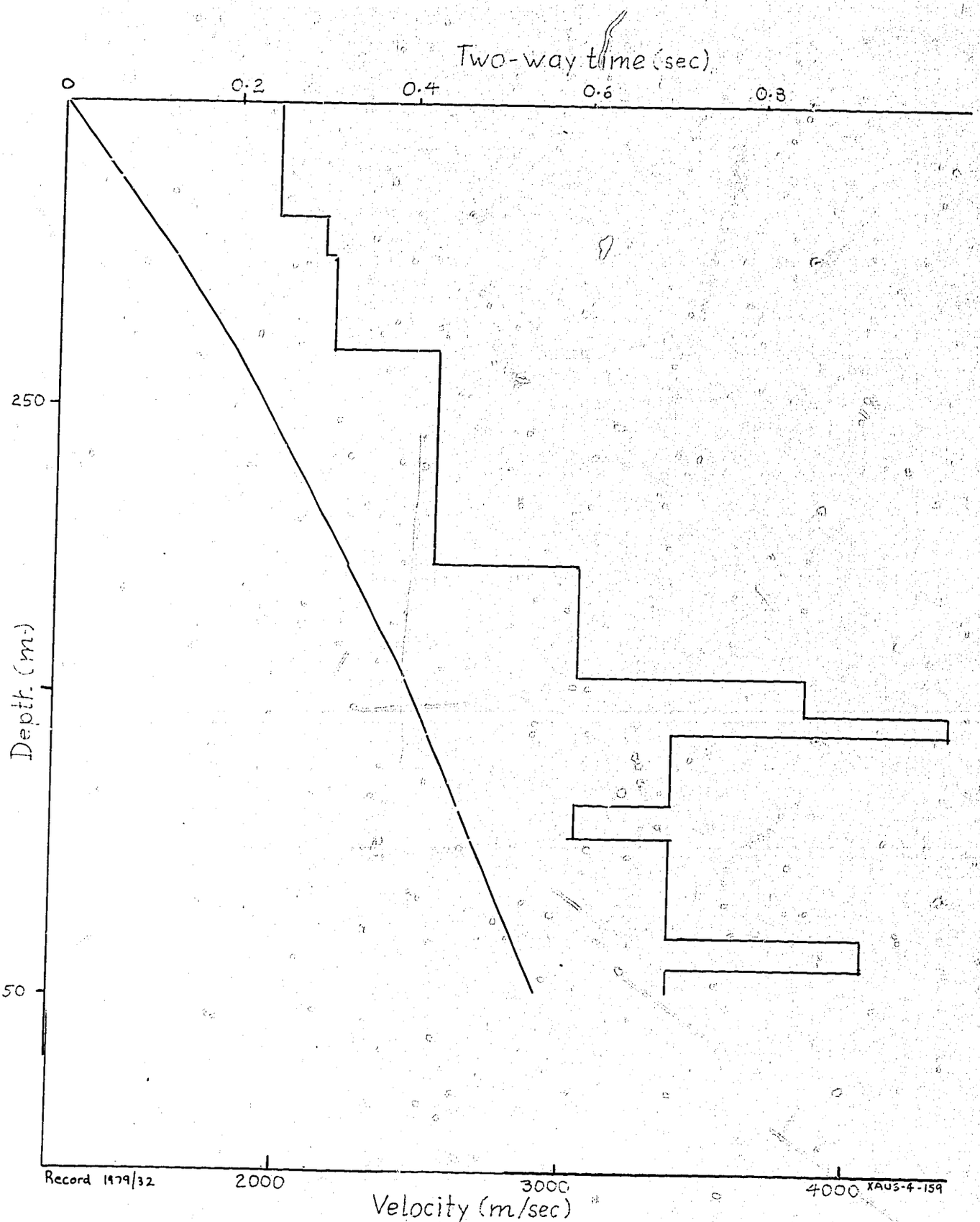
Crossland No.2

Figure A13.6



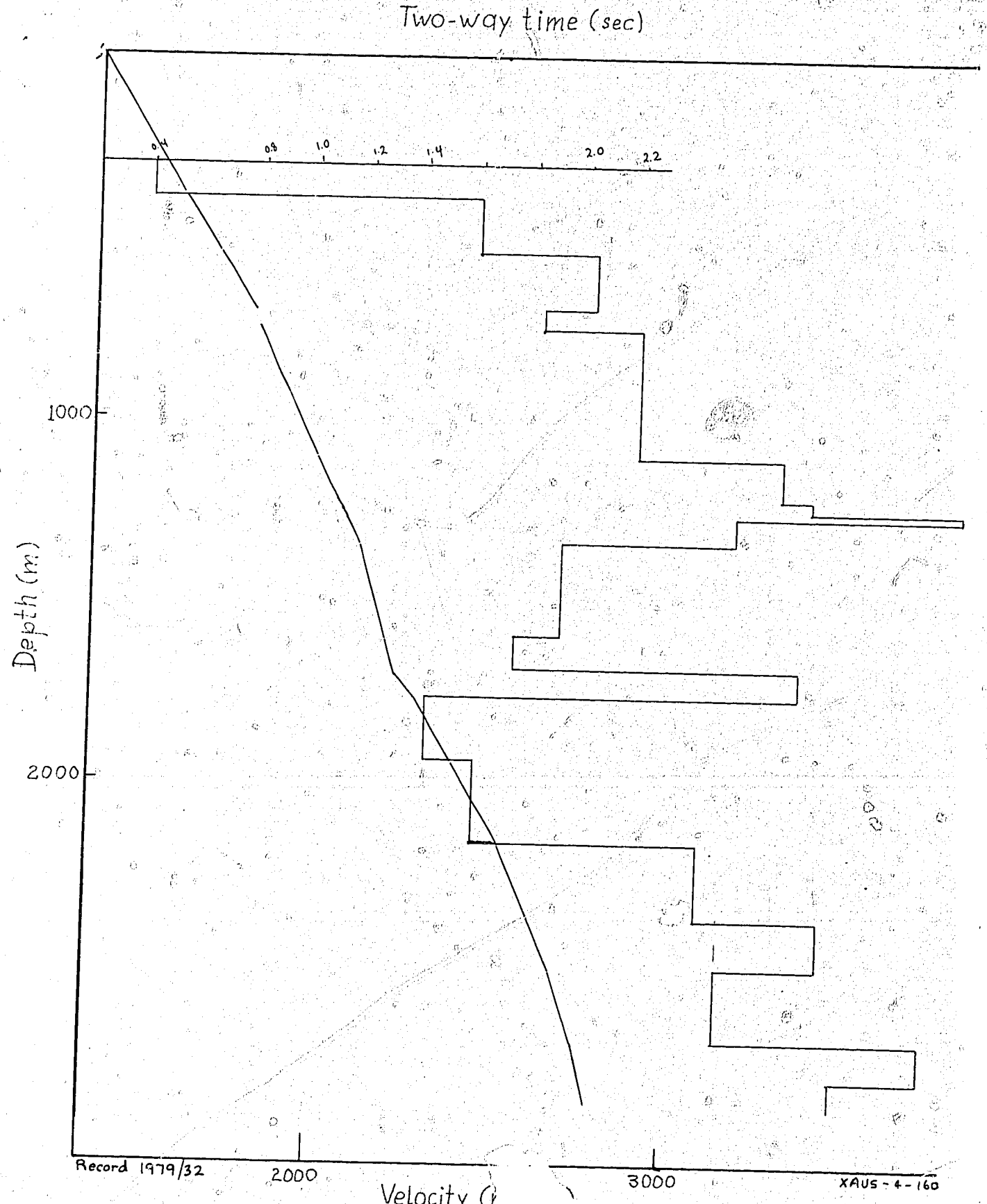
Crossland No.3

Figure A 13.7



Doran No.1

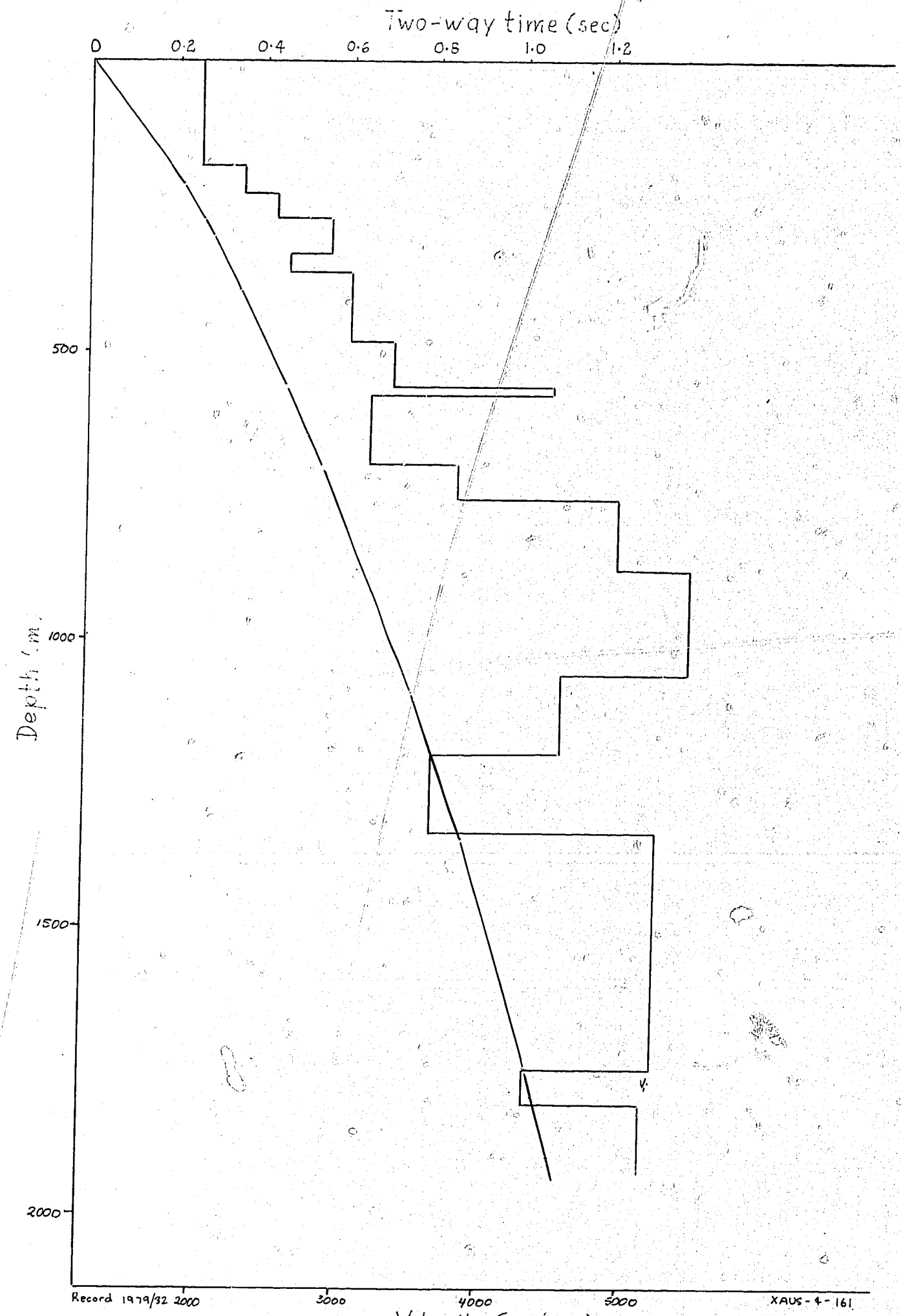
Figure A13.8



Velocity (

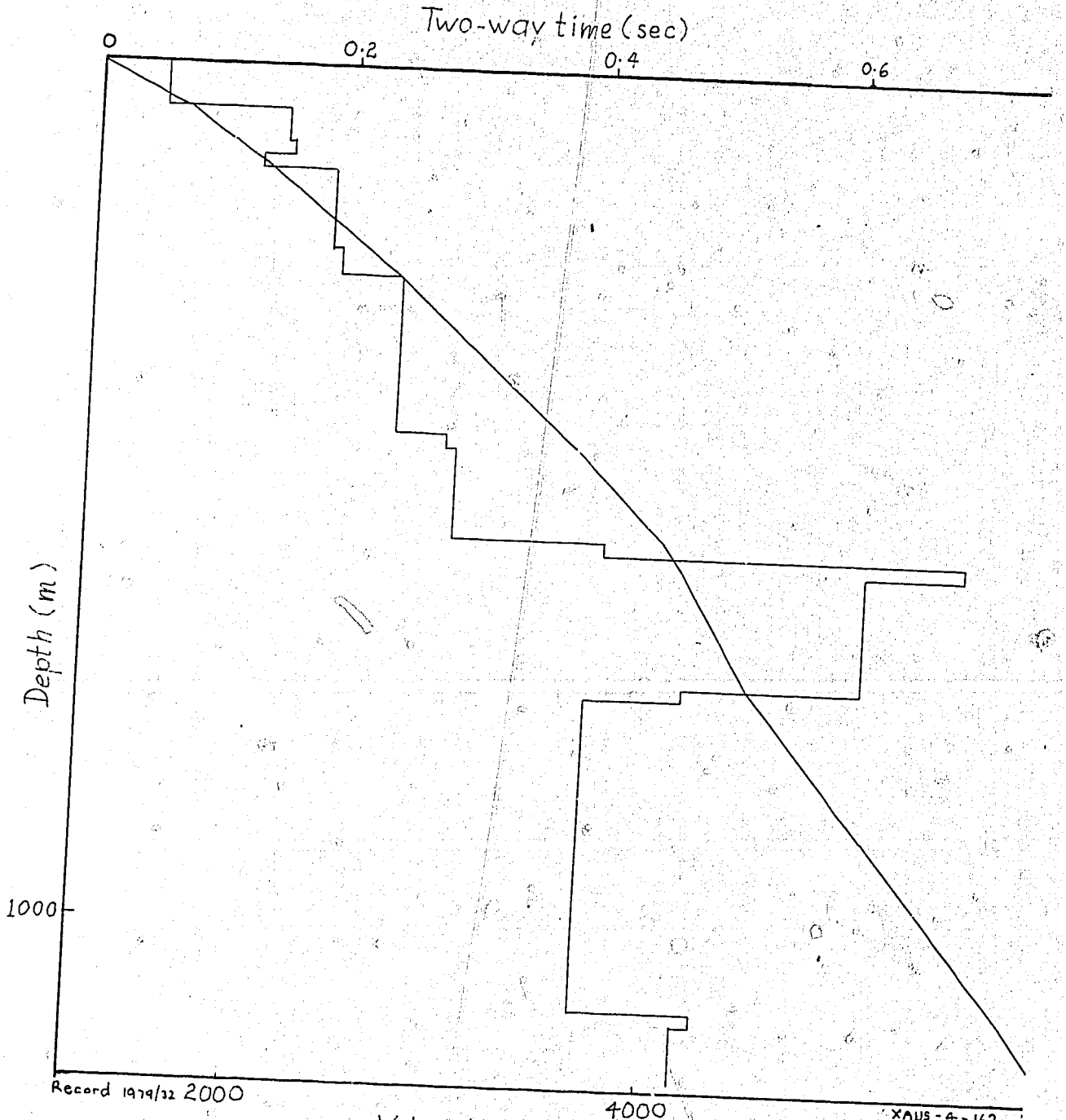
East Mermaid No.1

Figure A 13.9



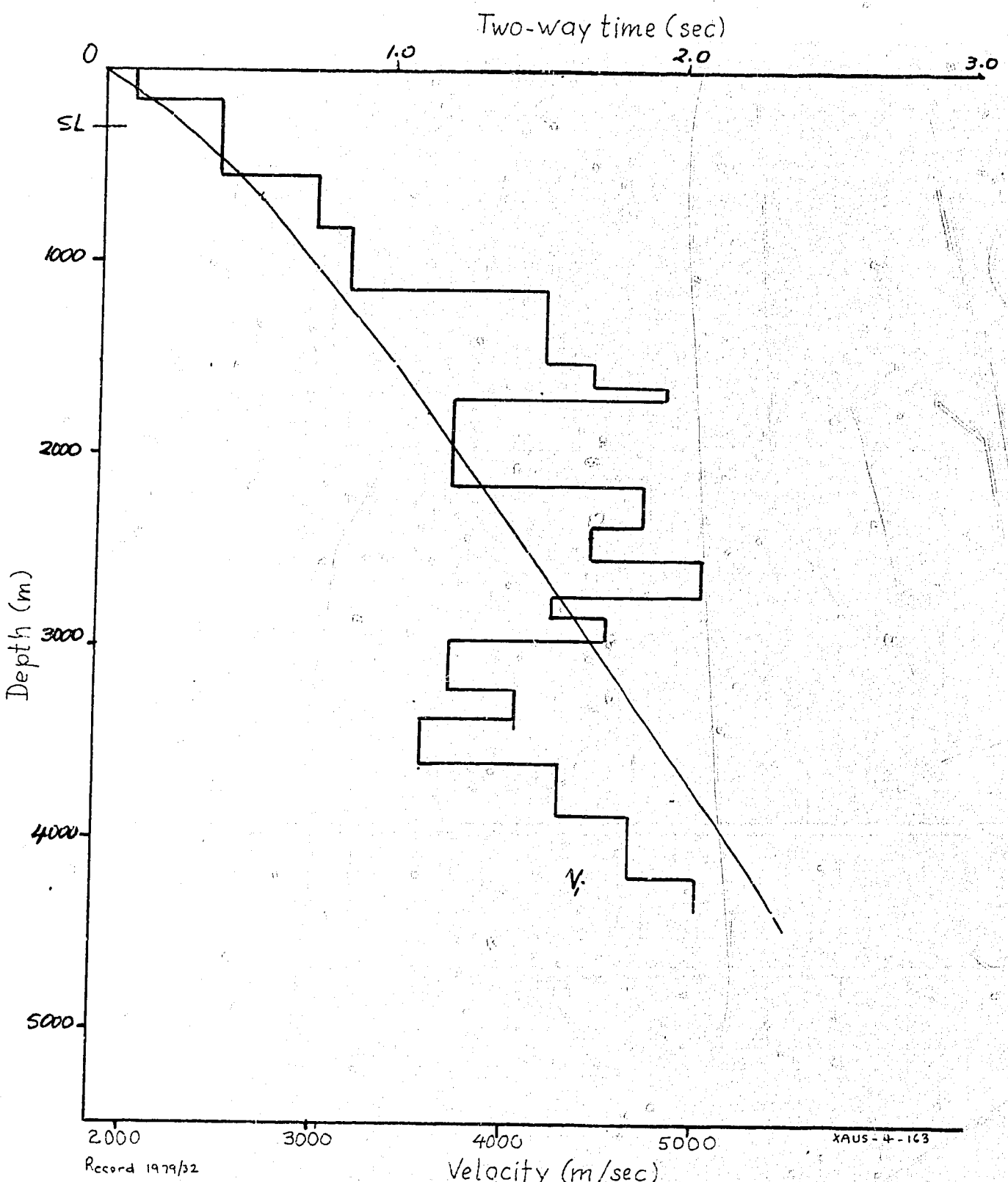
Edgar Range No.1

Figure A 13.10



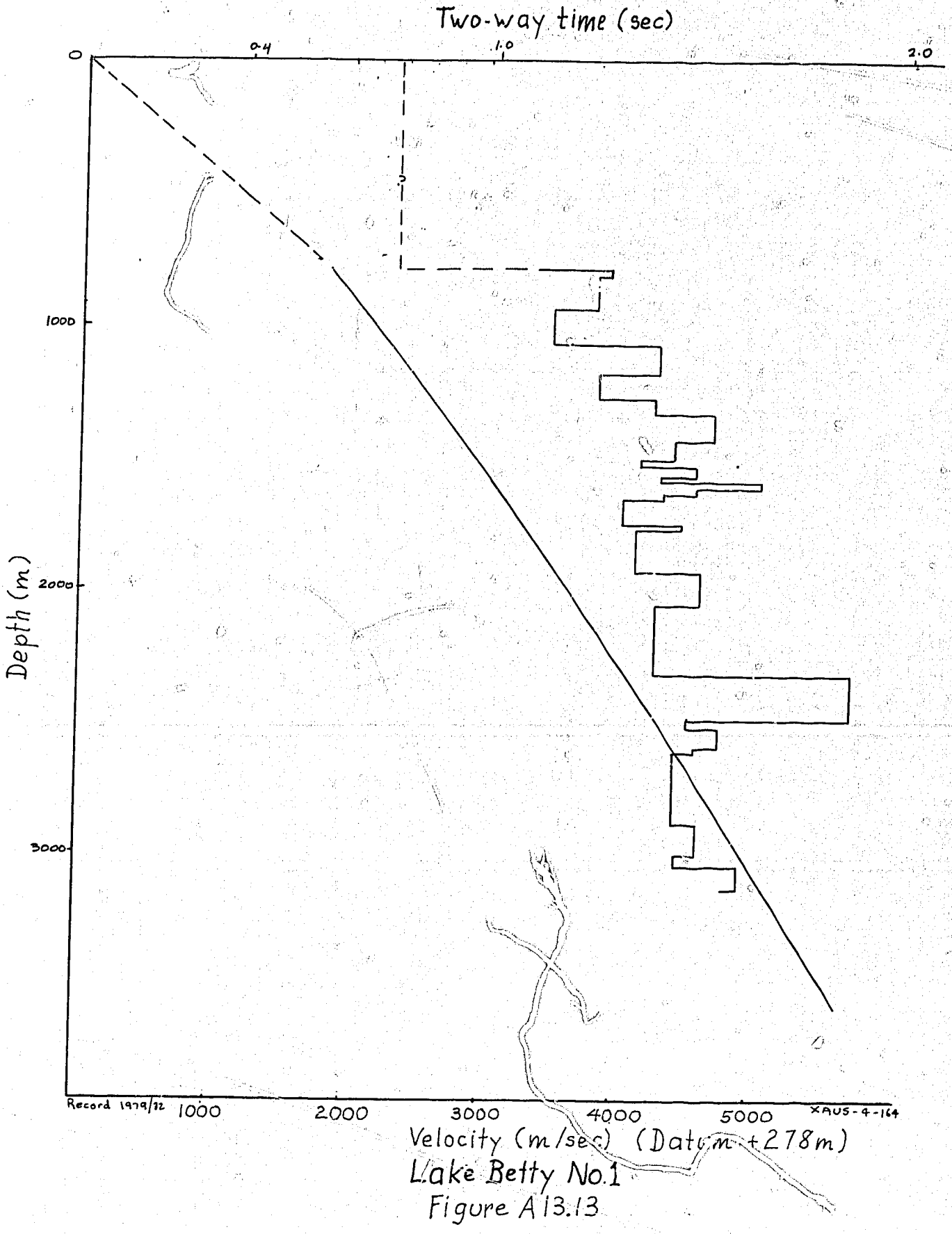
Kemp Field No.1

Figure A 13.11



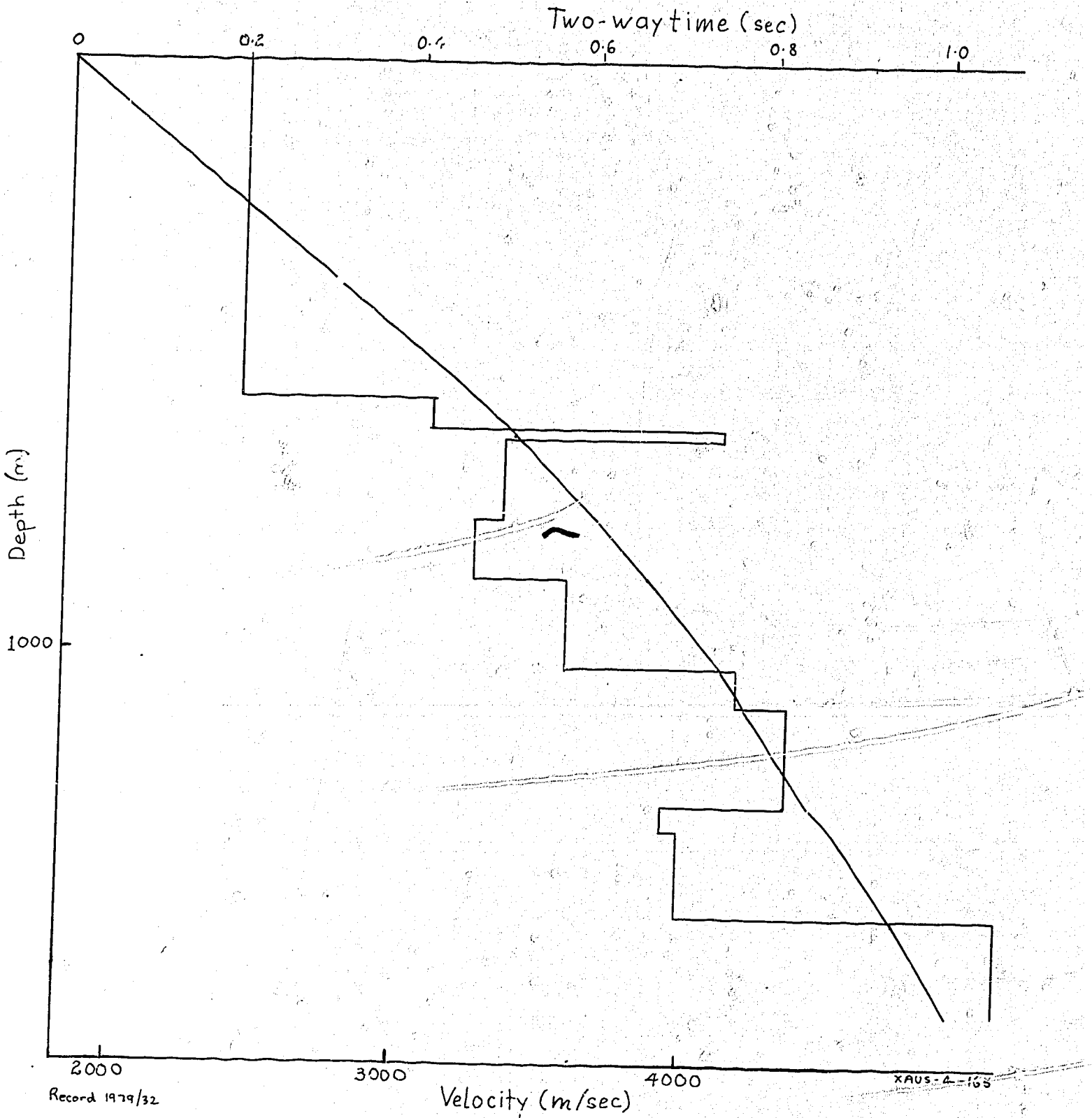
Kidson No.1

Figure A 13.12



Lake Betty No.1

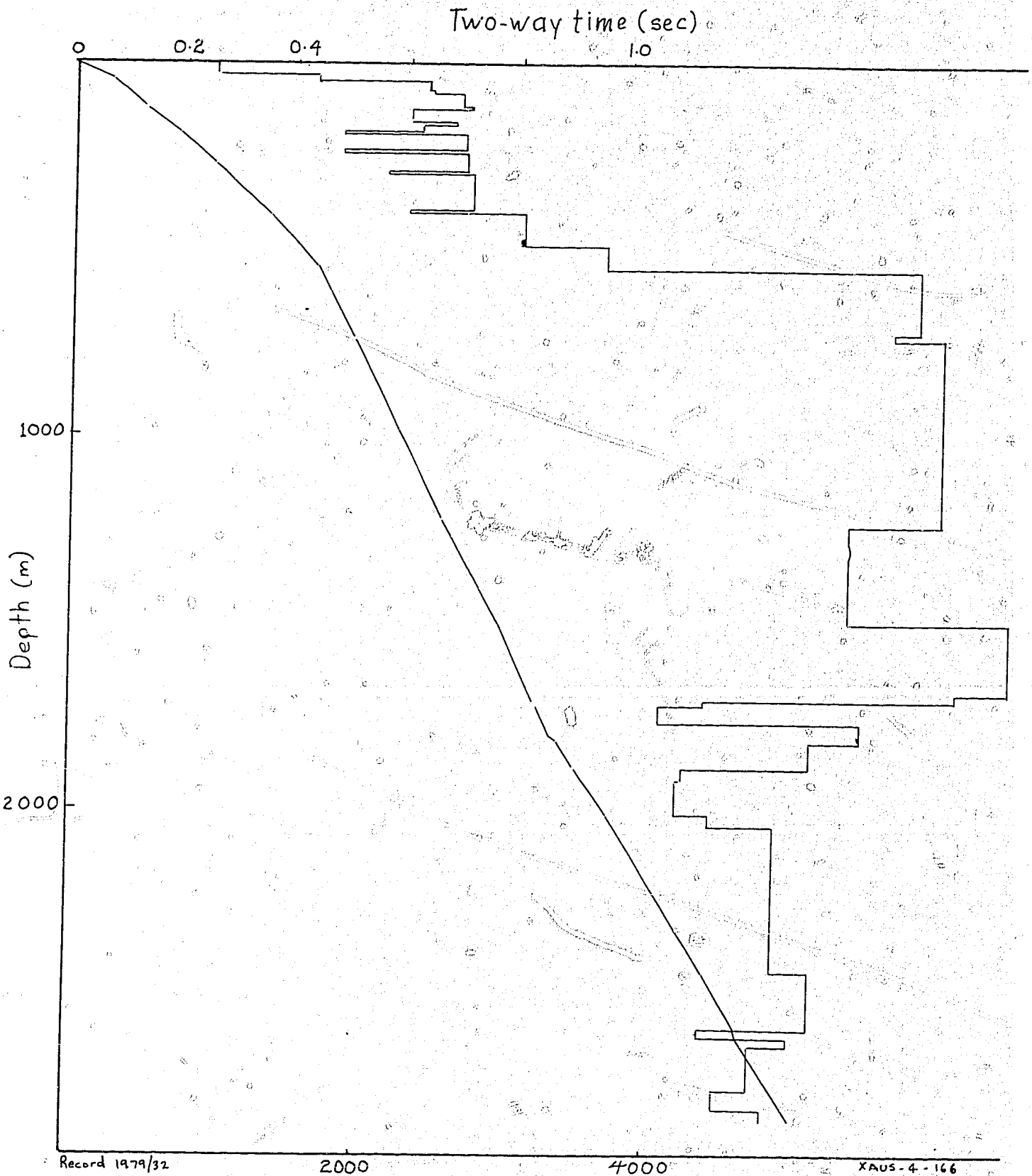
Figure A13.13



Record 1979/32

Langoora No.1

Figure A 13.14



Matches Spring No.1

Figure A 13.15

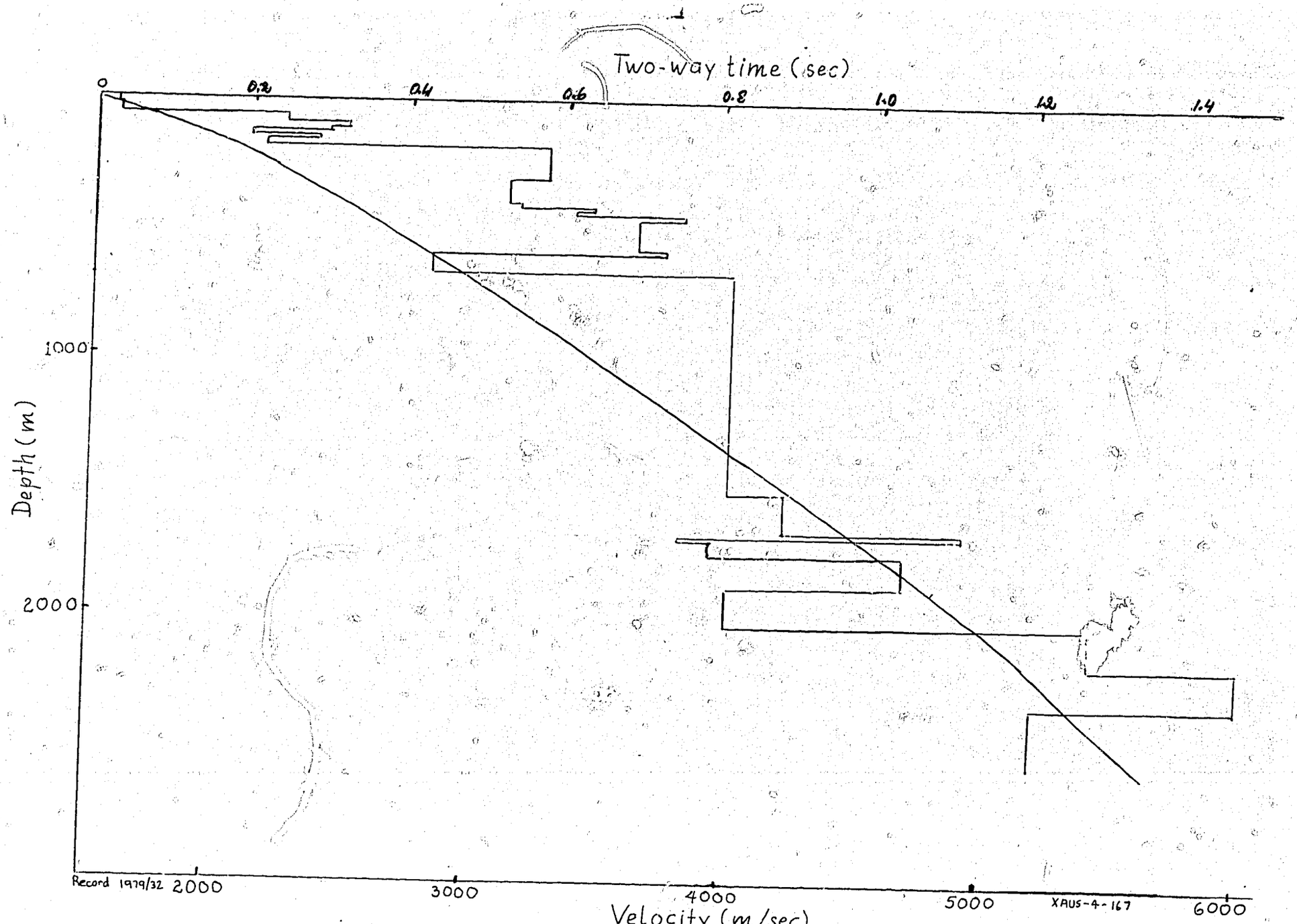
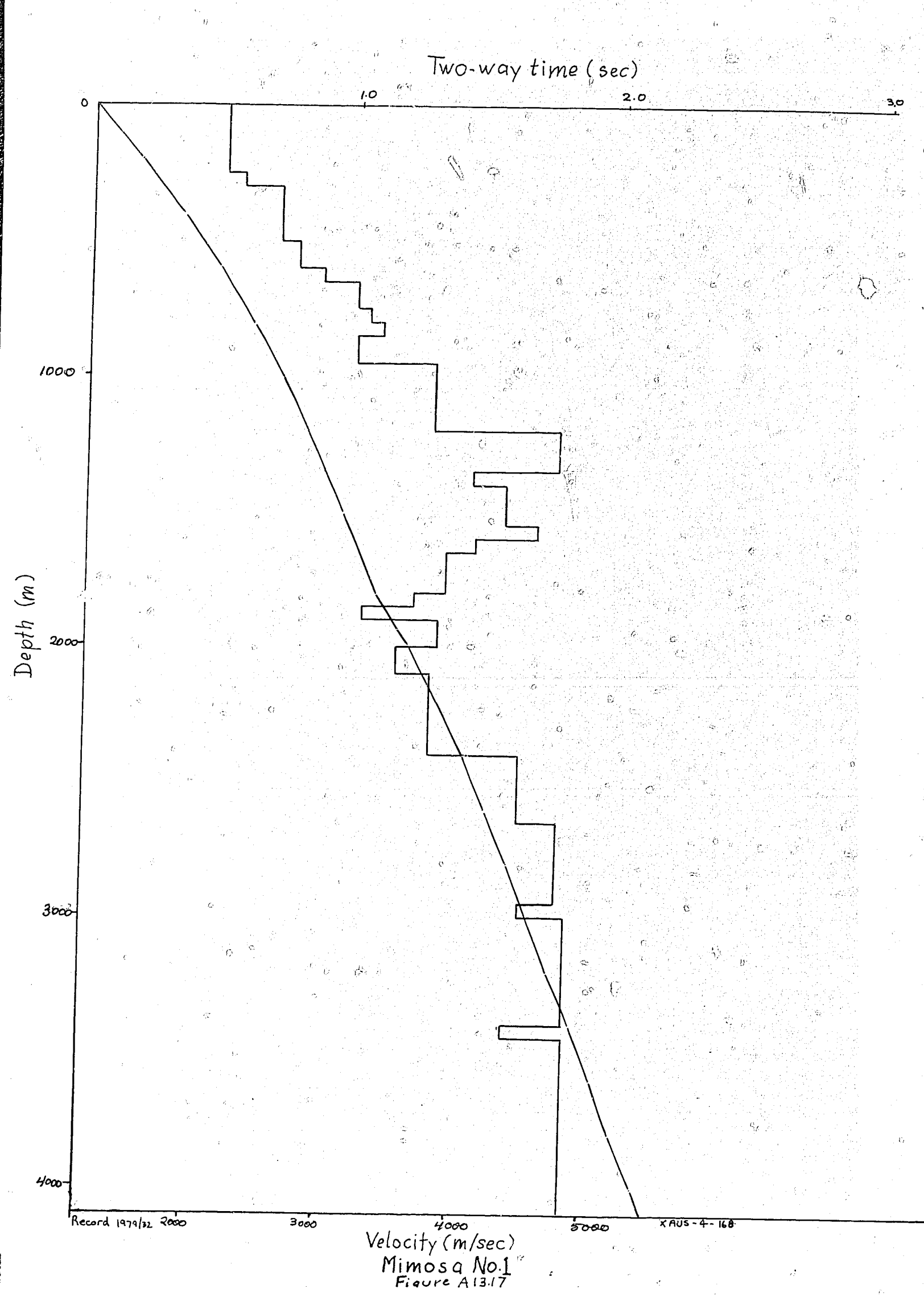
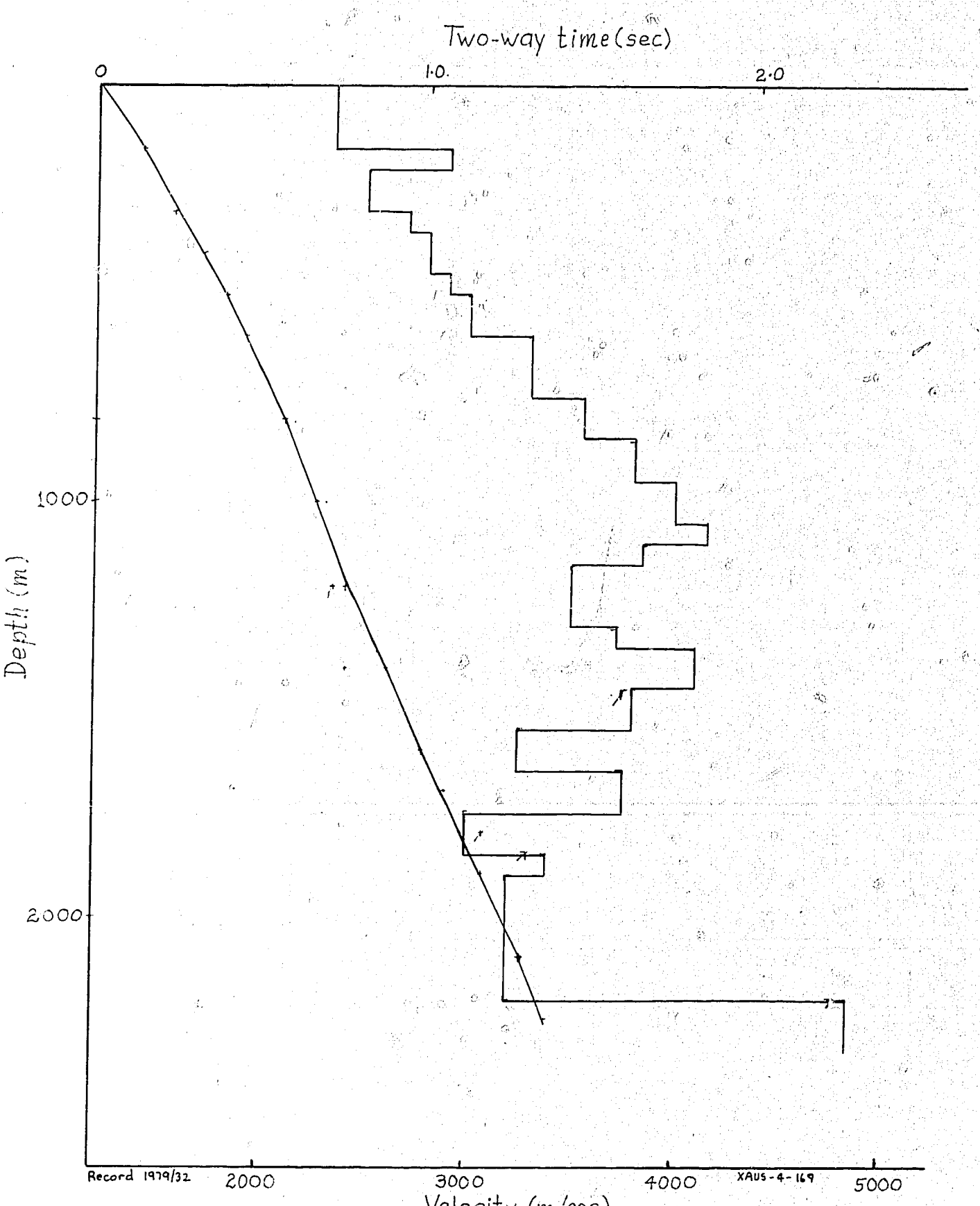


