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PERMIAN AND MESOZOIC GEOLOGY
OF THE DERBY AND MOUNT ANDERSON 1:250 000 SHEET AREAS,
WESTERN AUSTRALIA

by

R.W.A. Crowe (Geological Survey of Western Australia),
R.R. Towner, and D.L. Gibson

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SUMMARY

The Permian and Mesozoic geology of Derby and Mount Anderson Sheet areas is characterised by four major sedimentary cycles, each representing a marine transgression and regression with only minor continental deposition. The first cycle was deposited in the Late Carboniferous to Early Permian and was probably dominantly a glacial condition. A brief period of compressional tectonism preceded the second cycle, which occurred in a warmer climate during the rest of the Permian. Local tectonism then took place adjacent to the margins of the Fitzroy Trough and the third, Triassic cycle occurred, probably only to the north of the Fenton Fault. This was followed by a major period of compressional tectonism, probably during the Early or Middle Jurassic, which resulted in reverse movement along the margins of the Fitzroy Trough and folding within it. The fourth cycle of sedimentation started in the Middle Jurassic and continued until the Early Cretaceous. This was followed by minor faulting and gentle upwarping, probably during the Tertiary.

INTRODUCTION

The purpose of this report is to make available, as quickly as possible, stratigraphic information, field interpretations, and hypotheses that result from the second-edition mapping of the Derby and Mount Anderson Sheet areas* in 1976. The report only covers the Permian and Mesozoic geology of the area, and the rest of the stratigraphy will be described in the Explanatory Notes that accompany the maps (Towner & Gibson, in prep.; Gibson & Crowe, in prep.).

In many respects the work is a continuation of that carried out in adjoining NOONKANBAH in 1974 (Crowe & Towner, 1976c). Although time limitations did not allow the same amount of detailed work as that done in NOONKANBAH, many of the interpretations and hypotheses are the same. Most of the stratigraphic units recognized in NOONKANBAH were traced into the area though they were not recognizable everywhere. The Jurassic section only just extends into NOONKANBAH and was therefore not covered by Crowe & Towner (1976c). However, in the present study area it is well exposed. A problem with the Jurassic section is that the exposures are widely sep separated and correlation is therefore difficult. In previous mapping (Brunnschweiler, 1957; Guppy and others, 1958; Veevers & Wells, 1961) this' resulted in the definition of a large number of units with indefinite or unknown relations. However, since that time there has been a large increase in the amount of subsurface data available and this has enabled useto simplify the earlier interpretation of the stratigraphy. In making these simplifications, some nomenclature changes have been necessary and in some cases (Langey Shale, Jurgurra Sandstone, Mudjalla Sandstone) these changes have not yet been formally defined.

*Hereafter 1:250 000 Sheet area names are shown in capitals (NOONKANBAH) to distinguish them from place names.

The report is organized differently from previous reports (Yeates and others, 1975b; Crowe & Towner, 1976c; Towner and others, 1976) as much' of the information is given in tabular form. Part I of the text concentrates on the interpretation of the depositional environment and unusual or important features of each lithostratigraphic unit and the relevant information is summarized in tables. Part II is an account of the Permian and Mesozoic geological history of the area. Environmental models are used to explain the facies distributions and although there is only slight evidence for some of these models, it is felt that such suggestions are worth recording as they should form a basis for future work in the area.

The rocks are described according to the classification of Gilbert (in Williams and others, 1958). Grainsize is classified on the Wentworth scale, and terms used for bedding thickness are those of Ingram (1954). The classification of cross-bedding follows Potter & P Pettijohn (1963) and Reineck & Singh (1973), and that of flaser and lenticular bedding follows Reineck & Wunderlich (1968). Other terms used are referenced in the text.

All place names referred to are shown on the 1:250 000 geological maps (Enclosure 4). Most can be found on the existing 1:250 000 topographic maps, although for the latest topographic information the 1:100 000 maps should be used (topographic maps are available from the Division of National Mapping, Canberra or from the Department of Lands and Surveys, Perth). The more important place names are shown in Figure 1 together with the names of the structural subdivisions that are used in the text.

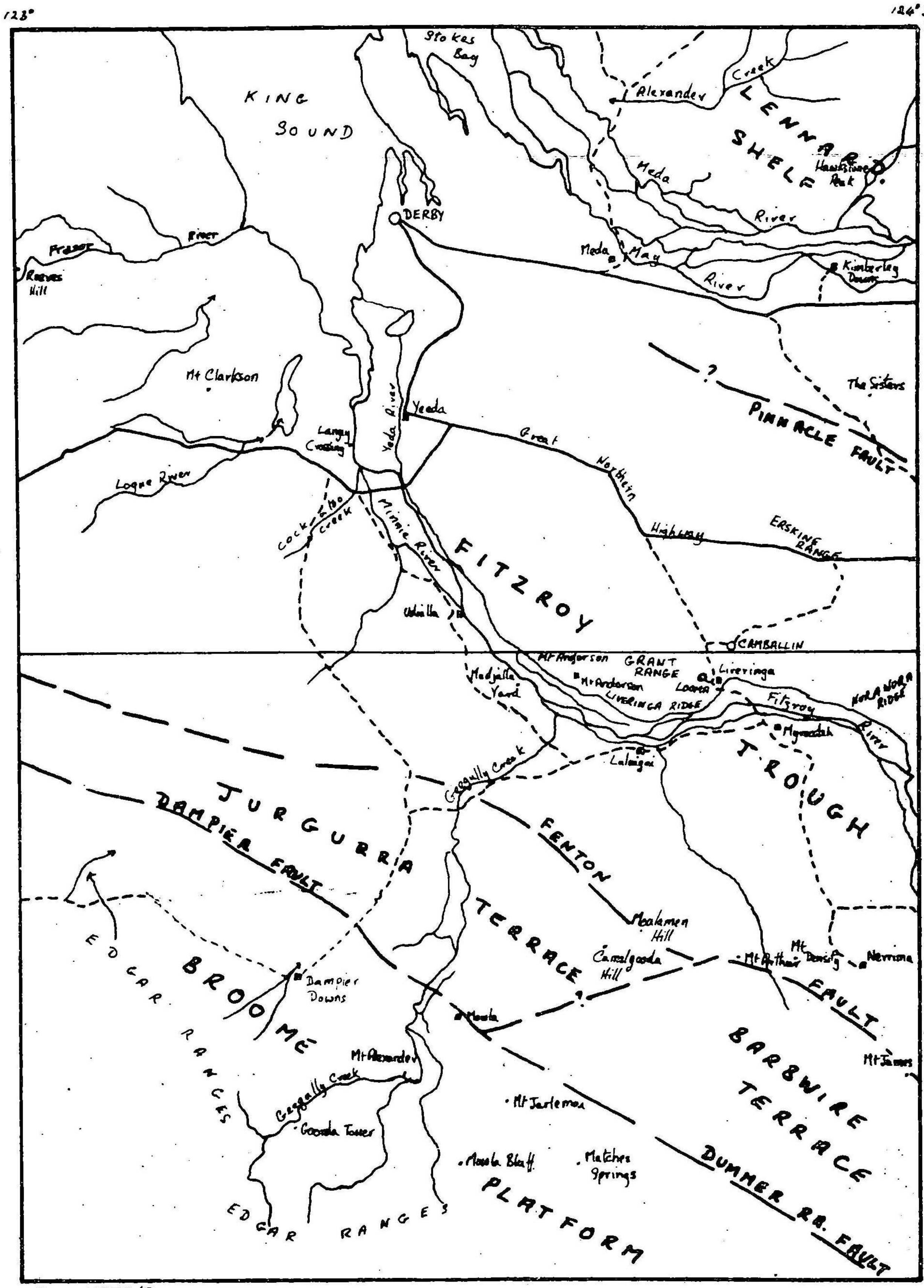

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Fig. 1 Sketch map showing structural subdivisions and main topographic features of DERBY and MT ANDERSON

O Town or settlement ■ Station homestead ~ Creek or river —— -- Road

SCALE 1 : 1 000 000

PART I

STRATIGRAPHY AND DEPOSITIONAL ENVIRONMENTS OF UNITS

LATE CARBONIFEROUS TO EARLY PERMIAN

GRANT GROUP

The Grant Group (Crowe & Towner, in press) consists of three formations, the lower Betty Formation, the middle Winifred Formation, and the upper Carolyn Formation. The upper part of the Carolyn Formation also contains two subdivisions, the Wye Worry Member and the uppermost Millajiddee Member (Crowe & Towner, 1976a). All these units are recognized in the area, although the two Carolyn Formation members are not everywhere recognizable (Tables 4 & 5). The Betty and Winifred Formations are not thought to crop out in the area but are recognized in bores (Appendix II).

BETTY FORMATION (Table 1)

The Betty Formation unconformably overlies Early Carboniferous, Early Palaeozoic, and Devonian rocks in the area. It progressively overlies younger rocks from the centre of the Fitzroy Trough outwards, and the basal boundary is a seismic reflecting horizon which has been mapped in many areas of the basin.

Little is known about the depositional environment of the Betty Formation. The one record of marine fossils in the southeastern part of the basin implies that it is at least partly marine. If the environment is marine, then such large thicknesses of sandstone are, in the absence of turbidite indicators, difficult to explain except in a shallow-water environment. The possible presence of dropstones within the sequence suggests a glacial climate. This is supported by the fact that the formation is thought to interfinger with parts of the glacial Paterson Formation in the southern part of the basin (Crowe & Towner, in press).

Unit Betty Formation | **Symbol** Pb | **Defined by** Crowe & Towner (in press)

Distribution In subsurface the unit occurs throughout the area except in DERBY. It is not thought to crop out.

Lithology Dominantly white to light grey sandstone, very fine to coarse-grained; minor conglomerate. Unit contains some calcareous and pyritic zones and some shale intervals. Fragments of various Precambrian rock types are reported from many wells (and may represent glacial dropstones).

Facies variations Facies appears to vary laterally and vertically although the facies have not been separately mapped.

Thickness Maximum thickness recorded in basin is 1714 m in WAPET Grant Range No.1 (Appendix II)

Type section locality Between 1058 and 1657 m in WAPET Lake Betty No.1 (MOUNT BANNERMAN: Lat.19°34'10"S, Long.126°19'52"E).

Age and criteria Late Carboniferous to Sakmarian based on palynological evidence (Gorter, in prep.). On Broome Platform and Jurgurra Terrace the unit is probably mostly Permian.

Fossils The only macrofossils are unspecified marine fossils in Aquitaine Wilson Cliffs No.1 (Aquitaine, 1969) (Wilson).

Relations Unconformably overlies pre-Permian rocks and is conformably overlain by the Winifred Formation.

Subdivisions None defined although there are fine-grained parts of the sequence that may be mappable in the subsurface.

Nature of exposure None.

Remarks A prospective reservoir for petroleum.

The formation contains a basal Late Carboniferous section which appears to be largely confined to the Fitzroy Trough (except in western parts of the area). This implies that deposition started in the Fitzroy Trough before spreading throughout the area in the Early Permian.

WINIFRED FORMATION (Table 2)

Little is known about the depositional environment of the Winifred Formation. The unit contains marine fossils in the southern part of the basin and so is at least partly marine. It may have been laid down in a glacial climate as a few clasts of Precambrian rock types are reported from some wells, and Towner and others (1976) believe parts of the unit are varved. The fine grainsize of the unit suggests deposition in deeper or quieter water than the Betty and Carolyn Formations.

CAROLYN FORMATION (Table 3)

The Carolyn Formation occurs throughout the Canning Basin except where it is cut out by the Jurassic unconformity. From work in adjoining NOONKANBAH, Crowe & Towner (1976c) were able to show that the formation is, at least locally, unconformably overlain by the Poole Sandstone. In one area this unconformity cuts out the uppermost Millajiddee Member (Crowe & Towner, 1976c) and a similar situation exists in DERBY and MOUNT ANDERSON.

Grant Range area

The best exposures of the Carolyn Formation in the area occur in the Grant Range (Section 1) and at nearby Mount Anderson and Mount Wynne (northern MOUNT ANDERSON). The formation is exposed in cliffs which are partly obscured by scree. Examination of the sedimentary structures is made difficult by the presence of a siliceous weathering skin on the rock surface and the structures can normally only be seen in caves and overhangs where the skin is eroded (Fig. 2).

Table 2

Unit Winifred Formation	Symbol Pw	Defined by Crowe & Towner (in press)

Distribution Not exposed. Intersected in the subsurface throughout the area except in NE DERBY and near Matches Springs where it is cut out by the Jurassic unconformity.

Lithology Predominantly grey shale, carbonaceous, pyritic; grading to siltstone, with thin interbeds of very fine-grained sandstone. Unit is coarser-grained towards base.

Facies variation The unit is difficult to recognize in some bores within the Fitzroy Trough, indicating that it may contain lithological variations.

Thickness	Type section locality
Max. intersection is 278 m in AFO Sisters No. 1 (Appendix II).	Lat.22°52'40"S, Long. 123°36'20"E (TABLETOP)

Age and criteria Sakmarian (sensu lato) based on palynological determinations (Gorter, in prep.).

Fossils Some unidentified crinoid, bryozoan, and echinoid fragments are recorded from the unit from WAPET Sahara No. 1 (SAHARA) to the south of the area (WAPET, 1966b).

Relations Interpreted to be conformably overlain by Carolyn Formation in bore sections. However Carolyn Formation overlaps the Winifred Formation in the northern part of the area. The lower boundary with the underlying Betty Formation is also interpreted to be conformable.

Subdivisions	Nature of exposure
None.	None.

Remarks Not easily recognized in bores within the Fitzroy Trough in this area. May be a cap rock for petroleum.

Table 3

Unit Carolyn Formation

Symbol Pc

Defined by Crowe & Towner (in press)

Distribution Throughout area; exposed in NE DERBY, in Grant Range and at Mount Arthur (MOUNT ANDERSON). Unit is cut out by unconformities in Edgar Range area.

Lithology Fine to coarse-grained quartz wacke and quartz arenite; minor feldspathic and lithic wacke, bedding poorly preserved, mainly planar-bedded, some large-scale trough cross-bedding, ripple marks, and scour-and-fill structures. Contains large-scale slump structures at Hawkstone Peak and in east Grant Range. Contains grey calcareous mudstone sequences ascribed to Wye Worry Member. See text for description of individual areas.

Facies variations Towards the top of the formation marked lateral facies variations are common and are difficult to map. There appears to be some lateral (as well as vertical) changes between Wye Worry and Millajiddee Member in central Grant Range. Sections at Mount Arthur and Hawkstone Peak are different again (see text).

Thickness 366 m in AFO Sisters No. 1 (Appendix II)

Type section locality Composite section at Lat.18°44'20"S, Long.124°55'52" E, and Lat. 18°41'53"S, Long.124°54'30"E (NOONKANBAH).

Age and criteria Late Sakmarian (sensu late) based on marine macrofossils (Dickins and others, in press). Palynological determinations indicate a Sakmarian (sensu lato) age (WAPET, 1973).

Fossils Eurydesma? sp. ind., Deltopecten lyonensis, Etheripecten cf. tenuicollis, Streblopteria sp., Keenia? sp. ind. in Wye Worry Member outside area.

Relationships Lower boundary with Winifred Formation is believed to be conformable in well sections in area. Unconformably overlain by Poole Sandstone in Grant Range; unconformity not seen elsewhere in area but may be present. Unit is cut out by unconformities in Edgar Range area.

Subdivisions

Millajiddee Member

Wye Worry Member

Undivided lower part

Nature of exposure High straight-sided cliffs or smooth scree slopes; appears rugged on aerial photographs.

Remarks Identification of members within Carolyn Formation could only be made in north-central and south-central Grant Range.

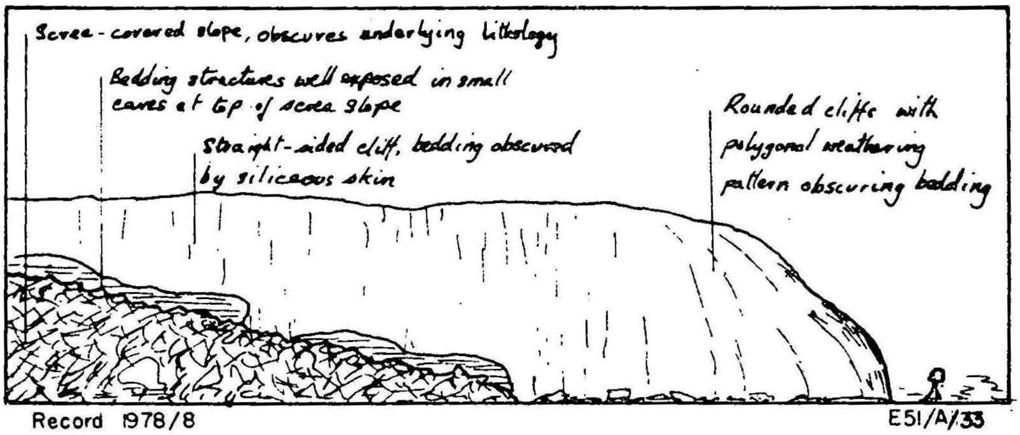

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Fig. 2 Diagram illustrating how different weathering patterns occur in the same lithology. The small caves at the top of the scree slopes are the only places where the sedimentary structures can be seen. The polygonal weathering pattern that occurs on the rounded cliffs is illustrated in Crowe & Towner (1976c; Plate 2)

In mapping the Carolyn Formation in adjoining NOONKANBAH (Crowe & Towner, 1976c; in prep.) the fine-grained shaly Wye Worry Member (Table 4) was found to be a useful marker. Typically the member crops out as smooth scree slopes due to its fine-grained shaly nature and this gives the unit a characteristic tone on the aerial photographs.

The photo-pattern was found to be a reliable identifying criteria in NOONKANBAH and it was consequently also used in the Grant Range area. In fact, identification of the Wye Worry Member by air-photo interpretation was commonly found to be more reliable than ground identifications. The reason is that, on the ground, complex structures, and the presence of scree and unusual weathering patterns tend to complicate the overall picture (Fig. 2). However, mapping of the Carolyn Formation members was only possible in the central and western parts of Grant Range and at Mount Anderson. In the eastern part of Grant Range, the structures are so complex that identification and mapping of the Wye Worry Member marker (at air-photo scale; 1:80 000) was not possible (see section below).

Another complication of the Grant Range sequence is the presence of vertical repetition of the Wye Worry and Millajiddee Members. In NOONKANBAH, Crowe & Towner (1976c) interpreted the Wye Worry and Millajiddee Member sequence as a single regressive cycle of deposition. In Grant Range, however, the sequence is repeated several times (at least three cycles were recognized) and the value of the Wye Worry Member as a marker is largely lost. Moreover, the Wye Worry and Millajiddee Members lens in and out over distances of a kilometre or so. As the whole sequence is complexly faulted, identification of the Carolyn Formation members is rather tentative in the Grant Range area. On the geological map (Gibson & Crowe, in prep.) only the uppermost members are shown for simplicity and the tongues of Millajiddee Member within the Wye Worry Member are not differentiated.

In the Mount Wynne area, shaly Wye Worry Member is exposed underneath laterite but other exposures of mainly sandstone could not be assigned to any of the members of the Carolyn Formation.

Mount Arthur area

In the Mount Arthur area (west central MOUNT ANDERSON) the Grant Group sequence consists of fine to medium and minor coarse-grained quartz wacke. There are large-scale trough cross-bedded parts which pass up into planar-bedded sections with current lineation. These, in turn, pass up into ripple cross-laminated beds and then the whole sequence is' repeated. The cycles are about 10 m thick and some contain intra-formational conglomerate beds at their bases, with abundant fossil wood fragments.

This facies could be correlated with either the Millajiddee Member or parts of the Carolyn Formation below the Wye Worry Member. However, the absence of the Wye Worry Member in such a thick section' (probably several hundred metres) suggests that the latter correlation is more likely. It is nevertheless possible that the Wye Worry Member has been faulted out by strike faults which are known to exist in the area. More detailed mapping in the vicinity of Mount Arthur would probably solve this problem.

Hawkstone Peak area

In the Hawkstone Peak area (northeast DERBY) the exposures consist mainly of fine to medium-grained, well-rounded, moderately to well-sorted quartz arenite and minor quartz-pebble conglomerate. The conglomerate occurs as crudely graded lenses at the base of trough cross sets which are mostly 0.5 m thick although some are thicker. Within this sequence there are steep-sided channels containing intraformational breccias (Plate 1) set in a poorly sorted lithic-wacke matrix. Some blocks are up to 3 m across. In places the larger blocks protrude into the underlying sediment and can be seen to have deformed it. Parts of the sequence are contorted by rheotropic deformation of the order of 10 m thickness.

This lithology is believed to be part of the Millajiddee Member. Although the sequence is not very similar to exposures of the Millajiddee Member in Grant Range, it does correlate with the upper part of the Millajiddee Member section exposed in the Lauris Range in NOONKANBAH (Section 18 of Crowe & Towner, 1976c).

G.S.W.A. F. 19. No. 3

Plate 1. Part of an intraformational breccia in an exposure of the Millajidee Member near Hawkstone Peak at Lat. 17°14' 30" S, Long. 124°09'00" E.

G.S.W.A. F. 18. No. 15

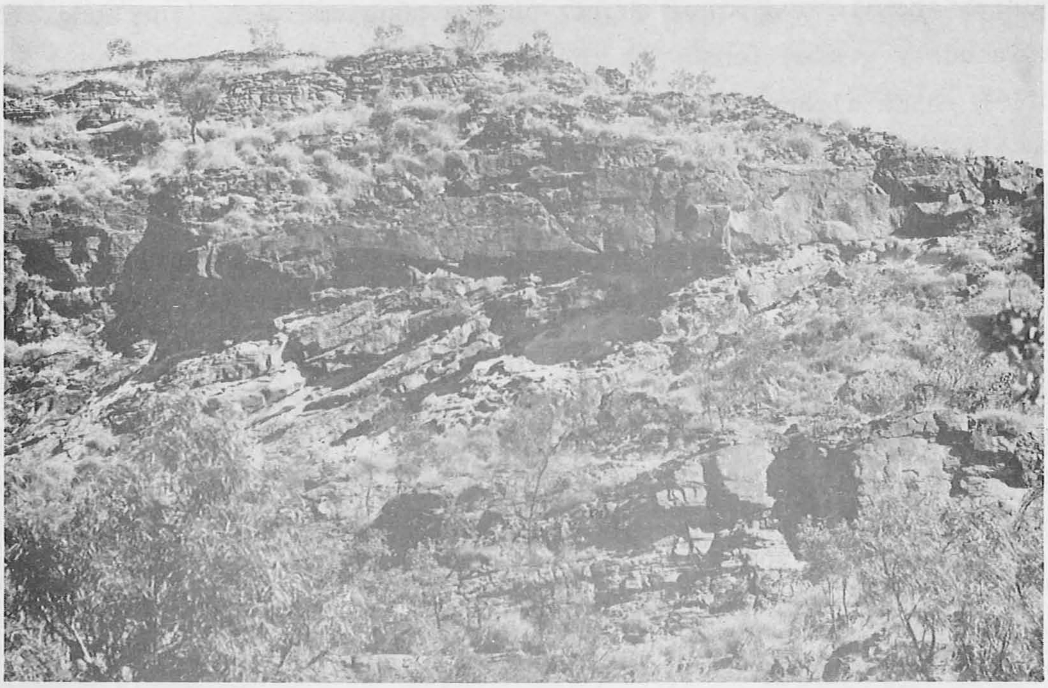

Plate 2. Intraformational unconformity in Carolyn Formation in east Grant Range (Lat. 18°02' 00" S, Long. 124°09'00" E). The underlying dipping beds are interpreted to be part of a large slump which has been planed off before deposition of the overlying horizontal sequence.

It seems as if the Hawkstone Peak and Lauris Range sections of the Millajiddee Member represent a facies variation of the Millajiddee Member that is not generally seen in the Fitzroy Trough. This is probably the reason why early workers in the area separated the Grant Group exposures on the Lennard Shelf from those in the Fitzroy Trough (Kraus, 1941; Findlay, 1942; see Guppy and others, 1958 for discussion). An explanation of this facies variation is given in the section on depositional environment and geological history.

Structures in eastern Grant Range

The structures in eastern Grant Range (referred to above) are of two types: tectonic post-depositional structures, and syn-depositional sedimentary structures.

As stated above, the detailed stratigraphy of eastern Grant Range could not be mapped at air-photo scale. However, at certain localities (e.g. Fig. 3) the Wye Worry Member marker was identified and this enabled some of the detailed stratigraphy to be mapped. Attempts to trace these stratigraphic levels around the range to the west failed because of structural complexities. In particular, very large-scale (several tens of metres) slump structures occur and have been planed off before deposition of the overlying beds (Plate 2). Such intraformational unconformities are thought to be partly responsible for the lateral discontinuities which make it difficult to trace the units.

Mapping in eastern Grant Range suggests that some faults have much greater throws than previously imagined (Guppy and others, 1958). The mapping suggests that some of the north-trending faults may have throws of at least 500 m. However, where these faults are traced southwards into exposures of the Poole Sandstone there is no displacement. Even allowing for differences in displacement across the crest of the Grant Range Structure (anticlinal) this anomaly cannot be explained unless faulting between deposition of the Carolyn Formation and Poole Sandstone is inferred. This inference could not be established on the more major faults but at Lat. 18^{o} 04'00", Long. 124^{o}08'05"E there is firm evidence of such faulting (see following section).

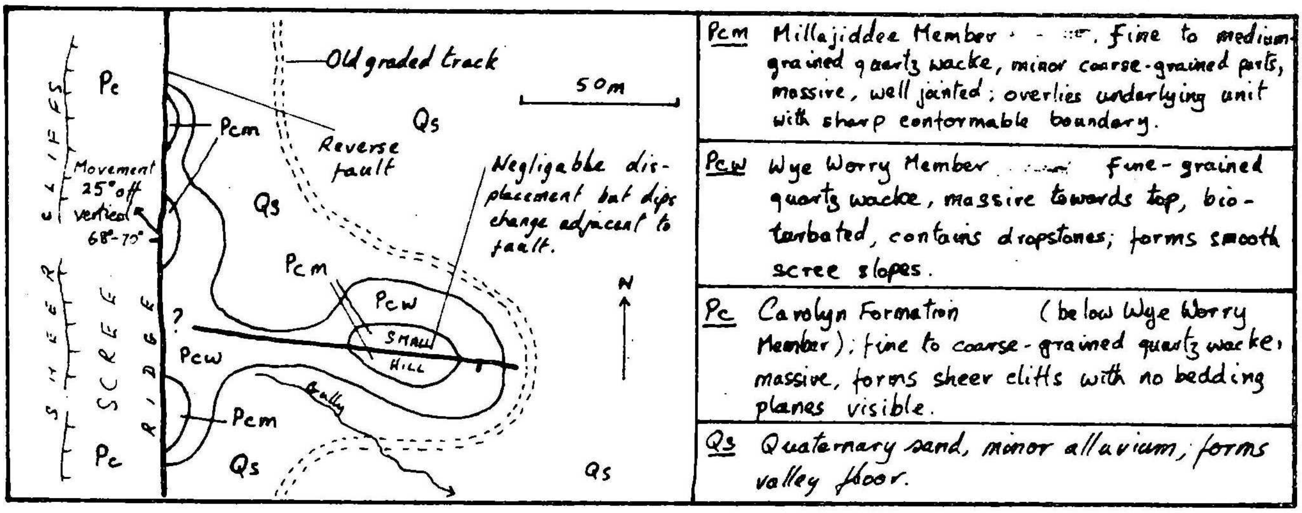

Fig. 3 Sketch map of small area in eastern Grant Range (Lat. 18° 01' 30"S, Long. 124° 08' 00"E) showing identification of reverse fault.

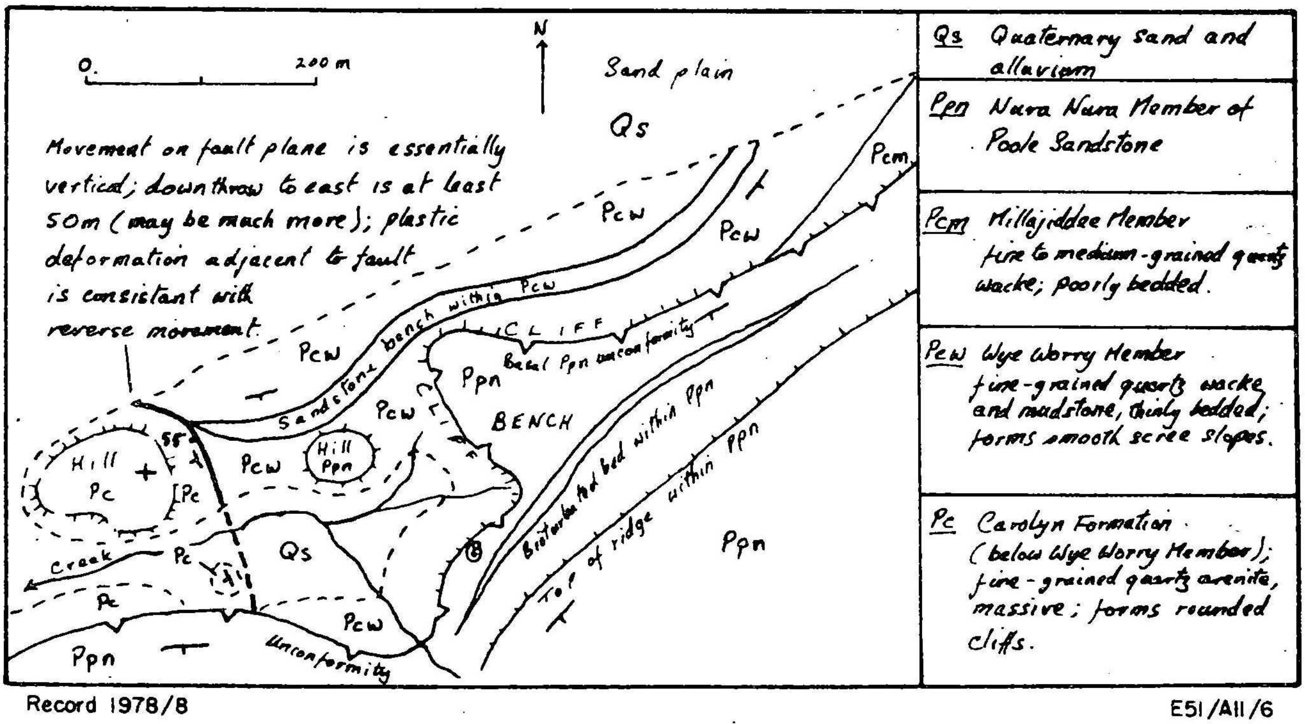

Fig. 4 Sketch map of part of southern flank of Grant Range (Lat. 18° 04' 00" S, Long. 124° 08' 05"E) showing identification of post-Carolyn-Formation pre-Poole-Sandstone reverse fault.

Table 4

Unit Wye Worry Member	Symbol Pcw	Defined by Crowe & Towner (1976a)

Distribution Only recognized at Mount Anderson and in the central Grant Range. Possibly cut out by Poole Sandstone/Grant Group unconformity in Mount Arthur area and is probably overlapped by Millajiddee Member at Hawkstone Peak. Not recognizable in subsurface sections.

Lithology Fine to medium-grained quartz and lithic wacke and mudstone, grey, calcareous; contains rare faceted and striated dropstones. Sedimentary structures are not well preserved because unit is normally covered by scree. Where unit passes up into Millajiddee Member it contains conglomerate lenses, small scour-and-fill structures, and some ripple marks and flaser and lenticular bedding. See Section 1 (Appendix I).

Facies variations Appears to alternate with Millajiddee Member in cyclical fashion. Also appears to pass laterally into Millajiddee Member or Carolyn Formation.

Thickness	Type section locality
At least 110 m in Grant Range.	Lat. 18°46'30"S, Long. 125°18'50"E (NOONKANBAH).

Age and criteria Late Sakmarian (sensu lato) based on marine macrofossils (Dickins and others, in press).

Fossils See under Carolyn Formation.

Relations The lower contact with the underlying part of the Carolyn Formation was not definitely identified. The upper boundary with the Millajiddee Member is conformable. The sequence of Wye Worry Member going up to Millajiddee Member appears to be repeated several times owing to interfingering in the central Grant Range.

Subdivisions	Nature of exposure / Remarks
	Nature of exposure Rather poor, due to cover of scree over most exposures.
	Remarks Difficult to recognize.

Unit Millajiddee Member	Symbol Pcm	Defined by Crowe & Towner (1976a)

Distribution Only recognized at Mount Anderson, in central Grant Range, and tentatively at Hawkstone Peak (NE DERBY). Not recognized in subsurface sections.

Lithology Mainly medium-grained, moderately sorted, quartz wacke; also fine and coarse-grained and mudstone parts; contains ripple marks and large-scale (mainly planar) cross-bedding; scour-and-fill structures and minor flaser bedding; forms resistant cliffs, and bedding is commonly masked by a thin siliceous skin produced by weathering. See Section 1 (Appendix I).

Facies variations Extensive pinching out of Millajiddee Member indicates interfingering with Wye Worry Member. Section at Hawkstone Peak contains intraformational breccia and large-scale slump structures which do not correlate directly with Grant Range exposures.

Thickness	Type section locality
Probably at least 75 m in Grant Range.	Lat. 18°45'00"S, Long. 124°55'25"E (NOONKANBAH)

Age and criteria Late Sakmarian (sensu lato) based on the late Sakmarian age of the underlying Wye Worry Member and the age of the overlying Nura Nura Member which appears to be late Sakmarian to early Artinskian (Thomas & Dickins, 1954; Glenister & Furnish, 1961).

Fossils Contains indeterminate wood fragments and trace fossils.

Relations The lower boundary with the underlying Wye Worry Member is conformable although the Wye Worry Member interfingers with the Millajiddee Member in the central Grant Range. The Millajiddee Member is overlain unconformably by the Poole Sandstone.

Subdivisions The threefold subdivision of the unit that was possible in NOONKANBAH could not be made in the exposures in DERBY and MOUNT ANDERSON.

Nature of exposure Forms rounded cliffs often covered by a siliceous skin or polygonal weathering pattern.

Remarks The unit is an excellent aquifer. Owing to the structural and stratigraphic complexities in the eastern Grant Range the unit cannot be confidently identified. The Millajiddee is difficult to recognize where the underlying Wye Worry Member

Most of the faults within the Fitzroy Trough have previously been described as normal. This is compatible with the tectonic model proposed by Rattigan (1967) and Smith (1968) where the faults within the trough are tensional and part of an en echelon fold pattern related to Middle Triassic/Early Jurassic right lateral wrench movement on the major faults that bound the trough (Fenton Fault and Pinnacle Fault; see Fig. 6). However, the rare occurrence of reverse faults was noted by Crowe & Towner (in prep.) in NOONKANBAH and further examples of reverse movement were discovered during this survey in the Grant Range (Figs. 3 & 4). The occurrence of these reverse faults in a tensional regime may therefore indicate that there was a separate period of compressional tectonism' within the Fitzroy Trough. The mapping suggests that this compressional movement occurred between deposition of the Carolyn Formation and the Poole Sandstone (see Figs. 3 & 4) as none of the reverse faults, so far identified, appear to displace the Poole Sandstone.

Another complication of the geology in the eastern Grant Range is the occurrence of wrench faulting. Horizontal slickensides occur in a fault zone at Lat. $18^{o}01'30''$S, Long. $124^{o}08'20''$E but the amount of movement could not be determined.

Depositional environment

Grant Range area: In the Grant Range area there is little evidence to indicate the depositional environment of the Carolyn Formation below the Wye Worry Member. Where the siliceous weathering skin is absent, sections are seen to be composed of thin-bedded, bioturbated, fine to medium-grained quartz wacke, quartz arenite, and minor feldspathic wacke (possibly theuupper part of the sequence). The lateral continuity of bedding in these sections suggests deposition in a large body of water. Scour-and-fill structures, flaser bedding, and mega-ripple cross-bedding are also present suggesting fairly shallow water (?above wave base) deposition from bedload. However, the bulk of the sequence below the Wye Worry Member in the Grant Range is composed of structureless, massive poorly sorted coarse-grained quartz wacke, the origin of which is problematical. A shallow-water marine environment appears to be the most likely environment capable of depositing such a thick homogenous sequence.

The Wye Worry Member in the Grant Range area consists of mainly fine-grained, grey, partly calcareous lithic wacke, mudstone, and quartz wacke. The sections are mainly thin-bedded or laminated with vertical burrows, bioturbated zones, and bedding-surface trace fossils. This lithology is very similar to the marine part of the Wye Worry Member in NOONKANBAH (Crowe & Towner, 1976c) and a similar depositional environment is inferred. The general absence of ripple marks, channel structures, and the poor sorting suggest deposition below wave base. The basal varved sequence that occurs in the Wye Worry Member in NOONKANBAH does not appear to be present in the area although faceted and striated dropstones occur sporadically throughout the sequence. The dropstones' are interpreted as glacial in origin.

The Millajiddee Member in the Grant Range is similar to the 'Lower' Millajiddee Member sequence in NOONKANBAH (Crowe & Towner, 1976c). It is composed of well-sorted quartz arenite with minor quartz wacke and contains scour-and-fill structures, ripple cross-lamination, flaser bedding, and minor large-scale trough and planar cross-bedding. The boundary between the Wye Worry Member and Millajiddee Member is gradational and represents an upwards increase in grainsize and sorting, indicating a shallowing of water depth. The structures within the Millajiddee Member are typical of sediment laid down above wave base, suggesting near-shore conditions.

The Wye Worry Member-Millajiddee Member sequence is repeated several times in the Grant Range area (Section 1) and one explanation for this is that there was an oscillating shoreline in the area. An alternative explanation is that the intervals of Millajiddee Member represent offshore sand bars and that the final regression is not preserved. The lenticularity of some of these intervals suggests this is the most likely alternative.

In the Mount Arthur area, sections of the Carolyn Formation are different from those in the Grant Range. The upward progression from trough cross-bedding to planar bedding to ripple cross-bedding is typical of channel point-bar deposits. These sequences are repeated several times and this supports the interpretation. Such sequences are often interpreted as fluviatile but they may also represent tidal or delta channel deposits in a near-shore environment. As correlation of this sequence with other parts of the Carolyn Formation is not possible at present, the exact nature of the meandering channels in the Mount Arthur area has not been established.

The exposures in the Hawkstone Peak area are assigned to the upper part of the Millajiddee Member. The sequence mainly consists of large-scale trough cross-bedded sandstone with pebble conglomerate at the base of the cross-sets. The conglomerates are interpreted as channel lags and the cross-sets are also believed to be channel deposits of possible fluvial origin. Intraformational breccias occur in steep-sided channels cut into this general lithology and their association with soft-sediment deformation structures suggests that they were deposited as mudflows. The association between mudflows and fluviatile deposits is characteristic of an alluvial fan environment.

The unconformity in the Grant Range area between the Carolyn Formation and the Poole Sandstone indicates that after deposition of the Carolyn Formation, the Grant Range area was uplifted, folded and faulted before deposition of the Poole Sandstone (see following section). The upper and middle parts of the Millajiddee Member that are believed to represent a regression in NOONKANBAH (Crowe & Towner, 1976c) do not appear to be present in the Grant Range and are probably cut out by this unconformity.

Table 6

Unit Poole Sandstone	Symbol Pp
Defined by Guppy and others (1952)	

Distribution Exposed on the flanks of the Grant Range, in the Mount Wynne/Nura Nura Ridge area, and in the Mount Arthur area. Subsurface information indicates the formation is present in all but the northeastern part of the area and where it has been cut out by the Jurassic unconformity.

Lithology Mainly fine-grained quartz and lithic wacke, thin-bedded, laminated; abundant ripple cross-bedding and trace fossils. Contains some medium to coarse-grained quartz wacke and arenite in the lower part. Flaser and lenticular bedding, wavy bedding and some large-scale, mainly planar, cross-bedding is present. Lenses of ferruginized clay pellet conglomerate, with abundant fossil wood fragments occur throughout. See Section 2 (Appendix I).

Facies variations See under Nura Nura Member and Tuckfield Member.

Thickness At least 250 m exposed in Grant Range. Maximum is 350 m in AFO Nerrima No.1(Appendix II).

Type section locality Southeast Grant Range (MOUNT ANDERSON: Lat.18°04'30"S, Long.124°08'30"E).

Age and criteria Late Sakmarian (sensu lato) to ?early Artinskian. The oldest limit is based on macrofossils from the Nura Nura Member (Glenister & Furnish, 1961; Dickins *in* Crowe & Towner, 1976c) and the younger limit is based on microfossils (Paten *in* Yeates and others, 1975b) and the age of the overlying Noonkanbah Formation.

Fossils Macrofossils from the Nura Nura Member are listed by Guppy and others (1958). Wood fragments and plant fossils are listed by Guppy and others (1958).

Relations Unconformably overlies the Grant Group. Upper boundary is not exposed but in subsurface sections it is sharp and is therefore thought to be a disconformity.

Subdivisions Christmas Creek Member (does not occur in area)
Tuckfield Member
Nura Nura Member

Nature of exposure Forms smooth, scree-covered hills and strike ridges.

Remarks Unit is a moderately good aquifer if sandstone sections are intersected.

TECTONISM BETWEEN DEPOSITION OF GRANT GROUP AND POOLE SANDSTONE

Guppy and others (1958) were the first to recognize an angular unconformity between the Grant Group and the Poole Sandstone. Later workers (e.g. Veevers & Wells, 1961) believed the boundary was only disconformable, but Crowe & Towner (1976b, 1976c) showed that in NOONKANBAH there was corroborating evidence of uplift, erosion and tilting between deposition of the two units, in addition to planed off slump structures which mark the unconformity.

The evidence given by Crowe & Towner was of two types. Firstly, from measured sections, they were able to show that in certain areas the upper part of the Carolyn Formation (their 'Upper Sandstone Unit') was missing, suggesting an unconformity. Secondly, a small lensoid between the two units was interpreted as a mudflow deposit and so was compatible with an environment where uplift was producing steep topography.

In MOUNT ANDERSON there is also good evidence of an unconformable relation between the Grant Group and the Poole Sandstone. In several places in Grant Range, beds of the Carolyn Formation are cut out by the unconformity at the base of the Poole Sandstone. In one area (Fig. 4) a fault exhibits significant (probably reverse) displacement in the Carolyn Formation but does not displace the overlying Poole Sandstone. Apparently this is the first recording of faulting between these two units and it supports Crowe & Towner's evidence of tectonism at this time in NOONKANBAH (Crowe & Towner, 1976c).

Crowe & Towner (1976c) suggested that in NOONKANBAH, the areas that are now anticlines acted as both positive and negative features at various times during Permian deposition and it could be that the Grant Group/Poole Sandstone unconformity is restricted to these major anticlines.

EARLY TO LATE PERMIAN

POOLE SANDSTONE

The Poole Sandstone was defined by Guppy and others (1952). The type area was designated in the Poole Range (NOONKANBAH) but later Guppy and others (1958) defined a type section in the Grant Range (Section 2). The basal Nura Nura Member was also defined by Guppy and others (1952) but their definition was inadequate and has therefore been expanded here. Crowe & Towner (in press) have named the widespread middle section of the formation the Tuckfield Member. The uppermost Christmas Creek Member (Crowe & Towner, 1976a) that occurs in NOONKANBAH does not occur in the area.

In some parts of the area (e.g. Mount Arthur) the members could not be reliably recognized and the exposures were therefore mapped as Poole Sandstone undivided.

NURA NURA MEMBER (Table 7)

The Nura Nura Member was defined by Guppy and others (1952) as consisting of 'calcareous sandstone, sandy limestone, and limestone, with bands of unsorted, coarser sediments' at Nura Nura Ridge (northeast MOUNT ANDERSON). In NOONKANBAH, Crowe & Towner (1976b; in prep.) extended this unit to include a wider variety of facies. Further more detailed work should allow these facies to be subdivided but at 1:250 000 scale mp mapping the member was taken to include the rocks between the distinctive boundaries of the post-Grant Group unconformity and the conformable, often sharp upper boundary with the Tuckfield Member ('middle Poole Sandstone' of Crowe & Towner, 1976b). In western NOONKANBAH, the upper part of the Nura Nura Member consists of a poorly bedded, well-sorted quartz arenite unit interpreted as a barrier bar deposit. A similar sandstone unit forms a distinctive marker (forming rugged terrain) along the northern and southern flanks of the Grant Range and although it occurs much higher in the section, it is correlated with the NOONKANBAH sandstone unit and is taken as the topmost part of the Nura Nura Member in the Grant Range area.

Table 7

Unit Nura Nura Member	Symbol Ppn	Defined by Guppy and others (1958)

Distribution Exposed at Nura Nura Ridge/Mount Wynne area and on the northern and southern flanks of Grant Range. Possibly exposed in Mount Arthur area. In the subsurface the unit occurs throughout the area except in northeast and where cut out by Jurassic unconformity.

Lithology In the Grant Range area the basal 10 m consists of fine-grained poorly laminated quartz arenite with abundant trough cross-bedding with some bioturbation and macro-fossils. Middle part consists of thin-bedded ferruginized, fine-grained quartz wacke and mudstone with lenses of clay-pellet conglomerate, ripple marks, wavy and flaser bedding. Top 25 m consists of moderately to well-sorted quartz wacke and quartz arenite with abundant trough and planar cross-bedding and rippled cross-lamination. Sorting and grainsize increase towards top. Intense ferruginization of some parts suggests they may have been calcareous before weathering. See Section 2.

Facies variations Unit is thinner and calcareous in Nura Nura Ridge area. Exposures in northern Grant Range appear to contain more abundant poorly bedded quartz arenite sections than in southern flank of range. Guppy and others (1958) point out that the unit exhibits marked changes in thickness over short distances.

Thickness 110 m in Grant Range.	Type section locality Nura Nura Ridge (MOUNT ANDERSON: Lat. 18°02'S, Long. 124°28'E).

Age and criteria Late Sakmarian based on macrofossils (Glenister & Furnish, 1961; Dickins *in* Crowe & Towner, 1976c).

Fossils Macrofossils from the unit are listed by Guppy and other (1958) and include brachiopods (Thomas, 1954; Coleman, 1957), Bryozoa (Crockford, 1957), foraminifera, ammonoids, molluscs (Thomas & Dickins, 1954), conodont fragments, crinoid ossicles, and ostracods.

Relations Lies unconformably on Carolyn Formation (Plate 3) and is conformably overlain by the Tuckfield Member.

Subdivisions	Nature of exposure / Remarks
Some characteristic subdivisions can be recognized in Grant Range; 25 m-thick cross-bedded, poorly laminated, fine to medium-grained quartz wacke and quartz arenite. Thin-bedded, ripple-marked, poorly sorted quartz wacke and mudstone with lenses of clay pellet conglomerate. Local, 10 m thick, cliff-forming well-sorted cross-bedded quartz arenite.	**Nature of exposure** Well exposed as small cliffs and scree-covered slopes in Grant Range. Poorly exposed at Nura Nura Ridge. **Remarks** Basal part of member is easily confused with top of Carolyn Formation as weathering pattern is similar.

G.S.W.A. F. 17 No. 13

Plate 3. Thin - bedded (scree-forming) Nura Nura Member of the Poole Sandstone showing the massive bench at the base of the unit. The contact with the underlying Carloyn Formation is exposed in the scree at the base of the hill. South flank of Grant Range (Lat. 18°02'50" S, Long. 124°09'00" E).

In the Nura Nura Ridge area some of the original exposures described by Guppy and others (1952; 1958) are now covered by the waters of Lake Josceline. The parts that are still exposed consistoof basal calcareous sandstone and fossiliferous limestone overlain by ferruginized sandstone which forms a small ridge near the lake. The ferruginization suggests that this sandstone was originally calcareous (this is a common weathering effect in the area) and the ridge is tentatively correlated with the sandstone marker that occurs at the top of the Nura Nura Member on the flanks of the Grant Range. Because there is a difference between the sections of the Nura Nura Member at Nura Nura Ridge and in the Grant Range it is herein proposed that the Grant Range section (Section 2) be taken as a reference section.

In the Mount Arthur area, the exposed section is not thick enough to confidently identify the Nura Nura Member. However, the ridges of Poole Sandstone at the western end of the Mount Arthur group of hills are lithologically similar to the Nura Nura Member in the Grant Range. The section at Mount Arthur itself is more like the Tuckfield Member. Complex strike faulting makes it difficult to establish the vertical sequence in the Mount Arthur area.

Depositional environment

The basal quartz arenite part of the Nura Nura Member that is seen in the Grant Range is interpreted as a transgressive sand body deposited as the sea moved over the pre-existing land surface. The clean, very well-sorted (with rounded grains) nature of the sedimentsis characteristic of intense re-working by wave action which would be expected in such an environment.

Such sand bodies can be deposited either as beaches or as off-shore sand bars. The abundance of large-scale trough cross-bedding in the unit suggests sand bars because trough cross-bedding is not common in beach deposits. As Visher (1965) has pointed out, rather special conditions are necessary for transgressive sand bodies to be preserved because as the transgression continues the sea tends to rework its own deposits. This would explain why the unit is only locally developed.

The middle part of the Nura Nura Member in the Grant Range contains ripple-marked, poorly-sorted interbedded sandstone and mudstone interpreted to have been deposited in a shallow sea (above wave base). The interbedding of sand and silt in such an environment is common because of the alternations between fast-moving and slack water due to tidal action.' Small scour-and-fill and bioturbation structures are also common and are compatible with the interpretation. Larger scours containing clay-pellet, intraformational conglomerate are associated with large-scale planar cross-sets and these are interpreted as channel deposits of tidal origin.

Towards the upper part of the Nura Nura Member in the Grant Range, there is an overall upward increase in grainsize and sorting to coarse-grained well-sorted quartz arenite at the top. This indicates that shallower-water conditions returned to the area. The abundance of large-scale planar and trough cross-bedding in this part of the sequence indicates deposition in channels and as mega-ripples. This, and the fact that the sequence passes upwards into further shallow-water deposits (of the Tuckfield Member) suggests that the upper part of the Nura Nura Member represents an offshore sand-bar deposit possibly of the barrier-bar type. This fits in with the interpretation placed on the similar sandstone unit which occurs at the top of the member in western NOONKANBAH (see above).

Visher (1965) states that a common physical characteristic of a transgressive sequence is that, above the basal beds, the sequence commonly passes sharply up into carbonates. This could be the situation in the Nura Nura Ridge area where the member contains limestone and calcareous sandstone near its base.