Figure A13 16 Mc Larty No.1

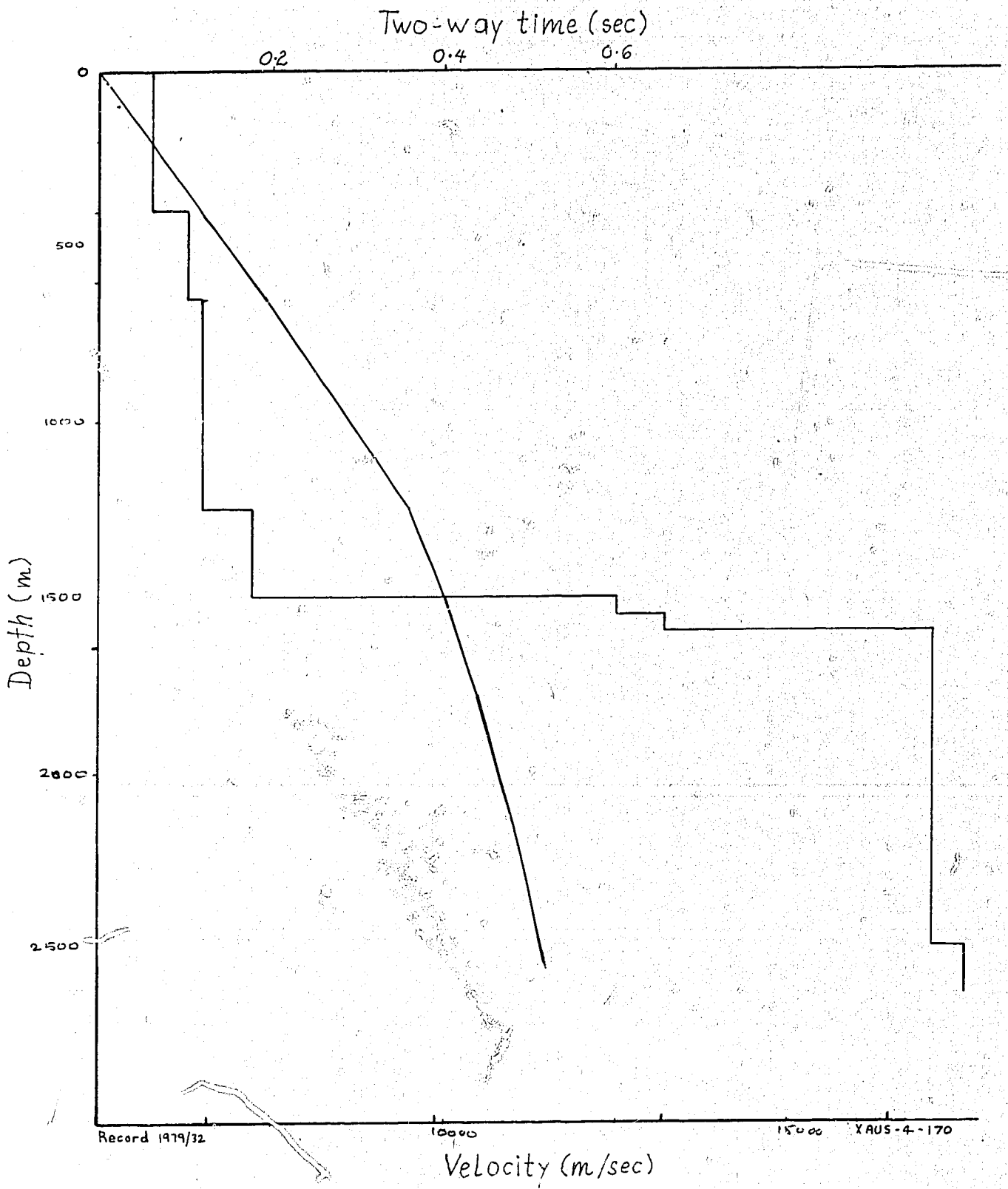


Mimosa No.1

Figure A13.17

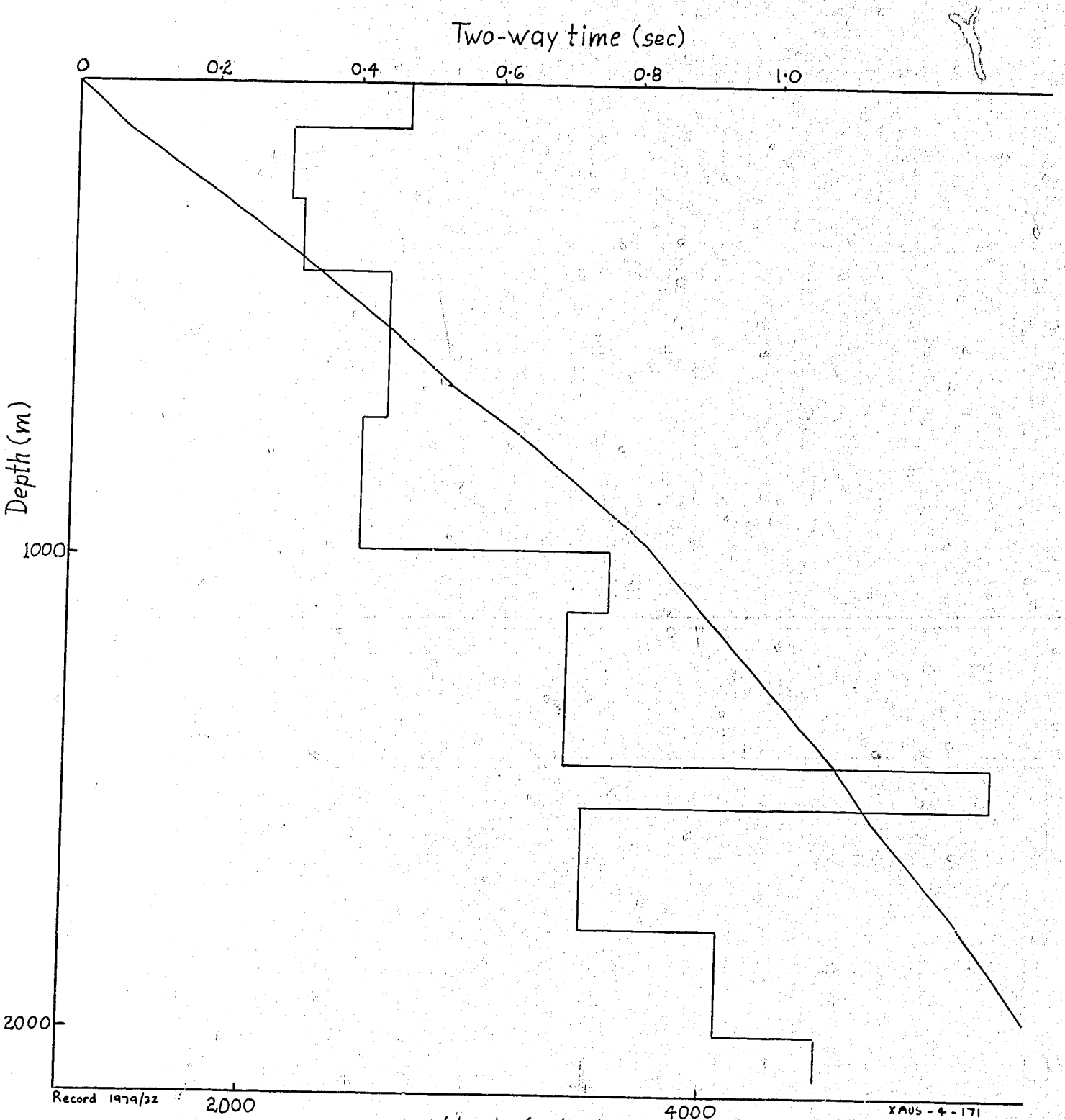


Mt. Hardman No.1
Figure A13.18



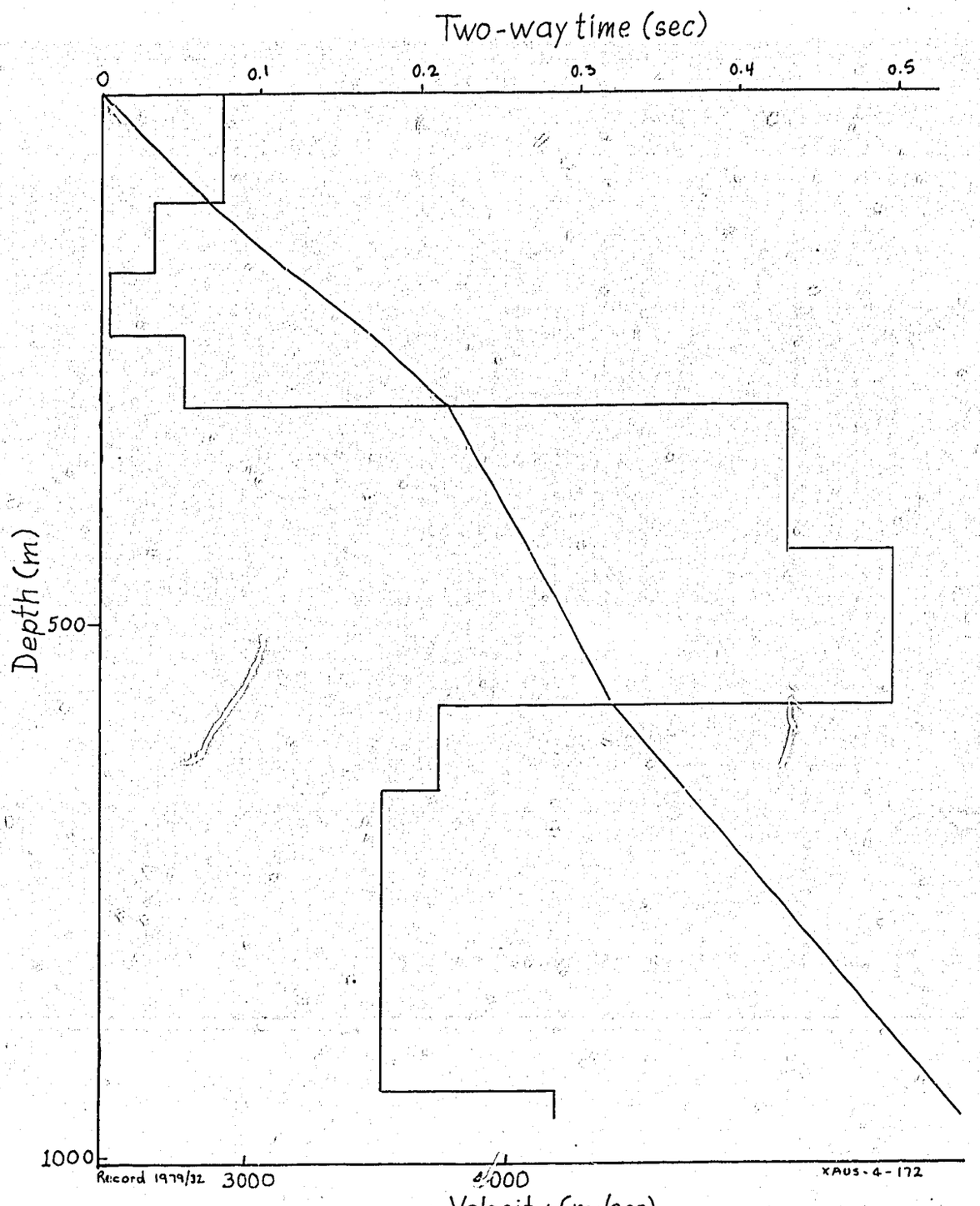
Mowla No.1

Figure A13.19



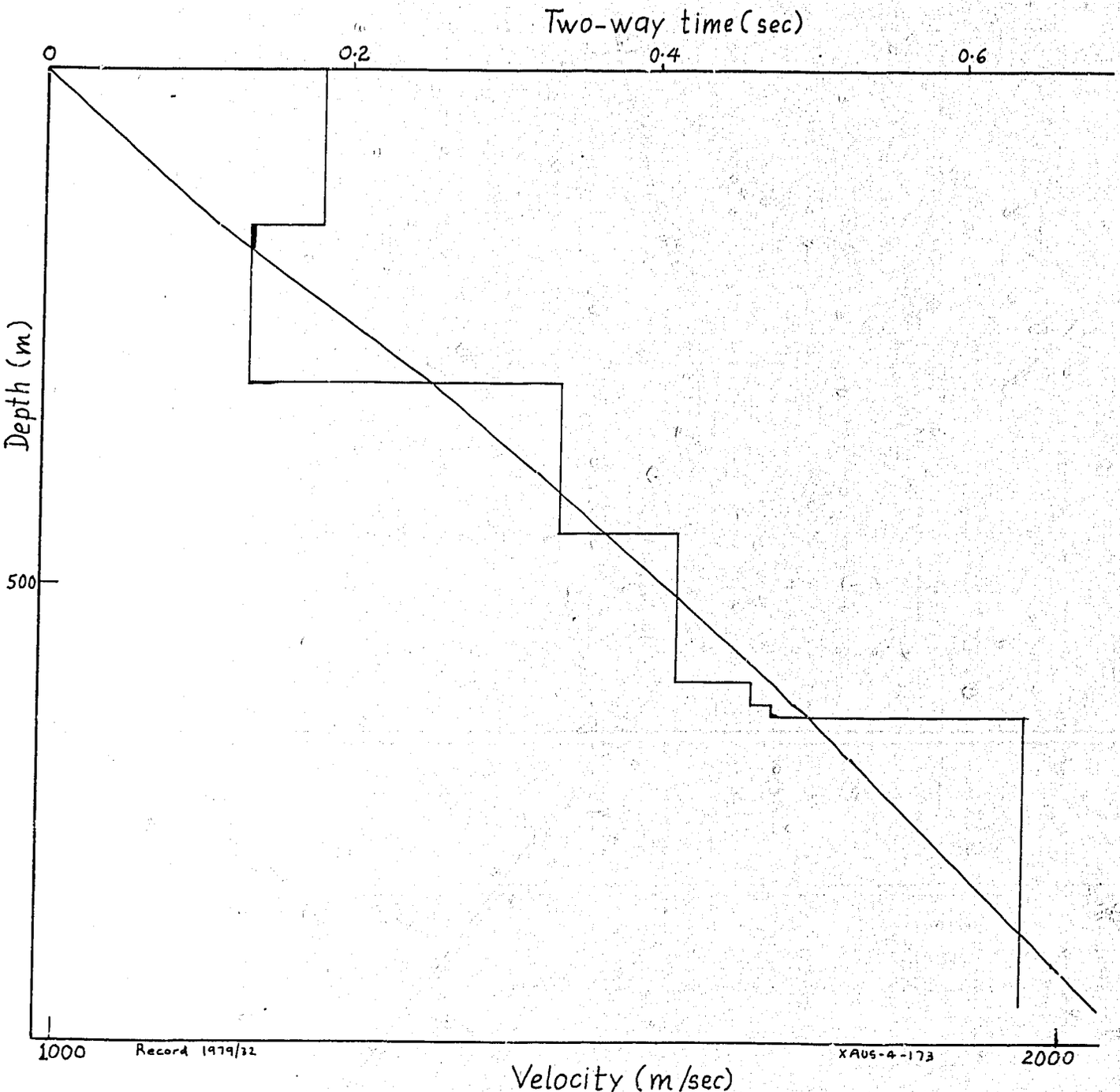
Munro No.1

Figure A13.20

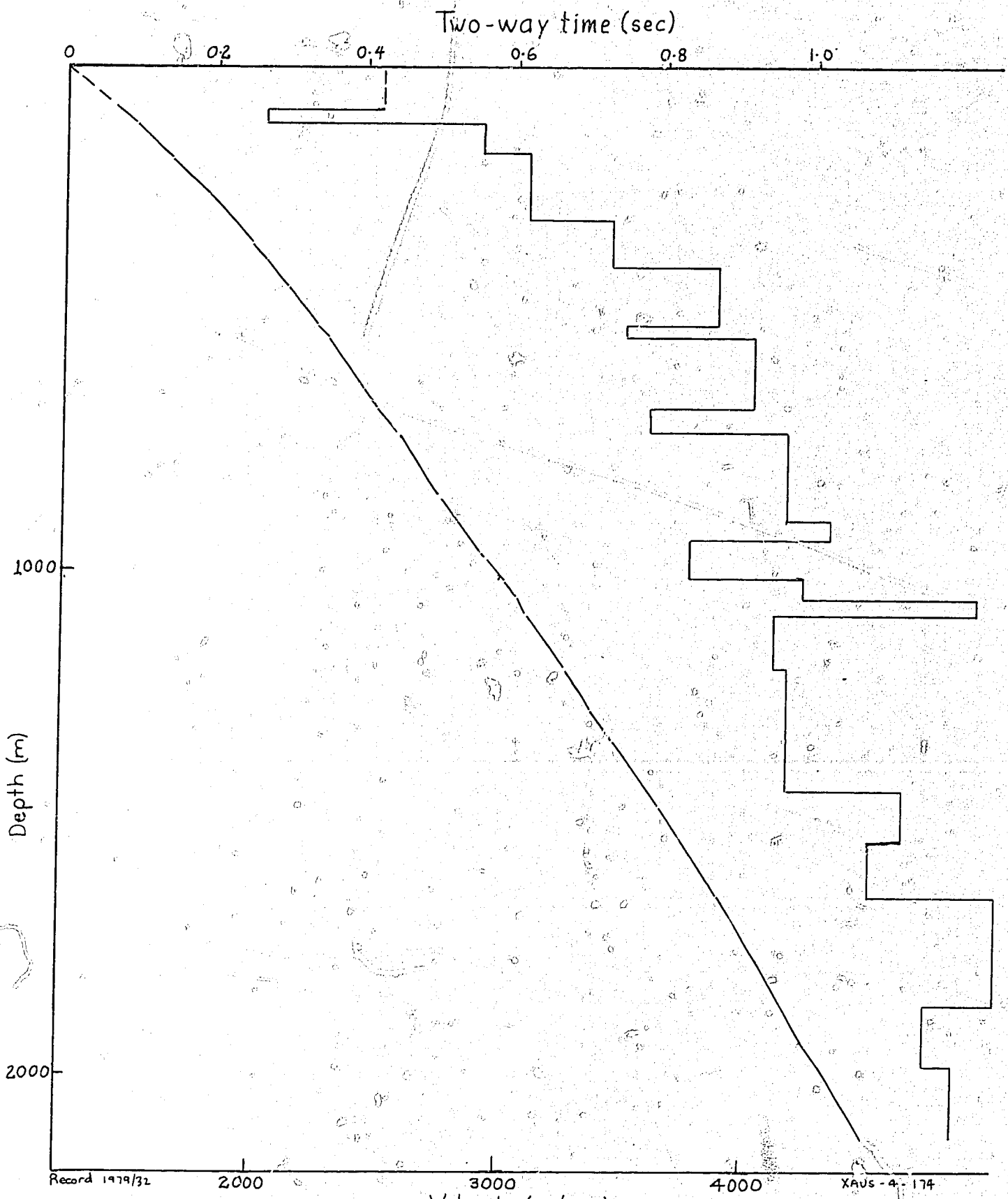


Napier No.4

Figure A 13.21

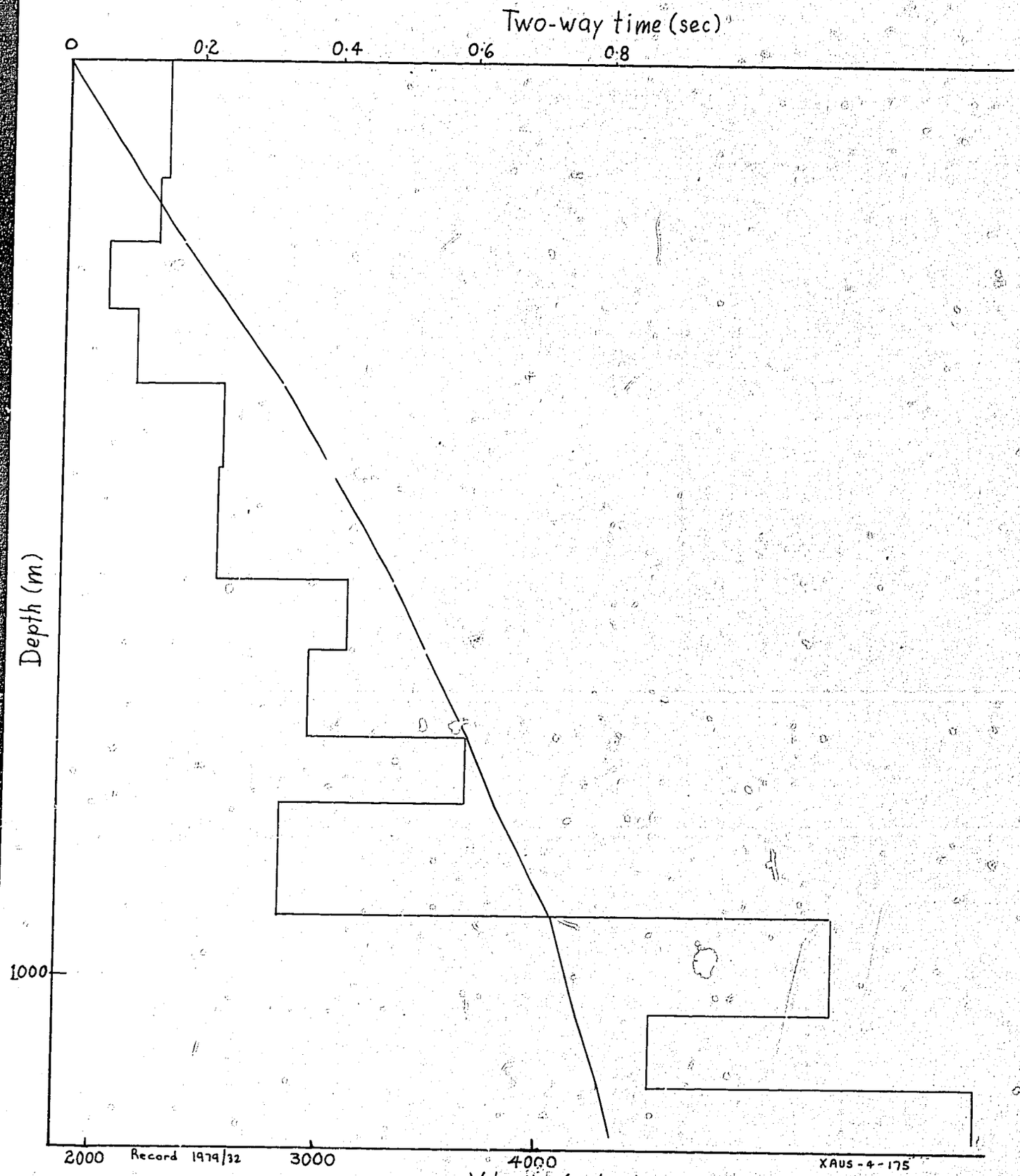