TUCKFIELD MEMBER (Table 8)

Exposures of the Tuckfield Member (Section 2) are lithologically similar to the exposures of the member in adjoining NOONKANBAH. However, in the Grant Range there appear to be more clay-pellet conglomerate lenses in the sequence.

Table 8

Unit Tuckfield Member	Symbol Ppt — Defined by Crows & Towner (in press)
Distribution Exposed in the Grant Range and Mount Wynne areas. Possibly present at Mount Arthur. In the subsurface it occurs throughout the area except in the north-east and where it is cut out by the Jurassic unconformity.	
Lithology Consists mainly of fine-grained quartz wacke, lithic wacke, and mudstone, well and poorly-sorted, thin-bedded, laminated; minor flaser bedding, abundant wavy bedding; some large-scale planar cross-bedding and abundant ripple cross-bedding. Ripple marks are mainly straight-crested and both symmetrical and asymmetrical. Lenses of clay pellet conglomerate up to 0.5m thick and 10m long occur throughout the sequence and contain abundant fossil wood fragments. Parts of sequence consist of laminated, fine-grained, well-sorted quartz arenite with current lineation and large-scale, low-angle planar cross-bedding. See Section 2.	
Facies variations The unit is laterally and vertically homogeneous although the middle part appears to contain a greater proportion of mudstone than the rest.	
Thickness At least 140 m present in Grant Range. Maximum subsurface intersection is 271 m in AFO Nerrima No. 1 (Appendix II).	Type section locality Mount Tuckfield (NOONKANBAH: Lat.18° 42'15"S, Long.124°53' 35"E).
Age and criteria Probably Artinskian as it is overlain by the Artinskian Noonkanbah Formation (Guppy and others, 1958) and it overlies latest Sakmarian Nura Nura Member (Glenister & Furnish, 1961).	
Fossils Contains abudant fossil wood fragments. Plants found in the unit are recorded in Guppy and others (1958). The only other fossils recorded are bedding-surface trace fossils and some burrows.	
Relations Conformably overlies the Nura Nura Member and is overlain by the Noonkanbah Formation. Lower boundary is not seen on surface in the area but farther east Crowe & Towner (1976c) postulate that it may be disconformable.	
Subdivisions None.	Nature of exposure Forms smooth rounded hills and strike ridges.
	Remarks A good aquifer.

Depositional environment

Crowe & Towner (1976b, c) suggested that the Tuckfield Member was deposited in a lagoonal environment on the basis of the abundance of shallow-water indicators (wave-formed ripple marks, etc.), the presence of plant material, and the lack of open-marine indicators. They suggested that the sandstone unit at the top of the Nura Nura Member in the west St George Range was a barrier-bar deposit and the this may have acted as the barrier responsible for restricting open-marine circulation during deposition of the Tuckfield Member.

This suggestion is extended here (Fig. 12) and the Tuckfield Member in DERBY AND MOUNT ANDERSON is similarly interpreted as a possible lagoonal deposit.

The member contains similar shallow-water indicators (e.g. Plate 4) as it does farther east with the exception of root-bearing beds which occur in NOONKANBAH. The greater abundance of clay-pellet conglomerate lenses is thought to be due to greater channel activity within the postulated lagoon. The conglomerate contains abundant fossil wood fragments, presumably derived from the vegetation that is indicated by the root horizons in NOONKANBAH.

Another difference between the NOONKANBAH and Grant Range sequences is that the exposures in Grant Range contain intervals of very well-sorted, laminated, fine and very fine-grained quartz arenite with current lineation on the bedding surfaces and which is arranged in low-angle planar cross-sets (Plate 5). These intervals are interpreted as beach deposits, suggesting that there may have been local emergence.

NOONKANBAH FORMATION (Table 9)

In MOUNT ANDERSON several exposures south of the Fitzroy Trough have been assigned to the Noonkanbah Formation by previous workers (Guppy and others, 1958). These exposures areedifferent to outcrops of the unit in the Fitzroy Trough.

G.S.W.A. F. 18, No. 16

Plate 4. Interference, straight-crested, symmetrical ripple marks in the Tuckfield Member of the Poole Sandstone. South flank of Grant Range (Lat. 18° 03'00" S, Long. 124°09'40" E).

G.S.W.A. F. 18, No. 8

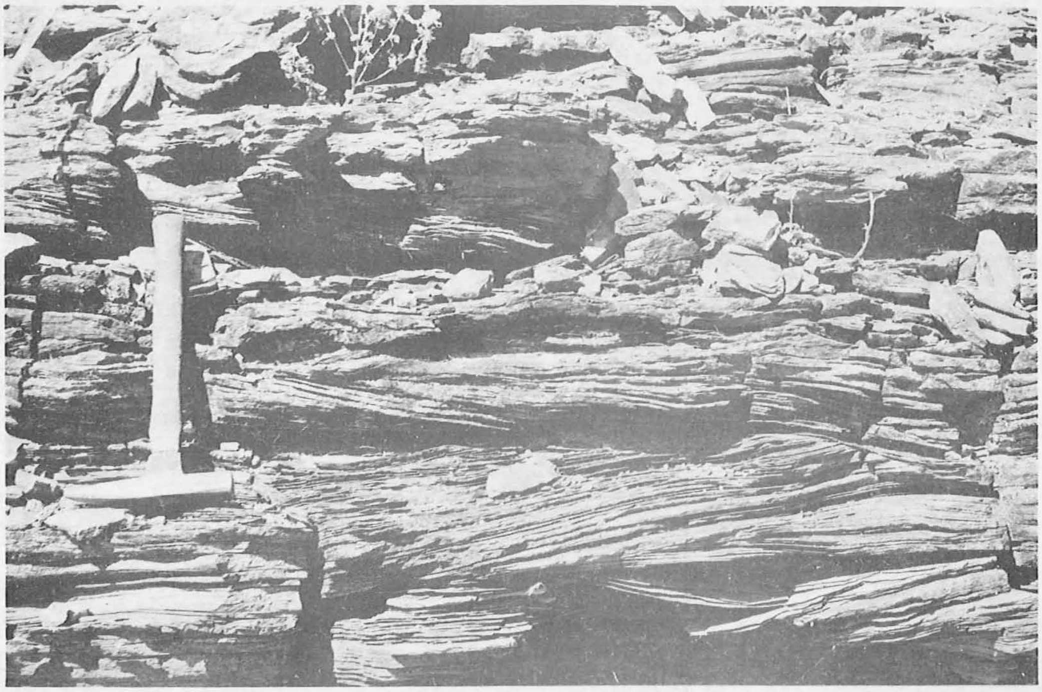

Plate 5. Low-angle cross-bedding in the Tuckfield Member of the Poole Sandstone. Note that foresets dip in opposite directions. Southern flank of Grant Range (Lat. 18°04'30" S, Long. 124°08'30" E).

34

Unit Noonkanbah Formation	Symbol Pn	Defined by Wade (1938) Guppy and others (1952)

Distribution Underlies much of the black-soil plains north of the Meda River and occurs as floaters. Occurs in gullies south of Jimbulara Ridge, and south and north of Grant Range. Identified in float southeast of Sandfly yard and around Mount Arthur and Nerrima Ridge.

Lithology Mainly mudstone, black, micaceous, partly pyritic, calcareous; interbedded with limestone, fossiliferous, grey, thin-bedded, finely crystalline, argillaceous in parts; and quartz wacke, very fine to medium-grained, scattered coarse grains and granules, moderate to poorly-sorted, thin-bedded, and calcareous matrix, contains lenses of very coarse-grained shelly sandstone.

Limestone interbeds occur throughout unit but sandstone appears more common towards base.

Facies variations In Nerrima Ridge area a well-defined marker bed is present; the Strophalosia kimberleyensis marker bed (Guppy and others, 1950). Located 23 m below top of formation, it occurs as a line of boulders and rubble on north and south flanks of Nerrima Dome. Facies changes are rare in the Noonkanbah Formation though outcrops south of the Fenton Fault appear coarser-grained and contain a large amount of terrigenous material.

Thickness	Type section locality
Average in area is about 300 m; maximum is 410 m in AFO Sisters No. 1 (Appendix II).	Near Bruten Hill (NOONKANBAH: Lat. 18°44'35"S, Long. 125°37'30"E)

Age and criteria Macrofossils indicate the unit is Artinskian (Guppy and others, 1958). Palynomorph assemblages confirm this date (Balme, 1967).

Fossils Very rich fauna consisting of brachiopods, bryozoans, corals, crinoids, foraminifera, molluscs, ostracods. Balme (1967), from examination of samples from Wapet Blackstone No. 1, believes the formation contains the Vittatina I, II, and III palynomorph zones.

Relations Lower contact with Poole Sandstone not exposed but thought to be conformable in bore sections. Farther east Crowe & Towner (1967c) postulated a disconformable relation.

Upper contact with Lightjack Formation is conformable and gradational as observed at Lower Liveringa Ridge (Section 3).

Subdivisions	Nature of exposure / Remarks
None.	**Nature of exposure** Very poor; occurs as soil float and is exposed in erosion gullies.
	Remarks Unit has a characteristic air-photo pattern of light-coloured (clayey) patches with bedding trends visible as out-crops or vegtation lines. A poor aquifer although it may contain or confine artesian aquifers particularly in faulted areas.

Exposures south of the Fenton Fault on Nerrima station contain a typical Noonkanbah Formation fauna but the lithology is different in that it contains lenses (up to a metre thick) composed of intraformational conglomerate with a few quartzite and hematitic extraclasts. The conglomerate lenses also contain abundant abraded fossil fragments.

Another atypical exposure of Noonkanbah Formation occurs in Geegully Creek at Lat. 18°19'00"S, Long. 123°43'35"E. It consists of mega-ripples of coarse-grained quartz wacke and granule conglomerate set in more typical grey calcareous mudstone (Plate 6). Although no fossils were found in this exposure it is assigned to the Noonkanbah Formation on the basis that nearby BMR Jurgurra Creek No.1 bore spudded in that unit.

Depositional environment

The Noonkanbah Formation contains a rich marine fauna which indicates an unrestricted marine depositional environment. The lithology of the unit in the Fitzroy Trough and Lennard Shelf is mainly laminated calcareous mudstone, suggesting deposition from suspension. The presence of pyritic zones indicate that quiet reducing conditions periodically prevailed. Cross-bedded sandstone beds near the base of the unit suggest shallow-water or near-shore conditions but the lack of current structures in the rest of the unit suggests that it was deposited below wave base (?30 m). Palaeontological evidence supports this interpretation as the mainly 'brachiopodal' assemblage was thought by Thomas (1958a) to indicate a water depth of 30-55 m.

The lenses of intraformational conglomerate that occur south of the Fenton Fault were probably deposited in channels which suggest shallower-water conditions in this area. The large amount of terrigenous material in mega-ripples in the Geegully Creek exposure also indicates shallow-water conditions with strong currents.

G.S.W.A. F. 18, No. 6

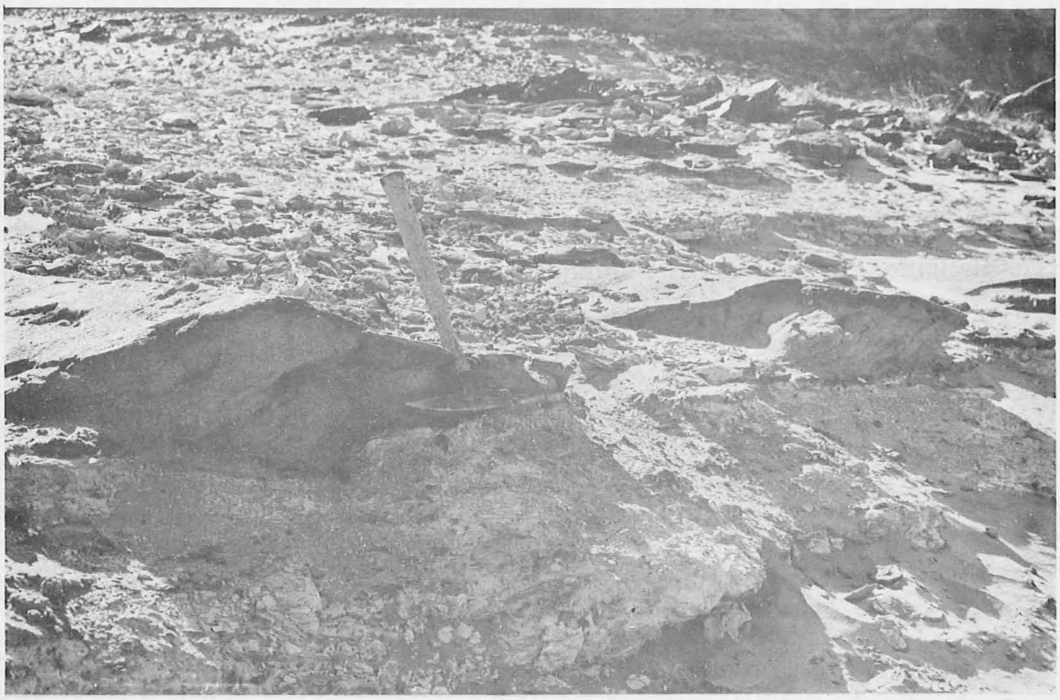

Plate 6. Mega ripples in an exposure in Geegully Creek (Lat. 18°19'00" S, Long. 123°43'35" E), which is assigned to the Noonkanbah Formation. There is good separation between the finer-grained lithic wacke on the ripple surfaces and the coarse-grained quartz wacke that forms the foresets.

LIVERINGA GROUP

The term 'Liveringa Group' was first used by Guppy and others, (1952) who later formally defined the sequence as the Liveringa Formation with three member subdivisions (Guppy and others, 1958). The sequence was then redefined as the Liveringa Group by Yeates and others (1975a) and they named the previous members as formations; the basal Lightjack Formation, the middle Condren Sandstone, and the upper Hardman Formation. The Hardman Formation was further subdivided into the lower, Kirkby Range Member; the middle, Hicks Range Sandstone Member; and the upper, Cherrabun Member (Yeates and others, 1975a).

The Condren Sandstone wedges out in NOONKANBAH (Crowe & Towner, 1976c) and is not thought to be present within DERBY and MOUNT ANDERSON However, the other subdivisions of the Liveringa Group have been mapped in the area. Each of the units within the Liveringa Group is characteristically a coarsening upwards cycle. The present mapping has suggested that further cycles may be developed in the area, but poor exposure, lack of distinctive markers, and little reliable subsurface control did not allow these cycles to be separated.

In DERBY and MOUNT ANDERSON there are no detailed and representative bore sections through the Liveringa Group and consequently a section from the northwestern corner of NOONKANBAH has been enclosed (Enclosure 1). The section is a composite of six continuous coreholes that were drilled by Australian Inland Exploration in 1971 in the Paradise station area. The section is herein proposed as a reference section for the Liveringa Group. It has been compiled from various sources which are acknowledged in the enclosure.

Enclosure 2 shows a correlation of bores drilled in DERBY by Conzinc Riotinto of Australia in 1973, for coal. The identifications of the units and the correlations are mainly ours.

LIGHTJACK FORMATION (Table 10)

Intersection in Derby Town Bore

The interval between 536.4 and 722.4 m in Derby Town Bore (Lat. 17°19'00"S, Long. 123°38'30"E) consists of silty, fine-grained, micaceous sandstone containing brachiopods, overlying sandy, micaceous, laminated to unbedded siltstone with thin beds of oolitic chamositic ironstone (Playford, 1957). Thomas (in Playford, 1957) identified the brachiopods, though not specifically and suggested that they might belong to the Hardman Formation. However, as he pointed out, the two forms also range down into the Noonkanbah Formation.

The oolitic ironstone from the bore is similar to oolite found in exposures of Lightjack Formation although the surface samples are replaced by limonite. It is therefore suggested that the Liveringa Group rocks in the Derby Town Bore belong to the Lightjack Formation.

Depositional environment

The upward overall increase in grainsize and sorting to the top of the middle sandstone unit indicates a regressive sequence.

In the lower part of the unit, large-scale cross-sets occur in association with scour-and-fill structures and fossiliferous clay-pellet conglomerates at the bases of the scours. These deposits are interpreted as channel deposits. At Mount Marmion (DERBY), wave-formed ripple marks occur in the deposits, indicating shallow-water deposition (above wave base) and it is therefore thought that the sequence is tidal. The presence of burrows and bioturbated zones within this part of the sequence is compatible with such an interpretation.

The middle sandstone unit (referred to as the 'middle plant-bearing member' by Guppy and others, 1958) consists mainly of laminated medium-grained quartz wacke which because of its position in the vertical sequence is interpreted as a barrier bar or beach deposit (see also Crowe & Towner (1976c).

The upper part of the formation, although not recognized on the surface, is inferred to be present in the southern part of the Fitzroy Trough. Crowe & Towner (1976c) suggested that this part was deposited in a lagoonal environment.

Table 10

Unit Lightjack Formation	Symbol Pj	Defined by Guppy and others (1958); Yeates and others (1975a)

Distribution In DERBY crops out as long strike ridges at Jimbulara, Willumbah, and Lower Liveringa Ridges and at Mount Marmion. In MOUNT ANDERSON, exposed at Liveringa Ridge, southeast of Mount Wynne and at Nerrima Ridge. Penetrated in eight wells in area.

Lithology Brown, fine to very fine-grained quartz wacke and mudstone, interbedded; with small lenses of coarse-grained quartz wacke commonly containing fossils; laminated to thin-bedded with wavy bedding and ripple marks. This passes up into middle part of medium-grained quartz wacke and quartz arenite, moderate to well-sorted, laminated to thin-bedded; trough cross-bedding and ripple cross-laimin-ations; contains abundant plant fossils and thin sandy coal seams in subsurface. Top part of unit consists of interbedded mudstone and fine-grained quartz wacke with abundant ripple marks. However, this upper part is probably only present in southern part of area. See Section 3.

Facies variations Appears to contain more coarse-grained quartz wacke and granule conglomerate in areas adjacent to Fenton Fault.

Thickness Thickest section is 167 m at Liveringa Ridge.	Type section locality Lightjack Hill (NOONKANBAH: Lat.18°59'S, Long.125°50'E)

Age and criteria Lower part is dated as late Artinskian to Kungurian based on macro and microfossils. Upper part is imprecisely dated as Permian by plant macrofossils and Late Permian by palynomorphs (WAPET, 1967b).

Fossils Contains a rick fauns including pelecypods, gastropods, brachiopods, bryzoans, foraminifera and rare ammonoids (Guppy and others, 1958; Thomas, 1954) from lower part of unit. Middle sandstone part of unit contains rich floras of Glossopteris and Gangamoptoris. Basal part of unit is assigned to the Vittatina III Assemblage of Balme (1967) and rest of unit is part of his Dulhuntyspora Assemblage.

Relations Conformably overlies Noonkanbah Formation. Probably disconformably overlain by Hardman Formation (Section 3). To southeast, overlain conformably by Condren Sandstone but this unit is missing in the area. Subsurface information (Galloway & Howell, 1975) suggests top part of Lightjack Formation is also missing in most of area.

Subdivisions Crowe & Towner (1976c) identified upper, middle, and lower parts of the formation to the east of the area. These subdivisions can be recognized in DERBY and MOUNT ANDERSON although subsurface information (Galloway & Howell, 1975) suggests that the upper part is absent in north.	Nature of exposure Poor, but is generally better exposed than other parts of Liveringa Group. Trend lines visible through soil cover in many areas. Remarks Contains colitic ironstone (Edwards, 1953) in MOUNT ANDERSON and in Derby Town Bore (Playford, 1957). Middle sandstone unit is probably a good aquifer.

J.M. Dickins (pers. comm.) has suggested that the fauna from exposures of Lightjack Formation in the western Fitzroy Trough may be slightly younger than the fauna from the same stratigraphic level in the Gregory Sub-basin. If correct, this evidence of diachronism supports the interpretation of the Lightjack Formation as a regressive sequence.

Subsurface information from the Kimberley Downs area (see Enclosure 2) shows that the Lightjack Formation may contain two coarsening-upward cycles. Without more detailed information it is difficult to interpret these cycles but it is suggested that the lower sandstone unit may represent another sand-bar deposit. The identifications of the boundaries of the Lightjack Formation in these bores is based on the electric-log characteristics.

HARDMAN FORMATION (Table 11)

The members of the Hardman Formation are poorly exposed and difficult to map in the area. With the mapping on NOONKANBAH, Crowe & Towner (1976c) were able to reliably establish the bio- and litho- stratigraphy of the Hardman Formation. This has enabled identification of the Hardman Formation members by their photo patterns and faunas, and by using the aerial photographs it has been possible on MOUNT ANDERSON to trace the units away from the identified localities. In this way, most of the Hardman Formation members beneath the gravel plains south of the Fitzroy River and within the Fitzroy Trough have been mapped.

Kirkby Range Member (Table 12)

Fossils in the Kirkby Range Member indicate marine deposition. The basal part of the unit consists of coarse-grained, medium-grained, and fine-grained sandstone beds interbedded with mudstone. The separation between the different grainsizes is good and indicates alternating current conditions so that the lower part of the unit was probably laid down in a tidal environment.

Table 11

Unit Hardman Formation	Symbol Ph	Defined by Guppy and others (1958); Yeates and others (1975a)

Distribution Extensively exposed south of Fitzroy River but crops out less north of the river where it is largely covered by Triassic rocks. In the subsurface the unit is confined to the Fitzroy Trough and southwestern Lennard Shelf except where cut out by Jurassic unconformity.

Lithology Interbedded sandstone and mudstone, ripple marks, scour-and-fill structures; lenses of coarse-grained sandstone and granule conglomerate; intervals of sandstone with large-scale cross-bedding. Unless fossils are found or a thick vertical sequence is exposed, the members of the Hardman Formation are difficult to recognize; in many areas the exposures can be traced several kilometres along strike because the trend lines show up as vegetation patterns. See Section 3.

Facies variations See under various members.

Thickness	Type section locality
See under members.	Mount Hardman (NOONKANBAH:Lat.18°18'45"S, Long.124°38'52"E)

Age and criteria See under members.

Fossils See under members.

Relations Unit is believed to disconformably overlie the Condren Sandstone (which is probably not present in this area) and the Lightjack Formation. The formation is largely conformably (but locally unconformably) overlain by Triassic rocks.

Subdivisions

Three Members;
- Cherrabun Member
- Hicks Range Sandstone Member
- Kirkby Range Member

Nature of exposure Exposed beneath gravel plains and as low strike ridges.

Remarks

Table 12

<u>Unit</u> Kirkby Range Member	<u>Symbol</u> Phk	<u>Defined by</u> Yeates and others (1975a)

<u>Distribution</u> Very poor exposure in area but can be identified as a lighter photo-pattern stratigraphically beneath the Hicks Range Sandstone Member and above the relatively prominent ridges of Lightjack Formation. Occurs throughout Fitzroy Trough and southwest Lennard Shelf except where cut out by Jurassic unconformity.

<u>Lithology</u> Basal parts consist of fine-grained quartz wacke and mudstone; slightly calcareous; laminated to thin-bedded, ripple-marked; lenses of granule conglomerate. Middle part is not exposed and probably consists mainly of mudstone. Upper part consists of fine-grained, laminated to thin-bedded quartz wacke with occasional pebbles; u-shaped burrows and concretions common; low-angle large and small-scale cross-bedding present. See Section 3.

<u>Facies variations</u> The unit is probably finer-grained (more mudstone) than in NOONKANBAH. It could not be separated from the overlying Hicks Range Sandstone Member in bore sections on the Lennard Shelf (see Enclosure 2), suggesting that there is a different facies present in that area.

<u>Thickness</u> 230 m at Liveringa Ridge appears to be maximum thickness in area.	<u>Type section locality</u> Millyit Range (CROSSLAND: Lat.19°09'39"S, Long. 125°34'24"E).

<u>Age and criteria</u> The fauna collected from the unit in NOONKANBAH has not been fully studied but it indicates a Late Permian age (Dickins <u>in</u> Crowe & Towner, 1976c).

<u>Fossils</u> A poorly preserved marine fauna was collected from the unit but has not yet been studied.

<u>Relations</u> At Liveringa Ridge, the lower boundary of the Kirkby Range Member with the Lightjack Formation is marked by a conglomerate bed suggesting a disconformable relation. This agrees with the regional relations as the Condren Sandstone and upper part of the Lightjack Formation are absent in this area. The upper boundary with the Hicks Range Sandstone Member was not seen but from subsurface data is believed to be conformable.

<u>Subdivisions</u> The unit becomes coarser-grained towards the top so that the upper part consists mainly of sandstone whereas the lower part is predominantly mudstone.	<u>Nature of exposure</u> Extremely poor in area. Occurs as scattered lines of calcareous float in soil. Some exposure at Liveringa Ridge. <u>Remarks</u> Mainly a poor aquifer although upper sandstone part has moderate potential.

The upper part of the unit is composed of relatively better-sorted sandstone with no mudstone interbeds. The sandstone contains large and small-scale cross-bedding and small scour structures suggesting deposition in small channels. There is a general upward increase in sorting and grainsize which indicates a regressive sequence and following Crowe & Towner (1976c), uthe upper sandstone part of the member is interpreted as an offshore sand bar of the barrier type.

Hicks Range Sandstone (Table 13)

The lower and middle parts of the Hicks Range Sandstone Member consist of interbedded sandstone and minor mudstone which are thinly bedded and contain abundant wave-formed ripple marks. This indicates shallow-water deposition in a wave-dominated environment. The vertical position of this sequence above the interpreted barrier-bar deposits (of the Kirkby Range Member) caused Crowe & Towner (1976c) to interpret a lagoonal environment of deposition and this interpretation is extended into the present survey area. The lack of marine macrofossils and the presence of plant fossils in the unit is compatible with this interpretation.