Velocity (m/sec)
Pender No. 1
Figure A13.22

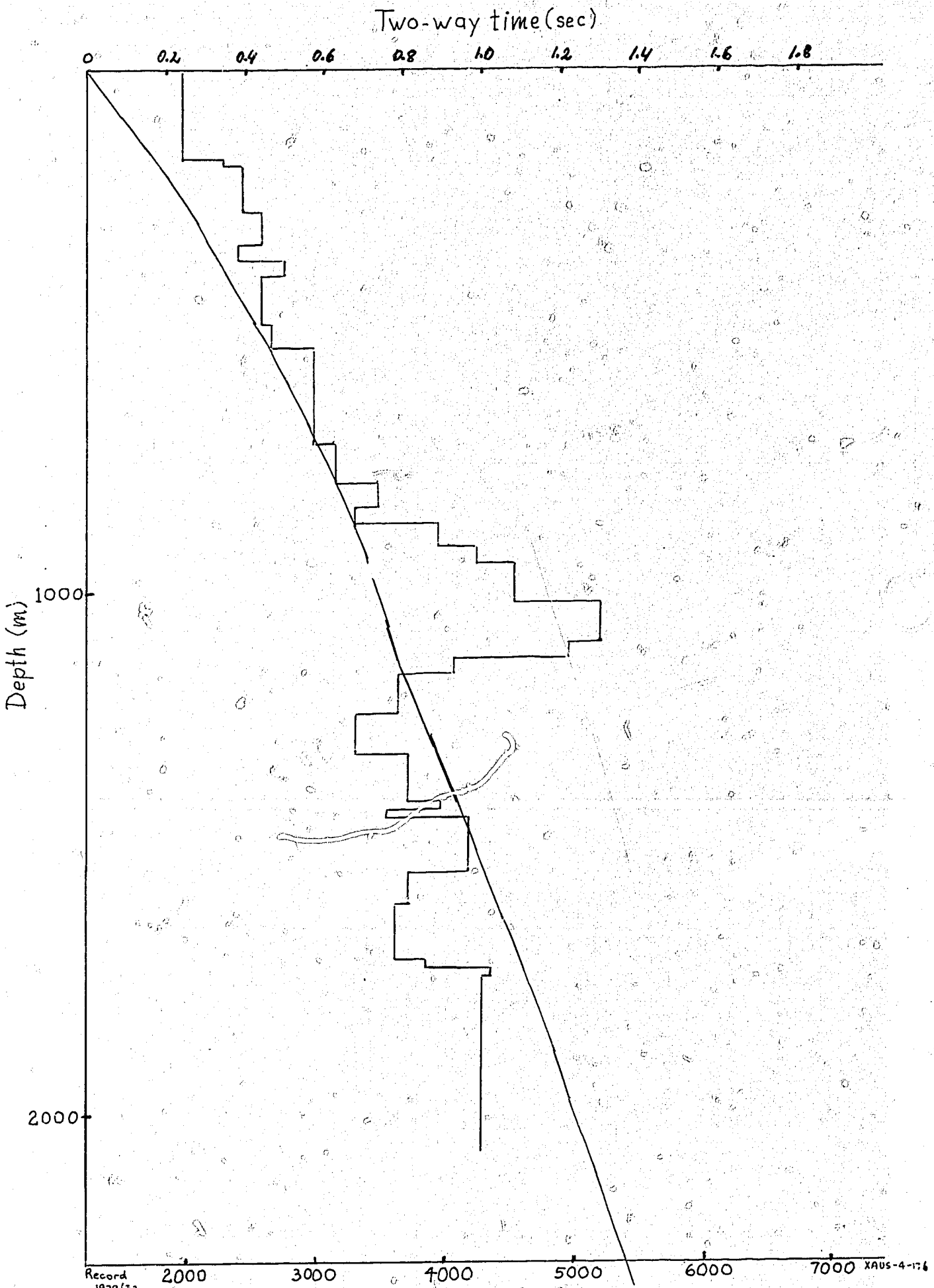


Point Moody No.1

Figure A13.23

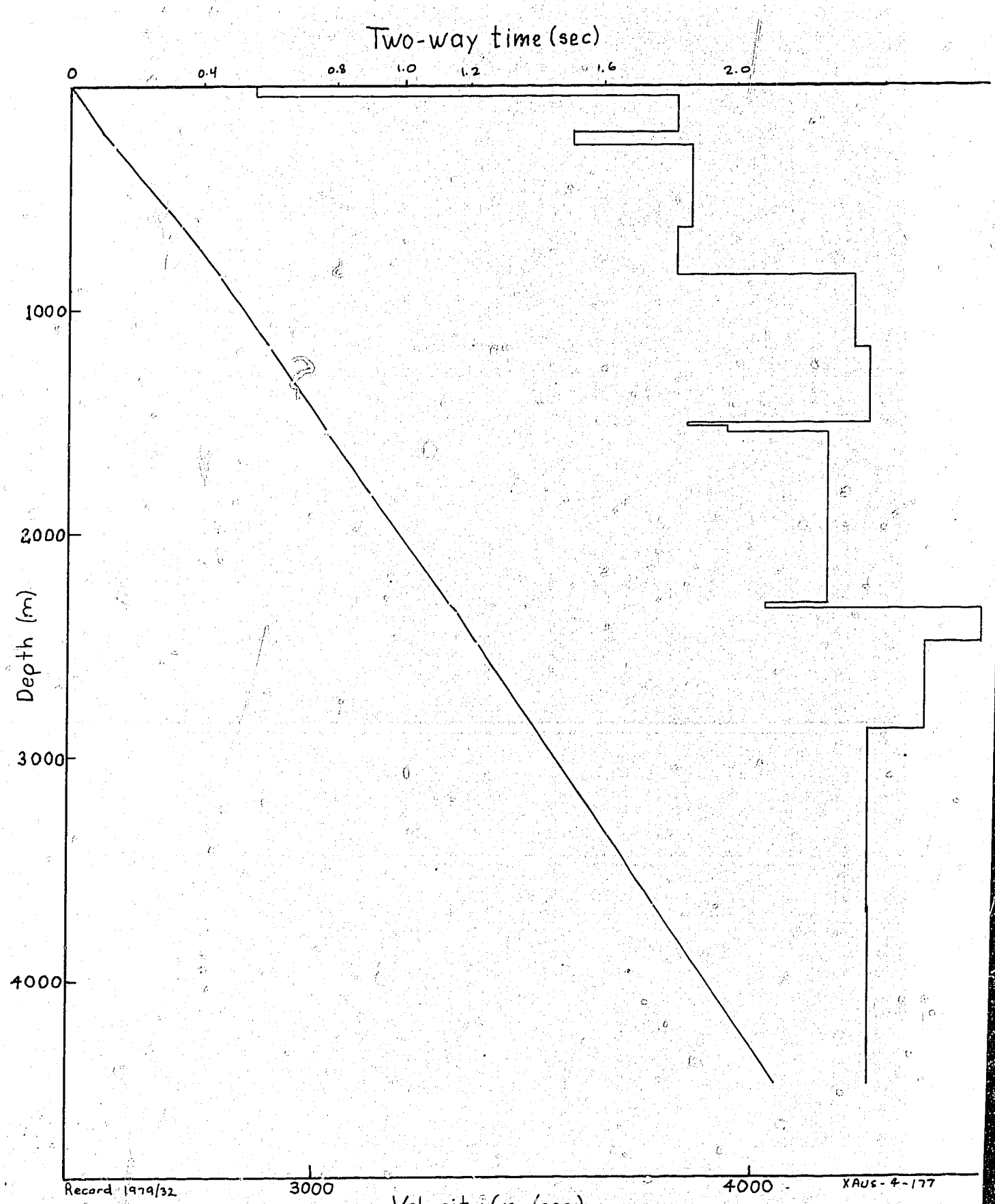


Roebuck Bay No.1
Figure A13.24



Sahara No.1

Figure A 13.25



St. Georges Range No.1
Figure A 13.26

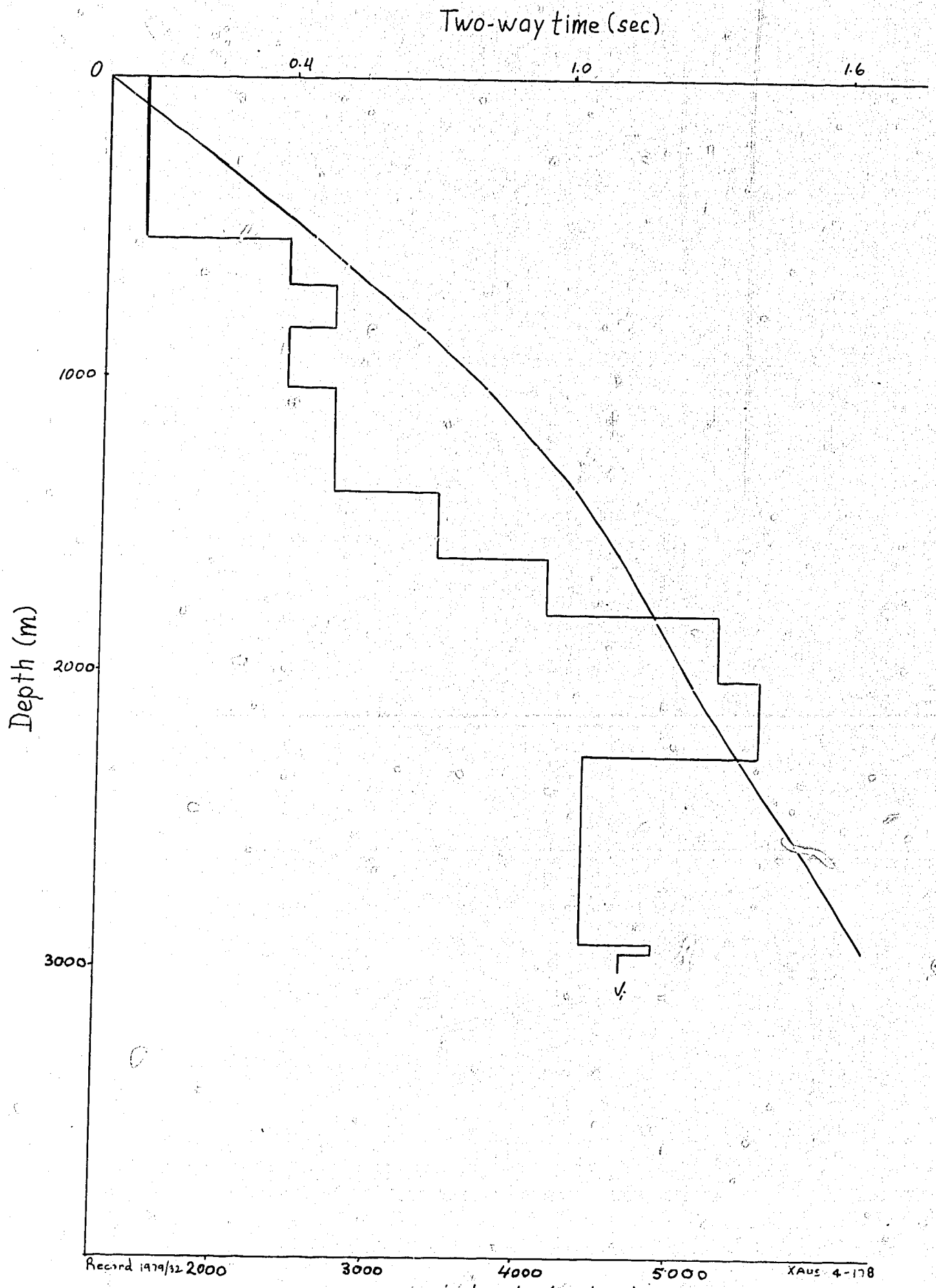
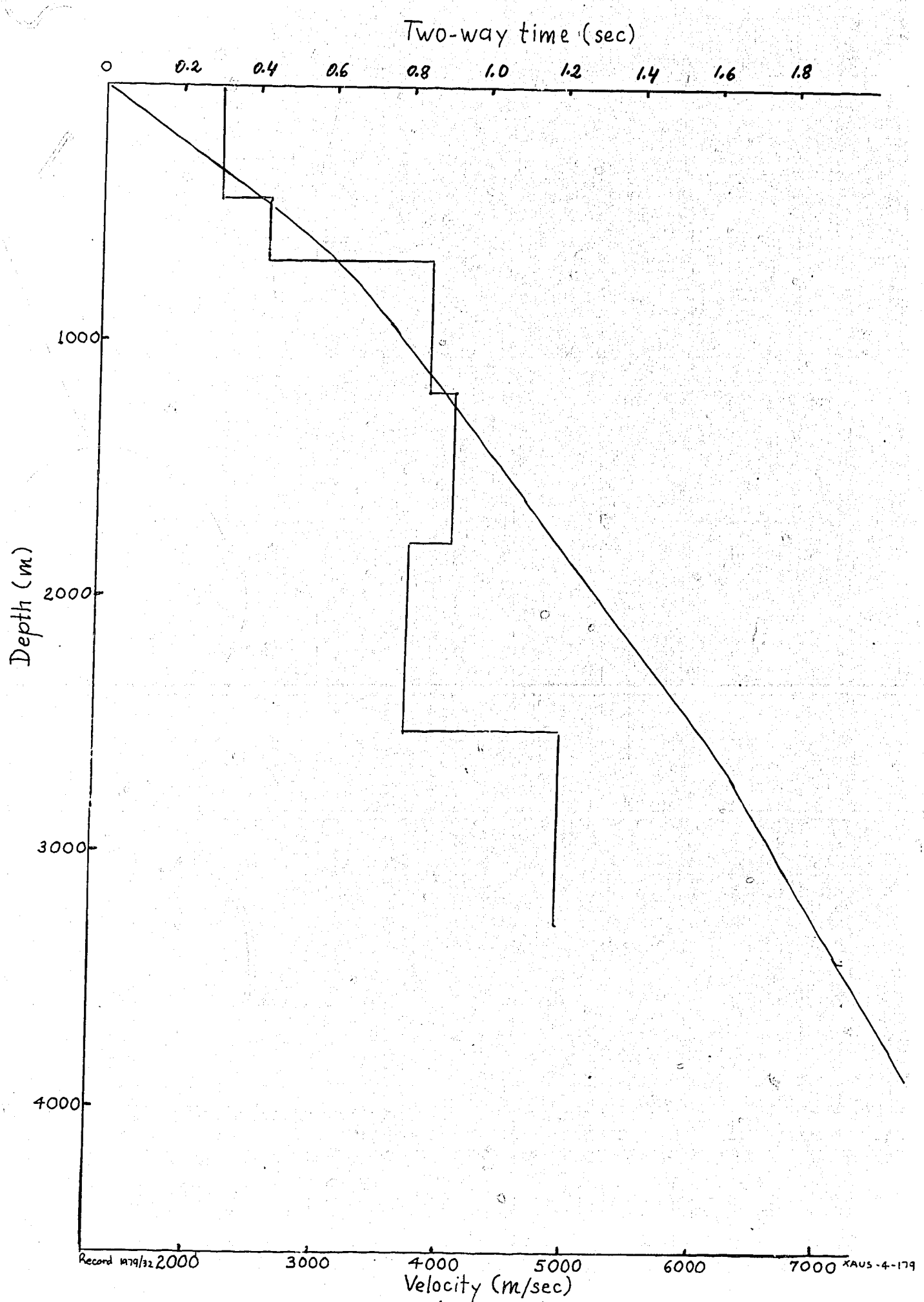
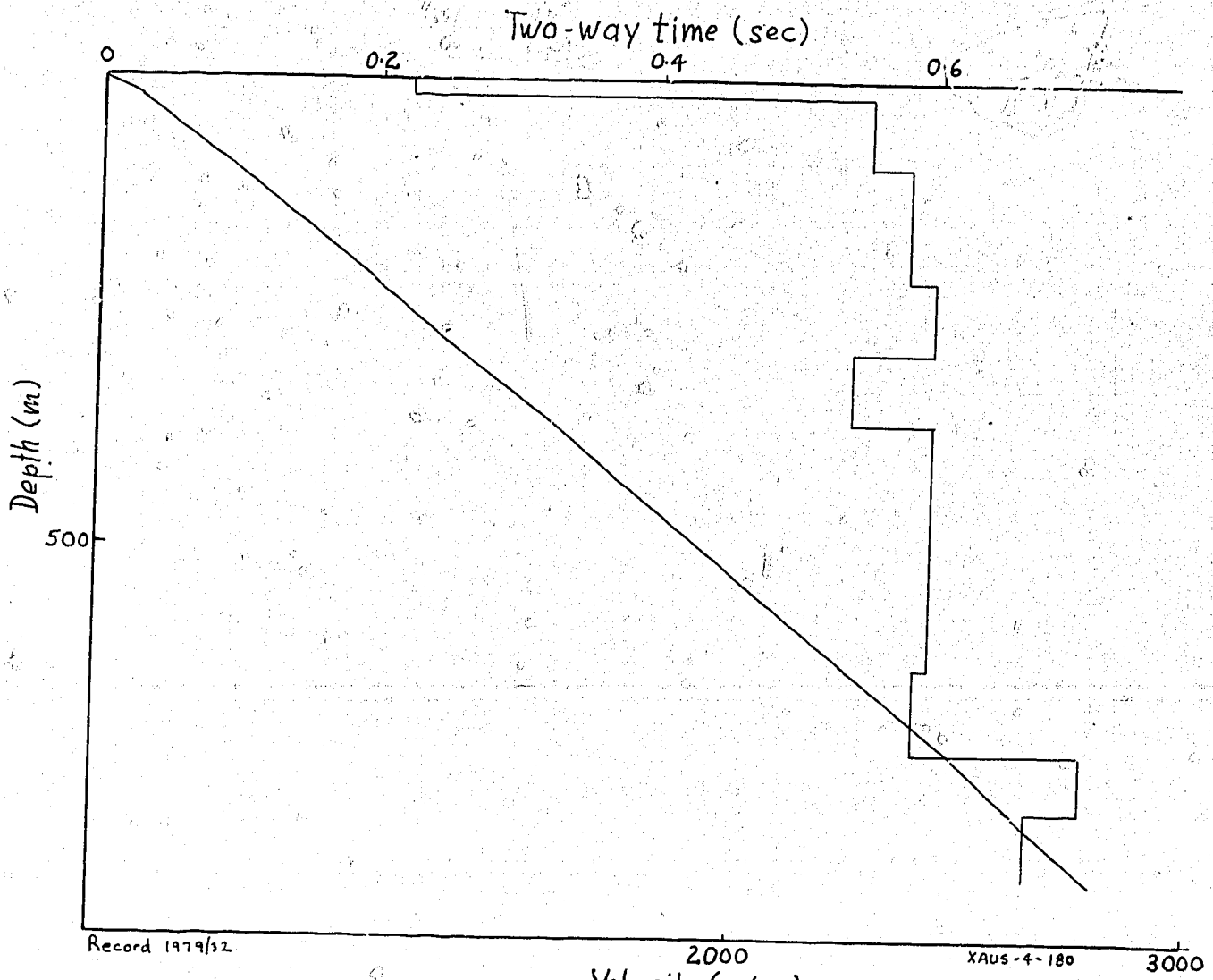