At Liveringa Ridge (Section 3) the uppermost part of the Hicks Range Sandstone Member that is preserved (the top of the section is eroded) consists of mega-ripples of coarse-grained quartz wacke and granule conglomerate interbedded with fine-grained quartz wacke and mudstone (Plate 7). Trough cross-bedding and ripple marks are also present, and some ripples contain opposing foresets (Plate 7) which suggests deposition in tidal channels. These deposits probably correlate with the channel deposits that Crowe & Towner (1976c) recognized at the top of the member in NOONKANBAH. They believed that these channel deposits represented the uppermost part of the regression that started during the deposition of the underlying Kirkby Range Member.

Table 13

Unit Hicks Range Sandstone Member	Symbol Phh	Defined by Yeates and others (1975a)

Distribution Exposed over large areas south of the Fitzroy River in the Fitzroy Trough but only one exposure in DERBY (northeast flank of Grant Range Structure) is assigned to the unit. In the subsurface the unit probably occurs throughout the Fitzroy Trough and southwestern Lennard Shelf except where it is cut out by the Jurassic unconformity.

Lithology Lower part (30 m) consists mainly of fine-grained quartz wacke, moderately to well-sorted, laminated to thin-bedded, contains wave-formed ripple marks and bioturbation structures. This passes gradationally up into interbedded mudstone and fine-grained quartz wacke which becomes coarser-grained towards the top. Planar and trough cross-bedding is present, both large and small scale; wavy bedding, bioturbation and trace fossils also present. Top part consists of 10 m-thick, medium-grained quartz arenite and quartz wacke (exposed in Dry Corner Syncline); contains fossil roots, trough cross-bedding, current lineation and cobbles of quartz and quartzite. See Section 3.

Facies variations The unit appears to be generally coarser-grained than in NOONKANBAH. Poor exposure makes facies variations difficult to recognize though subsurface information indicates that variations are present (see also under 'Facies variations' for Kirkby Range Member).

Thickness Incomplete section at Liveringa Ridge is 80 m thick. Unit reaches a thickness of as much as 325 m in NOONKANBAH.

Type section locality Hicks Range (CROSSLAND: Lat. 19°13'48"S, Long. 125°53'42"E).

Age and criteria Late Permian based on the ages of the underlying and overlying units.

Fossils No macrofossils have been found in the unit. Plant fossils and trace fossils occur but are not age-diagnostic.

Relations Subsurface information shows that the lower boundary of the unit with the underlying Kirkby Range Member is gradational and that the upper boundary with the overlying Cherrabun Member is a disconformity.

Subdivisions The uppermost sandstone part of the unit forms a strike ridge around the Dry Corner Syncline and forms a useful marker.

Nature of exposure Exposed as dark-coloured gravel plains and low strike ridges. Relatively well exposed at Liveringa Ridge.

Remarks The upper part of the unit is expected to be moderately good aquifer.

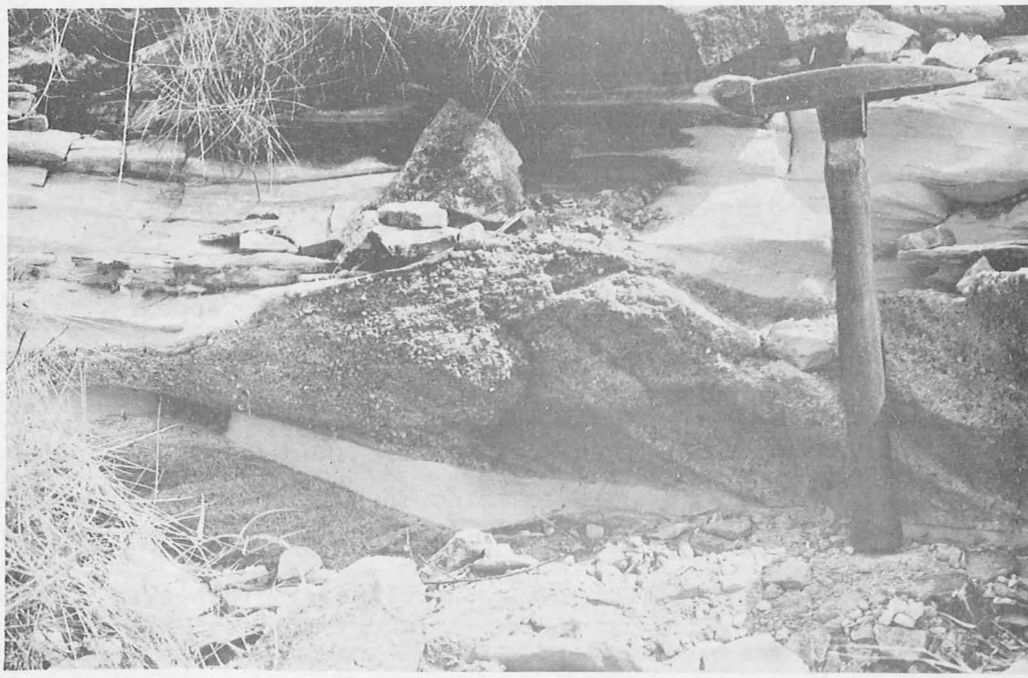

Plate 7. Mega ripple cross-bedding in the upper part of the section at Liveringa Ridge (Lat. 18°04'40" S, Long. 124°03'00" E). The exposure is assigned to the Hicks Range Sandstone Member of the Hardman Formation. Note the clear separation of mudstone and granule conglomerate and the fact the foresets dip in opposite directions within the same ripple.

Plate 8. Thinly bedded and laminated sandy mudstone of the Blina Shale at Erskine Range (Lat. 17°51'30" S, Long. 124°21'10" E). Note the abundant vertical burrows.

Cherrabun Member (Table 14)

Crowe & Towner (1976c) interpreted the Cherrabun Member as a regressive sequence disconformably overlying the Hicks Range Sandstone Member. Lack of exposure in the present survey area does not allow this interpretation to be expanded but there appears to be an overall upwards increase in grainsize which supports this interpretation.

In exposures adjacent to the Fenton Fault there is some evidence to suggest that the unit contains several coarsening-upwards cycles. It is suggested that this is due to additional fluctuation in the relative sea level (i.e. shoreline) in this area.

TECTONISM BETWEEN DEPOSITION OF PERMIAN AND TRIASSIC

The Millyit Sandstone overlies the Permian Hardman Formation with a slight angular unconformity (see under Millyit Sandstone) in the McLarty Syncline, adjacent to the Fenton Fault. On the Lennard Shelf, mapping suggests that the Triassic sequence also unconformably overlies the Permian in the Sisters Plateau/Warrawadda Structure area, adjacent to the Pinnacle Fault. However in the middle of the Fitzroy Trough (e.g. Myroodah Syncline) and on the northern part of the Lennard Shelf the Triassic rocks appear to conformably overlie the Permian. This indicates that there was local tectonism between deposition of the two sequences. The association of these local unconformities and the faults bounding the Fitzroy Trough suggests that the unconformities were caused by movement of these faults. The surrounding areas probably remained relatively stable.

TRIASSIC

MILLYIT SANDSTONE (Table 15)

The only exposure of Millyit Sandstone in the area occurs in the middle of the McLarty Syncline and consists of a low, scree-covered strike ridge. In adjoining NOONKANBAH this strike ridge diverges from the trend lines of the underlying Hardman Formation,

Table 14

Unit Cherrabun Member	Symbol Phc	Defined by Yeates and others (1975a)

Distribution The unit crops out widely on the gravel plains south of the Fitzroy River but only one exposure is identified in DERBY (between Cockatoo Creek and Minnie River). In the subsurface, the unit occurs in the Fitzroy Trough and southwestern part of the Lennard Shelf except where it is cut out in the west by the Jurassic unconformity.

Lithology Poor exposure makes description difficult. In NOONKANBAH the sections show that the unit contains a lower, commonly calcareous, mudstone part which contains a rich marine fauna. This passes up into an upper sandstone part which is cross-bedded (see Section 20 of Crowe & Towner, 1976c).

In this area the lithologies are consistent with the section described in NOONKANBAH.

Facies variations The exposure is too poor to enable recognition of lateral facies variations. However, exposures near to the Fenton Fault which are assigned to the unit on palaeontological grounds may contain additional coarsening-upwards cycles. Poor exposure, lack of distinct markers, and little subsurface control make mapping in this area difficult.

Thickness	Type section locality
No surface sections measured. In AIE Paradise No. 4 (NOONKANBAH) unit is 100 m thick (enclosure 1).	Spring Creek (CROSSLAND: Lat. 19°11'00"S, Long. 125°33'06"E).

Age and criteria Late Permian (possibly Tartarian) based on the fauna (Thomas 1954; Coleman, 1957; Dickins, 1963).

Fossils The Hardman Formation fauna listed by Guppy and others (1958, called Hardman Member by them) comes from the Cherrabun Member. Additional collections made in 1974 and 1976 have not yet been studied.

Relations The lower boundary with the Hicks Range Sandstone Member is thought to be disconformable. The unit is unconformably overlain by the Millyit Sandstone and the 'Mudjalla Sandstone Member'. The Blina Shale also overlies the unit and although the contact is not exposed there does not appear to be any angular relation.

Subdivisions	Nature of exposure / Remarks
The upper sandstone part of the unit could probably be separated from the lower mudstone part in bore sections.	**Nature of exposure** Crops out as gravel plains and low strike ridges. No good section exposed in the area.
	Remarks The top sandstone part of the unit may be a good aquifer where present.

Table 15

Unit Millyit Sandstone

Symbol TRm

Defined by Elliot (in McWhae and others 1958); Yeates and others 1975a)

Distribution Tentatively identified in one area (the middle of the McLarty Syncline). The unit occurs more extensively to the southeast of the area (Yeates and others 1975a).

Lithology Consists of fine-grained, micaceous, quartz wacke and minor mudstone, thinly bedded, minor low-angle cross-bedding, ripple marks; bioturbation is common; base is marked by a quartz-pebble conglomerate.

Facies variations To the southeast of the area the unit is lithologically more variable and contains a higher proportion of large-scale cross-bedding.

Thickness 10 m exposed in McLarty Syncline but may be 25 m present.

Type section locality Millyit Range (CROSSLAND: Lat. 19°12'00"S, Long. 125°33'30"E).

Age and criteria Earliest Triassic based on microflora. The unit contains a microflora belonging to Stage TR1b of Evans (1966) (Paten & Price, in Yeates and others, 1975b). Plant macrofossils indicate a Permian or Triassic age.

Fossils Contains plant macrofossils (White & Yeates, 1976), wood fragments, and a microflora described by Paten & Price (in Yeates and others, 1975b).

Relations Overlies the Hardman Formation with slight angular unconformity (based on air-photo evidence) in McLarty Syncline. Outside area the unit is overlain disconformably by the Blina Shale.

Subdivisions None.

Nature of exposure Poor, low strike, ridges.

Remarks Identified in area by lithology and stratigraphic position.

indicating a slight angular unconformity. This was the basis on which the exposure was considered to be Millyit Sandstone by Crowe & Towner (in prep.) as the Millyit Sandstone has the same relations in CROSSLAND.

Depositional environment

The poor exposure of Millyit Sandstone in the area does not allow the depositional environment to be interpreted. The position of the unit at the base of the marine Triassic sequence may indicate it is a transgressive sand body. However, farther southeast, Yeates and others (1975b) believed the unit had been deposited in channels and was possibly fluviatile.

BLINA SHALE (Table 16)

Depositional environment

Sedimentological evidence. The laterally continuous thin bedding in the Blina Shale suggests deposition in a large body of water. The fine grainsize (mudstone and sandy mudstone) indicates deposition from suspension, suggesting quiet conditions. In the upper part of the unit in Section 4 there are small vertical fissures filled with fine-grained quartz wacke. These are similar to structures described by Coneybeare & Crook (1968, plate 69b & c) and are interpreted as infilled fossil mudcracks. Similar structures are illustrated by Yeates and others (1975b, fig. 25) and they suggest periodic subaerial exposure. Also in Section 4, the Blina Shale becomes coarser-grained towards the top and contains small scour-and-fill structures and current ripple marks, suggesting some deposition by currents.

Mineralogical evidence. The presence of disseminated pyrite in subsurface sections of the unit indicates anaerobic, stagnant, reducing conditions. Organic matter is also well preserved in subsurface samples and this suggests poorly oxygenated bottom conditions. Glauconite is reported from the section in WAPET Meda No. 1 (WAPET, 1962a) and according to Porrenga (1967) this probably indicates slow sedimentation.

Unit Blina Shale	Symbol ℞b	Defined by Reeves (1951); Brunnschweiler (1954)

Distribution Occurs in low-lying synclinal areas such as the Dry Corner and Myroodah Synclines. Also occurs in Erskine Range/Sisters Plateau area. Intersected in many bores in the Fitzroy Trough and Lennard Shelf.

Lithology Consists mainly of buff-coloured, sandy mudstone and very fine quartz wacke, laminated to thinly bedded. Contains ripple marks and small scour-and-fill structures near the top. Characteristic closely-spaced vertical burrows occur throughout (Plate 8). Subsurface information shows that sandstone becomes predominant towards the base (WAPET 1967a, 1963). Several phosphatic bone beds occur, particularly near the base. Pyrite, glauconite, and organic matter reported from subsurface sections. See Section 4.

Facies variations Characteristically the unit contains remarkably little lateral variation.

Thickness Thickest section is 311 m in WAPET Blackstone No.1; (Appendix II) Erskine Range Section (No.4) is 32 m thick.

Type section locality Erskine Range (DERBY: Lat.17°51'S, Long.124°22'E).

Age and criteria Early Triassic (Scythian) based on palynological evidence (Balme, 1963, 1964, 1969) and on vertebrate evidence (Cosgriff, 1965, 1974).

Fossils Amphibians including *Deltasaurus pustulatus* and *Blinasaurus lenwoodi* (Cosgriff, 1965, 1969), the conchostracan *Isaura* (which occurs in thin coquinas), the brachiopod *Lingula*, bivalves (including cf. Pseudomonontis), fish (including *Ceratodus* and *Saurichthys*) and other vertebrate remains. Plant fossils also quite common. Contains rich microfloral assemblage (*Taeniaesporites* Assemblage of Balme, 1964).

Relations On field evidence Crowe & Towner (1976c) believe the Blina Shale overlies the Millyit Sandstone conformably and overlies the Permian either disconformably or with slight angular unconformity. The Blina Shale is overlain by the Erskine Sandstone. The contact is erosional and probably represents a slight time break.

Subdivisions None.

Nature of exposure Very poor, except in Erskine Range. Overlain by black-soil plains.

Remarks Can often be identified by light (clayey) colour on aerial photographs. Trend lines are visible as a streaky pattern on photos.

Fossil evidence. The presence of marine acritarchs in the microfossil assemblages and marine pelecypods indicates a marine influence in the environment. However, forms such as the conchostracan Isaura and the brachiopod Lingula are more suggestive of brackish-water conditions. McKenzie (1961) suggests that the amphibian remains and Dipnoan teeth recovered from the unit may represent death assemblages flushed into the environment by freshwater. According to Balme (1969), the unusually high proportion of vascular-plant spores within the formation suggests that they were derived from coastal marsh plants 'occupying a similar ecological niche to modern mangroves'.

Summary. The Blina Shale appears to have been deposited in a shallow, low-energy, near-shore environment of deposition with intermittent subaerial exposure. The unit probably represents deposition in a mud flat.

We agree with McKenzie (1961) who did not accept the lagoonal interpretation of Brunnschweiler (1954). However the paucity of open-marine indicators and the presence of brackish-water indicators in the fauna suggest that the area over which the Blina Shale was deposited was not directly connected to the ocean.

ERSKINE SANDSTONE (Table 17)

Depositional environment

In the underlying Blina Shale there is some evidence of an increase in sandstone content towards the top of the unit. This suggests that, if the Blina Shale and Erskine Sandstone are considered together, they may represent a regressive sequence. As the contact between the two units is erosional it is suggested that the regression may have been of the deltaic type (Selley, 1970).

The abundance of large-scale trough cross-bedding in association with intraformational conglomerate and ripple cross-lamination indicates deposition by currents in channels possibly of the distributary type. Current readings obtained by McKenzie (1961; see Fig. 5) suggest that the channels flowed towards the north or northwest. The upper part of the Erskine Sandstone contains intervals of planar-bedded mudstone and very fine-grained sandstone which are interpreted as overbank deposits laid down on the hypothetical delta plain.

Table 17

Unit Erskine Sandstone	**Symbol** Ʀe	**Defined by** Brunnschweiler (1954)

Distribution Occurs in MOUNT ANDERSON in Myroodah Syncline. Covers a wide area on the Lennard Shelf and Fitzroy Trough in DERBY. Best exposed in the Erskine Range and Sisters Plateau.

Lithology Consists mainly of fine and very fine-grained quartz wacke and quartz arenite, laminated to thin-bedded; contains large-scale trough and planar cross-bedding, clay pellet conglomerate and current ripple marks with some climbing-ripple cross-bedding. The upper part of the unit contains some parallel-laminated, very fine-grained quartz wacke and mudstone, interbedded. See Section 4.

Facies variations On a small scale, local facies variations are abundant but on a regional scale the unit is homogeneous although it may be slightly finer-grained at Derby than in the Erskine Range area.

Thickness 30 m exposed in Erskine Range. Maximum recorded thickness is 269 m in Myalls bore south of Derby, (Appendix II).

Type section locality Erskine Range (DERBY: Lat.17°50'S, Long.124°22'E)

Age and criteria Early to early Middle Triassic (Smithian to early Anisian) on the basis of microfossils (see Balme, 1969 ; Dolby & Balme, 1976). Macroflora agrees with this date (see Brunnschweiler, 1954 ; Helby, 1973).

Fossils Brunnschweiler (1954) lists the macroflora from the unit which includes Thinnfeldia (Dicroidium), and Gleichenites. Fossil wood is common in the unit and burrows are recorded from the upper part of the unit in Derby Town Bore (Playford,1957). No marine acritarchs are recorded from the microfossil assemblages.

Relations Overlies the Blina Shale disconformably and overlaps it and rests unconformably on Permian rocks on the Lennard Shelf. Erskine Sandstone is disconformably overlain by the Meda Formation although the upper surface is usually an erosion surface.

Subdivisions None.

Nature of exposure Forms low scarps in Sisters Plateau and more isolated mesas elsewhere.

Remarks Despite the fine grainsize of parts of the unit, the Erskine Sandstone is a remarkably good aquifer (P. Whincup, GSWA, pers. comm.).

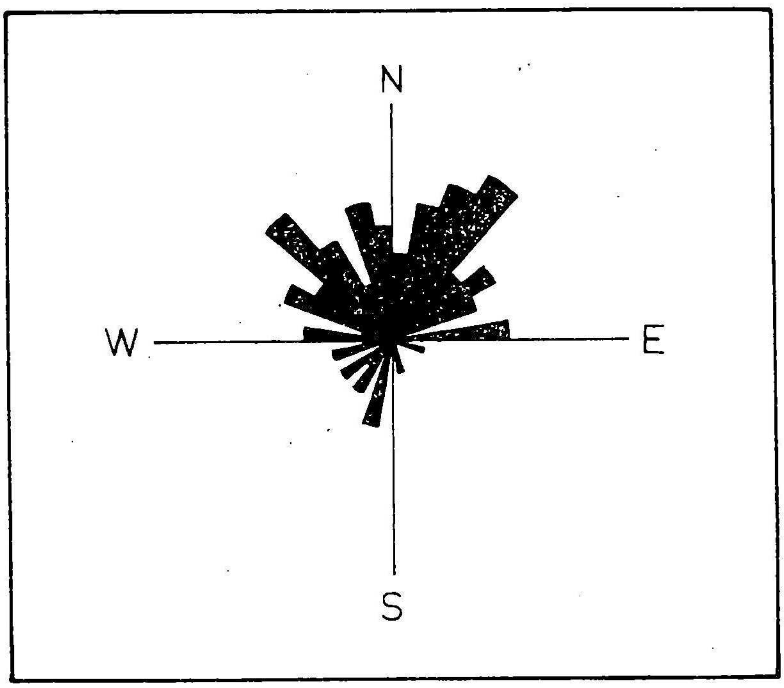

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Fig. 5 Rose diagram of current directions in the Erskine Sandstone at Erskine Range. Readings from 81 cross-sets. Adapted from McKenzie (1961).

Fossil evidence supports this interpretation. Pleuromeia occurs in the flora (Brunnschweiler, 1954) and is thought by Balme & Helby (1973) to be a plant group which rapidly colonized new areas formed by retreat of the sea.

In conclusion, we agree with McKenzie who believed that the Erskine Sandstone was deposited by a delta which debouched into the sea that deposited the Blina Shale.

TECTONISM BETWEEN DEPOSITION OF TRIASSIC AND JURASSIC

The main structural features exposed in the areasare the result of tectonism that occurred between deposition of the Triassic that this tectonism produced, can be dated as post-Middle Triassic and pre-? Middle Jurassic; however, the precise age limits of the formations that overlie and underlie the unconformity are not known. For simplicity the hiatus is referred to as the Jurassic unconformity in this report. It is possible that intrusion of the ?Jurassic Fitzroy Lamproite was related to this period of tectonism.

Rattigan (1967) and Smith (1968) have described the structural pattern in the Fitzroy Trough. The main features are that after the period of mainly tensional tectonics that produced growth movement along the major faults during the Palaeozoic and Triassic, the area underwent a major period of compressional tectonism. The mainly westerly-trending folds in the Fitzroy Trough are believed by Rattigan (1967) to be the result of compression between the northerly Kimberley Block and the southern part of the Canning Basin (including the Broome Platform). This compression resulted in right-lateral regional coupling which produced reverse movement along the previously normal faults and this in turn generated the en echelon pattern of major folds (Fig. 6). The predominantly north-trending faults that cut these folds fit in with the en echelon pattern and are believed to be tensional release features produced by the folding.

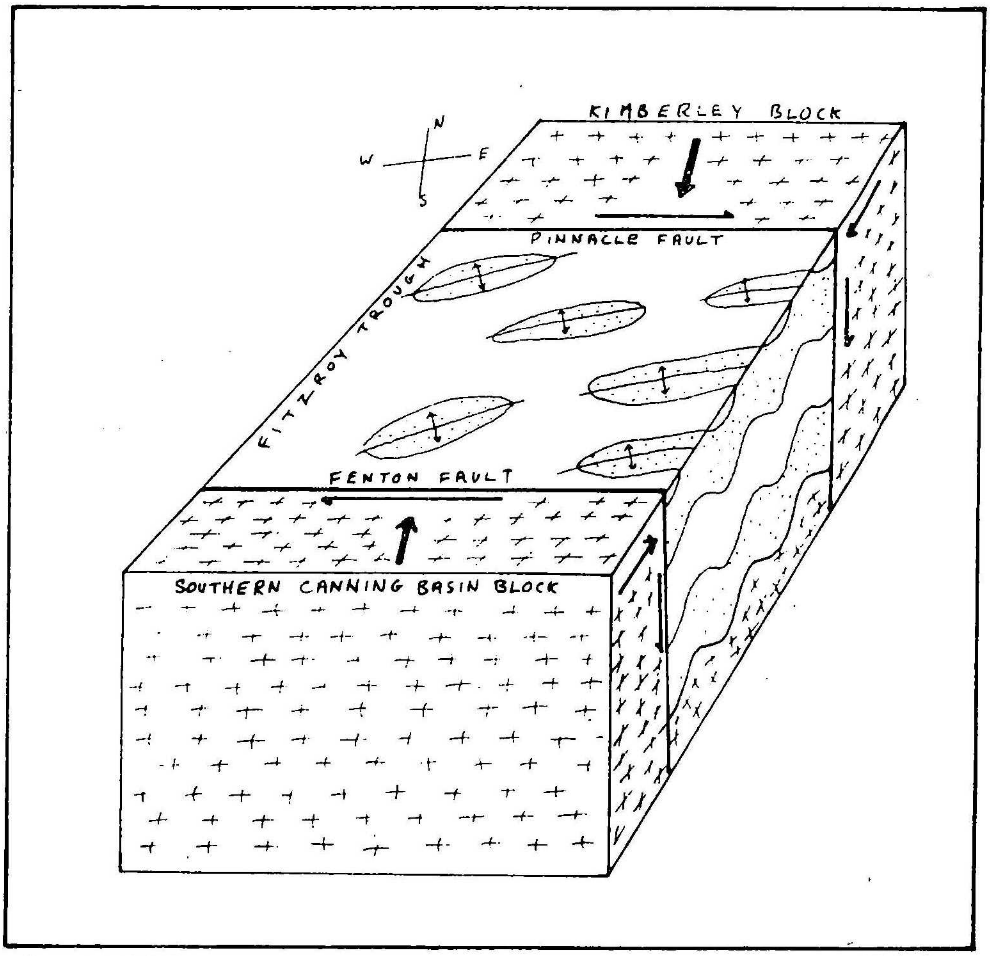

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Fig. 6 Block diagram showing inferred stress pattern of ?Jurassic tectonic event. Modified from Rattigan (1967).