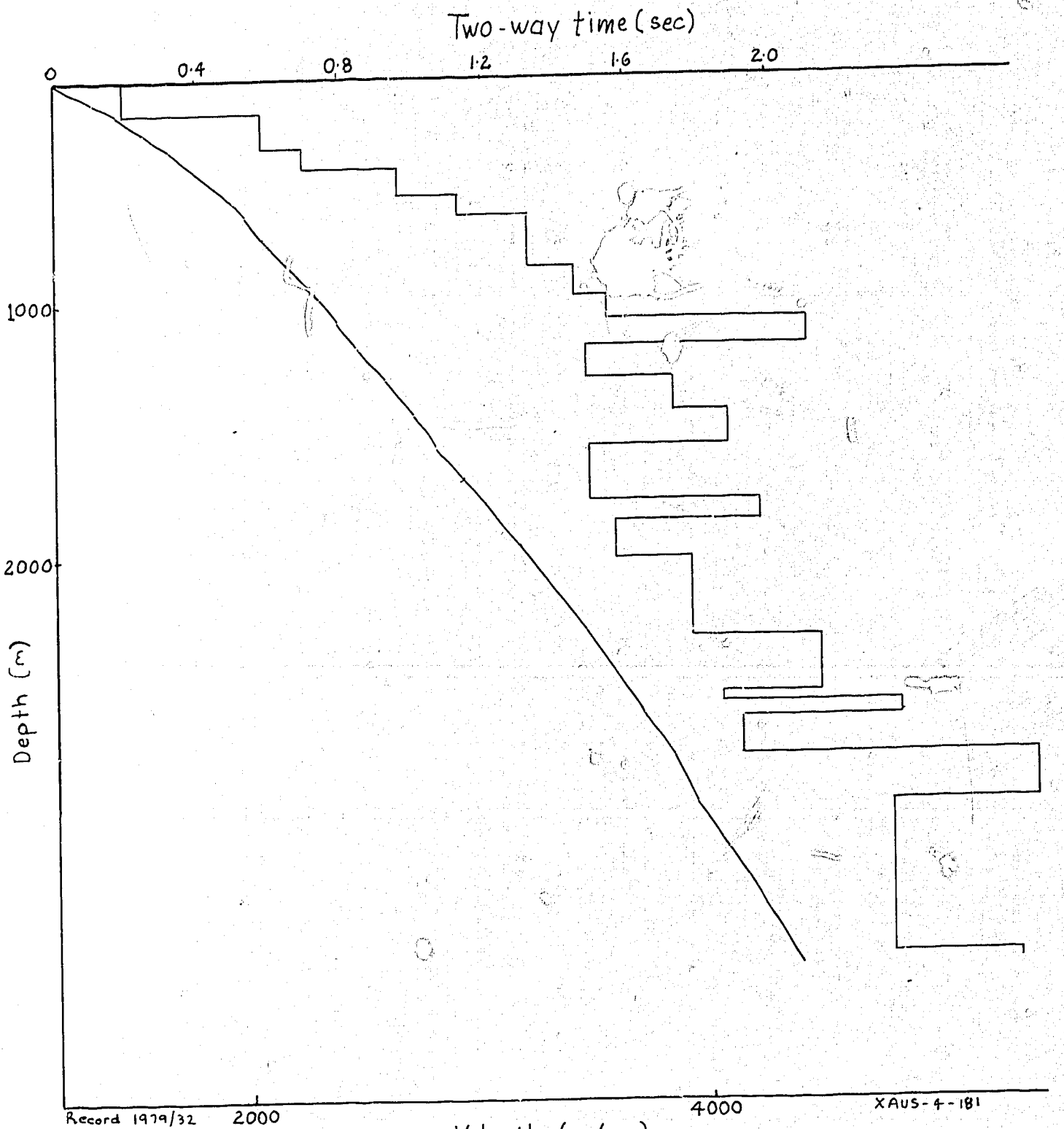
Figure A13-27 Tappers Inlet No.1



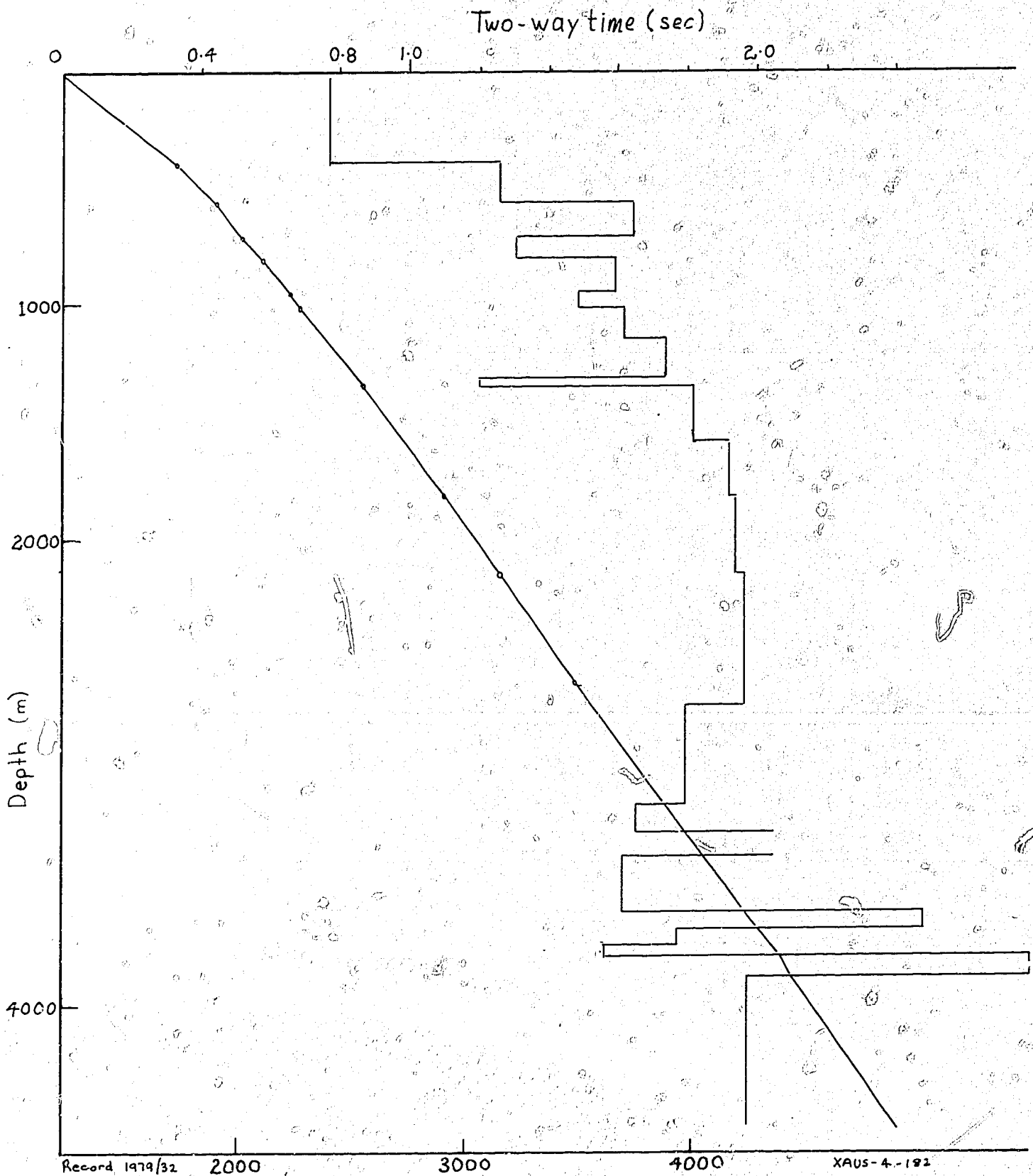
Willara No.1
Figure A13.28



Willara Hill No.1
Figure A13.29



Velocity (m/sec)
Wilson Cliffs No.1
Figure A 13.30



Yulleroo No.1.
Figure A13.31

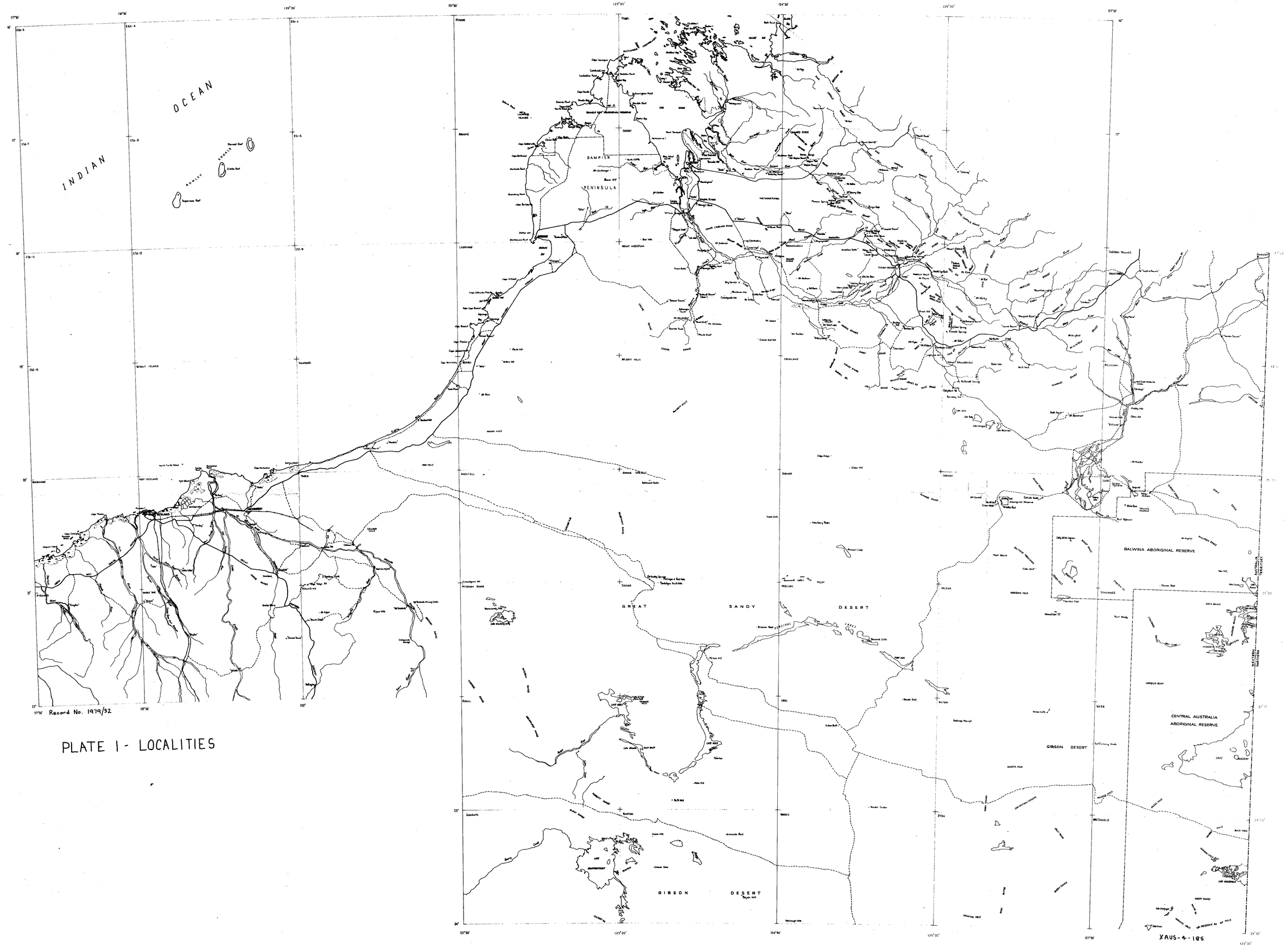


PLATE 1 - LOCALITIES

PLATE 2

CANNING BASIN
WESTERN AUSTRALIA
TOPOGRAPHY AND BATHYMETRY

0 — 100 — 200 km

Onshore Contour Interval 25m and 50m above mean sea level
Offshore Contour Interval 50m below mean sea level

INDIAN OCEAN

Rowley Shoals

WESTERN AUSTRALIA
NORTHERN TERRITORY

Explanatory Notes

1. Offshore, the contours below mean sea level were compiled from bathymetric data recorded on the seismic lines used in the Canning Basin Study. The 4000m contour was taken from Falvey (1972 a)
2. Onshore, the contours were produced from elevations measured during the course of gravity surveys and stored in the BMR Gravity Data Bank. These data are mainly barometric levels and are accurate to ±15 m.

XAUS-4-54

Record No 1979/32

PLATE 3 - SOLID GEOLOGY MAP

INDIAN OCEAN

IRONLEY SHOALS

4000m

200m

BASIN

MARGIN

PINNACLE FAULT

DUMPIER

FENTON FAULT

RANGE FAULT

MUELLER FAULT

STANSMORE FAULT

AUSTRALIA
WESTERN
NORTHERN
TERRITORY

Probable subcrop of 6 beneath

Probable subcrop of 10 beneath

Probable subcrop of 9

Probable subcrop of 8

Probable subcrop of 7

Scale 1:2500000

50 0 50 100 km

Simple Conic Projection with Standard Parallels 18°S and 36°S

	INTERVAL
CAINOZOIC	11
	10
CRETACEOUS	9
	8
	7
JURASSIC	6
TRIASSIC	5
PERMIAN	4
CARBONIFEROUS	3
DEVONIAN	2
SILURIAN	
ORDOVICIAN	1
CAMBRIAN	
PRECAMBRIAN	pε

Fault – onshore generalised from Basin Studies Group structure contour map for Base of Interval 4 and White & Yeates (1976); offshore generalised from Basin Studies Group structure contour map for Base of Interval 6

Geological boundary of interval. Generalised from Veevers & Wells (1960), Yeates & others (1975b), Towner & others (1976) and Basin Studies Group interpretation

Geological boundary showing subcrop of Interval

Fault inferred

6-8 ?

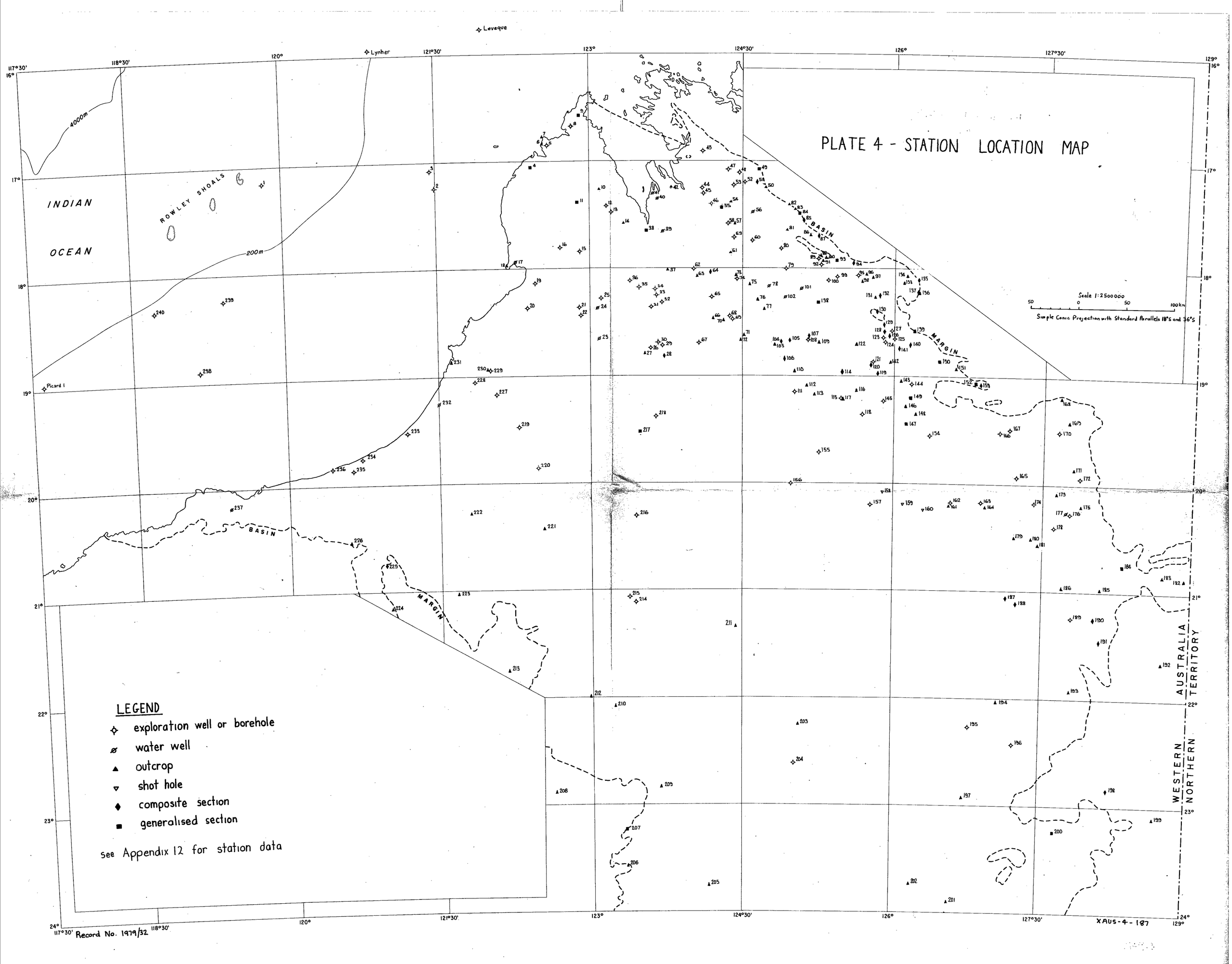
117°30' 118°30' 120° 121°30' 123° 124°30' 126° 127°30' 129°

16° 17° 18° 19° 20° 21° 22° 23° 24°

Record No. 1979/32

XAUS-4-186

PLATE 4 - STATION LOCATION MAP



Record No. 1979/32

XAUS-4-187

PLATE 5 – SEISMIC LINE AND WELL CONTROL LOCATION.

Scale 1:2 500 000

50 0 50 100 km

Simple Conic Projection with Standard Parallels 18°S and 36°S

LOCATION DIAGRAM



REFERENCE

- PETROLEUM EXPLORATION WELLS (REFER PLATE 16 TABLE 2.6.1 FOR NAME OPERATOR & TD)
- SEISMIC LINES SHOWING YEAR & LINE NUMBER.
- DASHED LINE INDICATES DATA FROM UNSUBSIDISED SURVEY.
- 68 SURVEY INDEX NUMBER (REFER TABLE 2.5.1)
- Derby TOWN

117°30' Record No. 1979/52 118°30'

XAUS-4-188

PLATE 6. - GRAVITY SURVEYS

INDIAN OCEAN

ROWLEY SHOALS

4000m

200m

BASIN

MARGIN

Scale 1:2500000

50 0 50 100 km

Simple Conic Projection with Standard Parallels 19°S and 36°S

LOCATION DIAGRAM

CANNING BASIN

WA NT QLD SA NSW VIC

6739 Area covered by gravity survey showing survey index number (6739)

For further detail, refer Table 2.2.1

Record No. 1979/32

XAUS-4-189

AUSTRALIA

WESTERN TERRITORY

NORTHERN

PLATE 7 - BOUGUER ANOMALY CONTOURS ONSHORE AND FREE AIR ANOMALIES OFFSHORE

Scale 1:2500000

50 0 50 100km

Single Cone Projection with Standard Parallels 18°S and 36°S

Data source BMR Gravity Data Bank

Contour interval 5 mgals

Sampling grid for contouring - 4 minutes of arc

Bouguer density 2·2 g/cm³

5 Bold numbers indicate anomalies referenced in text

Record No. 1979/32

XAUS-4-190

PLATE 8 - RESIDUAL TOTAL MAGNETIC INTENSITY

CONTOUR INTERVAL 50 nanoteslas

Scale 1:2500000

50 0 50 100km

Simple Conic Projection with Standard Parallels 18°S and 36°S

No Contoured Data

BASIN

MARGIN

BASIN

MARGIN

WESTERN AUSTRALIA

NORTHERN TERRITORY

After BMR, 1976 - Magnetic Map of Australia, Residuals of Total Intensity

Explanatory notes

1. The onshore data were compiled from aeromagnetic surveys adjusted to fit independent absolute Total Magnetic Intensity Data from which regional magnetic background was removed. The data were then upward continued to 3000 m above sea level.

2. The offshore data were compiled from BMR marine surveys from 1967 to 1973 and were adjusted to residuals by subtracting the Australian Geomagnetic Reference Field. The data give Total Magnetic Intensity residuals at sea level

117°30' 118°30' 120° 121°30' 123° 124°30' 126° 127°30' 129°

16° 17° 18° 19° 20° 21° 22° 23° 24°

Record No. 1979/32

XAUS-4-191

PLATE 9

Canning Basin Crystalline Basement Composition

INDIAN OCEAN

ROWLEY SHOALS

Pilbara Block metasediments, granites and Banded iron formations

Granite or low density metamorphics

High grade metamorphics

Granite

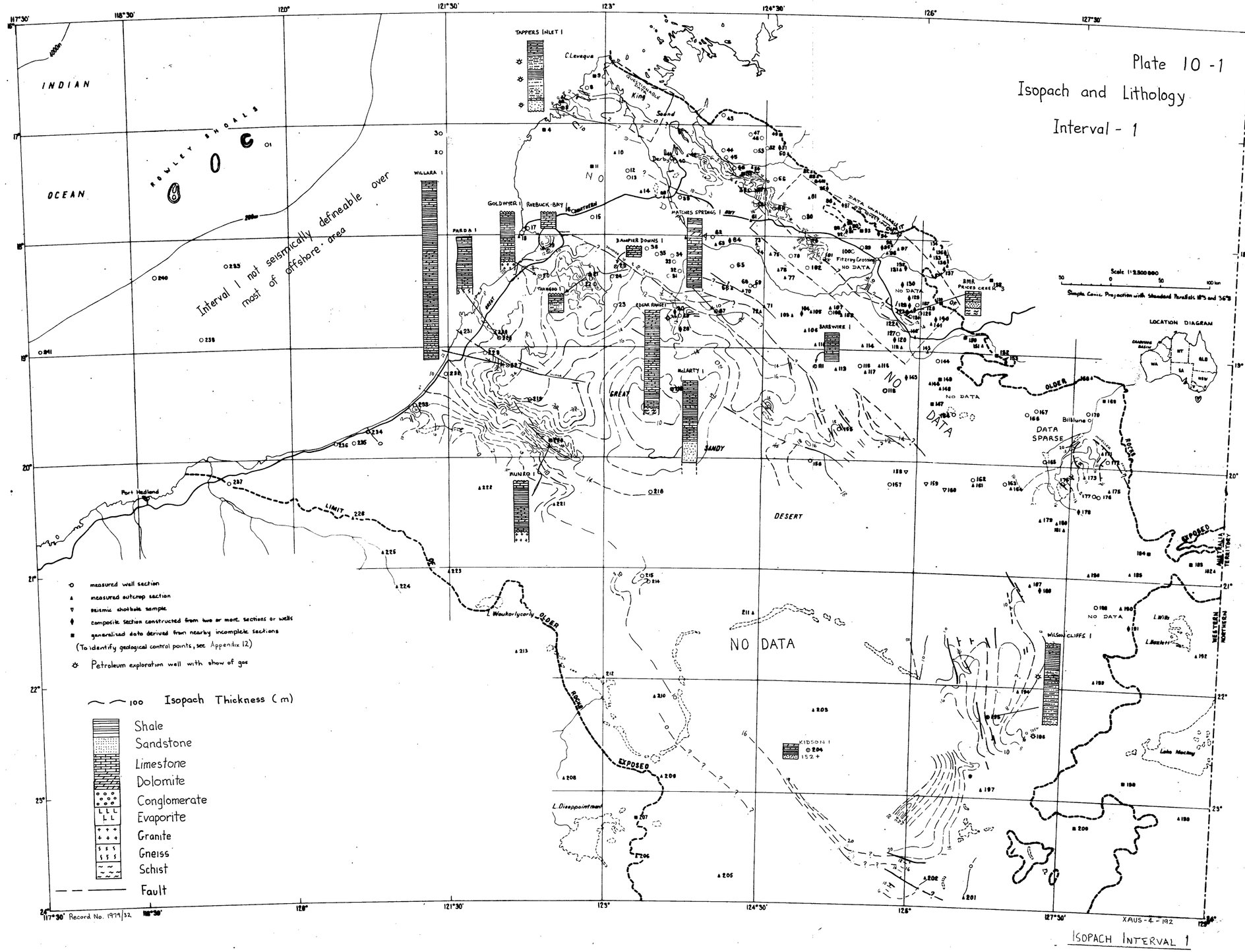
Granite

Granite

Plate 10-1

Isopach and Lithology

Interval - 1



Record No. 1979/32

XAUS-4-192

ISOPACH INTERVAL 1

MAP 10.1

Plate 10 - 2

Isopach and Lithology

Interval - 2

Interval 2 not seismically defineable over most of offshore area

Possibly present in this area

Scale 1:2 500 000

50 0 50 100 km

Simple Conic Projection with Standard Parallels 18°S and 36°S

LOCATION DIAGRAM

- measured well section
- measured outcrop section
- seismic shothole sample
- composite section constructed from two or more sections or wells
- generalised data derived from nearby incomplete sections

(To identify geological control points, see Appendix 12)

100 Isopach thickness (m)

Shale and siltstone
Sandstone
Limestone
Dolomite
Evaporite

Fault

INDIAN OCEAN

ROWLEY SHOALS

King Sound

Broome

Derby

Fitzroy Crossing

Port Hedland

L. Waukarlycarly

L. Diaeppointment

L. Wills

L. Mackay

Lake Betty

Billiluna

EXPOSED

EXPOSED

DESERT

GREAT SANDY

LIMIT

LIMIT

OLDER ROCKS

OLDER ROCKS

EXPOSED

WESTERN AUSTRALIA NORTHERN TERRITORY

TAPPERS HOLST 1

PAROO 1

EDGAR RANGE 1

MATCHES SPRINGS 1

McLARTY 1

GARDNER 1

CROSSLANDS 1

EAST TRAVERS 1

EAST WILLARA 1

WONDA 1

MUNRO 1

KEMP FIELD 1

SAHARA 1

KIDSON 1

WILSON CLIFFS 1

Record No. 1979/32

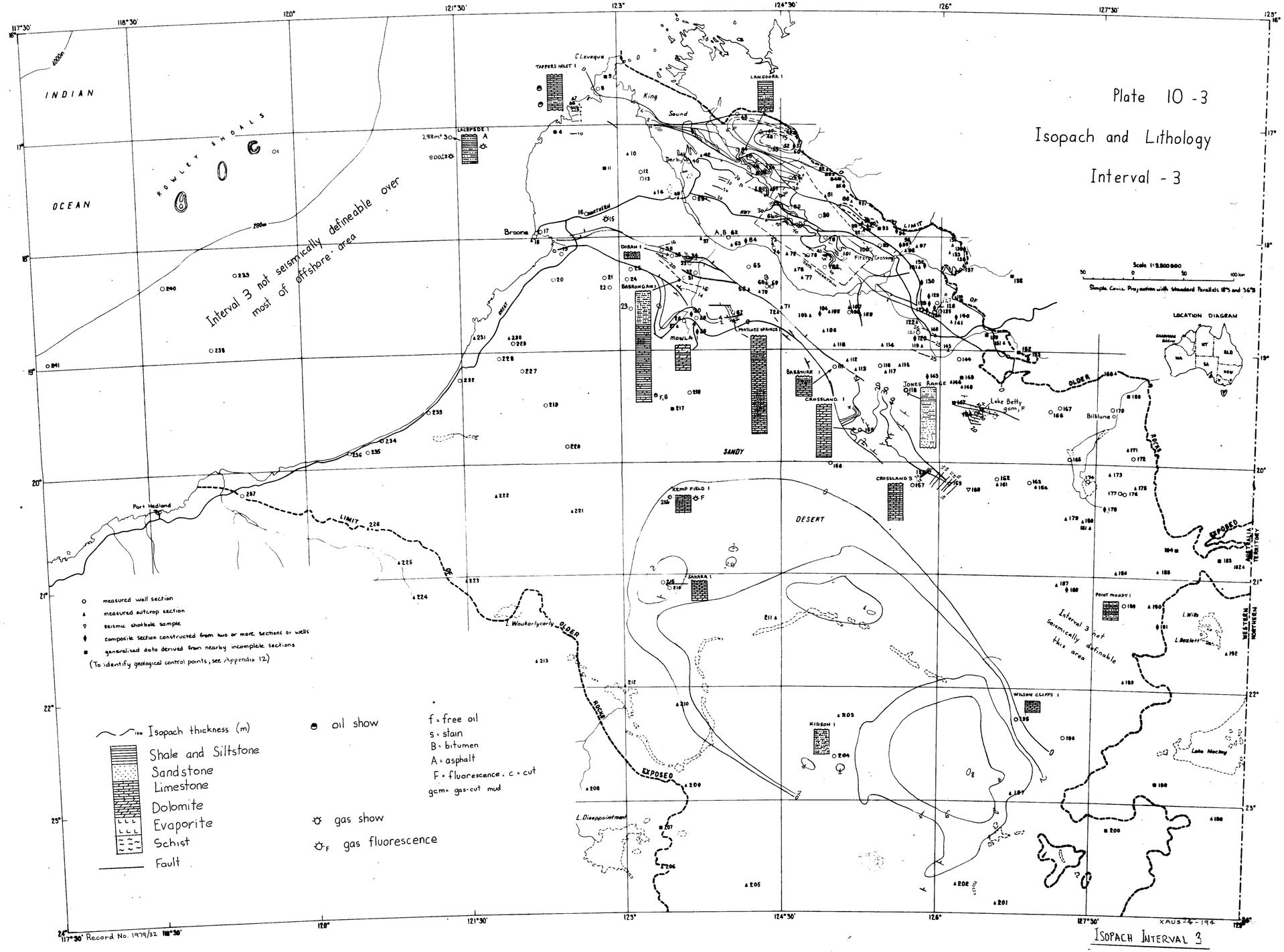
XAUS - 4 - 193

ISOPACH INTERVAL 2
+ GROSS LITHOLOGY
MAP 10-2

Plate 10 - 3

Isopach and Lithology

Interval - 3



Record No. 1979/32

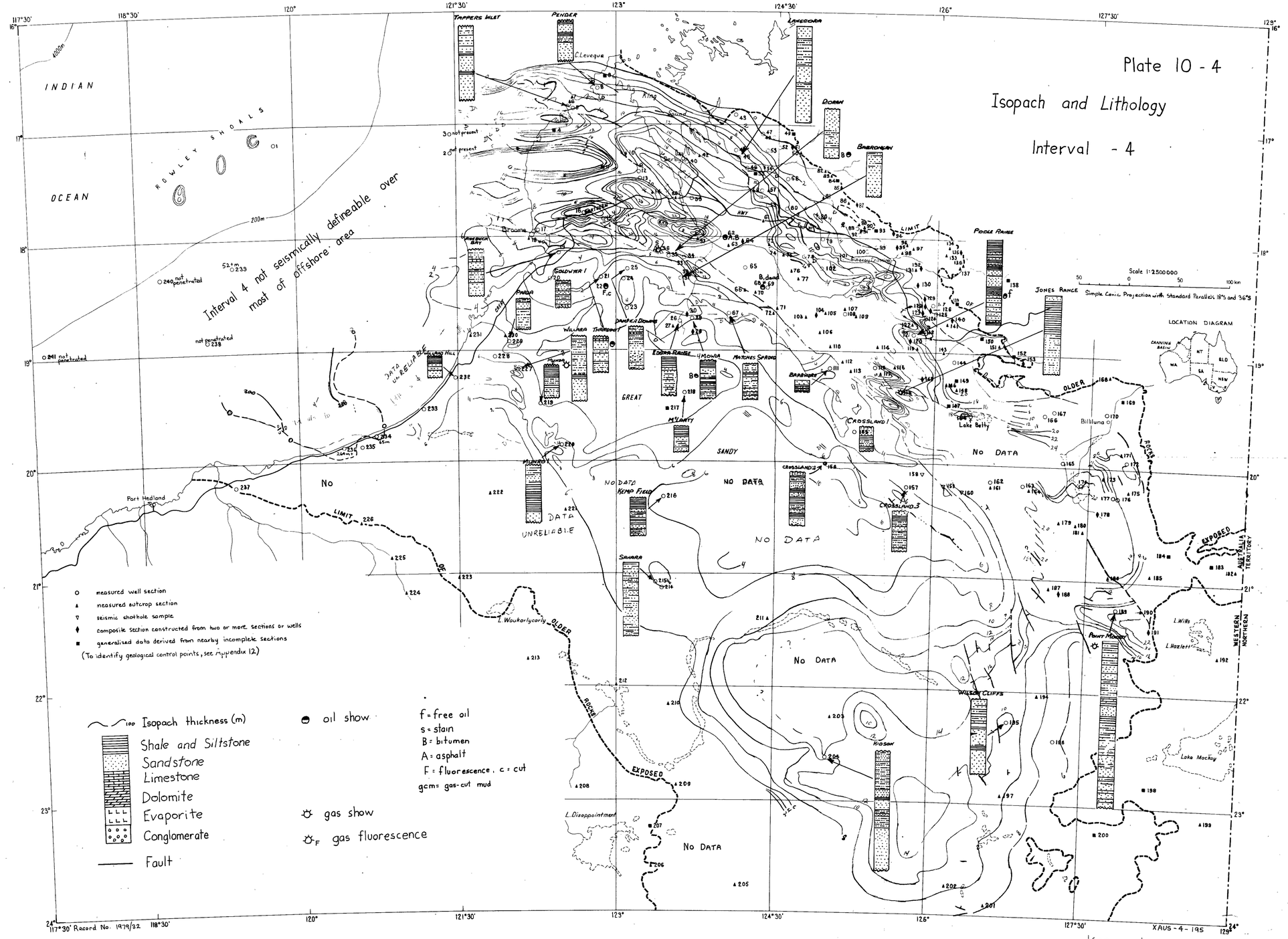
ISOPACH INTERVAL 3

MAP 10.3

Plate 10 - 4

Isopach and Lithology

Interval - 4



ISOPACH INTERVAL 4

MAP 10-4

Record No. 1979/32

Plate 10 - 5

Isopach and Lithology

Interval - 5

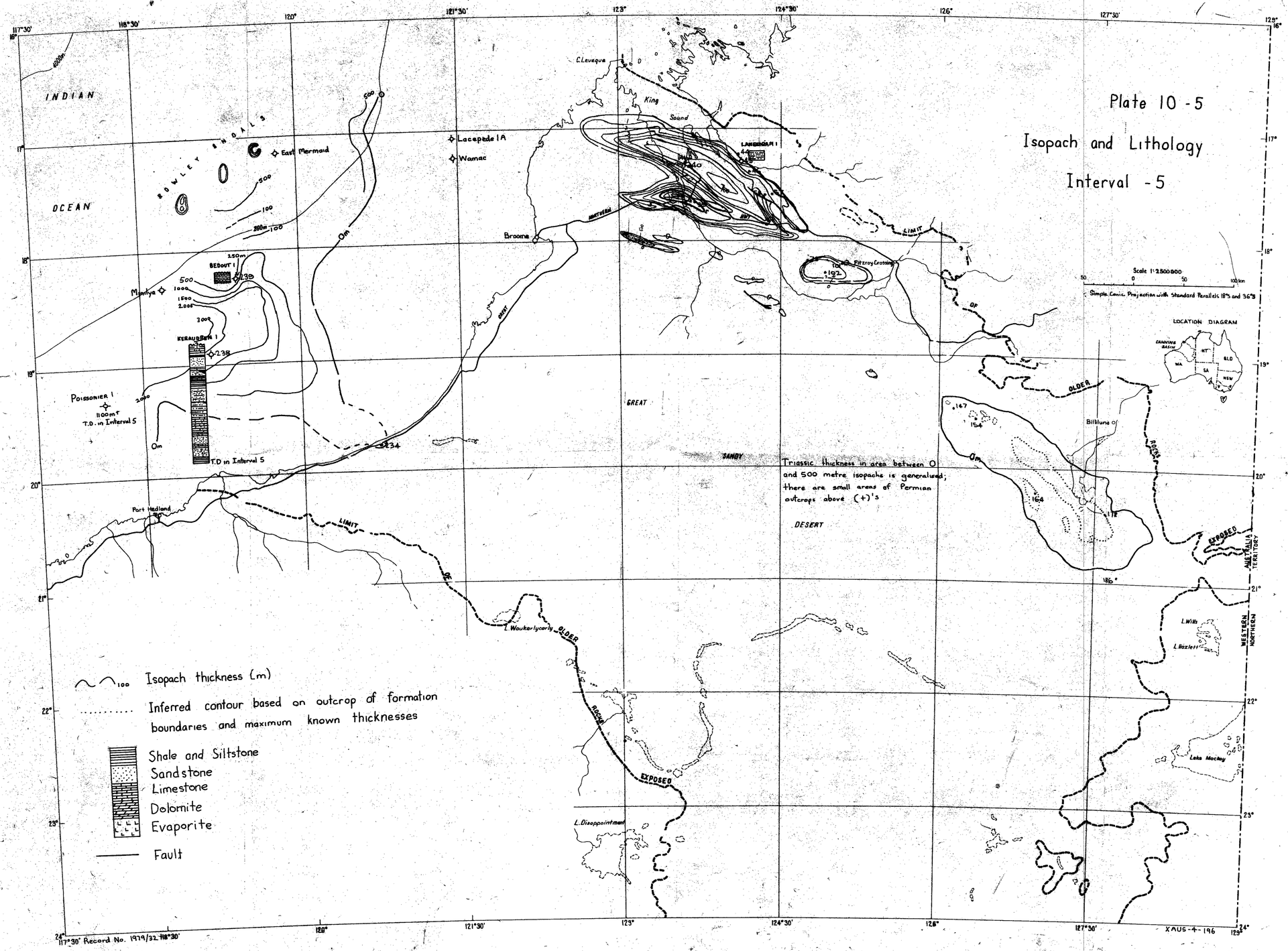
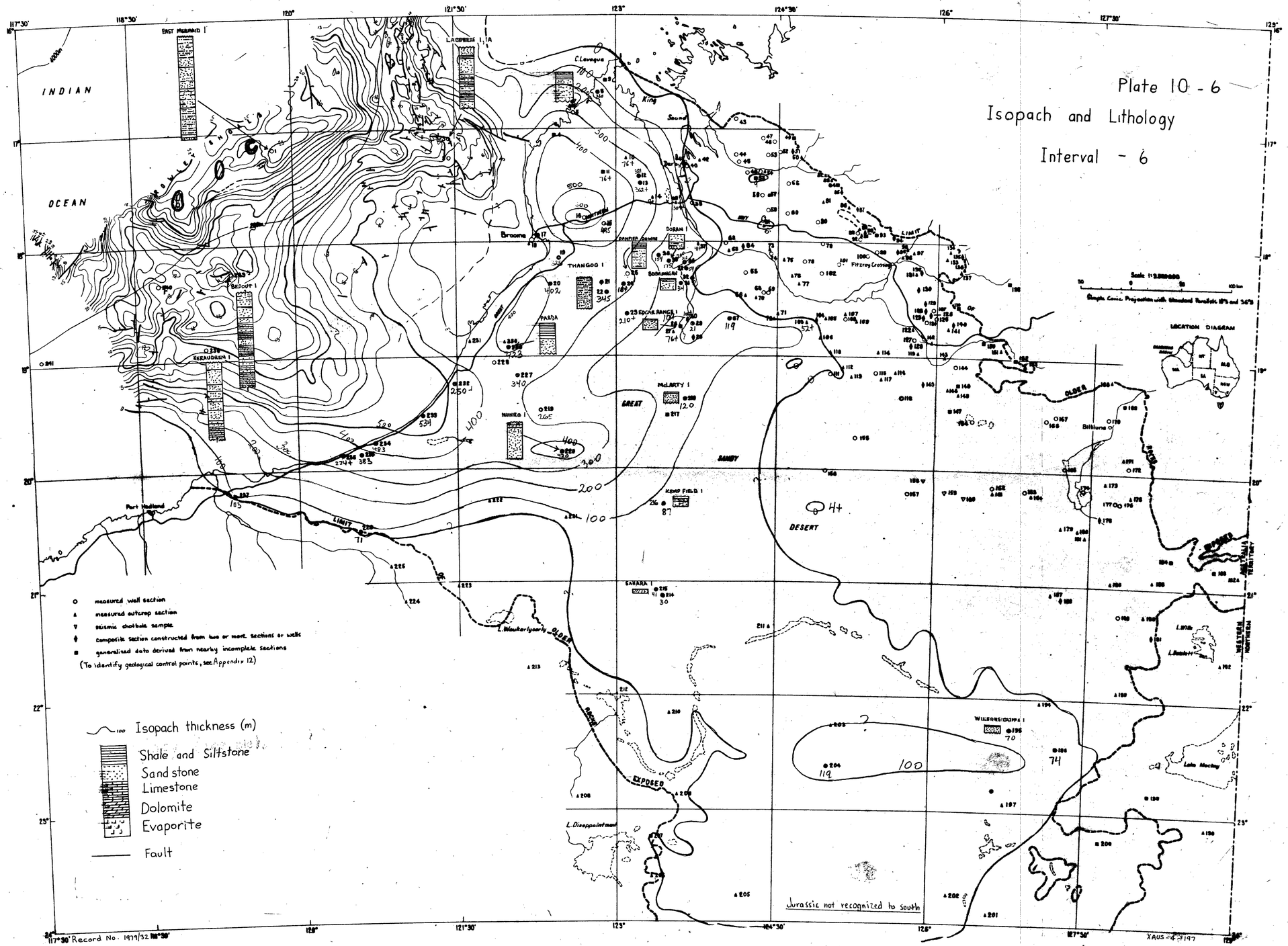


Plate 10 - 6

Isopach and Lithology

Interval - 6



Record No. 1979/32

ISOPACH INTERVAL 6
+GROSS LITHOLOGY

MAP 10.6

Plate 10 - 7

Isopach and Lithology

Interval - 7

INDIAN OCEAN

Broome

Port Hedland

King Sound

GREAT SANDY DESERT

EXPOSED

Scale 1:2,500,000

Simple Conic Projection with Standard Parallels 18°S and 36°S

LOCATION DIAGRAM

- measured well section
- measured outcrop section
- seismic shotbole sample
- composite section constructed from two or more sections or wells
- generalised data derived from nearby incomplete sections

(To identify geological control points, see Appendix 12)

— — — Limit of reliable data

~100 Isopach thickness (m)

Shale and Siltstone
Sandstone
Limestone
Dolomite
Evaporite

Fault

☼ gas show

Record No. 1979/32

ISOPACH INTERVAL 7

amended 15-10-75

+ GROSS LITHOLOGY

MAP 10.7

Plate 10 - 8

Isopach and Lithology

Interval - 8

Isopach thickness (m)

Shale and Siltstone

Sandstone

Limestone

Dolomite

Evaporite

Fault

Scale 1:2500000

Simple Conic Projection with Standard Parallels 18°S and 36°S

LOCATION DIAGRAM

ISOPACH INTERVAL 8
+ GROSS LITHOLOGY

MAP 10-8

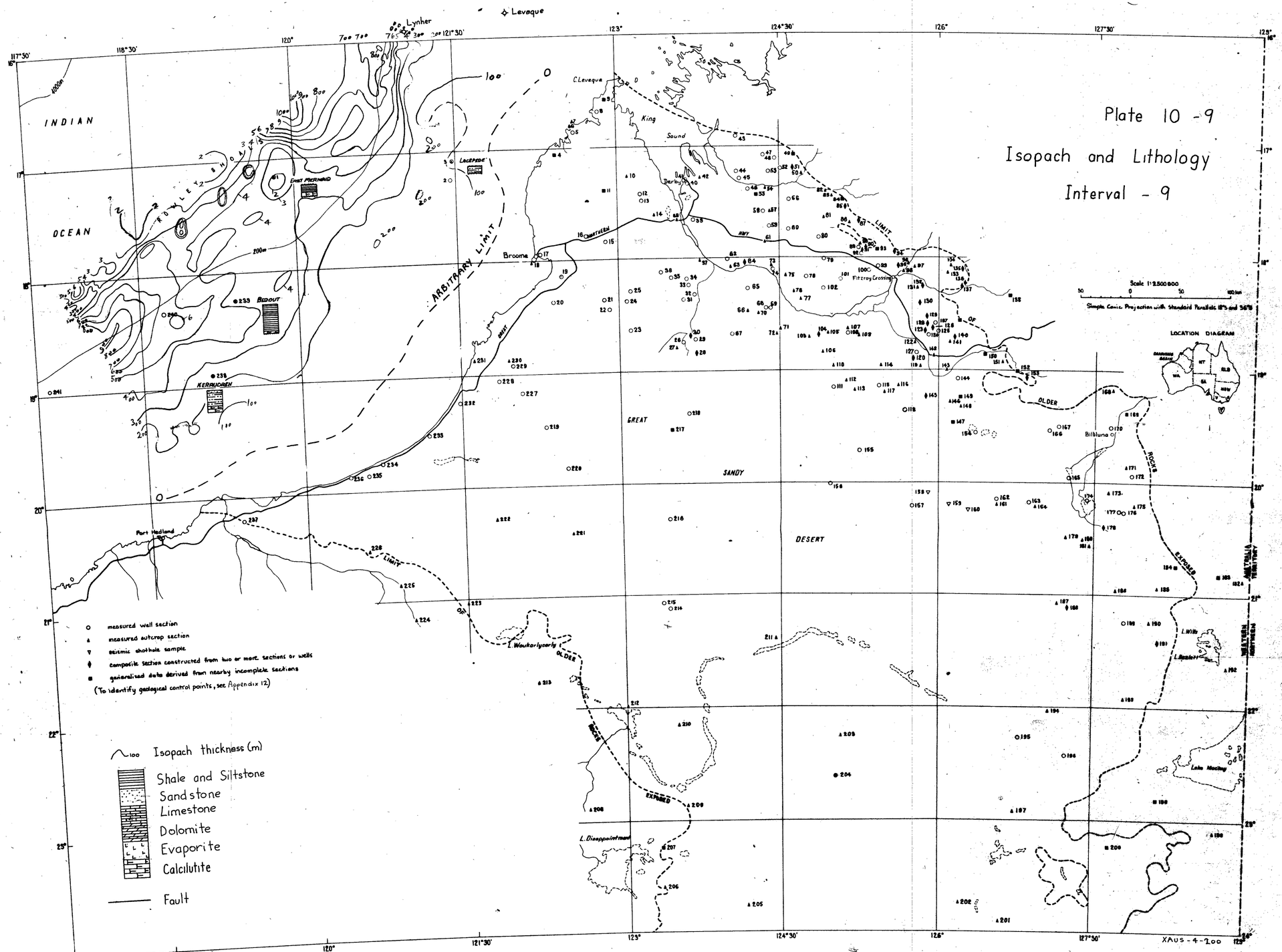
J. Carter

Record No. 1979/32. XAUS-4-199

Plate 10 - 9

Isopach and Lithology

Interval - 9



ISOPACH INTERVAL 9 - Canning Basin
+ GROSS LITHOLOGY
Author Objective Base Map

XAUS-4-100

Record No. 1979/32

MAP 10-9

Plate 10 - 10

Isopach and Lithology

Interval - 10

measured well section
measured outcrop section
seismic shothole sample
composite section constructed from two or more sections or wells
generalised data derived from nearby incomplete sections
(To identify geological control points, see Appendix 12)

100 Isopach thickness (m)

Shale and Siltstone
Sandstone
Limestone
Dolomite
Evaporite
Calcarenite

Fault

Scale 1:2,500,000
50 0 50 100 km
Simple Conic Projection with Standard Parallels 18°S and 36°S

LOCATION DIAGRAM

ISOPACH INTERVAL 10 + GROSS LITHOLOGY

Canning Basin
Author Objective Base Map
MAP 10.10

117°30' Record No. 1979/32 118°30'
XAus-4-201

Plate 10 - 11

Isopach and Lithology

Interval - 11

Scattered thin deposits of interval 11 up to 200m thick over most of onshore basin

- measured well section
- measured outcrop section
- seismic shothole sample
- composite section constructed from two or more sections or wells
- generalised data derived from nearby incomplete sections

(To identify geological control points, see Appendix 12)

Isopach thickness (m)

Shale and Siltstone
Sandstone
Limestone
Dolomite
Evaporite
Calcilutite
Calcarenite
Marl
Calcirudite

Fault

Scale 1:2 500 000

Simple Conic Projection with Standard Parallels 18°S and 36°S

LOCATION DIAGRAM

ISOPACH INTERVAL 11 - Canning Basin
+ GROSS LITHOLOGY

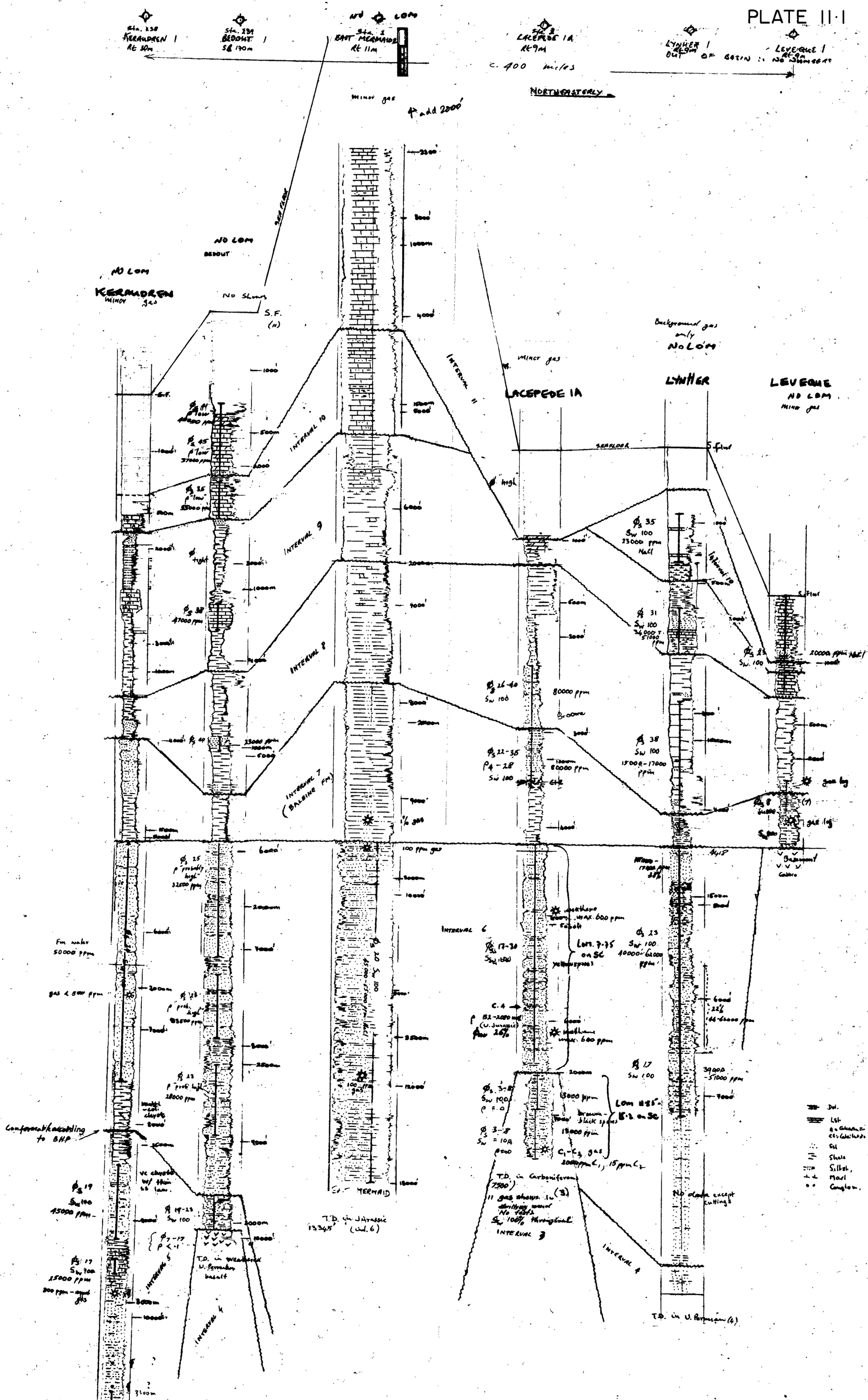
Author Objective Base Map

MAP 10·11

Record No. 1979/32

XAUS-4-202

PLATE II·1



Record No. 1979/32

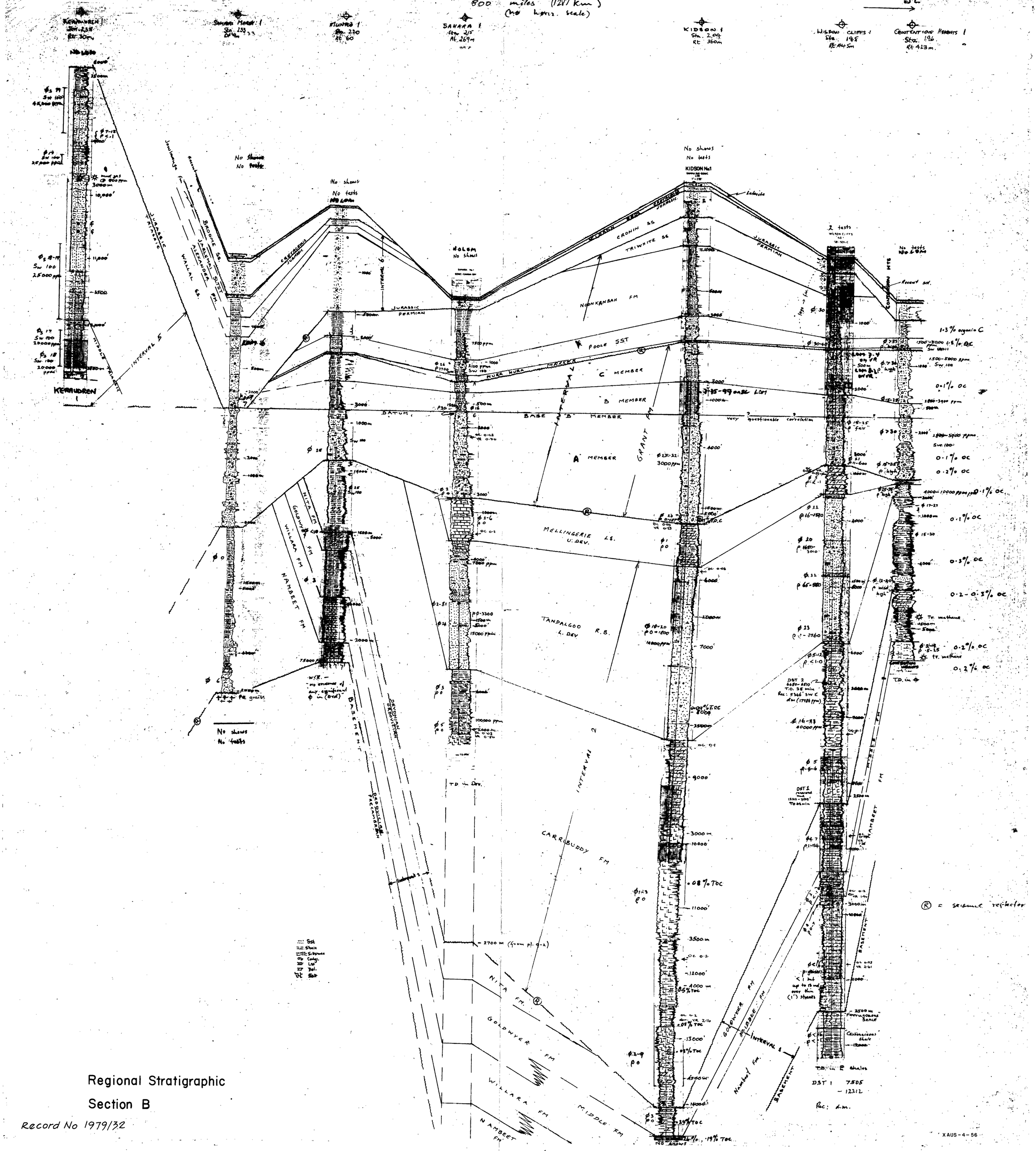
Regional Stratigraphic Section A

XAUS-4-55

PLATE 11.2

800 miles (1287 km)
(no horiz. scale)

SE →



Regional Stratigraphic
Section B

Record No 1979/32

XAUS-4-56

PLATE 11·3

CHIRUP 1 Sta. 236 RE 5m. | WALLAL 4&4A Sta. 234 RE 10m | SAMPHIRE MARSH 1 Sta. 233 DF 9m | WILLARA 1 Sta 227 RE 81m | PARDA 1 Sta. 229 RE 107 | GOLDWYER 1 Sta. 20 RE 82m | ROEBUCK BAY 1 Sta. A DF 62m | BARLEE 1 Sta. 16 DF 23m | FRASER R. 1 Sta. 12 DF 58m | PENDER 1 Sta. 8 RE 20m

450 miles

SAMPHIRE MARSH

SMR 49A WALLAL

NO LOM CHIRUP NJ

NO LOM

RECENT

BROOME SS

JOWLAENGAR

JARLEMAI

ALEXANDER

GRANT FM B member

GRANT FM A member

INTERVAL A

INTERVAL B

DATUM

No Shows No tests

NO LOM no tests

3 tests — sw "H"

NO LOM

No Shows No tests

BARLEE

EMERIAN ?