JURASSIC TO CRETACEOUS

WALLAL SANDSTONE (Table 18)

The term Wallal Sandstone was introduced by McWhae (*in* Johnstone, 1961), for the basal Jurassic sandstone unit that had been intersected in petroleum exploration wells in the western part of the basin. The formation was thought to correlate with the Jurgurra Sandstone (Table 19) which occurs in the area. More recent sursurface data have since confirmed this correlation and also shown that the unit' can be correlated with another unit, the Mudjalla Sandstone (Table 20). The present mapping has shown that both the Jurgurra and Mudjalla Sandstones probably only represent local facies and it is therefore proposed that they be considered members of the Wallal Sandstone. Because this nomenclature change has not been formally defined the Jurgurra Sandstone and the Mudjalla Sandstone are herein referred to as the Jurgurra Sandstone 'Member' and the Mudjalla Sandstone 'Member'.

McWhae (*in* Johnstone, 1961) believed that the Wallal Sandstone was deposited in a paralic, largely shallow-water, marine environment although parts of the unit may also be continental in origin. Because the formation is a subsurface unit, a detailed interpretation of its depositional environment is not attempted.

JURGURRA SANDSTONE 'MEMBER' (Table 19)

The present survey has shown that the Jurgurra Sandstone is probably at least partly of 2 aeolian origin (see below). It is likely that this facies is fairly restricted both laterally and vertically and it is therefore desirable at this stage to assign all subsurface intersections to the Wallal Sandstone, unless the 2 aeolian facies can be confidently recognized.

Table 18

Unit Wallal Sandstone	Symbol J1
Defined by McWhae (in Johnstone, 1961.	
Distribution	Occurs south of the Fenton Fault and in western DERBY and MOUNT ANDERSON.
Lithology	Sandstone, with subordinate siltstone, conglomerate, and lignitic beds.
Facies variations	In this report the Jurgurra and Mudjalla Sandstone 'Members' are considered facies of the Wallal Sandstone.
Thickness	Maximum recorded thickness in area is 168 m in WAPET Dampier Downs No.1; probably thicker in WAPET Fraser River No1
Type section locality	Between 279 and 587 m in BMR Stratigraphic Well No.4A (Wallal) (MANDORA: Lat.19°44'12"S, Long. 120°44'25"E)
Age and criteria	Microfossil evidence suggests a Toarcian to Oxfordian age (Passmore, in prep.). However Playford and others (1975) believe that a Bathonian to Oxfordian age seems most likely on stratigraphic grounds.
Fossils	Microflora and microplankton are described by Balme (1961).
Relations	Unconformably overlies various Palaeozoic units. Apparently conformably overlain by Alexander Formation.
Subdivisions	Jurgurra and Mudjalla Sandstone 'Members' are considered local facies of the Wallal Sandstone.
Nature of exposure	Not exposed except as separately-named 'members'.
Remarks	The unit is an important artesian aquifer in southern part of basin and can be expected to be a good aquifer in this area.

Table 19

Unit Jurgurra Sandstone 'Member' · **Symbol** J1j · **Defined by** Brunnschweiler (1954)	
Distribution Exposed in southern part of Jurgurra Creek and in scattered localities in the north-central part of the Edgar Range (MOUNT ANDERSON).	
Lithology Mainly quartz arenite and wacke, medium to coarse-grained, in places poorly sorted and micaceous; contains abundant large-scale trough cross-bedding and small-scale anastomosing ripple cross-lamination; contains minor mudstone beds and clay-pellet conglomerate at the bases of troughs. Unit contains abundant concretions in some areas (Plate 10). See Section 5.	
Facies variations As defined, the Jurgurra Sandstone 'Member' refers to one characteristic facies association so any marked variations should be termed Wallal Sandstone. Burne & Crowe (1977) recognize two major facies within the unit, a cross-bedded quartz arenite and a planar-bedded quartz wacke.	
Thickness 20 m exposed in Section 5.	**Type section locality** In Geegully Creek near Mount Alexander (Section 5, Lat.18°41'00"S, Long.123°39'20"E, MOUNT ANDERSON).
Age and criteria Bathonian to Oxfordian based on the age of the overlying unit and the age of the Wallal Sandstone.	
Fossils Brunnschweiler (1954) reported rare indeterminate marine pelecypods and Guppy and others (1958) recorded poorly preserved plant fossils. Root moulds and fragmentary plant fossils were found during the present survey.	
Relations The lower boundary of the unit with either part of the Wallal Sandstone or Palaeozoic rocks is not exposed. The upper boundary with the Alexander Formation was believed to be slightly disconformable by Brunnschweiler (1954), although our mapping shows that the two units may locally interfinger.	
Subdivisions Burne & Crowe (1977) recognize two main facies (see above).	**Nature of exposure** Exposed in gullies and at the bases of some small hills. **Remarks** Can be expected to be an excellent aquifer.

Depositional environment

Burne & Crowe (1977) have described an exposure of the Jurgurra Sandstone (at Lat. 18°32'30"S, Long. 123°40'55"E) in detail and conclude that it was deposited in an aeolian environment. Their interpretation is based on the fact that the original shape of the fossil dunes is preserved beneath an interdune (planar-bedded) facies (Plate 9) containing root moulds and some lenses of water-laid deposits. The dune facies consists of large-scale trough cross-bedded quartz arenite with fairly high foreset angles (up to 31°) and with some convex-upward foresets, a good indicator of an aeolian origin. This dune facies is very similar to the Jurgurra Sandstone at its type section and it is on this basis that it is considered wise to restrict the unit to deposits of probable aeolian origin.

The upper part of the Jurgurra Sandstone in Section 5 contains abundant sand-filled anastomizing holes which are interpreted as weathered-out fossil roots. They suggest that the dunes may have become stabilized by vegetation before being buried and transgressed by the sea which deposited the overlying Alexander Formation.

MUDJALLA SANDSTONE 'MEMBER' (Table 20)

Depositional environment

Abundant broad and shallow trough cross-bedding with basal conglomerate lenses and associated lenses of ripple-marked and planar-bedded mudstone suggest that the lower part of the unit was laid down in a fluviatile environment. The cross-bedded parts were deposited in channels and the fine-grained lenses probably represent overbank deposits. Figure 7 shows that the rivers that deposited the unit flowed westward.

The upper part of the unit consists of lower-energy deposits. It lacks any marine indicators and the ripple marks in it are all of the current type. The mainly conformable nature of the boundary with the underlying facies suggests that the planar-bedded facies may have been deposited in a floodplain or delta plain. There is an overall upward decrease in grainsize and sorting throughout the whole unit and this also suggests a floodplain interpretation.

G.S.W.A. F. 18 No. 4 Neg.

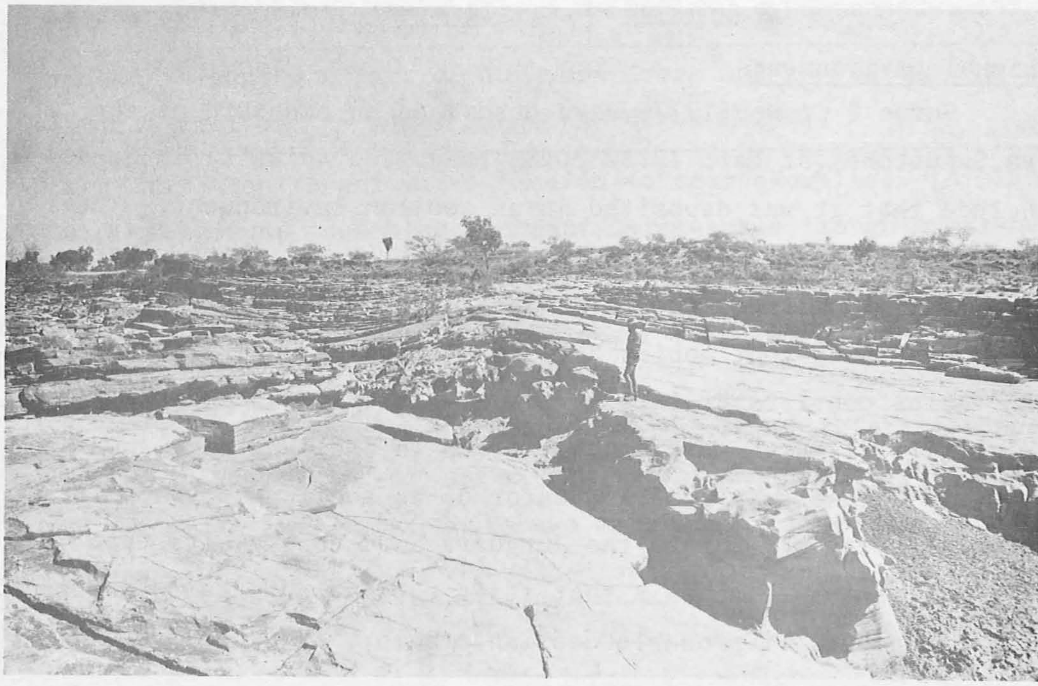

Plate 9. Exposure in Jurgurra Sandstone 'Member' in floor of Geegully Creek (Lat. 18°32'30" S, Long. 123°40'55" E) showing preserved dune which is overlain by thin-bedded interdune deposits (see Burne & Crowe, 1977).

G.S.W.A. F. 18, No. 1

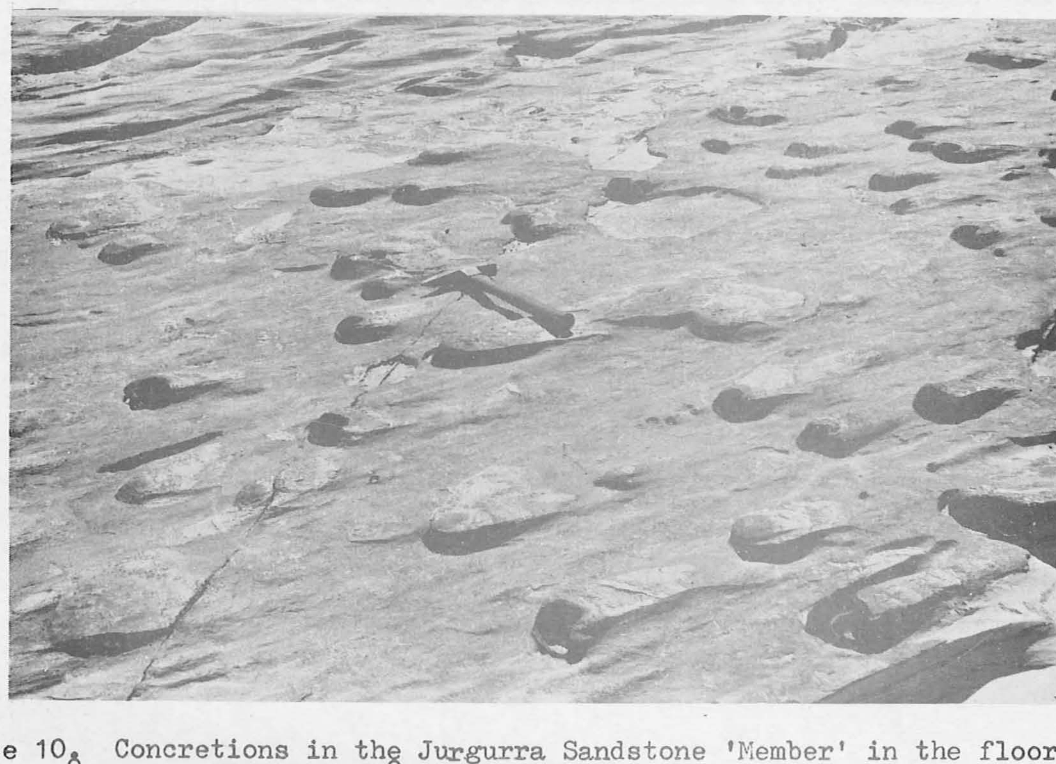

Plate 10. Concretions in the Jurgurra Sandstone 'Member' in the floor of (Lat. 18°32'30" S, Long. 123°40'55" E). The creek waters have selectively weathered out the concretions. Creek flow is from bottom left to top right part of photograph.

Table 20

Unit Mudjalla Sandstone 'Member'	Symbol Jlm	Defined by Guppy and others (1958)

Distribution Occurs west of Grant Range on southwest bank of Fitzroy River between Geegully and Cockatoo Creeks. A small exposure in Geegully Creek north of Wilsons Yard is also assigned to the unit, and outcrops at and near Frome Rocks may belong to the

Lithology Mainly medium to coarse-grained quartz wacke and arenite, poorly sorted; contains abundant large-scale, trough and apparently planar cross-bedding with lenses of conglomerate and siltstone. Also contains some small-scale ripple cross-lamination associated with the trough cross-bedding. Upper part conformably (and disconformably) overlies cross-bedded sequence and consists of mainly planar-bedded very fine to medium-grained quartz wacke which contains current ripple marks, wavy bedding and small scour-and-fill structures.

Facies variations Only the lower coarse-grained, cross-bedded facies and upper planar-bedded facies are known. Restricted area of exposure does not allow lateral facies variations to be recognize.

Thickness	Type section locality
41 m exposed but subsurface information (Russell, 1966a,b) suggests a maximum thickness of 80m (Enclosure 3)	Near Mudjalla Yard (MOUNT ANDERSON:Lat.18°03'05"S, Long.123° 47'40"E).

Age and criteria Plant fossils indicate a Jurassic age (Guppy and others, 1958). The unit is interpreted to be overlain by the Oxfordian Alexander Formation. As the unit is considered a facies of the Wallal Sandstone it may be as old as Bathonian.

Fossils Rare plant fossils, including conifers, are known from the unit (Guppy and others, 1958). Wood fragments are also common.

Relations The unit overlies probable Hardman Formation with an angular unconformity. It is thought to be overlain by the Alexander Formation (Enclosure 3). The unit may correlate with the Meda Formation as the two units contain similar conglomerate clasts.

Subdivision	
Upper fine-grained, mainly planar-bedded quartz wacke.	**Nature of exposure** Well exposed in gullies in and around Mudjalla Gully.
Lower coarse-grained, cross-bedded and conglomeratic quartz arenite and wacke.	**Remarks** Upper fine-grained part is recognizable by its lighter tone on the aerial photographs.

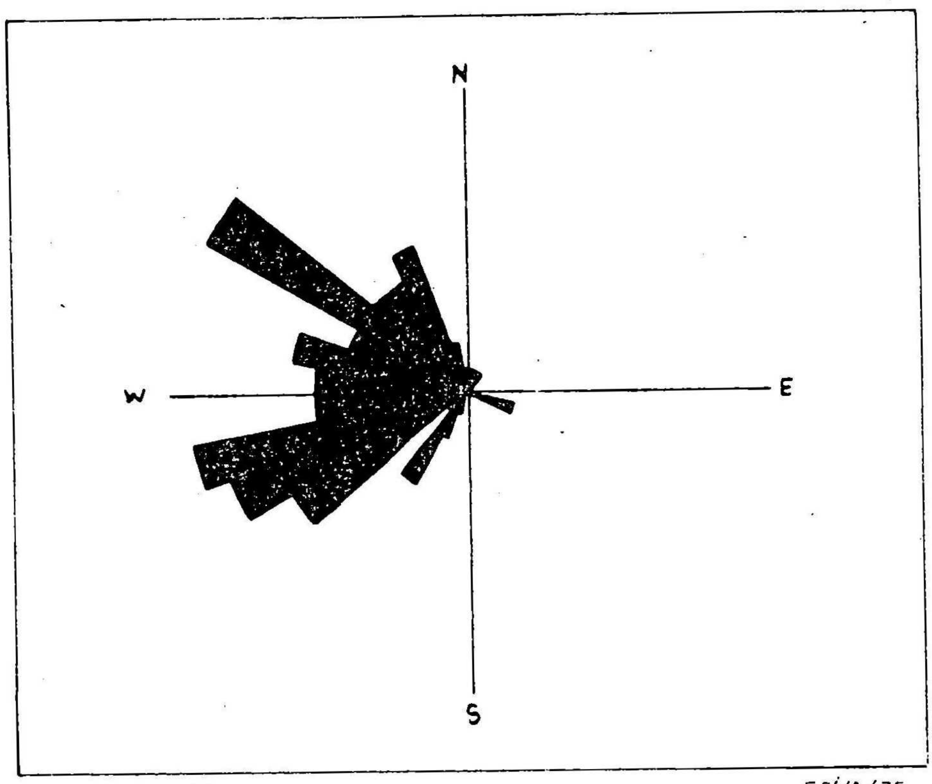

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Fig 7 Rose diagram of current directions in the Mudjalla Sandstone 'Member'. Readings from 50 cross-sets.

ALEXANDER FORMATION (Table 21)

The mapped distribution of the Alexander Formation differs considerably from that shown on the first edition maps (Guppy and others, 1958). One of the most important changes is that rocks that underlie the Barbwire Sandstone (previously James Sandstone in the area) in the Mount James area are now assigned to the the Alexander Formation. The presence of Alexander Formation in this general area was demonstrated by Crowe & Towner (in prep.) when they discovered Jurassic fossils in a deeply weathered exposure near Mount Fenton (NOONKANBAH). Williams & McKellar (1958) had previously mapped, on lithological grounds, some Alexander Formation underlying the Barbwire Sandstone at hills 5 km south of Mount James. However, they showed the gravel plains in that area as Liveringa Group. Our mapping suggests that there is no Liveringa Group exposed south of the Fenton Fault but that Williams and McKellar were correct in showing Barbwire Sandstone overlying Alexander Formation. The boundary is erosional and marked by a basal conglomerate in the Barbwire Sandstone. The exposures assigned to the Alexander Formation consist of interbedded mudstone and fine-grained quartz wacke containing wave-formed ripple marks and lenticular bedding.

Another change to the original mapping is that small exposures in the west bank of the Fitzroy River at Langey Crossing, which were originally considered Mudjalla Sandstone, are now assigned to the Alexander Formation.

These outcrops consist of interbedded laminated mudstone and fine-grained quartz arenite. Large, shallow scour-and-fill structures with foreset slip planes are present together with lenticular bedding containing wave-formed ripple marks. Bio- turbation is common and in some gravel pits adjacent to the river there are ?lenses of very coarse-grained quartz wacke which contains possible mega-ripple cross-bedding and indeterminate shelly fossils. The interpretation of the depositional environment (below) also suggests that this sequence is part of the Alexander Formation and not the Mudjalla Sandstone'Member'.

Table 21

Unit Alexander Formation

Symbol Ja

Defined by Brunnschweiler, 1954

Distribution Exposed mainly in Edgar Ranges, at Matches Springs and scattered exposures south of the Fenton Fault. An exposure along the west bank of Fitzroy River at Langey Crossing is also assigned to the unit. In the subsurface the unit occurs in western DERBY and MOUNT ANDERSON and south of the Fenton Fault in central and eastern MOUNT ANDERSON.

Lithology Consists mainly of fine to medium-grained quartz arenite and wacke; interbedded with mudstone and minor granule conglomerate, thin-bedded, wave and current ripples, flaser and lenticular bedding, wavy bedding, megaripples (Plate 12) and some large-scale trough cross-bedding. Some cross-bedded fining-upwards sequences with ripple-marked tops identified near top of unit. Bioturbation is common and fossils occur in lenses. Root moulds occur at one level in the southeastern Edgar Ranges. See Section 5.

Facies variations There are many local lateral and vertical changes in facies but the overall lithology is fairly uniform.

Thickness Maximum known thickness is 72 m in the Edgar Ranges. The unit thins to the north.

Type section locality Mount Alexander (Section 5; MOUNT ANDERSON: Lat. $18^{\circ}41'00"$S, Long. $123^{\circ}39'20"$E)

Age and criteria Late Oxfordian to early Kimmeridgian in the area on the basis of the macrofauna (Brunnschweiler, 1960) and microfossils (B Ingram, GSWA, pers. comm.).

Fossils Ammonoids, bivalves, brachiopods, ophiuroids (Brunnschweiler, 1954). Microfossils are known from petroleum and phosphate exploration wells (e.g. WAPET, 1962b). Trace fossils are also abundant in the unit.

Relations The unit is believed to conformably overlie the Wallal Sandstone in bore sections and to locally interfinger with the Jurgurra and possibly the Mudjalla Sandstone 'Members'. It is conformably overlain by the Jarlemai Siltstone (Plate 13). The formation is partly overlain by and is probably partly equivalent to the Barbwire Sandstone, south of Mount James.

Subdivisions None.

Nature of exposure Forms mesas and buttes with smooth, scree-covered slopes.

Remarks

G.S.W.A. F. 18, Nos 16 & 17

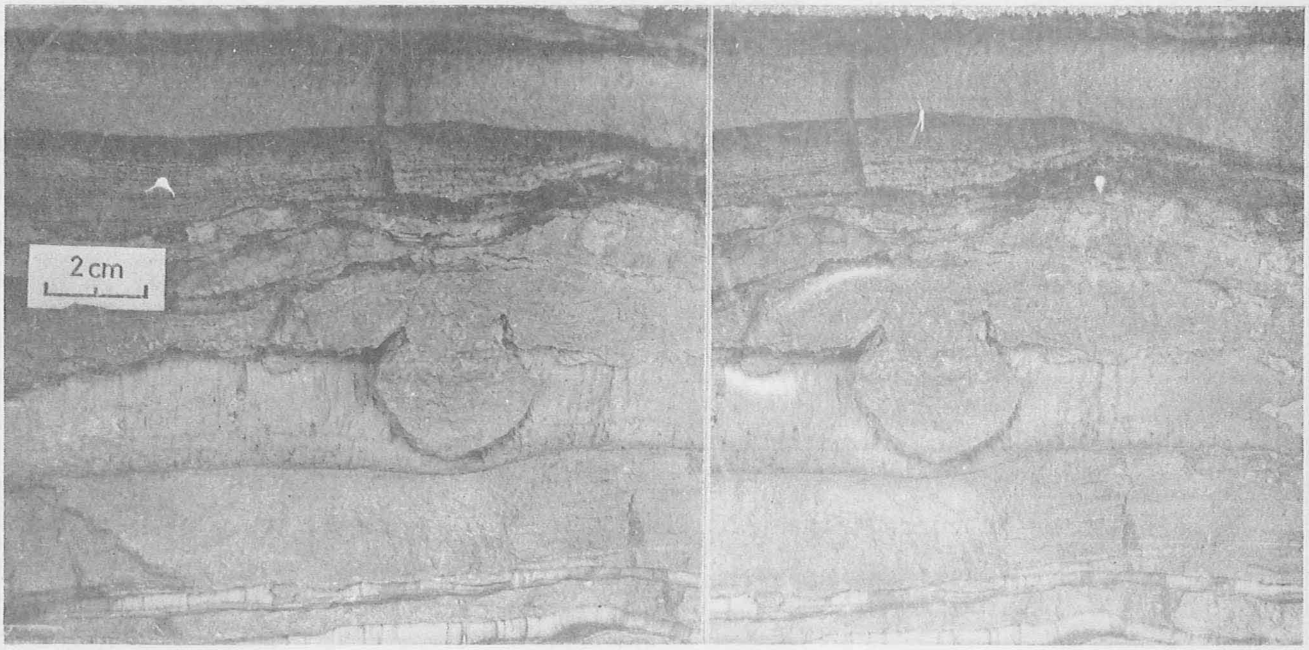


Plate 11. Stereopair showing the origin of a load cast in the Alexander Formation at Mount Alexander (Lat. 18°41'00" S, Long. 123°39'20" E). The sandstone forming the load cast is derived from the wave-formed ripple above and has squeezed into the underlying soft mudstone.

G.B/1531 & 1544

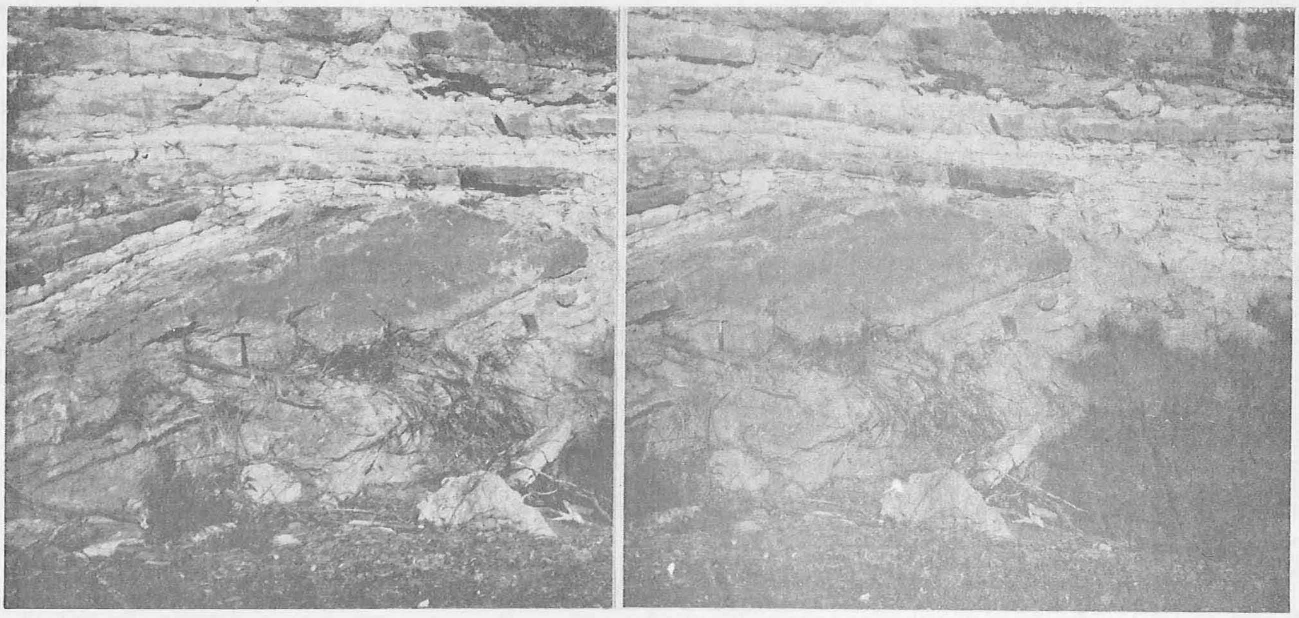


Plate 12. Stereopair showing a preserved megaripple overlain by draped sediments in the Alexander Formation exposed in a gully at Lat. 18°49'00" S, Long. 123°38'45" E. Hammer is inked in on left-hand print.