BROOME SS

Jarlemai ?

WALLAL

POOLE

GRANT FM C member

JURASSIC PERMIAN

No Shows No Lom

NO LOM PENDER

Lom ? R (max) 0.34

WALLAL

POOLE

NEOCOMIAN ?

ALBIAN

GRANT C

GRANT B

GRANT A

APPEES INLET

PENDER

PENDER TERRACE

LEVINGE SHELF

WILLARA DEPRESSION

WILLARA SUB-BASIN

NAMBEET FM

BROOME ARCH

Record No 1979/32

Regional Stratigraphic Section C

XAUS-4-57

PLATE 11·4

SAHARA 1
Sta. 215
Rt 269m

KEMP FIELD 1
Sta. 216
KB 238m

MCLARTY 1
Sta. 218
KB 194m

EDGAR RANGE 1
Sta. 26
KB 136m

BABRONGAN 1
Sta. 31
DF 110m

DORAN 1
Sta. 35
Rt 65m

CANDOORA 1
Sta. 45
DF 24m

MAY RIVER 1
Sta. 44
Rt 20m

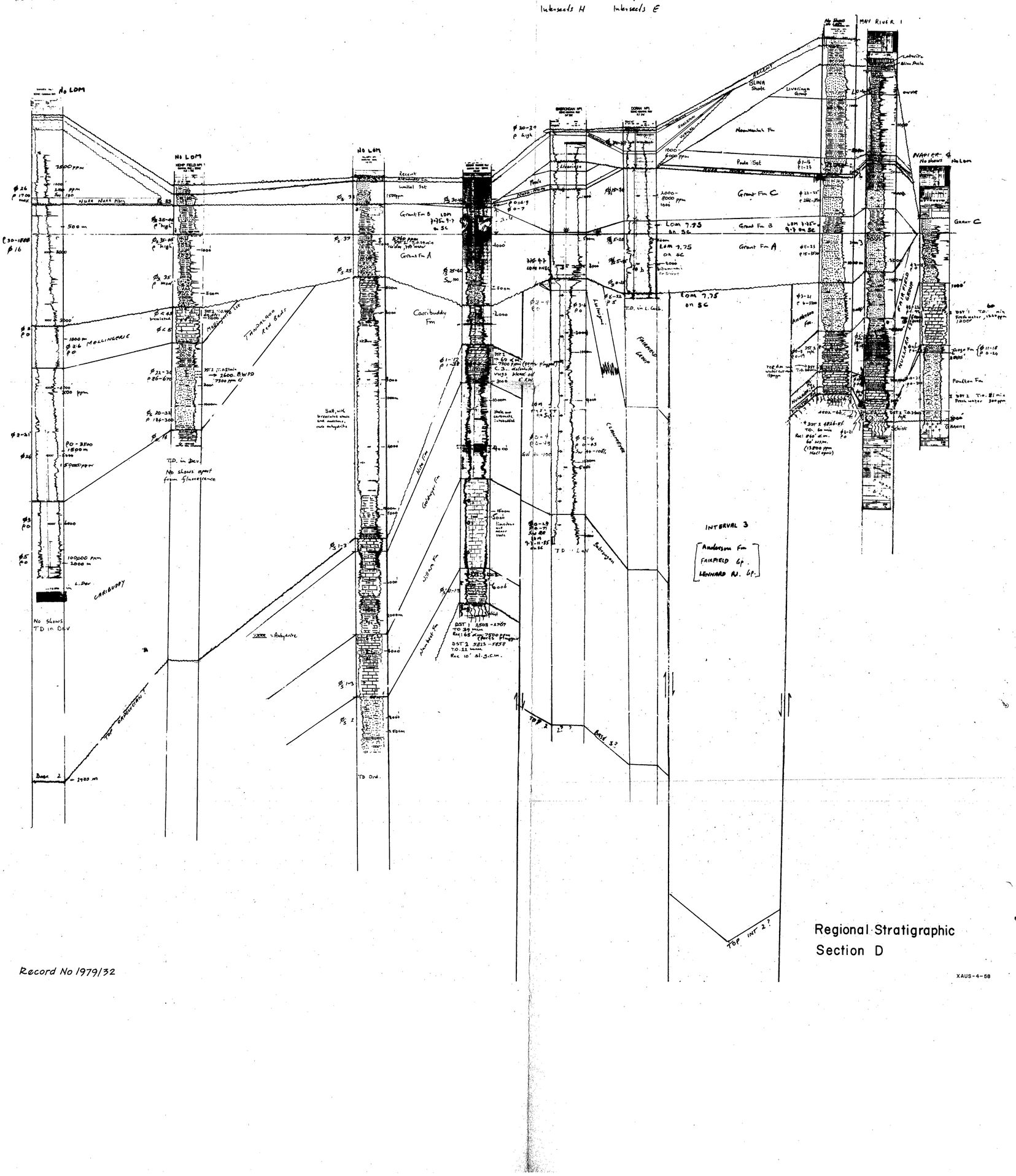
NAPIER 4
Sta. 43
KB 91m

NORTH

Intersects B

Intersects H

Intersects E



Regional Stratigraphic Section D

XAUS-4-58

Record No 1979/32

PLATE 11·5

LOGUE 1
Sta 36
RT 54m
NO DST'S

DORAN 1
Sta 35
RT 65m

FROME ROCKS 2
Sta 33
DF 90m

GRANT RANGE 1
Sta 62
DF 92m

BLACKSTONE 1
Sta 68
RT 65m.

HAWKSTONE PEAK 1
Sta 53
DF 52m

NAPIER 1
Sta 52
WB 74

SE

NE

No DST's
D intervals

Fresh water oil 80' in watervale sm strks in shell/ss

No DST's

No L.O.G. data

No L.O.G. data

No DST's

under casing

JURGURRA TERRACE

BASE "B" MEMBER

DATUM

GRANT FM.

INT 1

INT 2

INT 3

INT 4

INT 5

BABRONGAN

LAUREL

CLARKE RIVER

TERRACE

LENNARD SHELF

EDGAR RANGE

Notes ALL Salinities are given in ppm NaCl equiv.

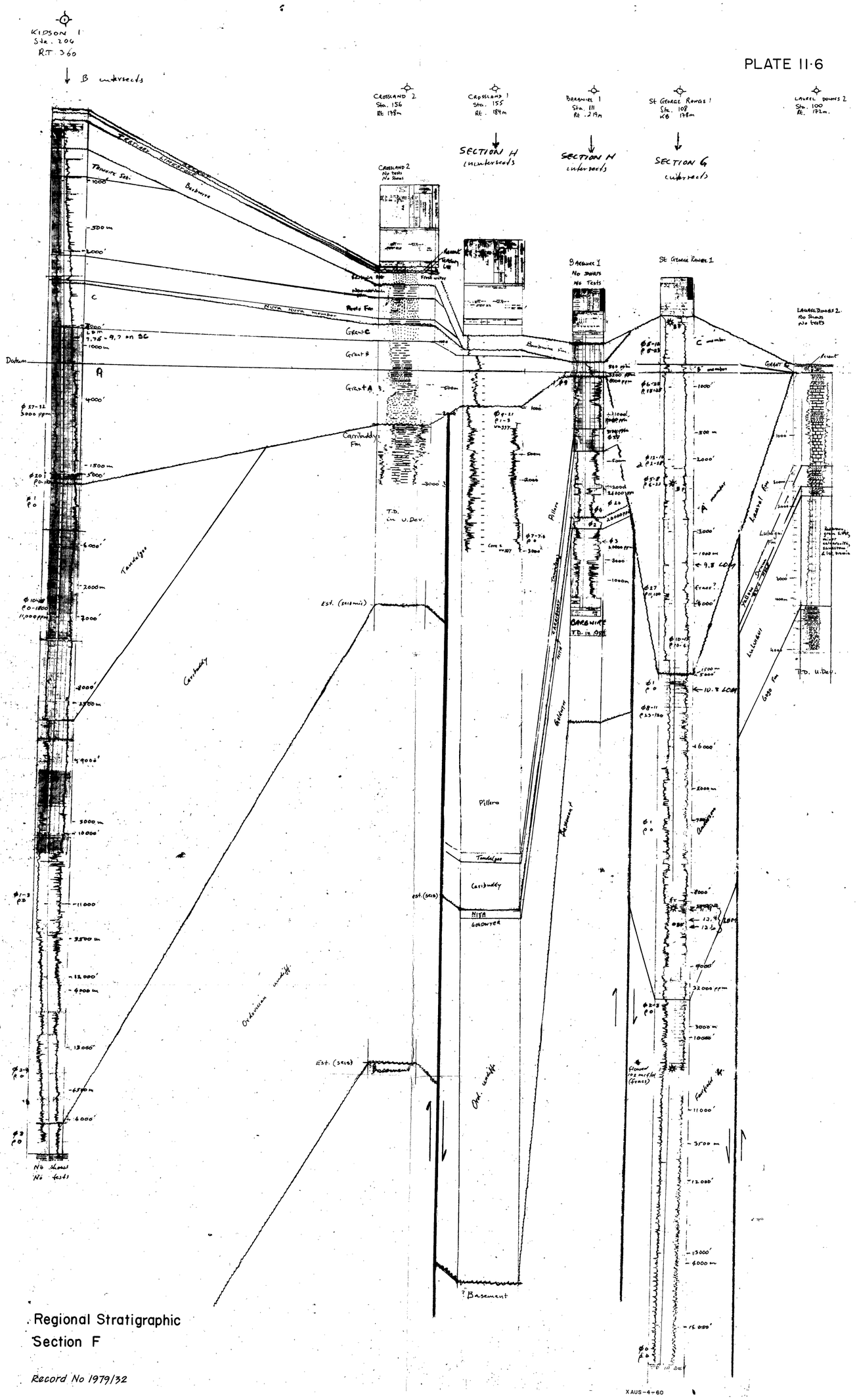
SECTION E

Record No 1979/32

Regional Stratigraphic Section E

XAUS-4-59

PLATE 11·6



Regional Stratigraphic
Section F

Record No 1979/32

XAUS-4-60

PLATE II·7

East Mermaid 1
Sta. 1
RL 11m

Lacepede 1A
Sta. 3
RL 9m

Tappers Inlet 1
Sta. 5
RL 12m

Napier 4
Sta. 43
W.D. 91m

May River 1
Sta. 64
RL 20m

Landsdowne 1
Sta. 95
DF 24m

Medea 1
Sta. 96
DF 30m

Blackstone 1
Sta. 58
RL 69m

The Sisters 1
Sta. 59
RL 93m

Mimosa 1
Sta. 60
RL 58m

Palm Springs 1
Sta. 80
RL 121m

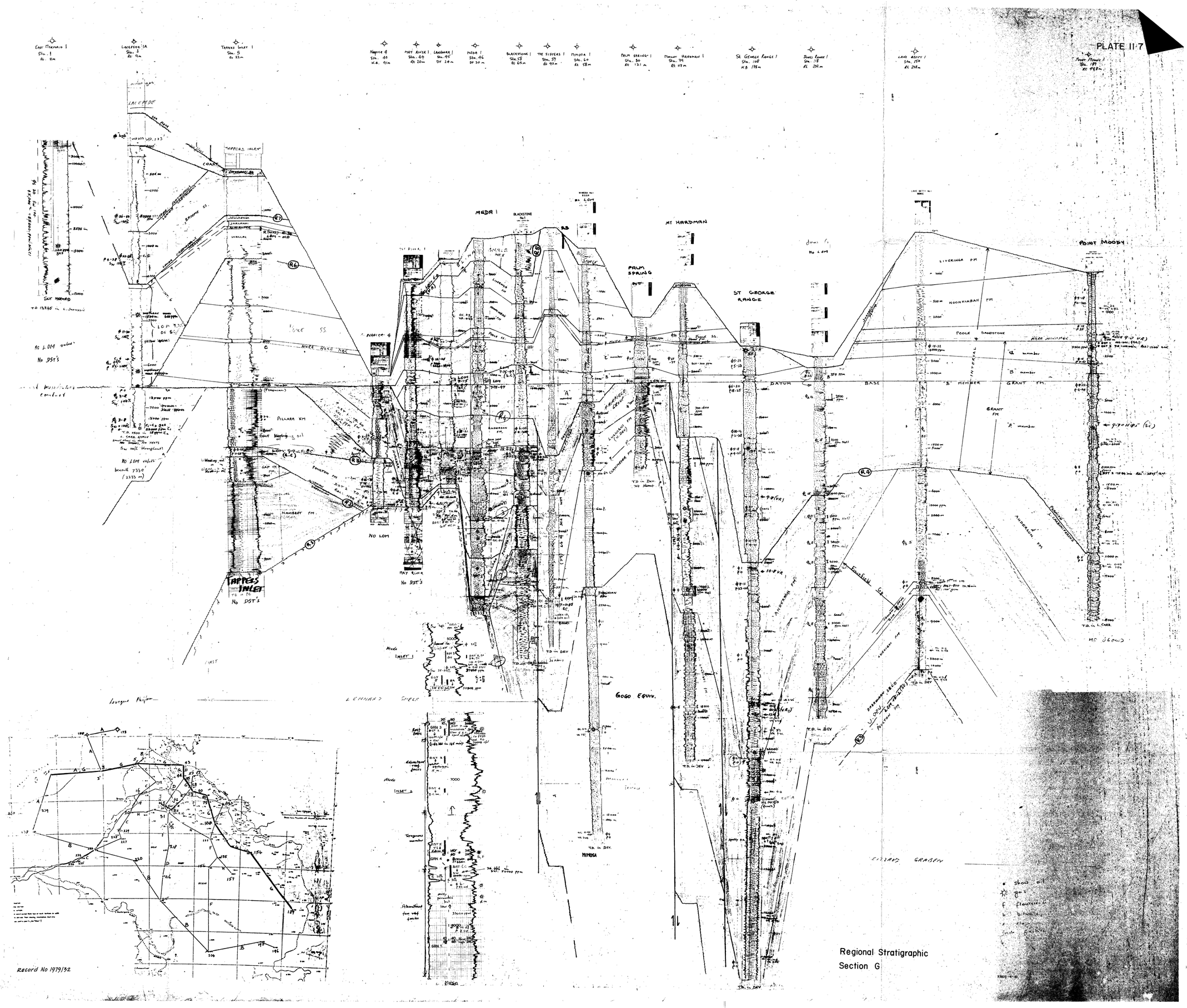
Mount Hardman 1
Sta. 94
RL 117m

St George Range 1
Sta. 108
KB 139m

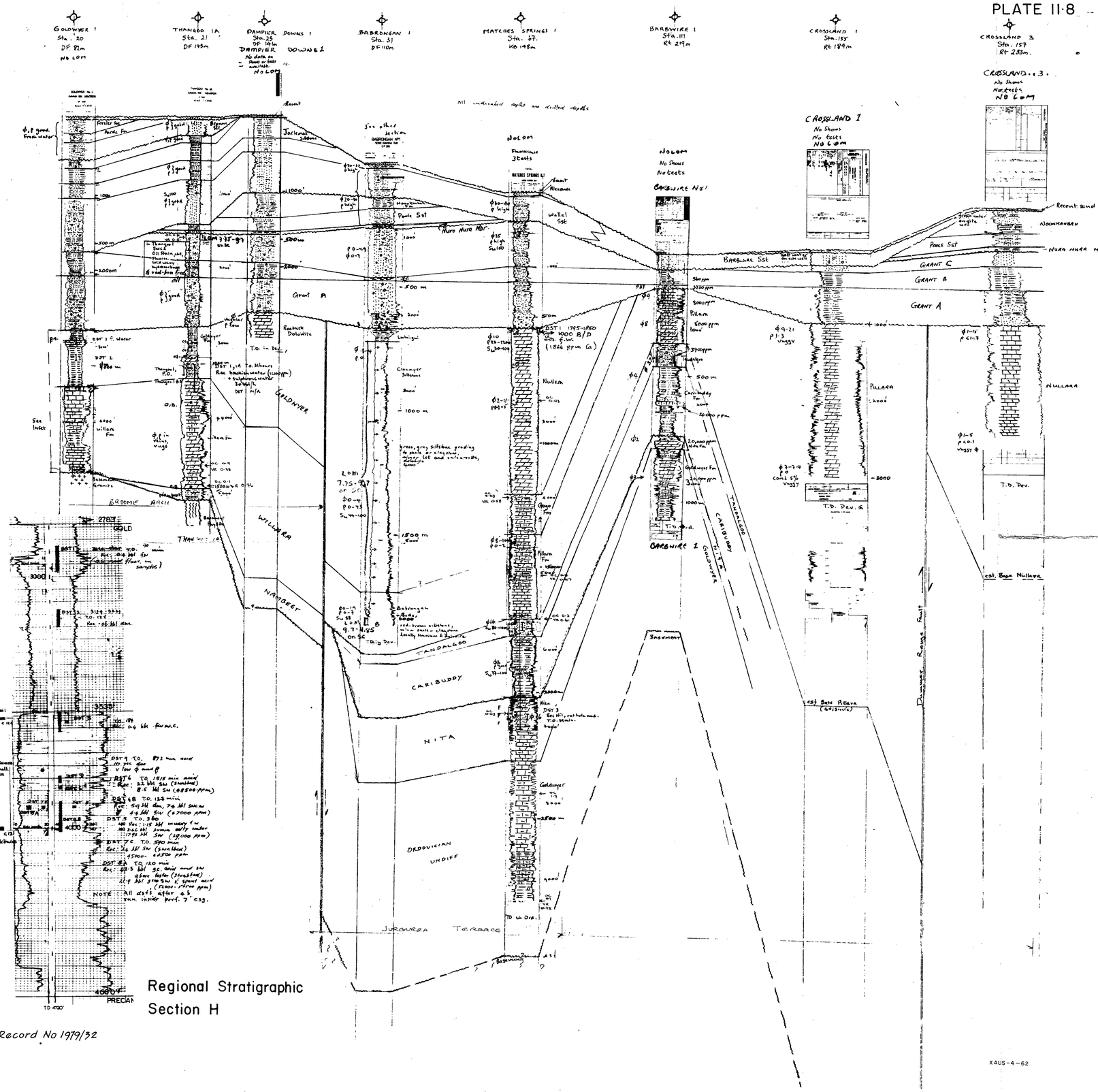
Jones Range 1
Sta. 118
RL 201m

Lake Keogh 1
Sta. 154
RL 216m

Point Moody 1
Sta. 181
RL 98.8m



Regional Stratigraphic Section G


GOLDWYER 1
Sta. 20
DF 82m
NO LOM
THANGOO 1A
Sta. 21
DF 193m
DAMPIER DOWNS 1
Sta. 25
DF 161m
DAMPIER DOWNS 1
No data on Shows or tests available.
NO LOG
BARROWMAN 1
Sta. 31
DF 110m
MATCHES SPRINGS 1
Sta. 67.
KB 198m
BARDWIRE 1
Sta. 111
RT 219m
CROSSLAND 1
Sta. 155
RT 189m
CROSSLAND 3
Sta. 157
RT 283m.
CROSSLAND 3.
No Shows
No tests
NO LOM
CROSSLAND 1
No Shows
No tests
NO LOM
All indicated depths are drillers depths
Recent sand
Woonmarrah
Nura Nura Mbr
Grant C
Grant B
Grant A
Nullara
Pillara
T.D. Dev.
Test Base Nullara
Basement
Dampier Range Fault
Goldwyer
Nullara
Pillara
Willara
Nambeet
Tandalgoo
Caribuddy
Nita
Ordovician Undiff
Jurgurra Terrace
Precam
TD 4720'
Regional Stratigraphic Section H
Record No 1979/32
XAUS-4-62

MEGA INTERVALS	AGE (APPROX.)	PALAEO LATITUDE	INTERVAL	OFFSHORE: BEDOUT SUB-BASIN, LEVEQUE SHELF	PENDER TERRACE	LENNARD SHELF	MARGARET TERRACE	BILLILUNA SHELF	BALGO TERRACE	FITZROY GRABEN WEST	FITZROY GRABEN EAST	JURGURRA TERRACE	BARBWIRE TERRACE	BROOME ARCH	WILLARA SUB-BASIN	KIDSON SUB-BASIN	WALLAL EMBAYMENT	PILBARA SHELF	TABLETOP SHELF	RYAN SHELF
MEGA INTERVAL C	T	18°-43° S	11	MIOCENE-RECENT CARBONATES	BORDA SST	WARRIMBAH CONGLOMERATE		WOLF GRAVEL	LANFORD BEDS GREGORY BEDS	WARRIMBAH CONGLOMERATE				BOSSUT FM	BOSSUT FM		BOSSUT FM	OAKOVER BEDS ? BOSSUT FM		
			10	U. PALAEOCENE & EOCENE Clst, CARB & SST	EMERIAN SST PENDER BAY Cgl					EMERIAU SST						LAMPE BEDS			LAMPE BEDS	LAMPE BEDS
	K		9	U. CRETACEOUS Clst, Carb, Sst, Marl																
			8	L. CRETACEOUS Claystone & SST	BROOME SST	LEVEQUE SST, PARDA BROOME SST MELLIGO SST				? PARDA FM BROOME, MELLIGO		? BROOME SST		PARDA FM FREZIER SST BROOME, MOWLA	PARDA FM, FREZIER ANKETELL FM BROOME SST	ANKETELL FM KIDSON BEDS BEGAN CLAYSTONE	ANKETELL FM BROOME SST	ANKETELL FM BROOME SST	KIDSON BEDS, BEGAN CLAYSTONE SAMUEL FM	KIDSON BEDS
			7	BALEINE FM																
	J	43°-47° S	6	U. JURASSIC MARINE CLASTICS L-M JURASSIC DETRIC CLASTICS	JOWLANGA FM JARLEMAI SLTST ALEXANDER FM WALLAL SST	JOWLANGA FM JARLEMAI SLTST ALEXANDER FM WALLAL SST	MEDA FM			JOWLANGA FM JARLEMAI SLTST ALEXANDER FM WALLAL SST MUDTALLA SST MEDA FM	BARBWIRE SST	JOWLANGA FM JARLEMAI SLTST ALEXANDER FM JURGURRA SS WALLAL SS JAMES SST	BARBWIRE SST	JOWLANGA FM JARLEMAI SLTST ALEXANDER FM JURGURRA SST WALLAL SST CRONIN SST	JOWLANGA FM JARLEMAI SLTST ALEXANDER FM WALLAL SST	? JARLEMAI SLTST ALEXANDER FM WALLAL SST CRONIN SST	JOWLANGA FM JARLEMAI SLTST ALEXANDER FM WALLAL SST CALLAWA FM	JOWLANGA FM JARLEMAI SLTST ALEXANDER FM ? WALLAL SST CALLAWA FM	CRONIN SST	CRONIN SST
MEGA INTERVAL B	Tr		5	LOWER UPPER TO LOWER TRIASSIC	ERSKINE SST BLINA SH	ERSKINE SST BLINA SH	ERSKINE SST BLINA SH		EERSKINE SST BLINA SH MILLYIT SST	EERSKINE SST BLINA SH ? MILLYIT SST	ERSKINE – CLIVINA SST BLINA SH MILLYIT SST									
	P	47°-60° S	4	BEDOUT VOLCANICS U. PERMIAN SST IN LYNHER 1 PROBABLY PRESENT LOCALLY	? NOONKANBAH Fm POOLE SST GRANT C B	LIGHTJACK Fm NOONKANBAH Fm POOLE SST GRANT C B ?	HARDMAN Fm CONDREN SST LIGHTJACK Fm NOONKANBAH Fm POOLE SST GRANT C	GRANT C	HARDMAN Fm CONDREN SST LIGHTJACK Fm NOONKANBAH Fm POOLE SST GRANT C B A	HARDMAN Fm CONDREN SST LIGHTJACK Fm NOONKANBAH Fm POOLE SST GRANT C B A	HARDMAN Fm & GODFREY BEDS CONDREN SST LIGHTJACK Fm NOONKANBAH Fm POOLE SST GRANT C B A	LIGHTJACK Fm NOONKANBAH Fm POOLE SST GRANT C B A	CONDREN SST LIGHTJACK Fm NOONKANBAH Fm POOLE SST GRANT C B A	LIGHTJACK Fm NOONKANBAH POOLE SST GRANT C B A	CHIRUP FM POOLE SST GRANT C B A	TRIWHITE SST NOONKANBAH Fm POOLE SST GRANT Fm C B A	CHIRUP FM GRANT C B A	PATERSON Fm GRANT Fm C B A	TRIWHITE SST NOONKANBAH Fm POOLE SST PATERSON Fm GRANT C B A	BUCK Fm
MEGA INTERVAL A	C	20°-47° S	3	ANDERSON Fm PRESENT	PILLARA Fm	ANDERSON Fm LAUREL Fm YELLOW DRUM SST GUMMOLE Fm FAIRFIELD GP LAMBERD RIVER GP WALLARA LST VINTAGE LST BULGA DOWNS LST PICEA HILLS Fm NAPIER Fm VAN EMMENBURG C BEDAL CLAY STONY CK CONG WARLEIN HILLS Fm PILLARA LST SAVAGE LST GOGO Fm	ANDERSON Fm FAIRFIELD GROUP LOWNDES RIVER GROUP? LULLUNGUL Fm CLANMEYER Fm GOGO Fm EQUIVALENT	KNOBBY SST	PRESENT FORMATIONS UNKNOWN	ANDERSON Fm FAIRFIELD GROUP LENNARD RIVER GROUP LULLUNGUL Fm BASEDOGAN BEDS ?	ANDERSON Fm FAIRFIELD GROUP LENNARD RIVER GROUP LULLUNGUL Fm ? PRESENT	FAIRFIELD GROUP LENNARD RIVER GROUP LULLUNGUL Fm BASEDOGAN BEDS	PILLARA Fm	LOWNDES RIVER GROUP	MELLINJERIE LST			? PRESENT
	Du	20°-15° S																		
	DL	15°-20° S	2	PRESENT	POULTON Fm	POULTON Fm	POULTON Fm		PRESENT	POULTON Fm	PRESENT	TANDALGOO RED BEDS CARRIBUDDY Fm	TANDALGOO RED BEDS CARRIBUDDY Fm	? TANDALGOO RED BEDS CARRIBUDDY Fm	CARRIBUDDY Fm	TANDALGOO RED BEDS CARRIBUDDY Fm				? PRESENT
	O	5°-11° S	1	PRESENT	GAP CK Fm NAMBEET Fm	GAP CK Fm EMANUEL Fm	NITA Fm GOLDWYER Fm ? GAP CK Fm ? EMANUAL Fm	CARRANYA BEDS	PRESENT	PRESENT	PRESENT	NITA Fm GOLDWYER Fm WILLARA Fm NAMBEET Fm	PRESENT	NITA Fm – ROEBUCK DOL GOLDWYER Fm WILLARA Fm "MIDDLE Fm" NAMBEET Fm	NITA Fm GOLDWYER Fm WILLARA Fm NAMBEET Fm	? NITA Fm GOLDWYER Fm WILLARA Fm "MIDDLE Fm" NAMBEET Fm	? GOLDWYER Fm ? WILLARA Fm NAMBEET Fm	? PRESENT	? PRESENT	PRESENT
	€ & PE	10°-60° W	B	HIGH GRADE METAMORPHICS, BASICS & GRANITE SIMILAR TO THOSE FOUND IN A BELT EXTENDING NW FROM THE RUDALL METAMORPHICS. BANDED IRON FMNS & BASICS IN THE SOUTH WEST. METAMORPHICS, BASICS & GRANITE SIMILAR TO THOSE IN THE KING LEOPOLD MOBILE ZONE IN THE NORTH EAST.	METAMORPHICS BASIC IGNEOUS ROCKS SIMILAR TO THOSE OF THE KING LEOPOLD MOBILE BELT	METAMORPHICS, BASIC IGNEOUS ROCKS, & GRANITES SIMILAR TO THOSE IN THE KING LEOPOLD MOBILE BELT	As for Lennard Shelf IN PART ? PROTEROZOIC SEDIMENTS	PROTEROZOIC SEDIMENTS.	? PROTEROZOIC SEDIMENTS & BASIC IGNEOUS ROCKS. ALSO? PROTEROZOIC SEDIMENTS OVERLYING GRANITES - TANAMI BLOCK METAMORPHICS IN THE EAST	METAMORPHICS & BASIC IGNEOUS ROCKS PROBABLY SIMILAR TO THOSE IN THE KING LEOPOLD MOBILE BELT	"THICK ? PROTEROZOIC SEDIMENTS, SIMILAR TO THOSE EAST OF THE HALLS CREEK MOBILE BELT" LARGE BASIC BODIES. ? PROTEROZOIC SEDIMENTS OVERLYING GRANITES TANAMI BLOCK METAMORPHICS IN THE EAST	METASEDIMENTS AND BASIC PLUGS.	METAMORPHICS AND BASIC DYKES & PLUGS; POSSIBLY OVERLAIN IN PART BY ? PROTEROZOIC SEDIMENTS	GNEISS SCHIST PHYLLITE GRANITE ? PROTEROZOIC SEDIMENTS	GRANITE IN THE SOUTH; BASIC IGNEOUS ROCKS IN THE NORTH; POSSIBLY OVERLAIN IN PART BY ? PROTEROZOIC SEDIMENTS.	SHALE (WILSON CLIFFS) BASIC IGNEOUS ROCKS IN WEST AND IN NORTH, PROBABLY ALSO METASEDIMENTS; THESE MAY BE OVERLAIN IN PART BY ? PROTEROZOIC SEDIMENTS	GRANITE	ARCHEAN SEDIMENTS BANDED IRON FORMATIONS AND BASIC VOLCANICS, BASIC IGNEOUS INTRUSIVES GRANITE.	PROTEROZOIC SEDIMENTS incld. DOLOMITE + possibly evaporites; HIGH GRADE METAMORPHICS SIMILAR TO RUDALL METAMORPHIC COMPLEX. ALSO METAMORPHICS WITH THICK INTERLAYERED BASICS. ARCHEAN SLTST	HEAVITREE QUARTZITE PROTEROZOIC SEDIMENTS DOLOMITE ? METAMORPHICS, SIMILAR TO ARUNTA BLOCK.

Formation correlations within Intervals

Record No 1979/32

XAUS-4-67

PLATE 12·2

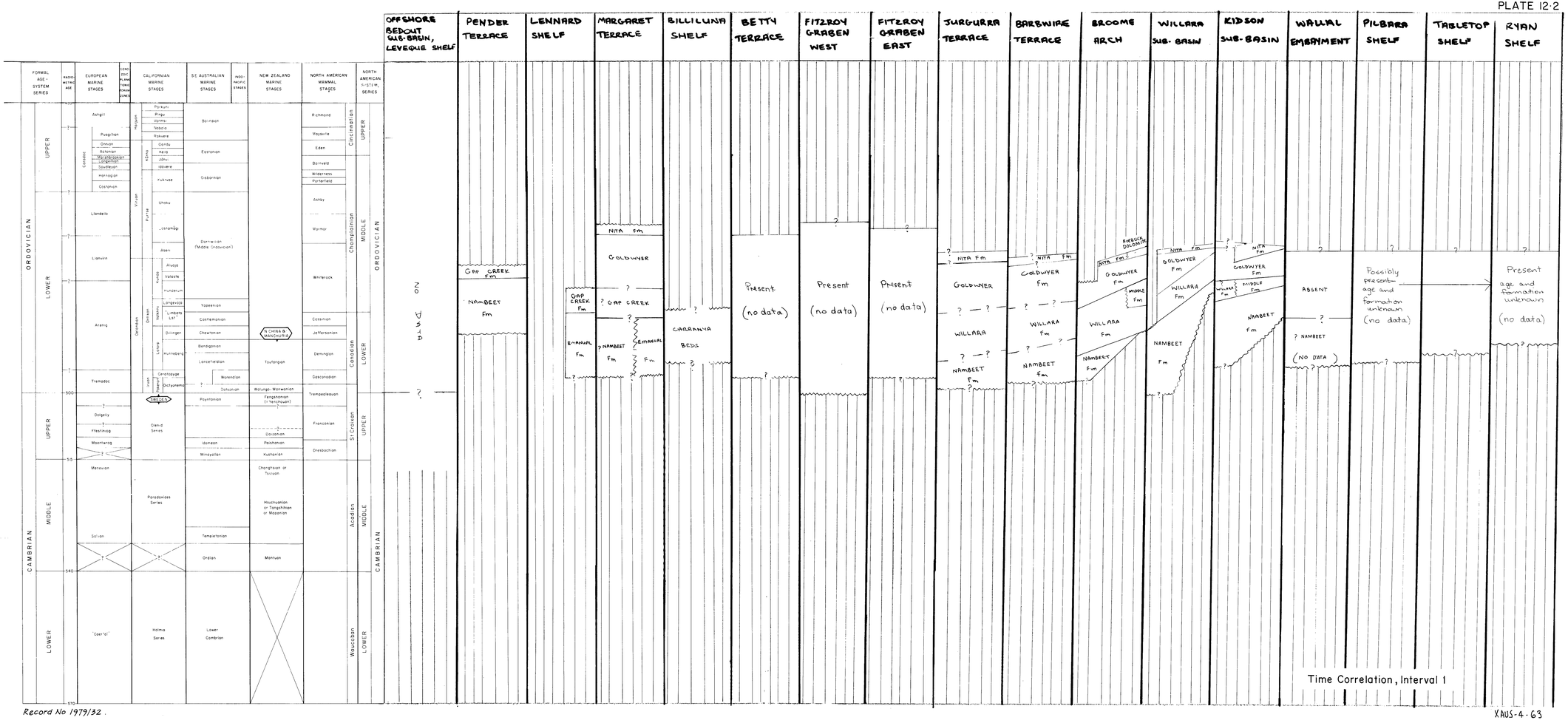
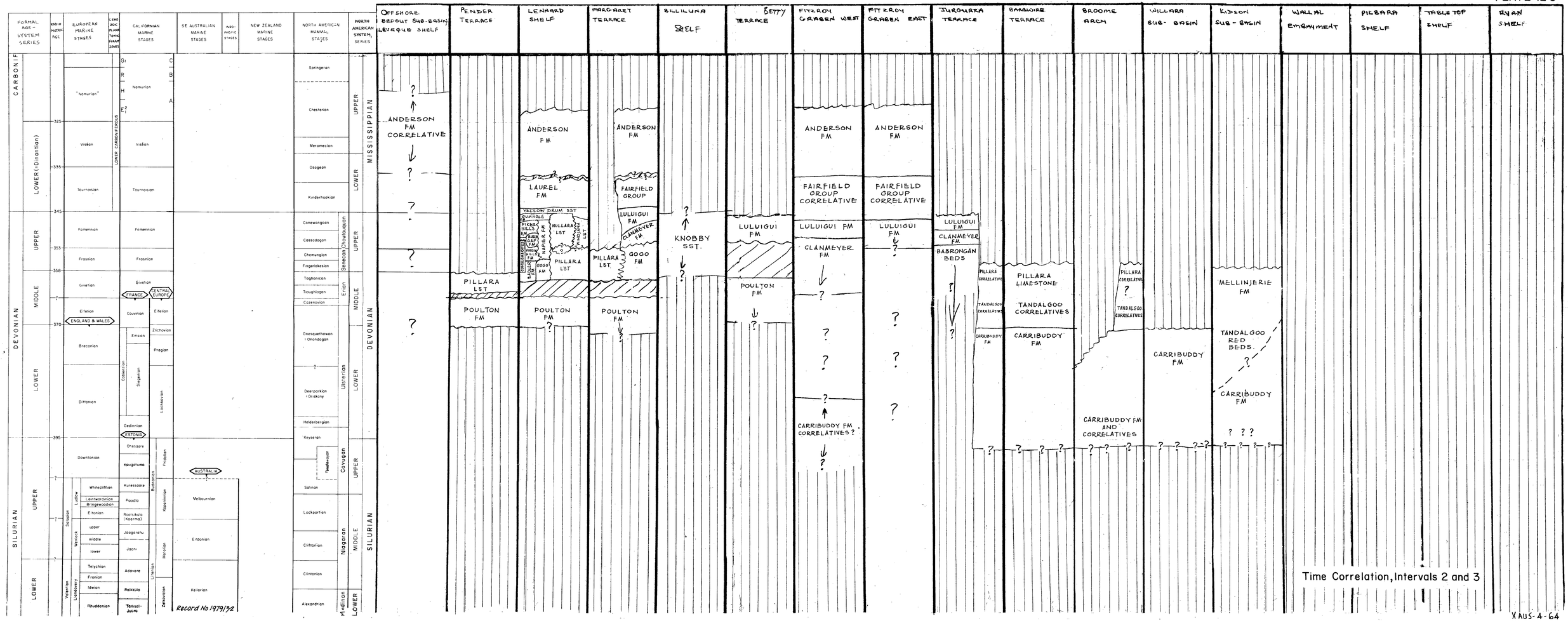
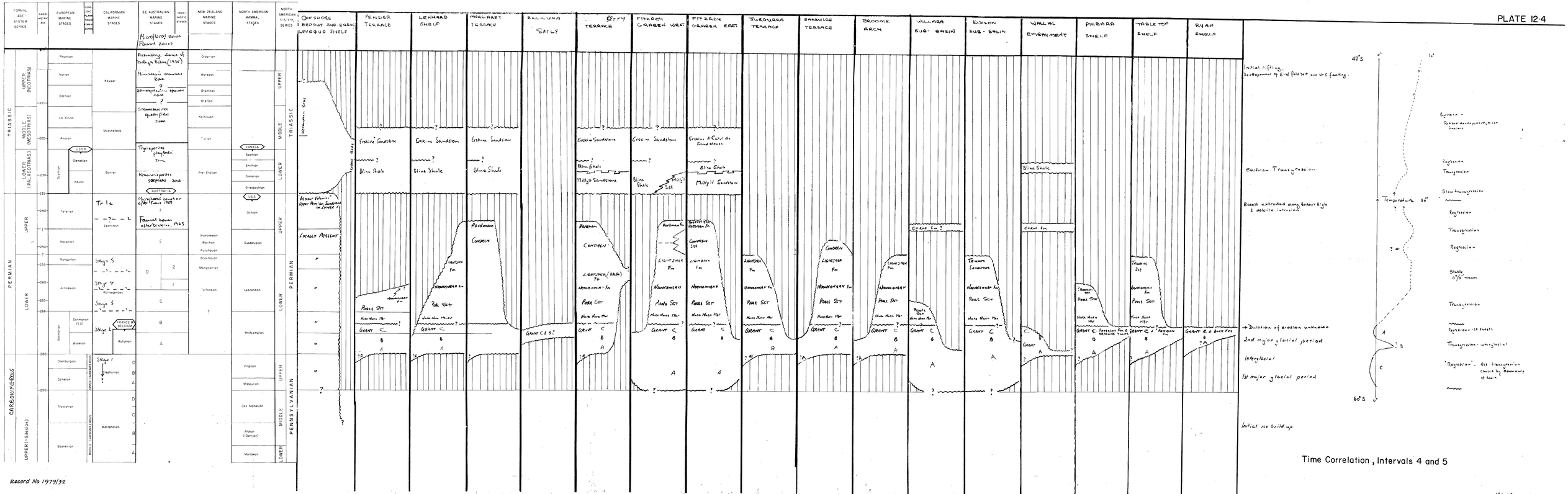

FORMAL AGE – SYSTEM SERIES
RADIOMETRIC AGE
EUROPEAN MARINE STAGES
CENOZOIC PLANKTONIC FORAMINIFERAL ZONES
CALIFORNIAN MARINE STAGES
SE AUSTRALIAN MARINE STAGES
INDO-PACIFIC STAGES
NEW ZEALAND MARINE STAGES
NORTH AMERICAN MAMMAL STAGES
NORTH AMERICAN SYSTEM SERIES
OFFSHORE BEDOUT SUB-BASIN, LEVEQUE SHELF
PENDER TERRACE
LENNARD SHELF
MARGARET TERRACE
BILLILUNA SHELF
BETTY TERRACE
FITZROY GRABEN WEST
FITZROY GRABEN EAST
JURGURRA TERRACE
BARBWIRE TERRACE
BROOME ARCH
WILLARA SUB-BASIN
KIDSON SUB-BASIN
WALLAL EMBAYMENT
PILBARA SHELF
TABLETOP SHELF
RYAN SHELF
ORDOVICIAN
CAMBRIAN
UPPER
MIDDLE
LOWER
Cincinnatian
Champlainian
Canadian
St Croixan
Acadian
Waucoban
Ashgill
Caradoc
Llandeilo
Llanvirn
Arenig
Tremadoc
Dolgelly
Ffestiniog
Moentwog
Menevian
Solvan
'Caerfai'
Payntonian
Idamean
Mindyallan
Ordian
Lower Cambrian
Templetonian
Eastonian
Gisbornian
Yaseenian
Castlemaonian
Chewtonian
Bendigonian
Lancefieldian
Waroonian
Dolcetonian
Darriwilian (Middle Ordovician)
Mt CHINS & MANCHURIA
Toufangian
Fengshanian (=Yanchepian)
Dapingian
Floian
Dresbachian
Franconian
Trempealeauan
Gasconadian
Cassinian
Jeffersonian
Demingian
Whiterockian
Marmorian
Ashbyan
Porterfieldian
Wilderness
Eden
Maysvillian
Richmondian
Changhsian or Tsinanian
Mayhewan
Mountainian or Tangshanian or Mapanian
Kushanian
Parahnanian
Dolcetonian
Orthidiella Series
Olenid Series
Parabolinites Series
Holmia Series
Idamean
Mindyallan
Payntonian
Dolcetonian
Waroonian
Lancefieldian
Bendigonian
Chewtonian
Castlemaonian
Yaseenian
Darriwilian
Gisbornian
Eastonian
Boomerangian
Undillan
Dats

PLATE 12·3


FORMAL AGE - SYSTEM SERIES
RADIO METRIC AGE
EUROPEAN MARINE STAGES
CENOZOIC PLANKTONIC FORAM ZONES
CALIFORNIAN MARINE STAGES
SE AUSTRALIAN MARINE STAGES
INDO-PACIFIC STAGES
NEW ZEALAND MARINE STAGES
NORTH AMERICAN MARINE STAGES
NORTH AMERICAN SYSTEM, SERIES
CARBONIF
DEVONIAN
SILURIAN
UPPER
MIDDLE
LOWER
LOWER (+Dinantian)
Namurian
"Namurian"
Visean
Tournaisian
Famennian
Frasnian
Givetian
Eifelian
Couvinian
Emsian
Siegenian
Gedinnian
Pragian
Zlichovian
Ulsterian
Cayugan
Niagaran
Springeran
Chesterian
Meramecian
Osagean
Kinderhookian
Conewangoan
Cassadagan
Chemungian
Fingerlakesian
Senecan
Chautauquan
Taghanican
Tioughniogan
Erian
Cazenovian
Onesquethawan + Onondagan
Deerparkian + Oriskany
Helderbergian
Keyserian
Tonoloway
Salinan
Lockportian
Clintonian
Alexandrian
MISSISSIPPIAN
DEVONIAN
SILURIAN
Whitcliffian
Kurnessaare
Paadla
Rootsikula (Kaarma)
Jaagarahu
Jaani
Adavere
Raikküla
Tonsal-Juuru
Lenterdonian
Bringewoodian
Eltonian
upper
middle
lower
Telychian
Fronian
Idwian
Rhuddanian
Ludlow
Wenlock
Llandovery
Silurian
Downtonian
Breconian
Dittonian
Givetian
Eifelian
Zlichovian
Pragian
Ulsterian
Gedinnian
Pridolian
Ludfordian
Gorstian
Homerian
Sheinwoodian
Telychian
Aeronian
Rhuddanian
Melbournian
Eifelian
Keilorian
Record No 1979/32
OFFSHORE BASIN OUT SUB-BASIN LEVEQUE SHELF
ANDERSON FM CORRELATIVE
PENDER TERRACE
PILLARA LST
POULTON FM
LENNARD SHELF
ANDERSON FM
LAUREL FM
YELLOW DRUM SST
QUANBUN FM
PIKER HILLS FM
NULLARA LST
BANK CLIFF FM
NAPIER FM
WINDJANA LST
IRWIN HILLS FM
SADLER FM
GOGO FM
PILLARA LST
POULTON FM
MARGARET TERRACE
ANDERSON FM
FAIRFIELD GROUP
LULUIGUI FM
CLANMEYER FM
PILLARA LST
GOGO FM
POULTON FM
BILLILUNA SHELF
KNOBBY SST.
BETTY TERRACE
LULUIGUI FM
POULTON FM
FITZROY GRABEN WEST
ANDERSON FM
FAIRFIELD GROUP CORRELATIVE
LULUIGUI FM
CLANMEYER FM
CARRIBUDDY FM CORRELATIVES ?
FITZROY GRABEN EAST
ANDERSON FM
FAIRFIELD GROUP CORRELATIVE
LULUIGUI FM
JURGURRA TERRACE
LULUIGUI FM
CLANMEYER FM
BABRONGAN BEDS
PILLARA CORRELATIVE
TANDALGOO CORRELATIVES
CARRIBUDDY FM
BARNWIRE TERRACE
PILLARA LIMESTONE
TANDALGOO CORRELATIVES
CARRIBUDDY FM
BROOME ARCH
PILLARA CORRELATIVE
TANDALGOO CORRELATIVES
CARRIBUDDY FM AND CORRELATIVES
WILLARA SUB-BASIN
CARRIBUDDY FM
KIDSON SUB-BASIN
MELLINJERIE FM
TANDALGOO RED BEDS.
CARRIBUDDY FM
WALLAL EMBAYMENT
PILBARA SHELF
TABLE TOP SHELF
RYAN SHELF
Time Correlation, Intervals 2 and 3
XAUS-4-64



Record No 1979/32

XAUS-4-65

FORMAL AGE – SYSTEM SERIES		RADIO METRIC AGE	EUROPEAN MARINE STAGES	CALIFORNIAN MARINE STAGES	S.E. AUSTRALIAN MARINE STAGES	INDO-PACIFIC STAGES	NEW ZEALAND MARINE STAGES	NORTH AMERICAN MAMMAL STAGES	NORTH AMERICAN SYSTEM, SERIES
QUAT.	PLEISTOCENE	1.8	Calabrian	Hanian		?	Haweran	Irvingtonian	QUATERNARY
TERTIARY	PLIOCENE	5.5	Astian / Piacenzian / Zanclean / Tabianian	Wheelerian / Venturian / Repettian	Kalimnan / Cheltenhamian	Tn	Waiarekan	Blancan	
	MIOCENE UPPER	10.5	"Messinian"	Delmontian / Mohnian	Mitchellian	Tg	Kapitean	Hemphillian	
	MIOCENE MIDDLE	14	Tortonian / Serravallian / Longhian	Luisian / Relizian 14.7 / 15.3	Batesfordian / Balcombian	9 / Inner T1 / 12 / 13 / 15	Tongaporutuan / Waiauan / Lillburnian / Clifdenian / Altonian 15.2	Clarendonian 12 / Barstovian 13 / Hemingfordian 21.3	
	MIOCENE LOWER	22.5	Burdigalian / Aquitanian	Saucesian	Longfordian	Te2	Awamoan 16.8 / Hutchinsonian / Otaian	Arikareean 26	
	OLIGOCENE UPPER	30	Chattian	Zemorrian 22.5	Janjukian	Te1	Waitakian	Whitneyan	
	OLIGOCENE LOWER (INC)	32	Rupelian / Lattorfian	Refugian		Tc	Duntroonian	Orellan	
	EOCENE UPPER	36	Priabonian	Narizian	Alpingan	Tb	Whangaroan	Chadronian	
	EOCENE MIDDLE	45	Lutetian	Ulatisian	Johannian	Ta3	Runangan	Duchesnian	
	EOCENE LOWER	49	Ypresian	Penutian		Ta2	Kaiatan	Uintan	
	PALEOCENE UPPER	53.5	Thanetian	Bulitan	Wangerripian	Ta1	Bortonian / Porangan / Haretaungan	Bridgerian	
	PALEOCENE LOWER	60	Montian / Danian	Ynezian / "Donian"		Tp	Mangaorapan / Waipawan	Wasatchian	
MESOZOIC	CRETACEOUS UPPER	65	Maastrichtian	Hesperian		?	Teurian	Clarkforkian	
		70	Campanian					Tiffanian	
		76	Santonian					Torrejonian	
		82	Coniacian					Dragonian / Puercan	
		88	Turonian	Venadan			Haumurian		
		94	Cenomanian				Piripauan		
	CRETACEOUS LOWER	100	Albian				Teratan		
		106	Aptian				Mangaotanean		
		112	Aptian				Arowhanan		
		118	Barremian				Ngaterian		
		124	Hauterivian	Mathilan			Motuan		
		130	Valanginian				Urutawan		
		136	Berriasian				Korangan		
		176	Purbeckian	GERMANIC			Mokoiwan	Puercan	
	JURASSIC UPPER	140	Portlandian / Kimmeridgian	Malm				Othnian	
		157	Oxfordian				Heterian		
	JURASSIC MIDDLE	162	Callovian	Upper Dogger			Temokan		
		167	Bathonian	Middle Dogger					
		172	Bajocian	Lower Dogger					
	JURASSIC LOWER	178	Toarcian	Upper Lias			Urutapan		
		183	Pliensbachian	Middle Lias					
		188	Sinemurian	Lower Lias			Arturoan		
		195	Hettangian						
	TRIASSIC		Rhaetian		Assemblage Zones of Dulty & Balme (1975)		Otapirian		

OFFSHORE BEDOUT SUB-BASIN LEEUWIN SHELF	PENDER TERRACE	LENNARD SHELF	MARGARET TERRACE	BILLILUNA SHELF	BETTY TERRACE	FITZROY GRABEN WEST	FITZROY GRABEN EAST	JURGURRA TERRACE	BARBWIRE TERRACE	BROOME ARCH	WILLARA SUB-BASIN	KIDSON SUB-BASIN	WALLAL EMBAYMENT	PIERRARA SHELF	TABLE TOP SHELF	RYAN SHELF
Sands & marls, coral	Sand, limonite / calcar. sandst.	Calcarenite, conglomerate	Alluvium, diapiric gravels	Marl, gravel, alluvium	Lateritic beds / Gregory Beds (equiv.)	Warrimbah Conglomerate	Alluvium Sand	Alluvium Sand, ?	Alluvium, Sand	Alluvium Sand, Beagle Fm, Calcrete, etc.	Alluvium Sand, Broome Fm, Calcrete	Alluvium Sand, Calcrete	Alluvium, Sand, Eyeast Fm, Calcrete	Oakover Beds, Broome Fm, ? Calcrete	Alluvium, Sand D	Alluvium, Sand
Calcrete & Cavity Formation	Boora Sandstone															
	Laterization															
	Emerian Sandstone & Ponder Bay Conglomerate					Emerian SST						Lampe Beds & Lake George Beds			Lampe Beds	Lampe Beds
Claystone										Beagle Fm, Pender Ss	Beagle Fm, ? Anketell Fm	? Anketell Fm, Beagle Claystone, Knave Beds	Anketell Fm, Broome Sandstone	Anketell Fm, Broome Sandstone	Knave Beds, ? Beagle Claystone, Sawpit Fm	Knave Beds
Siltstone, Claystone, Gamma Equivalent	Brooms Sandstone	Brooms & Melligo SST				? Parda Fm, Broome & Melligo Sandstone		? Broome Sandstone		Beagle Fm, Pender Ss, Brooms Sandstones	Brooms Sandstone					
?	Baleine Fm															
	Jowlaenga SST, Jarlemai Siltst, Alexander Fm	Jowlaenga SST, Jarlemai Siltst, Alexander Fm				? Jowlaenga SST, Jarlemai Siltst, Alexander Fm	Jowlaenga SST, Jarlemai Siltst, Alexander Fm	Jowlaenga SST, Jarlemai Siltst, Alexander Fm		Jowlaenga SST, Jarlemai Siltst, Alexander Fm	Jowlaenga SST, Jarlemai Siltst, Alexander Fm	Jowlaenga SST, Jarlemai Siltst, Alexander Fm	Jowlaenga SST, Jarlemai Siltst, Alexander Fm	Jowlaenga SST, Jarlemai Siltst, Alexander Fm		
Jurassic Marine Clastics	Wallal SST	Wallal SST	Medo Fm			Wallal SST	Medo Fm	Wallal SST	Barbwire SST	Wallal SST	Jurgurra SST, Cronin SST, Wallal SST	Wallal SST, ? Cronin SST	Wallal SST, ? Cronin SST	Callawa Fm	Callawa Fm	Cronin SST	? Cronin SST
Jurassic Deltaic Clastics								James SST	Barbwire SST							

Collision of Timor & Australian Plate? (Veevers & McElhinny, 1976)

Laterization — Perth Basin at ~Jmy
Fitzroy Volcanics

Initial glaciation of Antarctica 38my

Rifting Australia / Antartica 53my (Weissel & Hayes, 1972)

Rise of mid-oceanic ridges ?