Unit Barbwire Sandstone	Symbol Jb	Defined by Guppy and others (1958)

Distribution Occurs in isolated exposures along Fenton Fault. Exposures south of Mount James and at Camelgooda Hill are also assigned to the unit.

Lithology Fine to coarse-grained quartz wacke and conglomerate, poorly sorted; contains large-scale planar and trough cross-bedding. Conglomerate contains intra-formational clasts in places, but characteristically consists of quartz and quartzite pebbles. contains minor beds of mudstone and is normally intensely ferruginized, in places converted to ferricrete.

Facies variations Exposure at Camelgooda Hill are tentatively assigned to the unit and if the correlation is correct then the Camelgooda Hill sequence could be considered a fine-grained facies of the Barbwire Sandstone.

Thickness 33 m thick at Mount James.

Type section locality Barbwire Range (NOONKANBAH: Lat.18°58'S, Long.125°01'E).

Age and criteria Plant fossils indicate a Jurassic or Early Cretaceous age (White & Yeates, 1976).

Fossils Only some trace fossils recorded from area. Yeates and others (1975b) record plant fossils from the unit.

Relations Unconformably overlies Permian rocks. Appears to overlie, and is possibly partly laterally equivalent to the Alexander Formation. Top of unit is everywhere eroded. May correlate with the Mowla Sandstone, Meda Formation and/or the Wallal Sandstone (see Fig. 15).

Subdivisions

Nature of exposure Occurs as very ferruginized cappings to hills along Fenton Fault.

Remarks Includes James Sandstone (Crowe & Towner, in press).

These outcrops consist of interbedded laminated mudstone and fine-grained quartz arenite. Large, shallow scour-and-fill structures with foreset slip planes are present together with lenticular bedding containing wave-formed ripple marks. Bio-turbation is common and in some gravel pits adjacent to the river there are ?lenses of very coarse-grained quartz wacke which contains possible mega-ripple cross-bedding and indeterminate shelly fossils. The interpretation of the depositional environment (below) also suggests that this sequence is part of the Alexander Formation and not the Mudjalla Sandstone 'Member'.

Depositional environment

The presence of marine fossils in the Alexander Formation shows that it was deposited under marine conditions. The abundance of wave-formed ripples (e.g. see Plate 11) indicates it was deposited mainly above wave base. The presence of flaser, lenticular and wavy bedding suggests deposition during periods of slack and fast-moving water such as occurs in the tidal zone. Cross-bedded, fining-upwards sequences are interpreted as channel deposits of tidal origin. The interpreted root moulds in the southeastern Edgar Ranges indicate temporary emergence in that area.

The formation exposed near Langey Crossing is similarly believed to have been deposited in a tidal environment. The scours are interpreted as tidal channels and the wave-formed ripple marks suggest deposition in water probably not more than 30 m deep. The occurrence of quartz arenite in the sequence is also typical of near-shore deposition where wave action is responsible for a high degree of sorting.

BARBWIRE SANDSTONE (Table 22)

The Barbwire Sandstone was previously mapped as James Sandstone in the area. However, Crowe & Towner (in press) have extended the term Barbwire Sandstone to include the James Sandstone as the two units are similar.

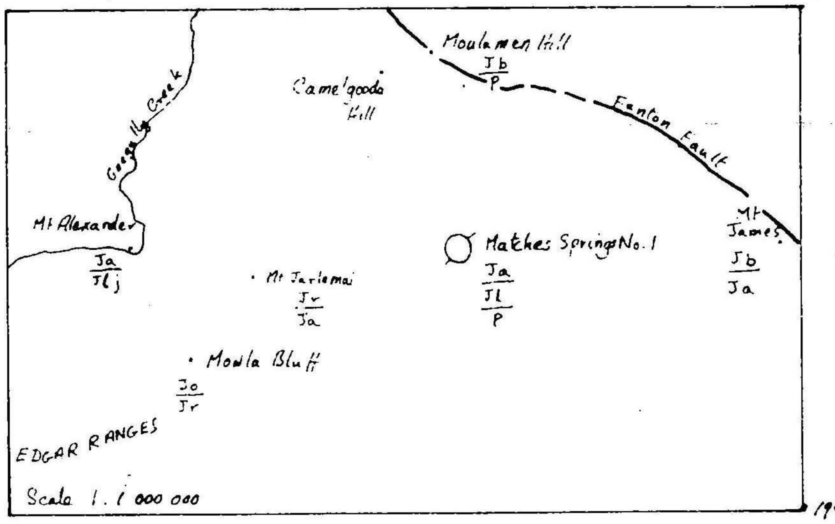
The Barbwire Sandstone may be correlated with the Meda Formation which only crops out in DERBY. The correlation is based on the fact that the two units contain similar pebbles of quartzite that are not commonly found in units older than Jurassic. On the gravel plains south of the Fitzroy River, many patches of gravel contain similar quartz and quartzite pebbles. Such pebbles are not common in the underlying Permian rocks and so it is thought that they represent deflation material from a thin veneer of Jurassic sediments that has been eroded away. This interpretation is supported in NOONKANBAH where Crowe & Towner (in prep.) mapped several exposures in this veneer. The inference of this interpretation is that the extensive gravel plains represent sediments that may have been continuous between the Barbwire Sandstone and Meda Formation.

Camelgooda Hill

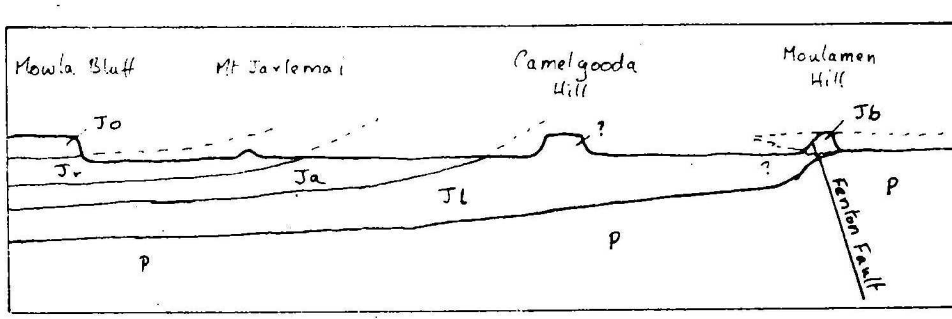
The section exposed at Camelgooda Hill does not correlate well with any of the defined units.

The sequence consists of fine-grained quartz wacke and quartz arenite with minor mudstone. Large troughs (2 m wide and 1 m deep) occur within the unit and contain poorly laminated foresets which pass upwards into climbing ripple cross-lamination. Minor intraformational conglomerate occurs at the bases of the troughs together with a few plant and wood fragments. Other parts of the sequence are mainly planar-bedded but they contain abundant current ripple marks.

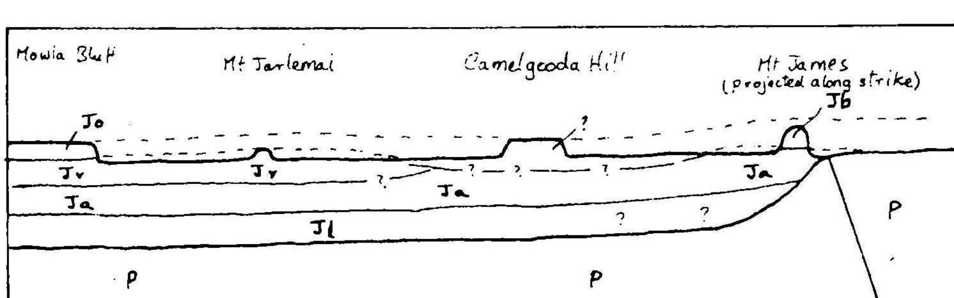
On lithological grounds the unit could correlate with any of the non-marine Jurassic units (except the Jurgurra Sandstone 'Member'). Figure 8 shows two alternative correlations of the Camelgooda Hill sequence. We prefer alternative B because it appears to better explain the environmental interpretations for the units and it is on this basis that the Camelgooda Hill sequence is tentatively assigned to the Barbwire Sandstone. More subsurface information is needed before our correlations can be verified.



Locality sketch showing units identified.
P - Permian; Jl - Wallal Sandstone; Jlj - Jurgurra Sandstone 'Member'; Ja - Alexander Formation; Jr - Jarlemai Siltstone; Jb - Barbwire Sandstone; Jo - Mowla Sandstone.



A CORRELATION OF CAMELGOODA HILL SEQUENCE WITH WALLAL SANDSTONE (This correlation ignores relation seen at (Mount James).



B CORRELATION OF CAMELGOODA HILL SEQUENCE WITH BARBWIRE AND MOWLA SANDSTONES (This correlation projects relation at Mt James along strike)

Fig. 8 Schematic diagrams showing two possible correlations of sequence at Camelgooda Hill.

Depositional environment

Exposures of the Barbwire Sandstone at Mount James (and at hills 5 km south of there) are considered fluviatile. This interpretation is based on the abundance of trough cross-bedded units which commonly fine upwards. Current ripple marks also occur in the finer-grained parts of the sequence and are interpreted as overbank deposits. There is an overall upward reduction in grainsize in the unit in exposures farther east and this supports the fluviatile interpretation. The presence of conglomerate in the sequence suggests moderate to high-energy deposition.

Sections of the Barbwire Sandstone to the northwest, along the Fenton Fault, are too poorly exposed to allow interpretation of theiroorigin but the sections visited are lithologically similar to the section at Mount James.

The section at Camelgooda Hill is also interpreted as a fluviatile (or possibly delta-plain) deposit. The large scours are typical of channel deposits. Abundantly ripple-marked planar beds in the sequence are interpreted as overbank or levee deposits laid down on a flood or delta plain. The fine grainsize and the predominance of planar-bedded units in the sequence suggests lower-energy deposition than occurred in the Barbwire Sandstone. If the correlation shown in Figure 8B is correct then the facies at Camelgooda Hill can be considered transitional between the Mowla Sandstone and Barbwire Sandstone at Mount James.

MEDA FORMATION (Table 23)

The Meda Formation only occurs in DERBY and as stated above (under Mudjalla Sandstone 'Member' and Barbwire Sandstone) the unit could be correlated with either the Mudjalla Sandstone 'Member' or the Barbwire Sandstone. Such correlations are based on the fact that the Jurassic continental facies (excluding the Jurgurra Sandstone 'Member') contain similar pebbles of quartz and quartzite. This is an admittedly slender line of evidence but it is on this basis that we consider the unit is probably Jurassic. The possibility that the unit is younger cannot, however, be ruled out.

Unit Meda Formation	Symbol Jd	Defined by Guppy and others (1958)

Distribution Only occurs in DERBY at Erskine Range and in isolated exposures on Meda and Kimberley Downs stations and to the south of Derby.

Lithology Consists mainly of fine to coarse-grained quartz wacke and granule and pebble conglomerate; contains large-scale trough cross-bedding and some current ripple marks. Conglomerate clasts include rock types from the underlying Erskine Sandstone but mainly consist of white quartz and quartzite. Overall the unit is poorly sorted although individual beds are graded and some are well sorted. Most exposures are very ferruginized. See Section 4.

Facies variations None.

Thickness A maximum thickness of about 7 m is exposed in the Erskine Range.

Type section locality Erskine Range (DERBY: Lat.17°51'S, Long.124°22'E).

Age and criteria Believed to be Jurassic as it contains a similar range of extraclasts to other Jurassic units (e.g. Barbwire Sandstone and Mudjalla Sandstone 'Member'). If this correlation is correct then the Meda Formation is probably Late Jurassic.

Fossils Wood fragments are the only fossils recorded from the unit.

Relations Disconformably overlies the Erskine Sandstone and the top is eroded. The lower boundary is strongly erosional and if it is an angular relation then this was not recognized in the small areas of exposure.

Subdivisions None.

Nature of exposure Good at tops of hills.

Remarks

Depositional environment

The generally poorly-sorted nature of the sediment and the presence of abundant large-scale trough cross-bedding with associated current ripple marks suggest deposition in channels. The strongly erosional base of the unit and the occurrence of wood fragments is compatible with this interpretation. It is thought that the unit is probably fluviatile.

JARLEMAI SILTSTONE (Table 24)

Since the area was originally mapped by Guppy and others, (1958) and Brunnschweiler (1957) there has been a substantial increase in the knowledge of the subsurface Jurassic geology. This has enabled correlations to be made so that some surface-defined units can now be discarded.

The Langey Shale (Guppy and others, 1952; Playford and others, 1975) was originally defined from gravel pits near the now-abandoned Langey Crossing at the mouth of the Fitzroy River. The gravel pits are now filled in and the only unit exposed is the Alexander Formation. As the Langey Shale can now be shown to be equivalent to the Jarlemai Siltstone (Enclosure 3) it is proposed to discard the term Langey Shale. Drilling in the area has shown that the base of the Jarlemai Siltstone contains a glauconitic, phosphatic bed (Russell, 1966a, b, reported in Playford and others, 1975) and if this should prove to be a useful marker it would be possible to restrict the term Langey Shale to this unit. As the glauconitic bed no longer appears to crop out this has not been attempted here.

Another unit that is now assigned to the Jarlemai Siltstone is the Fraser River Limestone (Guppy and others, 1952). Although this unit was never defined, it was mapped as a separate unit and correlated with the Langey Shale (Brunnschweiler, 1957). Our mapping showed this unit to be mainly shale containing marine fossils with only minor 'limestone' (calcareous mudstone) intervals. Although Brunnschweiler (1957) probably visited different exposures to ours we have little hestiation in equating the unit with the

Table 24

Unit Jarlemai Siltstone	Symbol Jr	Defined by Brunnschweiler (1954)
Distribution Occurs in southern MOUNT ANDERSON in Edgar Ranges and isolated exposures. Exposures of shale in Fraser River area (DERBY) are also assigned to unit.		
Lithology Consists mainly of white, red, yellow, and purple mudstone which is commonly sandy. Contains scattered coarse grains of sand and granules. Bedding is very poor so the unit appears massive. Upper 30 to 50 m in eastern Edgar Ranges consists predominantly of quartz wacke. Whole of unit appears bioturbated and this may explain the lack of bedding. In subsurface the unit is glauconitic and phosphatic. Selenite and pyrite are common accessory minerals. The unit contains rare pebbles. See Sections 6 & 7 (Appendix I).		
Facies variations The upper part of the unit in the eastern Edgar Ranges is mainly sandstone and considered a local facies.		
Thickness About 90 m thick in Edgar Ranges and possibly more than 160 m thick in Fraser River area.	**Type section locality** Mount Jarlemai (MOUNT ANDERSON: Lat. 18°42'55"S, Long. 123°48'40"E).	
Age and criteria Middle Oxfordian to early Tithonian on palynological grounds (Balme *in* Cranwell, 1964). However basal part of unit in Langey Crossing area is only Kimmeridgian (B Ingram, pers. comm.).		
Fossils Includes pelecypods, belemnites, ammonites, and brachiopods (Brunnschweiler, 1954, 1957; includes 'Langey Crossing Marl' fauna). Palynomorphs are described by Balme (*in* Cranwell, 1964).		
Relations Overlies Alexander Formation conformably (Plate 13). Is overlain ?conformably by the Jowlaenga Formation and possibly disconformably by the Melligo Sandstone. Mowla Sandstone interfingers with upper part of unit and overlies with local disconformity.		
Subdivisions In eastern Edgar Ranges the unit contains a fine-grained (mudstone) lower part and a coarser-grained (sandstone) upper part. The upper sandstone part appears to wedge out to west.	**Nature of exposure** Forms mesas and buttes with sheer sides and scree slopes.	
	Remarks Mowla Bluff is proposed as a reference section. It covers the upper part of the formation which is not exposed in the type section. Streaky airphoto patterns in southwest DERBY are believed to indicate Jarlemai Formation subcrop.	

Jarlemai Siltstone. The correlation is also supported by the identification of Jarlemai Siltstone at the top of the section in WAPET Fraser River No. 1 (BMR Basin Studies Group, pers. comm.).

Depositional environment

The Jarlemai Siltstone was deposited in a marine environment as indicated by the marine fossils. The fossils are haphazardly arranged in the unit, indicating that they do not represent a death assemblage that has been washed into the unit. The whole unit is characteristically very poorly bedded or massive and this may be due to the loss of bedding structures by intense bioturbation. Such bioturbation has certainly occurred because the rock (particularly at Mowla Bluff) is filled with clay-marked burrows and trails.

The unit lies above the transgressive tidal deposits of the Alexander Formation (Plate 13) and beneath the regressive sequences of the Mowla Sandstone (in the Mowla Bluff area) and the Jowlaenga Formation and Melligo Sandstone (in the western DERBY area). This suggests that the Jarlemai Siltstone was deposited at the peak of the Jurassic transgression probably in a fairly shallow shelf sea. The lack of any well-defined current structures suggests deposition below wave-base with little influx of terrigenou material.

Palynological datings from bores in the Langey Crossing area indicate that the palynological time zones are compressed (B. Ingram, pers. comm.). This may be explained by the presence of intraformational unconformities or by slow deposition. As no major disconformities appear to be present in the area, we prefer the latter explanation.

In conclusion, most of the evidence indicates that the Jarlemai Siltstone was laid down in a stable shelf sea and that a slow rate of deposition may be responsible for intense organic reworking resulting in the destruction of bedding structures.

MOWLA SANDSTONE (Table 25)

Brunnschweiler (1954) believed the boundary between the Mowla Sandstone and the underlying Jarlemai Siltstone was disconformable in places and transitional in others and on this basis he assigned the unit to the Jurassic. McWhae and others (1958) disregarded Brunnschweiler's field evidence of local transitions and, seeing only the disconformity, argued that an Early Cretaceous age was more likely.

Unit Mowla Sandstone	Symbol Jo	Defined by Brunnschweiler (1954) and Guppy and others (1958)

Distribution Occurs in small areas in centres of synclines in area at Matches Springs, Mowla Bluff, and to the east of Mounts Jarlemai and Troy.

Lithology Basal part consists of poorly-sorted pebble conglomerate which fills channels cut into the underlying Jarlemai Siltstone (Plate 14). The conglomerate passes into fine to coarse-grained, medium to thin-bedded, trough cross-bedded quartz arenite with occasional pebbles. This in turn passes up into partly bioturbated, arenite and wacke with some clay pellet conglomerate. At the top, the unit contains ripple-marked, fine-grained micaceous quartz wacke and mudstone with some plant fragments and climbing ripples. See Section 7.

Facies variations None observed.

Thickness Maximum recorded thickness is 15 m near Matches Springs (Smith & Williams, 1955).	**Type section locality** Mowla Bluff Section 7; MOUNT ANDERSON: Lat. 18°49'20"S, Long. 123°38'50"E).

Age and criteria Probably Tithonian on the basis that it interfingers with the middle Oxfordian to early Tithonian Jarlemai Siltstone.

Fossils Fragmentary indeterminate plant fossils found in upper part of unit.

Relations Erosional and interfingering lower boundary with the Jarlemai siltstone. Top of unit is everywhere eroded.

Subdivisions Bottom of unit is conglomeratic.	**Nature of exposure** Good; forms small hills with scree slopes.
	Remarks

Our mapping shows that Brunnschweiler (1954) was correct and werrecognize the boundary as an interfingering relation with small channels of Mowla Sandstone facies becoming increasingly abundant towards the top of the Jarlemai Siltstone (see Section 7 and Plate 14). Consequently the Mowla Sandstone is again considered Jurassic.

Possible Mowla Sandstone in the western Edgar Ranges

At Lat. 18°50'00"S, Long. 123°17'00"E in the western Edgar Ranges there is a thin unit of clean, well-sorted medium-grained quartz arenite. The unit occurs as boulders overlying the Jarlemai Siltstone and so it may correlate, on stratigraphic grounds, with either the Mowla Sandstone or the Jowlaenga Formation/Melligo Sandstone sequence.

The boulders contain large-scale planar cross-bedding with some interlaminated coarse-grained quartz arenite and a few pebbles. The lithology best resembles the Mowla Sandstone and so the unit is tentatively assigned to this formation.

Depositional environment

The lower part of the Mowla Sandstone contains abundant large scours with conglomeratic bases associated with trough cross-bedding. These sequences are interpreted as channel deposits (Plate 14) and they pass upwards into finer-grained sediment which is predominantly planar-bedded and which contains abundant current ripple marks.interpreted as overbank or levee deposits.

The upper part of the Jarlemai Siltstone in the eastern Edgar Ranges becomes increasingly coarser-grained towards the top. This suggests that it marks the start of the Late Jurassic marine regression from the area. The Mowla Sandstone is believed to represent the top part of this regressive sequence and the nature of the erosional contacts between the two units and the presence of channel deposits suggest that the regression was of the deltaic type in this area. Consequently the lower part of the Mowla Sandstone is interpreted as predominantly a distributary deposit and the upper parts as delta-plain or inter-distributary deposits.

GB/1529 & 1540

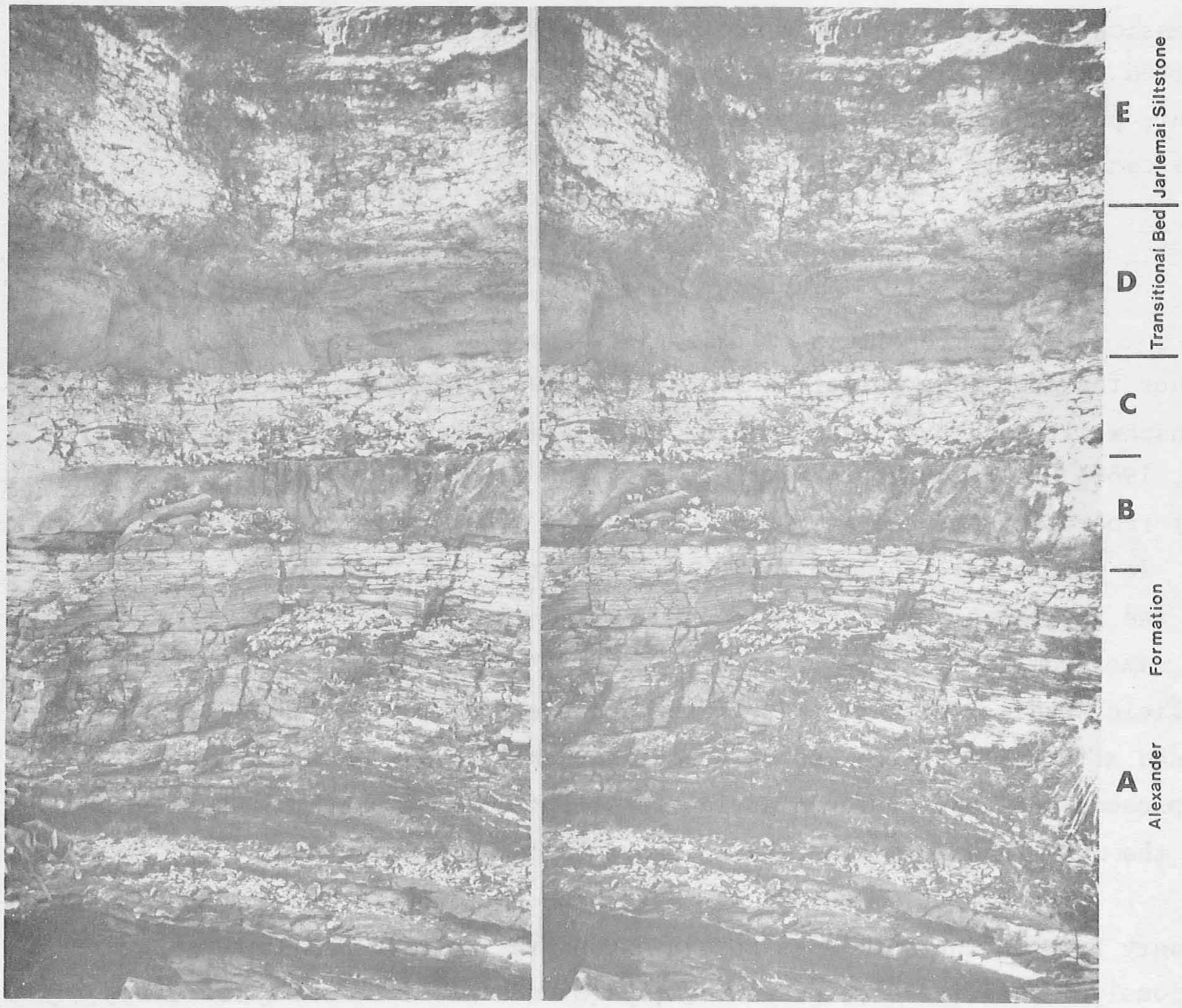


Plate 13. Stereopair showing contact between Alexander Formation and Jarlemai Siltstone at Lat. 18°55'30" S, Long. 123°40'00" E. A: Interbedded sandstone and sandy mudstone with a rich but poorly preserved fauna of bivalves and rare ammonoids and ophiuroids. B: Massive fine to medium-grained quartz wacke. C: Well-bedded, rippled mudstone with lenticular beds of sandstone. D: Massive fine to medium-grained quartz wacke. E: Poorly bedded to massive, sandy mudstone; bioturbated.
BMR Negative Nos. GB/1539 & 1540

This interpretation allows the Mowla Sandstone to be tentatively correlated with the section exposed at Camelgooda Hill (see under Barbwire Sandstone). As the Mowla Sandstone is regarded as representing the retreat of the Jurassic sea from the area, it can also be correlated with the Jowlaenga Formation/Melligo Sandstone sequence exposed in DERBY. However there is good evidence to suggest that the regression from DERBY occurred much later than it is thought to have occurred in MOUNT ANDERSON. Further palaeontological work is needed on this part of the sequence before the diachronous nature of the Jurassic rocks can be fully understood.

JOWLAENGA FORMATION (Table 26)

Previous reports show that there has been some doubt about whether the Jowlaenga Formation is Late Jurassic or Early Cretaceous. Brunnschweiler (in Guppy and others, 1952; and Brunnschweiler 1954; 1957; 1960) believed the unit to be Neocomian on palaeontological grounds. Later reports by Stevens (1965) and Skwarko (1970) suggest a Tithonian age. In particular, Skwarko (1970) believed that the fossils collected from the Jowlaenga Formation at Mount Clarkson by Brunnschweiler in fact came from the Melligo Sandstone (termed "Melligo Quartzite" by him). Our field studies indicate that there is no Melligo Sandstone (as defined) exposed at Mount Clarkson and it seems that Skwarko has only recognized its presence because he found Aptian fossils there. To us this suggests that the Jowlaenga Formation may be as young as Aptian.

Some of the confusion may have been based on the fact that the boundary between the Jowlaenga Formation and the Melligo Sandstone was previously identified as a disconformity (Brunnschweiler, 1957) and that, therefore, a time break between the two units was explicable. However, the present survey has shown that the boundary is inter-fingering (Section 8) so that a time break is not necessary. We believe that the boundaries between the Jarlemai Siltstone, Jowlaenga Formation, and the Melligo Sandstone are essentially conformable and do not represent major time breaks. With the present dates assigned to the units (see Playford and others, 1975) this is difficult to explain because of the time range involved. Further palaeontological work is probably necessary to resolve this problem.

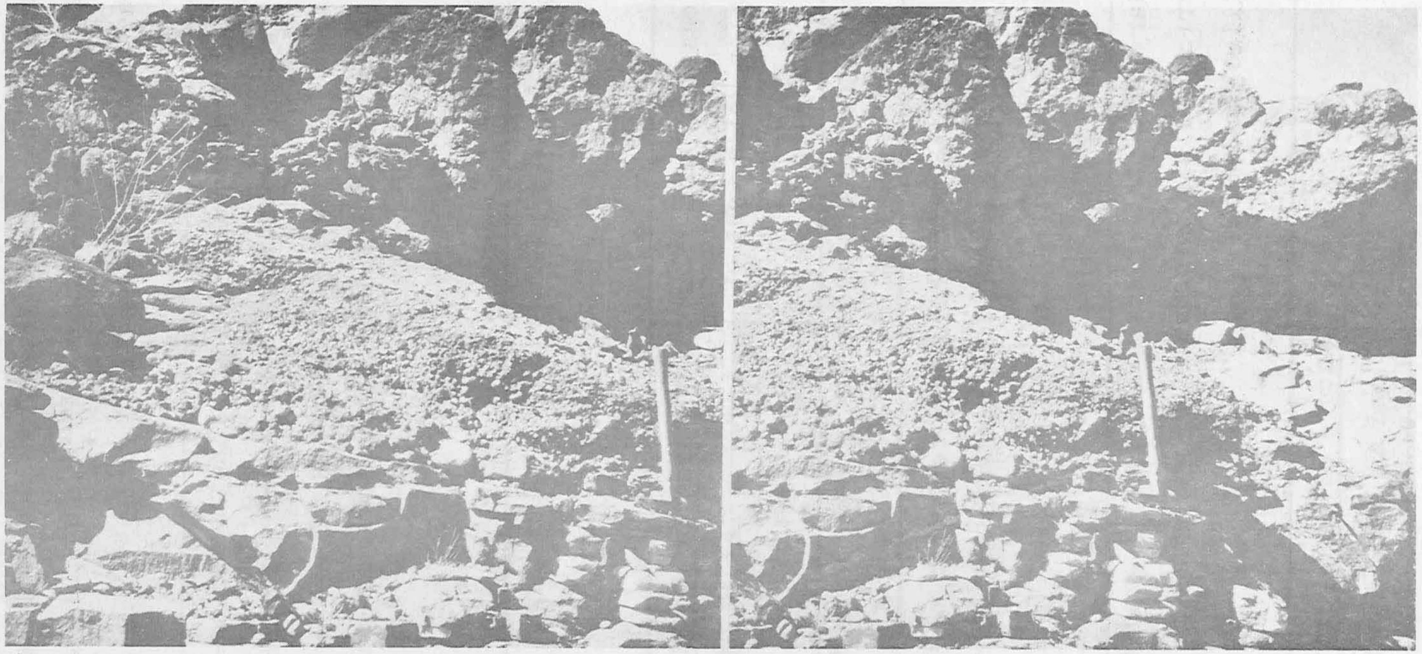


Plate 14. Stereopair showing local disconformity between sandy mudstone of the Jarlemai Siltstone (at base) and channel - fill conglomerate of the Mowla Formation at Lat. 18°47' 45" S, Long. 123°44'20" E, near Mowla Bluff. BMR Negative Nos GB/1519.

Unit Jowlaenga Formation	Symbol Jw	Defined by Brunnschweiler (1957); Guppy and others (1958); McWhae and others(1958).

Distribution Only recognized on surface in western DERBY but may be present in parts of western MOUNT ANDERSON as it is recognized (BMR Basin Studies Group, pers. comm.) in bores just west of the Sheet area boundary.

Lithology Consists of interbedded mudstone and fine to medium-grained quartz wacke with quartz arenite near the top. Both large and small-scale cross-bedding are present and lenses of intraformational conglomerate containing fossils also occur. Towards top unit consists of laminated, well-sorted sediment with scour-and-fill structures and bioturbated zones.

Facies variations None observed.

Thickness Generally less than 40 m thick in petroleum-exploration wells west of the area.

Type section locality Mount Jowlaenga (BROOME: Lat.17°23'S, Long.122°57'E)

Age and criteria There is some doubt about the age of the unit (see text).

Fossils Bivalves and belemnites which have been described by Teichert (1950), Brunnschweiler (1951, 1954, 1957, 1960). Plant fossils are described by White (in Veevers & Wells, 1961).

Relations Lower boundary with the Jarlemai Siltstone is gradational. Upper boundary has previously been described as disconformable but our evidence shows that it interfingers with the Melligo Sandstone.

Subdivisions None.

Nature of exposure Exposed in scree slopes and as small benches.

Remarks The unit may be a correlative of upper sandstone part of the Jarlemai Formation that occurs in the eastern Edgar Ranges.

Depositional environment

The lithology of the Jowlaenga Formation is transitional between that of the underlying Jarlemai Formation and that of the overlying Melligo Sandstone. The lower boundary is probably gradational (Rattigan & Elliott, 1954) and there is an increase in sandstone towards the top of the unit. This, together with the presence of marine fossils, indicates that the unit was laid down as the sea that deposited the Jarlemai Formation became shallower. The unit contains small scour-and-fill structures, bioturbated zones, and some large and small-scale cross-bedding; all features of shallow-water sediments deposited in the tidal zone. The presence of interpreted sand-volcano structures at the contact with the overlying Melligo Sandstone (which is interpreted as a beach deposit) is compatible with this interpretation (see under Melligo Sandstone).

MELLIGO SANDSTONE (Table 27)

Depositional environment

The Melligo Sandstone consists of very well-sorted mainly fine-grained quartz wacke commonly cemented by opaline silica. The unit is interpreted as a beach deposit on the basis of its high textural maturity, the presence of parallel lamination, primary current lineation, and the unit's position above the shallow-water marine deposits of the Jowlaenga Formation. The small fossils which occur at the base of the unit are also compatible with the beach environment.

At Dampier Hill there are two cycles of Jowlaenga Formation/ Melligo Sandstone deposition (Section 8) and this suggests that the shoreline oscillated as it retreated from the area.

At the contact between the Melligo Sandstone and the Jowlaenga Formation there is an unusual lenticularity. Figure 9 shows the nature of these lenses of Melligo Sandstone which occur at the boundary. The presence of small centrally located protrusions at the tops of some of the lenses and the occurrence of convex-upwards foresets within them suggest that the lenses may represent sand-volcano deposits (R.V. Burne, pers. comm.). Such structures are

Table 27

Unit Melligo Sandstone	Symbol Km	Defined by Brunnschweiler (1957); McWhae and others (1958).

Distribution Occurs in a strike ridge and line of mesas in western DERBY. Tentatively identified exposures occur in Fraser River area. The unit also occurs on Valentine Island in King Sound (Brunnschweiler, 1957).

Lithology At Dampier Hill, the unit consists of fine to medium-grained quartz wacke which is very well sorted. The grains are spherical to well rounded and the unit is laminated. The laminations are mainly planar and current lineation is common. Brunnschweiler (1957) stated that the unit also contains coarse-grained sandstone and minor conglomerate. The unit is characteristically white but contains abundant liesegang bands. The matrix is commonly opaline silica. See Section 8.

Facies variations None recognized.

Thickness Brunnschweiler (1957) believed the unit reached a thickness of 21 m but Rattigan & Elliott (1954) show a maximum of 43 m.

Type section locality None defined.

Age and criteria Dated as Aptian on palaeontological evidence (Brunnschweiler, 1957 and Skwarko, 1970). The unit contains *Fissilunula clarkei*, a key Aptian fossil.

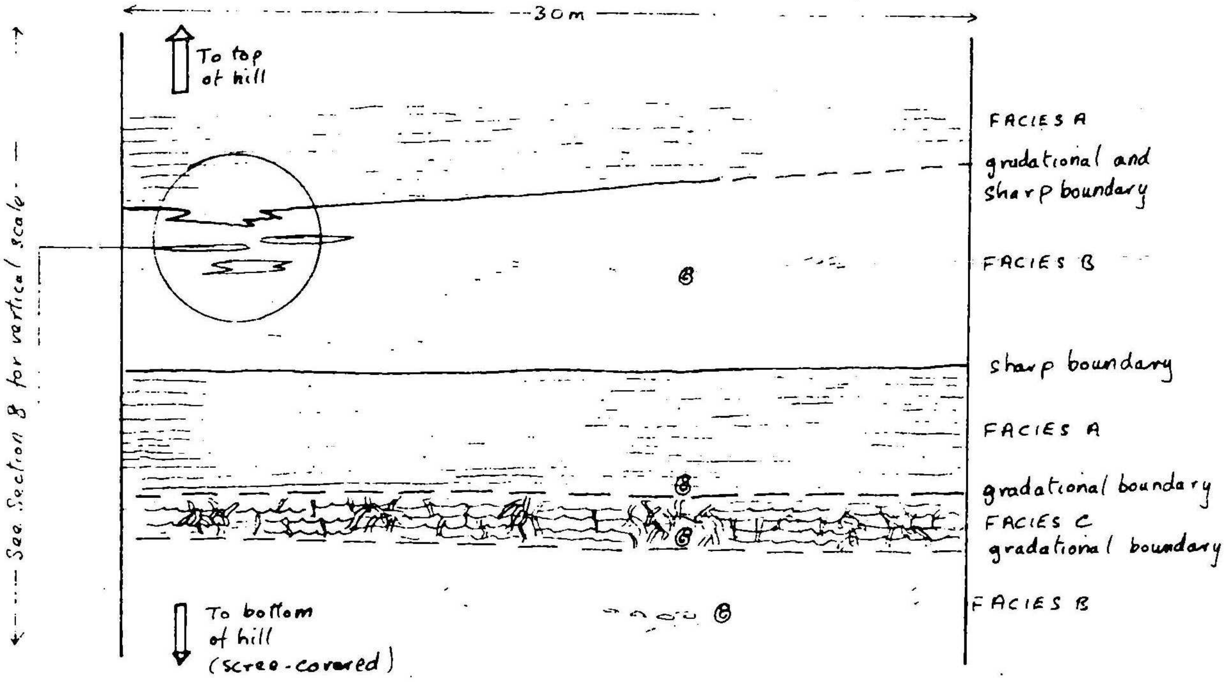
Fossils Bivalves and belemnites described by Brunnschweiler (1957) and Skwarko (1970).

Relations The base of the unit appears to be erosional (Brunnschweiler, 1957) but at Dampier Hill it is interfingering. The top is either covered by Cainozoic deposits or eroded.

Subdivisions None.

Nature of exposure Well exposed in quarries at Dampier Hill and adjacent to Great Northern Highway.

Remarks Known locally as 'Kimberley Colourstone' due to the purple and red liesegang banding. Used as building stone.



Facies A (Melligo Sandstone); White very fine-grained quartz arenite with siliceous cement. Planar laminated with current lineation on bedding planes

Facies B (Jowlaenga Formation); Brown fine-grained quartz arenite with no cement. Contains locally abundant clay-pellet conglomerate which follows foresets of large-scale trough cross-bedding. Lamination is faint.

Facies C (Transitional); Mainly light brown or white quartz arenite with minor amounts of matrix. Contains abundant ripple cross-lamination and wavy bedding which is mainly destroyed by burrows (0.5 - 1cm thick). This facies does not appear to occur along upper boundary of second cycle.

Diagrams showing nature of lenses of facies A which occur in facies B.

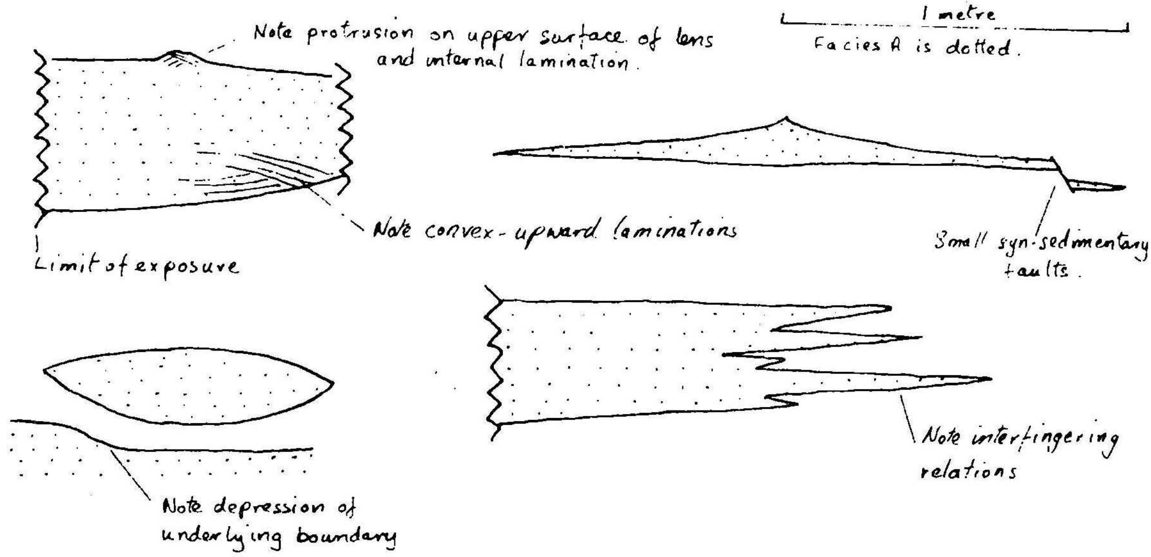


Fig. 9 Relations between Jowlaenga Formation and Melligo Sandstone at Dampier Hill.

common in the near-shore environment (Coneybeare & Crook, 1968) andy they form by dewatering of underlying saturated sediment as it becomes overloaded.

In conclusion, the Melligo Sandstone represents the beach deposits of the Jurassic marine regression which in the western DERBY area is interpreted as a linear shoreline regression.

FITZROY LAMPROITE

The Fitzroy Lamproite (Casey, 1958; Thomas, 1958b; Veevers, 1958) only occurs at one locality in this area: Rice Hill, its type section (Lat. 17°57'S, Long. 124°19'E; Playford and others, 1975). At this locality the unit forms either a flow or a sill according a Prider (1960) and consists of alkaline leucite lamproite.

The unit has been dated as Jurassic by the Rb-Sr method (Prider, 1960; Kaplan and others, 1967) but Tertiary dates have been obtained by the K-Ar method (Kaplan and others, 1967; Wellman, 1973). Kaplan and others favoured the Rb-Sr Jurassic age and attributed the Tertiary re-setting of the K-Ar date to later movement along the margins of the lamproite bodies. On the other hand, Wellman stated that there was no evidence of post-emplacement Tertiary tectonism and consequently preferred the younger age. Since, contrary to Wellman's statement, there is evidence of minor Tertiary movement involving tilting and faulting in the area (Brunnschweiler, 1957; Wright 1964) we believe that the age of the lamproites is still in doubt.

STRUCTURAL PATTERNS IN THE EDGAR RANGES-MATCHES SPRINGS AREA

Smith & Williams (1955) carried out detailed mapping in the eastern Edgar Ranges and in Matches Springs, and showed that the area is characterized by apparently random folding and associated faulting of the Jurassic Alexander Formation, Jarlemai Siltstone, and Mowla Sandstone. Their mapping showed that displacements on the faults are generally small (less than 30 m) and that the faults dip towards the centre of synclines. The fold structures mapped by Smith & Williams were considered by them to be drape folds caused largely by differential compaction of beds over an irregular pre-Jurassic topography. The random orientation of all the Mesozoic fold axes appears to form a dendritic pattern (Fig. 10) and they interpreted the small-scale strike faults as probably associated with the compaction of the draped sediments. Subsequently, Total Mowla No 1 (Total, 1969) was drilled in 1969 close to the axis of Smith and Williams' Alexander Syncline. Total (1969) showed that the well spudded directly into Permian rocks. However, recent micro-palaeontological work by J. Backhouse and E.M. Kemp (written communications) indicates that Jurassic rocks are present in the top 274 m of the well (Fig. 21, Appendix II). The base of the Wallal Sandstone is deeper in this well than elsewhere in the area, indicating a syncline, but the Wallal Sandstone and Alexander Formation are interpreted to be no thicker than in other wells or outcrop in the area; thus Smith & Williams' interpretation is not supported by the results of this well.

The dendritic pattern mapped by Smith & Williams (Fig. 10) suggests that the pre-Wallal Sandstone drainage flowed northwestwards, and if their theory is correct, it implies that this part of the Broome Platform was a positive feature in pre-Jurassic times.'

POST-EARLY CRETACEOUS TECTONISM

The Late Jurassic and Early Cretaceous rocks in the area presently occur topographically above the main level of the land underlain by the Fitzroy Trough. In particular, the Edgar Ranges occur some 100 m above that level. Wright (1964) believes this topographical difference was caused by Miocene tilting about a coastal hinge line and this agrees with Brunnschweiler's (1957) theory that the Dampier Peninsula was upwarped and the King Sound area downwarped. This doming of the Dampier Peninsula (forming the Fraser River Structure, DERBY) is inferred by Brunnschweiler to have been responsible for diverting the Fitzroy River from its original course towards Roebuck Bay (to the west of the area) towards its present course where it flows into King Sound.

Jurassic rocks adjacent to the Fenton Fault also show evidence of being faulted. However, as Williams & McKellar (1958) point out, the amount of throw on these faults is probably very small. The sense of movement is normal and the faulting was probably related to the uplift of the Edgar Ranges area on the Broome Platform.

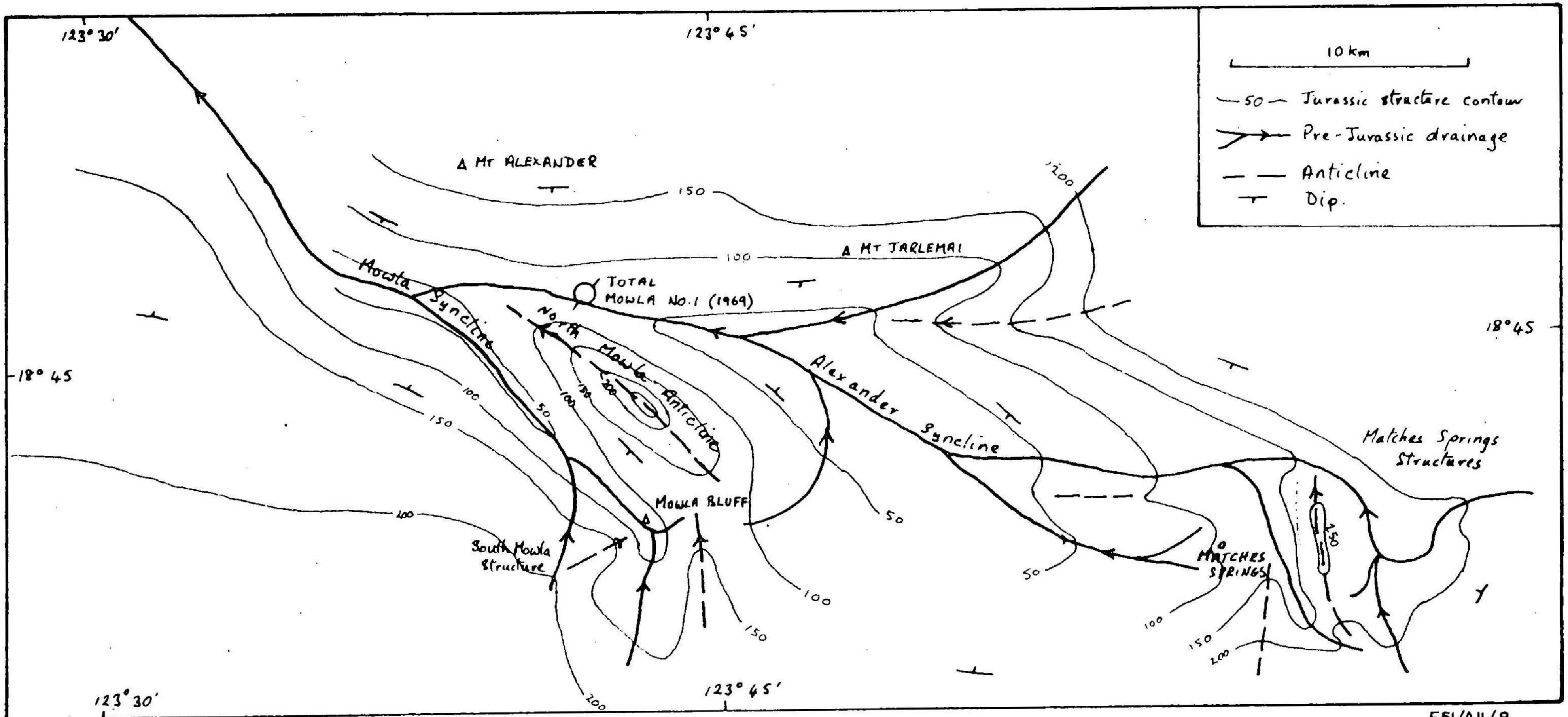


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Fig. 10 Pre-Jurassic drainage pattern in Edgar Ranges / Matches Springs area. An interpretation of the origin of the Edgar Range Folds. Adapted from Smith & Williams (1955).

PART II

GEOLOGICAL HISTORY

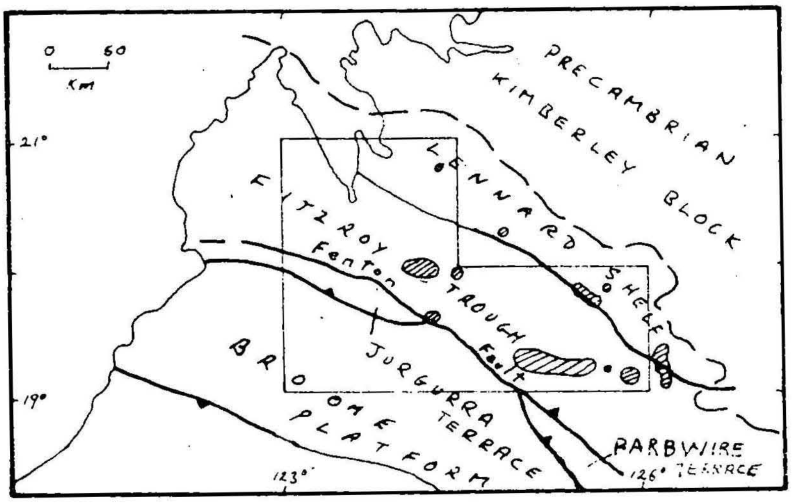
LATE CARBONIFEROUS TO EARLY PERMIAN

After deposition of the Early Carboniferous rocks, the area underwent an extensive period of uplift and erosion before sediment of the Grant Group was deposited in the Late Carboniferous. The lower part of the Betty Formation (Carboniferous part) is mainly confined to the Fitzroy Trough and so it is probable that this was an area of faster subsidence than the rest of the Canning Basin, as it was throughout most of the Palaeozoic. It is not certain whether the Betty Formation is a continental or marine deposit but it contains tentatively identified glacial erratics suggesting the presence of ice. Outside the area the unit contains some marine fossils so possibly it was laid down in a sea with floating ice. This phase of deposition continued into the Early Permian (Sakmarian) when the inferred sea spread over the whole area. It is thought that the next unit, the Winifred Formation, may indicate a relative rise in the water level as it consists of finer-grained sediments.