Break up Unconformity Australia / ? India (Perth Basin)
Bomy (Veevers, et al. 1975)
~ 137.5 My ◦ J & K boundary

Time Correlation, Intervals 6 to 11

Initial rifting
Development of E-W fold belt and N-S faulting

47°S — 0° — 32° — Temperature

Record No 1979/32

XAUS-4-66

PLATE

Plate 13 -1
Structure contours (unmigrated)
Interval 1

INDIAN OCEAN

ROWLEY SHOALS

4000m

200m

BASIN

MARGIN

Scale 1:2500000

50 0 50 100km

Simple Conic Projection with Standard Parallels 18°S and 36°S

LOCATION DIAGRAM

CANNING BASIN

WA NT QLD SA NSW VIC

-2813

-1382

-1345

-1245

-1780

-1671

-2006

-2046

-3058

Fault

Pinnacle F.

Mackerel F.

Mermaid F.

Dampier F.

Muiron F.

Scott F.

Hanson F.

Subsurface control

20 Structure contour, depth in metres × 10^2

Fault

WESTERN AUSTRALIA — NORTHERN TERRITORY

XAUS-4-203

BASE INTERVAL 1

Record No. 1979/32

Plate 13 -2
Structure contours
Interval 2

- measured well section
- measured outcrop section
- seismic shothole sample
- composite section constructed from two or more sections or wells
- generalized data derived from nearby incomplete sections

(To identify geological control points, see Table 1)

- Subsurface control
- ~~20 Structure contour, depth in metres × 10^2
- —— Fault

Scale 1:2 500 000

50 0 50 100 km

Simple Conic Projection with Standard Parallels 18°S and 36°S

LOCATION DIAGRAM

CORRELATION UNCERTAIN

Record No. 1979/32

XAUS-4-204

CASE INTERVAL 2

(10-12-75)

Plate 13 -3
Structure contours
Interval 3

Scale 1:2500000
50 0 50 100 km
Simple Conic Projection with Standard Parallels 19°S and 36°S

LOCATION DIAGRAM

measured well section
measured outcrop section
seismic shothole sample
composite section constructed from two or more sections or wells
generalised data derived from nearby incomplete sections
(To identify geological control points, see Table 1)

Subsurface control
20 Structure contour, depth in metres × 10^2
Fault

Record No. 1979/32

XAUS-4-205

BASE INTERVAL 3
(10-12-75)

Plate 13 -4
Structure contours
Interval 4

Scale 1:2 500 000
50 0 50 100 km
Simple Conic Projection with Standard Parallels 18°S and 36°S

LOCATION DIAGRAM

measured well section
measured outcrop section
seismic shothole sample
composite section constructed from two or more sections or wells
generalized data derived from nearby incomplete sections
(To identify geological control points, see Table 1)
Subsurface control
20 Structure contour, depth in metres × 10^2
Fault

Record No. 1979/32

XAUS 4 - 206

BASE INTERVAL 4
(Amended 9.12.75)

MAP 9.4

Plate 13-5
Structure contours
Interval 5

INDIAN OCEAN

ROWLEY SHOALS

GREAT SANDY DESERT

Broome

Port Hedland

Derby

King Sound

C. Leveque

Fitzroy Crossing

Billiluna

L. Waukarlycarly

L. Disappointment

L. Wills

L. Hazlett

Lake Mackay

4000m

200m

LIMIT OF OLDER ROCKS EXPOSED

NORTHERN TERRITORY

WESTERN AUSTRALIA

Scale 1:2 500 000

50 0 50 100 km

Simple Conic Projection with Standard Parallels 18°S and 36°S

LOCATION DIAGRAM

DAMPIER BASIN

NT QLD WA SA NSW V

- Subsurface control
- ~~20 Structure contour, depth in metres × 10^2
- —— Fault

117°30' 118°30' 120° 121°30' 123° 124°30' 126° 127°30' 129°

16° 17° 18° 19° 20° 21° 22° 23° 24°

Record No. 1979/32

XAUS-4-207

BASE INTERVAL 5
(Amended 9-12-75)

MAP 9.5

Plate 13-6
Structure contours
Interval 6

- measured well section
- measured outcrop section
- seismic shothole sample
- composite section constructed from two or more sections or wells
- generalized data derived from nearby incomplete sections

(To identify geological control points, see Table 1)

—— −300 Structure contour in metres, sign indicates above or below sea level

● 239 / −754 Well or bore intersecting base of Interval, showing control point numbers (239), and depth of horizon in metres relative to sea level (−754), or (nd) if not detected.

—— Fault

Scale 1:2 500 000

50 0 50 100 km

Simple Conic Projection with Standard Parallels 18°S and 36°S

LOCATION DIAGRAM

Record No. 1979/32

XAUS-4-208

BASE INTERVAL 6
11-11-75

Plate 13-7
Structure contours
Interval 7

Scale 1:2 500 000

50 0 50 100 km

Simple Conic Projection with Standard Parallels 18°S and 36°S

LOCATION DIAGRAM



- measured well section
- measured outcrop section
- seismic shothole sample
- composite section constructed from two or more sections or wells
- generalized data derived from nearby incomplete sections

(To identify geological control points, see Table 1)

—— −300 Structure contour in metres, sign indicates above or below sea level

● 239 −754 Well or bore intersecting base of Interval, showing control point numbers (239), and depth of horizon in metres relative to sea level (−754), or (nd) if not detected.

—— Fault

Record No. 1979/32

XAUS-4-209

BASE INTERVAL 7

(12-11-15)

Plate 13 - 8
Structure contours (unmigrated)
Interval 8

measured well section
measured outcrop section
seismic shothole sample
composite section constructed from two or more sections or wells
generalised data derived from nearby incomplete sections
(To identify geological control points, see Table 1)

—— -300 Structure contour in metres, sign indicates above or below sea level

● 239 / – 754 Well or bore intersecting base of Interval, showing control point numbers (239), and depth of horizon in metres relative to sea level (-754), or (nd) if not detected.

—— Fault

Scale 1:2500000
Simple Conic Projection with Standard Parallels 18°S and 36°S

LOCATION DIAGRAM

Record No. 1979/32

XAUS-4-210

BASE INTERVAL 8
(12-11-75)

MAP 9.8

Plate 13 - 9
Structure contours (unmigrated)
Interval 9

Scale 1:2 500 000
50 0 50 100 km
Simple Conic Projection with Standard Parallels 18°S and 36°S

LOCATION DIAGRAM

measured well section
measured outcrop section
seismic shothole sample
composite section constructed from two or more sections or wells
generalized data derived from nearby incomplete sections
(To identify geological control points, see Table 1)

—— -300 Structure contour in metres, sign indicates above or below sea level

● 239 / — 754 Well or bore intersecting base of Interval, showing control point numbers (239), and depth of horizon in metres relative to sea level (-754), or (nd) if not detected.

—— Fault

Record No. 1979/32

XAUS-4-211

BASE INTERVAL 9

Plate 13 – 10
Structure contours (unmigrated)
Interval 10

— -600- Structure contour in metres, sign indicates above or below sea level, contour interval 100 metres.

● 239 / -754 Well or bore intersecting base of Interval, showing control point number (239) and depth of horizon relative to sea level (-754);

—·—·— Subsurface limit of Interval

D Fault (normal or reverse); D on down thrown side.

Scale 1:2 500 000
50 0 50 100 km
Simple Conic Projection with Standard Parallels 18°S and 36°S

LOCATION DIAGRAM
CANNING BASIN
WA NT QLD SA NSW VIC

Base Interval 10
(12-11-75)

Xaus-4-212

117°30' Record No. 1979/32. 118°30'

Plate 13 – 11
Structure contours (unmigrated)
Interval 11

INDIAN OCEAN

ROWLEY SHOAL

MERMAID FAULT

King Sound

C. Leveque

Broome

Derby

Fitzroy Crossing

Port Hedland

GREAT SANDY DESERT

OLDER ROCKS

EXPOSED

LIMIT

L. Waukarlycarly

L. Disappointment

Lake Mackay

L. Wills

L. Hazlett

Billiluna

NORTHERN HWY

GREAT NORTHERN HWY

WESTERN AUSTRALIA / NORTHERN TERRITORY

Scale 1:2 500 000

50 0 50 100 km

Simple Conic Projection with Standard Parallels 18°S and 36°S

LOCATION DIAGRAM

CANNING BASIN

WA NT QLD SA NSW V

- measured well section
- measured outcrop section
- seismic shothole sample
- composite section constructed from two or more sections or wells
- generalised data derived from nearby incomplete sections

(To identify geological control points, see Table 1)

—— −300 Structure contour in metres, sign indicates above or below sea level

● 239 / −754 Well or bore intersecting base of Interval, showing control point numbers (239), and depth of horizon in metres relative to sea level (−754), or (nd) if not detected.

—— Fault

117°30' 118°30' 120° 121°30' 123° 124°30' 126° 127°30' 129°

15° 16° 17° 18° 19° 20° 21° 22° 23° 24°

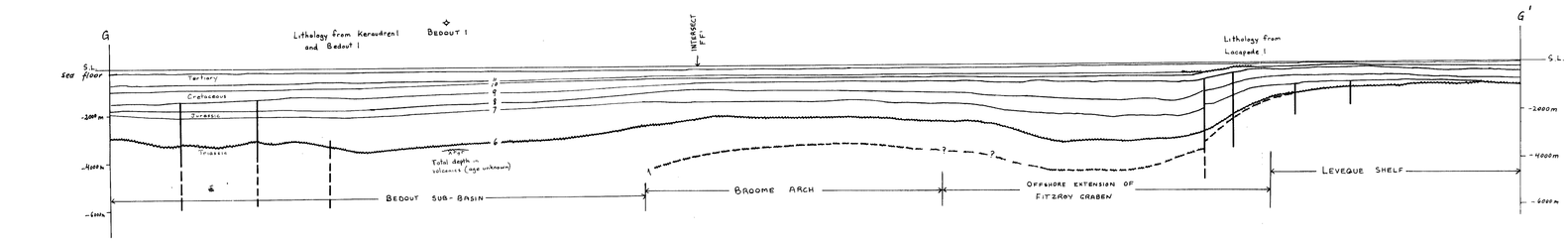
Record No. 1979/52

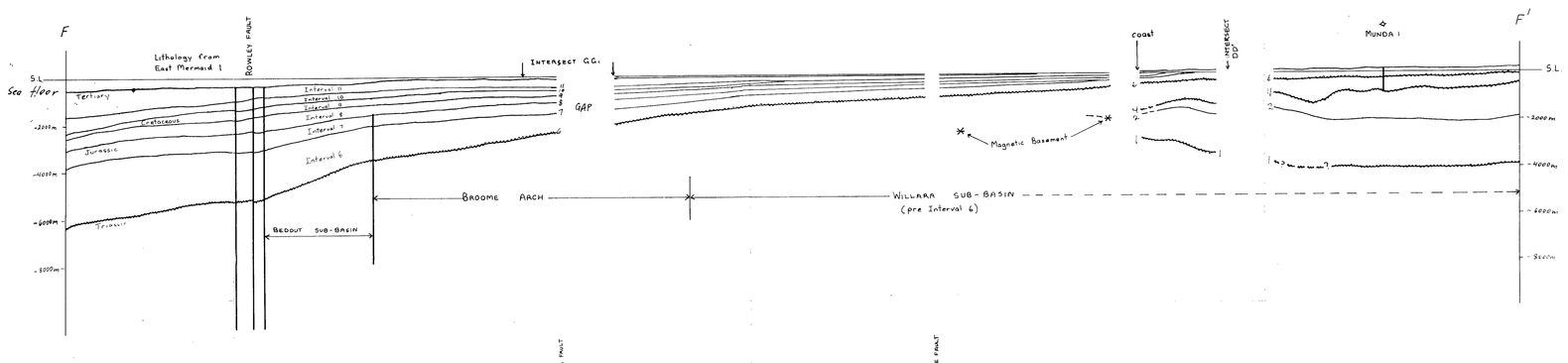
XADS-4-213

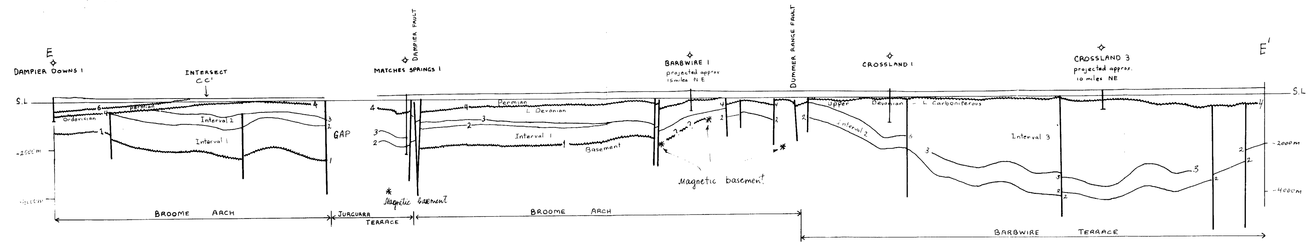
BASE INTERVAL 11
CANNING BASIN
~~Author Objective Base Map~~
~~18-2-75~~
(12-11-75)

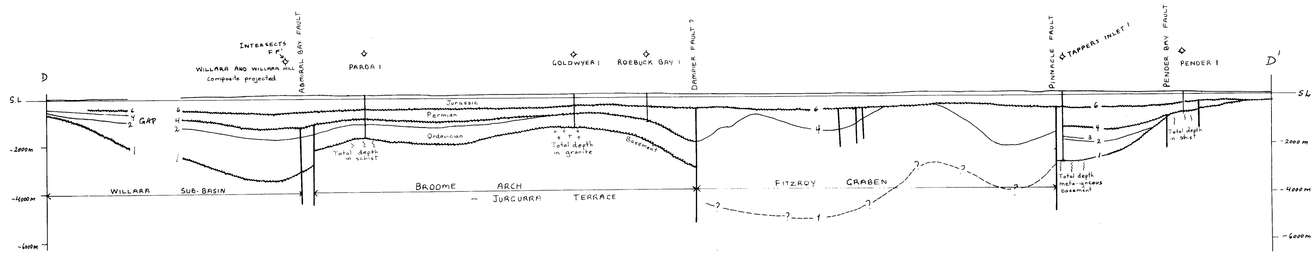
Map 9.11

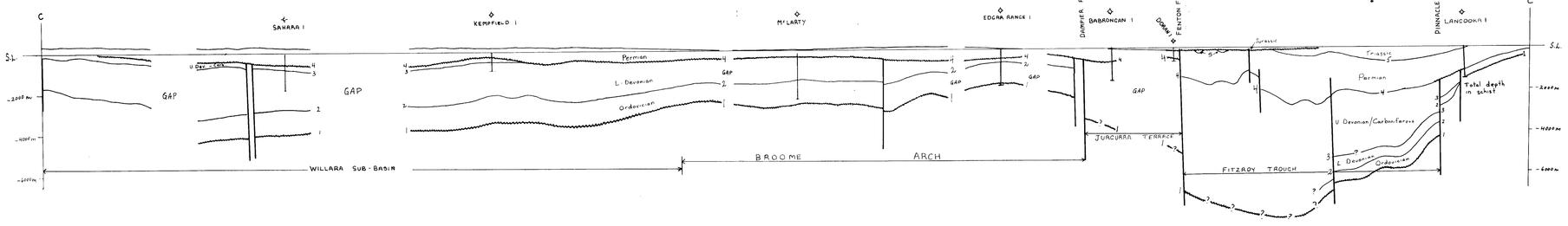
PLATE 14 - REGIONAL STRUCTURAL SECTIONS

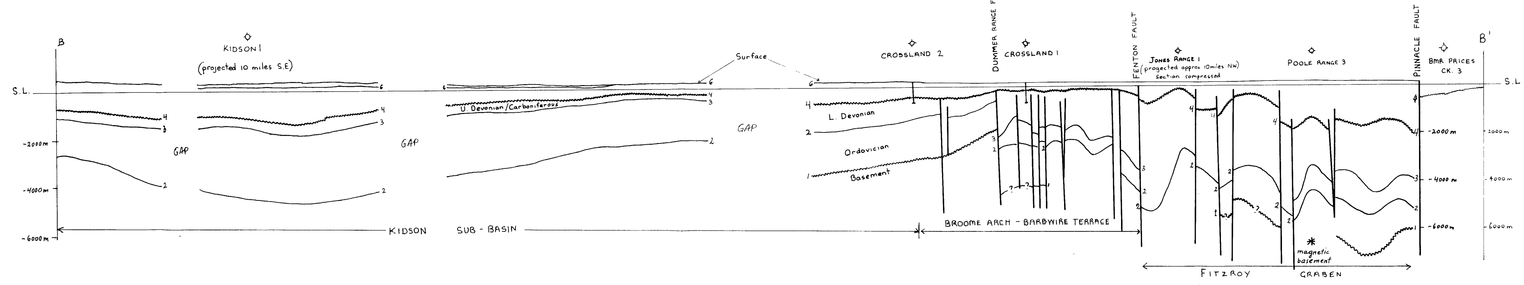


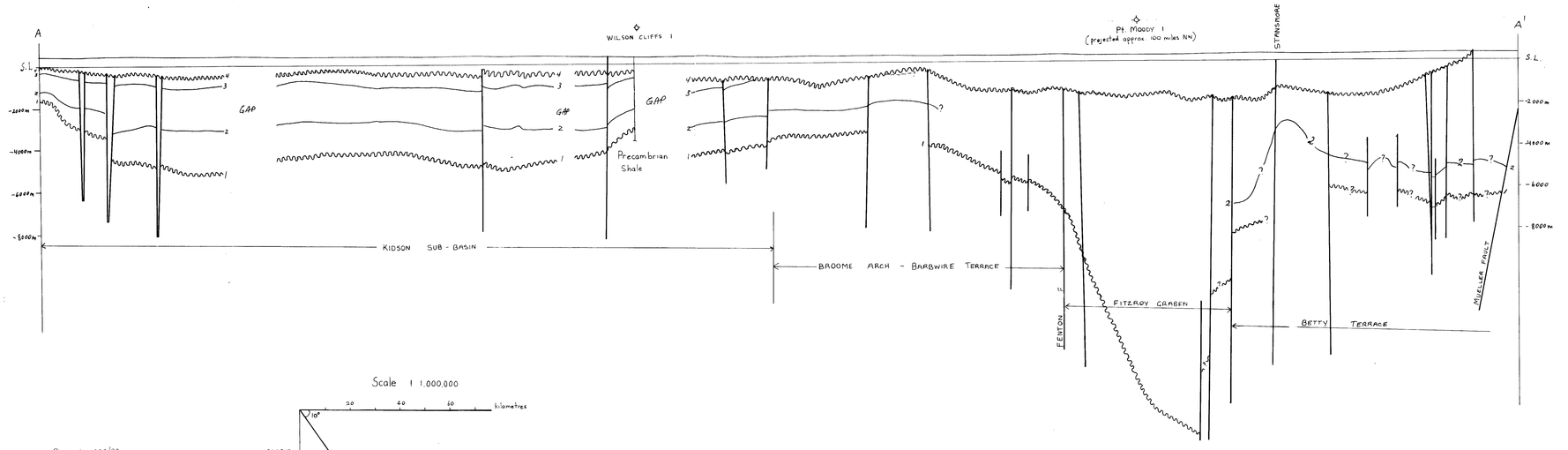




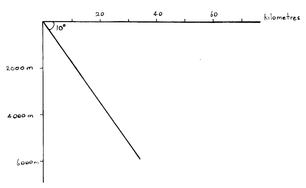








Scale 1 1,000,000

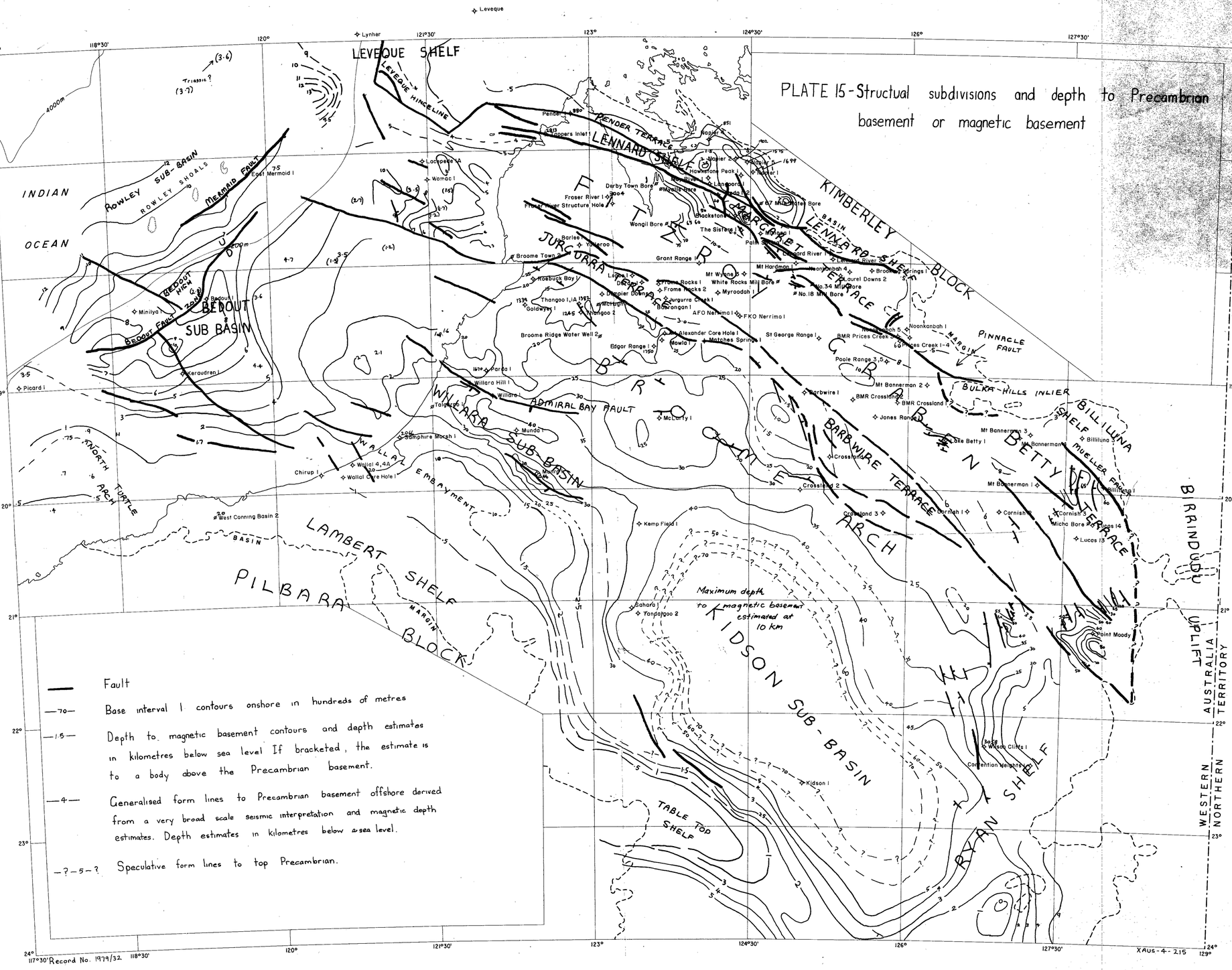


Record 1979/32

XAUS-1-214

Pl 15

PLATE 15 - Structual subdivisions and depth to Precambrian basement or magnetic basement



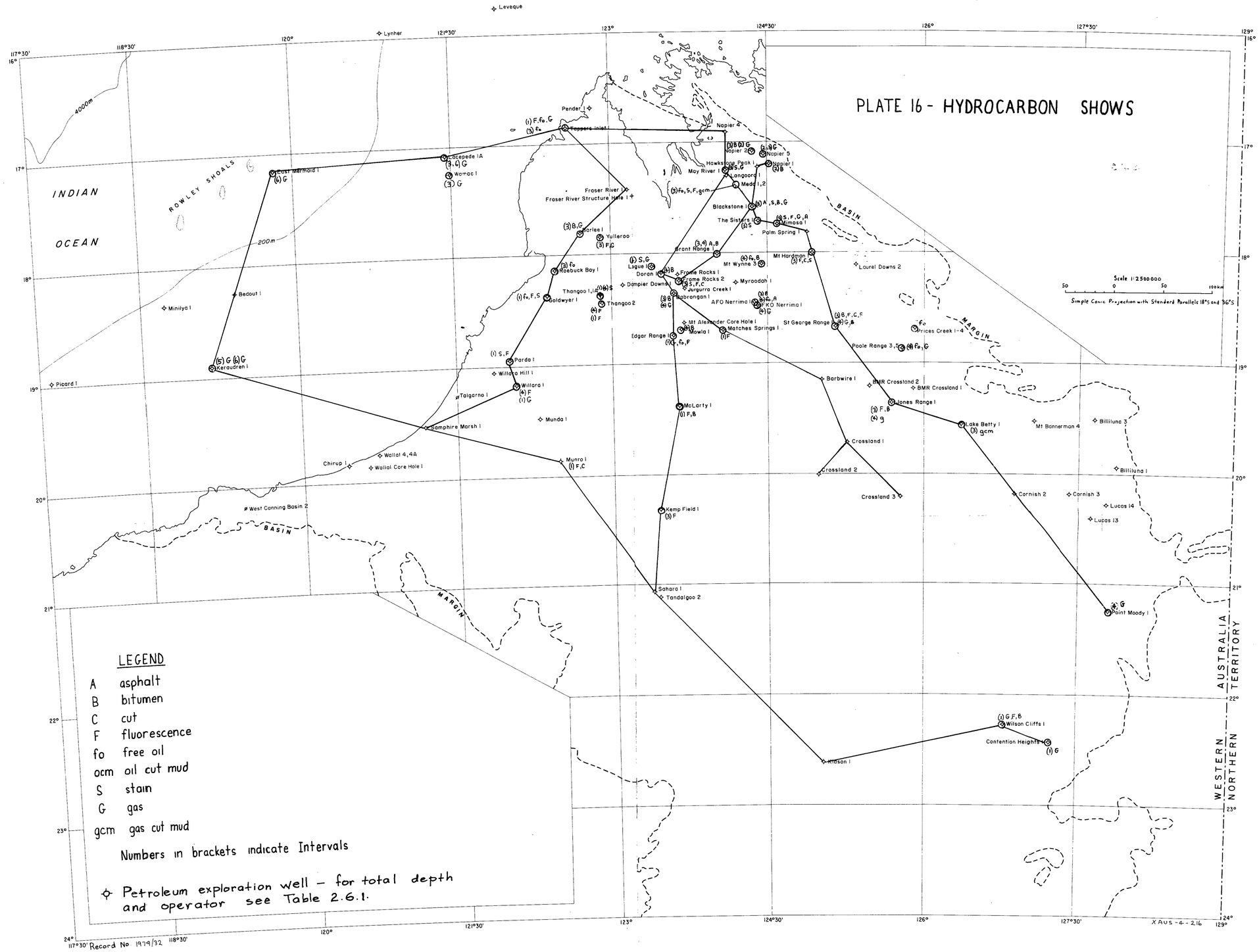
Record No. 1979/32

XAus-4-215

5-10-76 nem

MAP 2

PLATE 16 - HYDROCARBON SHOWS



LEGEND

A	asphalt
B	bitumen
C	cut
F	fluorescence
fo	free oil
ocm	oil cut mud
S	stain
G	gas
gcm	gas cut mud

Numbers in brackets indicate Intervals

☼ Petroleum exploration well – for total depth and operator see Table 2.6.1.

Record No 1979/32

XAus-4-2.16

pl 16

5.10.76 nrm