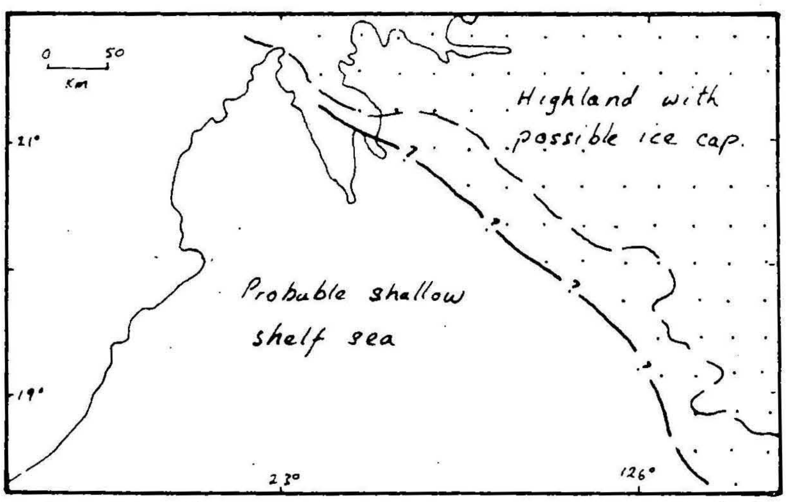
Deposition of the Carolyn Formation is thought to have occurred in a shallow sea, probably still under the influence of a cold climate (Fig. 11B). This sea is then believed to have retreated from the area south of the Fenton Fault. Exposures of Carolyn Formation in the Mount Arthur area represent near-shore conditions at that time (Fig. 11C). The presence of varves at the base of the Wye Worry Member to the east of the area led Crowe & Towner (1976c) to postulate deposition in a quiet-standing body of relatively fresh water which contained floating ice (Fig. 11C). This water body may have been a restricted arm of the sea that deposited the Wye Worry Member in the study area because later the same body of water became connected to the sea as indicated by the lack of varves and the presence of marine fauna (Crowe & Towner, 1976c). The barrier responsible for the marine restriction could have been sand bars that are interpreted to have been present in the Grant Range area during this time (Fig. 11C & D). Sand bar development probably continued in the Grant Range area throughout the rest of Wye Worry Member deposition.

Fig. 11

PALAEOGEOGRAPHIC MAPS FOR CAROLYN FORMATION



A. Showing area covered by this report together with area covered by Crowe & Towner (1976c). Also shows structural subdivisions and relevant exposures of Carolyn Formation.



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B. CAROLYN FORMATION, PRE-WYE WORRY MEMBER. Basin area was probably covered by a shallow shelf sea depositing clastics. Shoreline facies not identified but distribution of unit suggests it was just basinward of present basin margin

The sea then started to retreat from the area leaving the regressive deposits of the Millajiddee Member behind. As the regression continued alluvial plains formed over the area. Crowe & Towner (1976c) describe fossil ice wedges at this level and these indicate that the climate was still cold and that permafrost conditions probably prevailed on the newly formed alluvial plains (Fig. 11E). To the east of the area (and probably also within the area) the upper part of the Millajiddee Member is extensively slumped. This is tentatively interpreted to be due to 'ice tectonics' where the slumping is produced by melting and/or moving ice. However slumping associated with steep-sided scours and intraformational breccias such as occur at Hawkstone Peak are interpreted as due to deposition by mudflows on alluvial fans which were probably shed from the upstanding Kimberley Block (Fig. 11F). The presence of melting ice on the Kimberley Block would explain the rapid sedimentation which produced such alluvial fans.

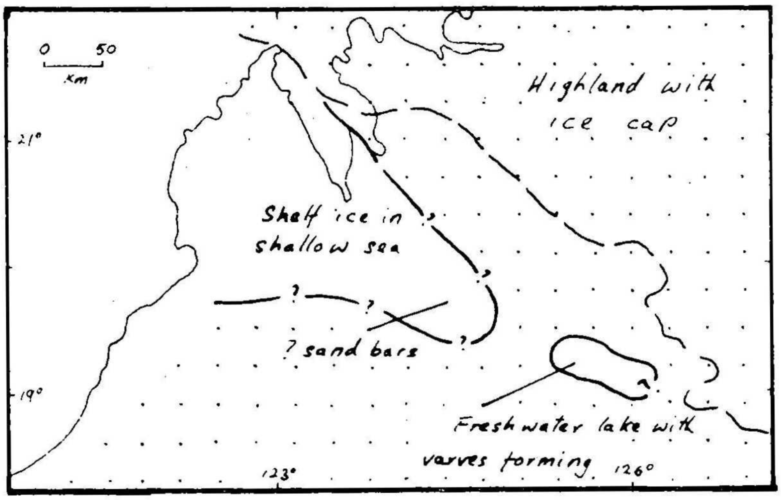
After deposition of the Grant Group the area was folded and faulted. At least some of the faults are of the reverse type (if not all of them) and it is consequently inferred that this period of tectonism was compressional. The area was then eroded and although no sediments of this erosion cycle were found in the area, some were discovered by Crowe & Towner (1976c) to the east.

EARLY TO LATE PERMIAN

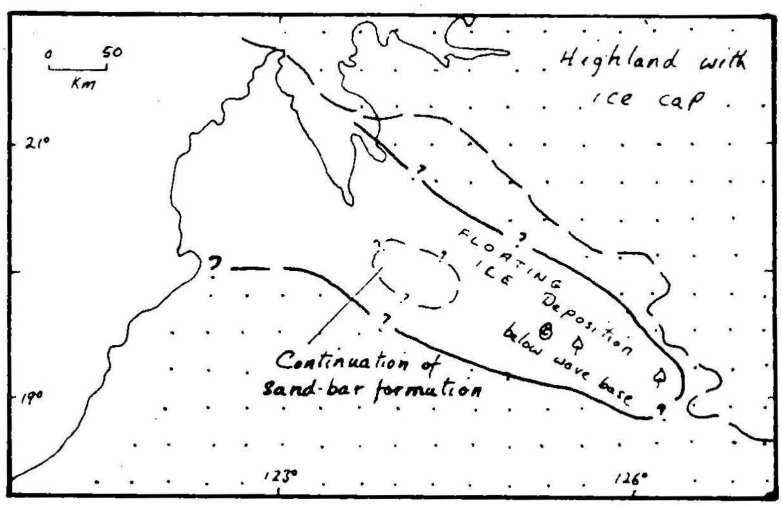
The area was probably eroded to a fairly flat plain before the next marine transgression occurred in the Early Permian and deposits of the Nura Nura Member of the Poole Sandstone were laid down. This sea probably covered all of the area (except perhaps the extreme northwest) and its diverse fauna indicates that the climate was relatively warm in comparison to the cold climate of Grant Group deposition. This sea is interpreted to have become progressively shallower as an extensive barrier-bar system migrated westwards across the area (Fig. 12).

During this time a westward-flowing river system was debouching via a delta into the sea to the east of the area (Fig. 12; Crowe & Towner, 1976b). Between this delta and the barrier bar system a lagoon is believed to have existed. The lagoon is interpreted to have gradually covered the whole of the area (at least within the Fitzroy Trough) and the Tuckfield

Fig. 11 (cont.)



C. LOWER WYE WORRY MEMBER. Probable regression of sea from southern part of basin. Sea withdraws or is cut off from eastern Fitzroy Trough and freshwater lake with floating ice forms. Cut-off may be due to sand-bar development in Grant Range area.



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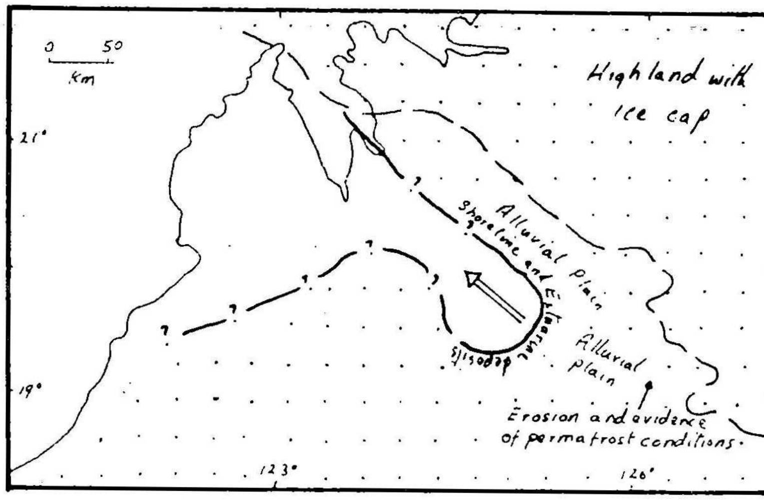
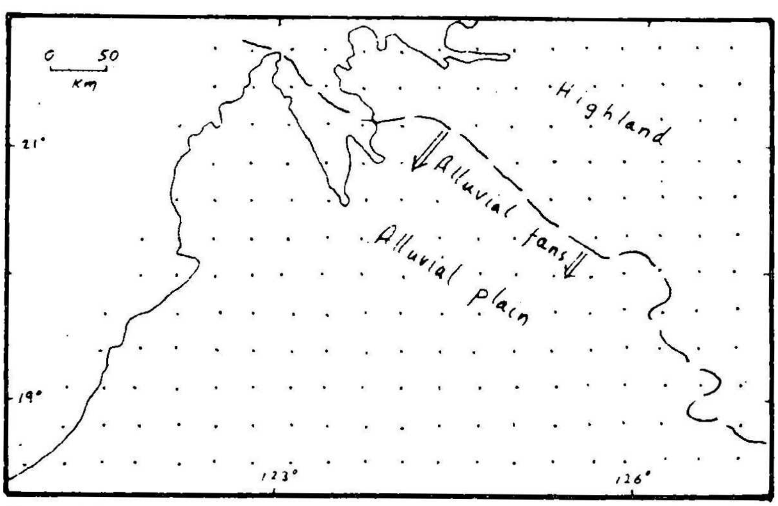
D. MIDDLE WYE WORRY MEMBER. Rise in relative sea level allows sea to reach at least as far as Mount RAMSAY Sea then becomes shallower marking the end of Wye Worry Member deposition.

Fig. 11 (cont.)



E. LOWER MILLAJIDDEE MEMBER. Permafrost conditions prevail in east while shoreline retreats from Fitzroy Trough.



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F. UPPER MILLAJIDDEE MEMBER. Area becomes land. Alluvial fans shed from upstanding Kimberley Block highlands. Fitzroy Trough is an alluvial plain. Extensive slumping of sediments due to dewatering caused by deglaciation and/or to uplift, folding, and faulting that followed deposition of the Carolyn Formation.

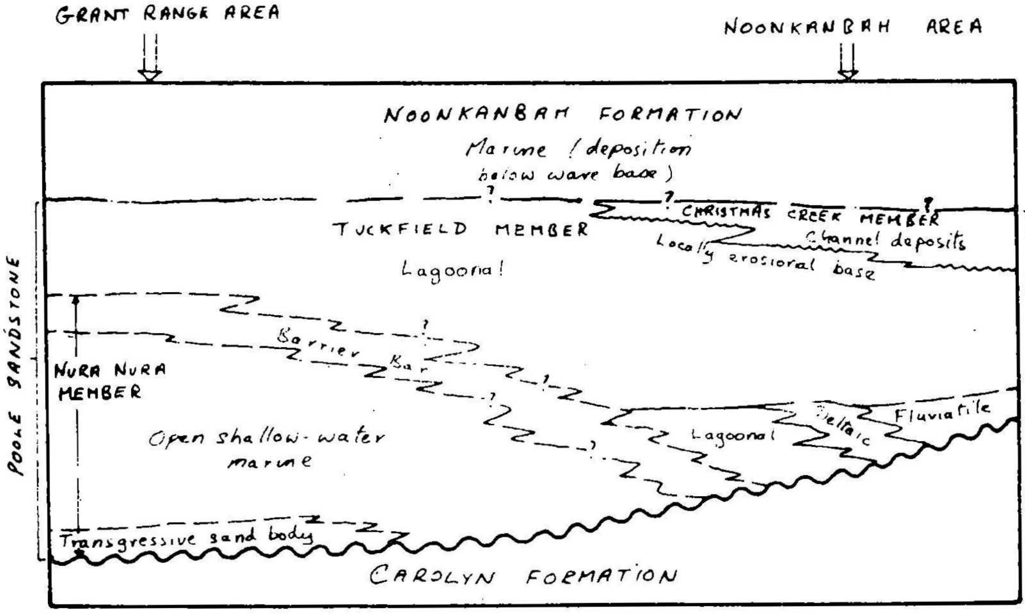

Fig. 12 Diagrammatic relations of facies within the Poole Sandstone between Grant Range(mount ANDERSON) and NOONKANBAH (see also Crowe & Towner, 1976c). Boundaries as in Fig. 13.

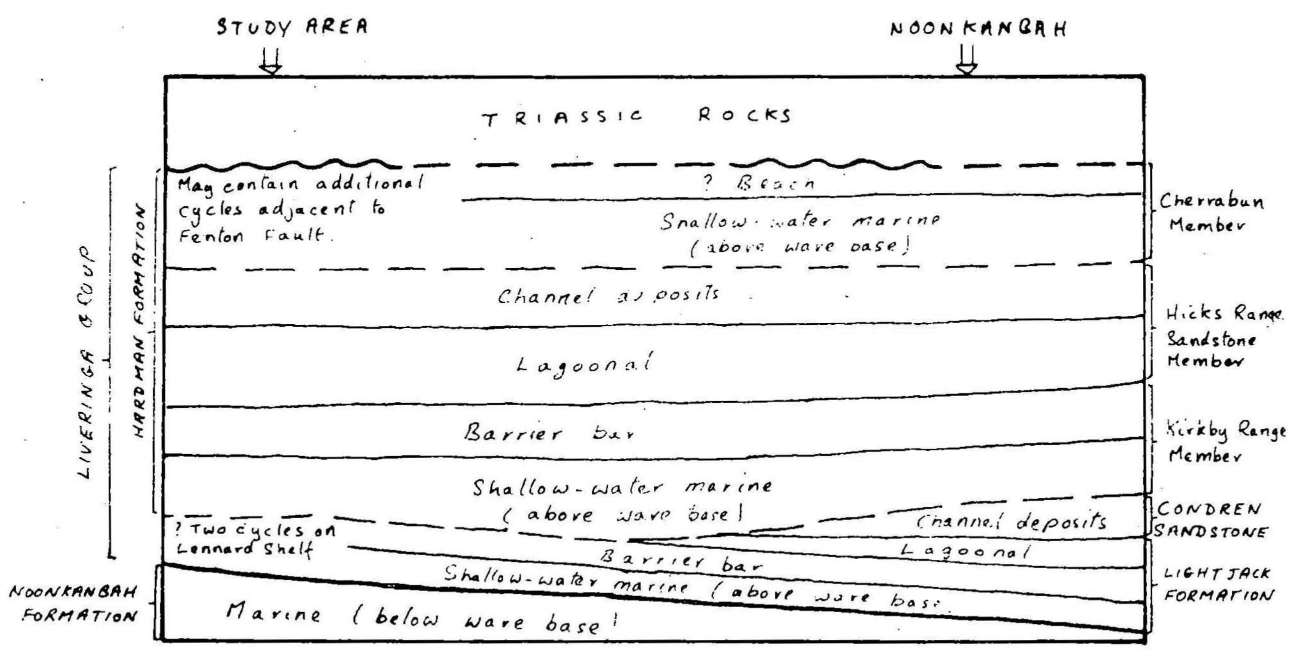

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Fig. 13 Diagrammatic relations of facies within the Liveringa Group between the study area and NOONKANBAH (see also Crowe & Towner, 1976c).

Boundaries:- ——— conformable, – – – disconformable, ∿∿∿ angular unconformity.

Member was laid down in it. Channels within this interpreted lagoon may have been tidal in origin. However the absence of a marine fauna in the unit suggests that there was no open connection with the sea that deposited most of the Nura Nura Member. As deposition of the Tuckfield Member continued, differential subsidence of the Fitzroy Trough was taking place. The homogeneity of the Tuckfield Member facies shows that subsidence was roughly keeping pace with deposition. However, the fact that the Tuckfield Member is thicker in anticlinal areas (Crowe & Towner, 1976c) indicates that these areas were subsiding at a slightly faster rate than surrounding areas.

After deposition of the Poole Sandstone, open marine conditions returned to the area. This may have been due to a rise in relative sea level or it could have been due to sediment starvation of the complex. The former alternative is preferred because the boundary between the Poole Sandstone and the Noonkanbah Formation is abrupt (it may be disconformable) and appears to represent a sudden change to deposition below wave base. Moderate-depth marine deposition continued throughout the Artinskian and into the Kungurian as the Noonkanbah Formation was laid down. However, the presence of some shallow-water indicators in the formation on the Jurgurra Terrace suggests that this area may have been positive with respect to the Fitzroy Trough. The exposures of the formation on the Jurgurra Terrace also contain substantial coarse-grained material, which poses a problem because there is no known nearby source for this material. It is possible, therefore that parts of the Broome Platform may have formed islands at this time, as was probably the case during the Mesozoic.

During the Kungurian, barrier sand bars spread across the area as the sea retreated. The middle part of the Lightjack Formation is believed to have been deposited as such sand bars (Fig. 13) and it marks the beginning of a paralic phase of deposition which occurred in the Late Permian. The area may have been subjected to subaerial deposition after the Lightjack Formation was laid down but if so, then the deposits (Condren Sandstone) were removed before the next marine incursion (represented by the Kirkby Range Member) took place. After this latter incursion, the sea again regressed from the area (Hicks Range Sandstone Member) before a final transgression and regression occurred (Cherrabun Member). Figure 13 shows the relation of these three depositional regressive cycles and it can be seen that in the study area additional cycles may be present. It is difficult to believe that this cyclic deposition (represented by the Liveringa Group) was brought about entirely by changes in relative sea level caused by tectonism. No angular relations are known in the sequence and it is therefore more likely that the cycles were caused by other means. Crowe & Towner (1976c) believed that the deltaic model described by Scruton (1960) offers a better explanation.

Scruton (1960), in describing the Mississippi delta deposits, explained how a delta lobe builds into the sea and deposits a typical regressive sequence until that lobe is abandoned owing to lateral migration of the debouching river. When this happens a new delta lobe is built elsewhere and with continuing subsidence of the basin (due in part to the increased load of sediment) the first lobe may be buried and preserved. Should the river change its course again a further lobe may be built out over the first and in this way a vertical sequence of regressive cycles can be built up. As Crowe & Towner (1976c) point out, this is the simplest explanation of the complex facies within the Liveringa Group and it is consequently thought that the group represents the deposits of a large imbricate delta that built out into, and gradually filled in, the Late Permian sea in the area.

No deposits of the Liveringa Group are known south of the Fenton Fault in the area and although some parts of the group may have been deposited and subsequently eroded, it is more probable that the Broome Platform and the Barbwire and Jurgurra Terraces were positive features during the Late Permian and that the sea had largely regressed from them by that time.

After the final regression of the sea from the area in the Late Permian, there was probably minor movement along the faults which bound the Fitzroy Trough. This movement is inferred to have been the cause of minor folding which occurred in these areas before the Triassic cycle of deposition began.

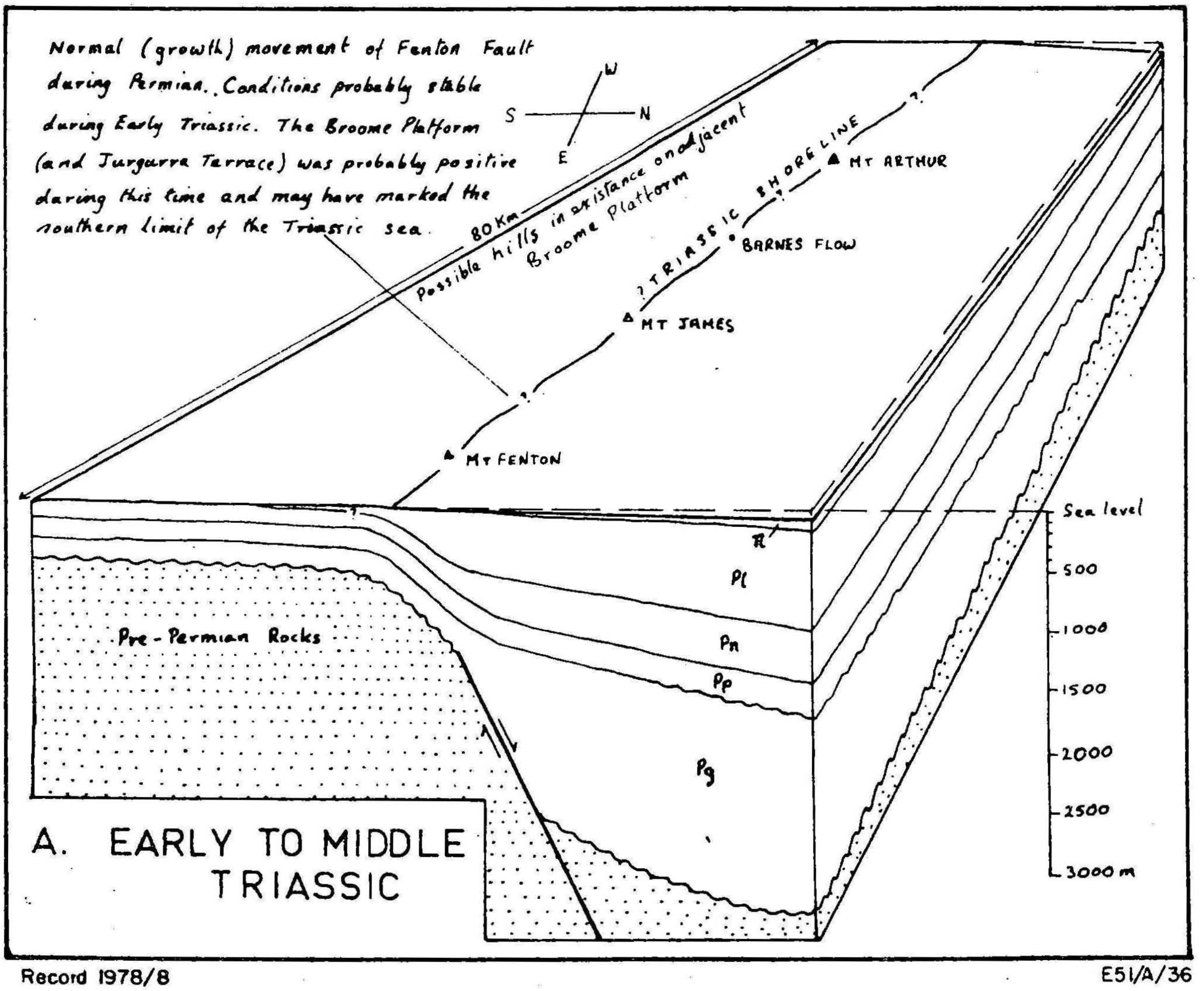
TRIASSIC

Not much is known about the earliest Triassic deposition in the area. Farther to the southeast, it is thought that deposition started in a continental environment (Yeates and others, 1975b), but the deposits of the Millyit Sandstone in the study area may represent the start of the transgression which occurred in the Early Triassic. This transgression deposited muds of the Blina Shale and it is thought that deposition occurred mainly in very shallow water. The evidence suggests that the area experienced intermittent subaerial exposure and we believe that the Blina Shale represents deposition in a mudflat. It is also thought that the sea that deposited this sequence may not have been directly connected to the oceans. The distribution of the Blina Shale shows that the sea covered the Fitzroy Trough and Lennard Shelf but that it may not have extended south of the Fenton Fault. Evidence from the overlying Erskine Sandstone suggests that the Broome Platform may have been upstanding at this time (see also Fig. 14).'

The Erskine Sandstone is interpreted to have been deposited by a delta and it marks the retreat of the Triassic sea from the area. Current directions in the Erskine Sandstone indicate that the channels probably flowed towards the north and this suggests that the source area may have been the area south of the Fenton Fault. The indication of pre-Jurassic valleys in the Edgar Ranges/Matches Springs area (see under 'Structural patterns in the Edgar Ranges/Matches Springs area') suggests that hills existed in this area. The interpreted drainage pattern (Fig. 10) also shows a flow off the Broome Platform, so that the combined evidence for the Broome Platform being a Triassic positive feature is fairly strong.

The Erskine Sandstone is the last record of Triassic sedimentation in the area, but in WAPET Fraser River No. 1 dolerite-gabbro intrusions were intersected in Carboniferous rocks (WAPET, 1956b) and these are believed to be Triassic (Playford and others, 1975). The source or style of the intrusions is not known.

Fig. 14 Schematic block diagrams showing relations between structure and sedimentation during Triassic (A) and Jurassic (B). Adapted and updated from Williams & McKellar (1958).



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Symbols used; Pg - Grant Group; Pp - Poole Sandstone; Pn - Noonkanbah Formation; Pl - Liveringa Group; R - Triassic formations.

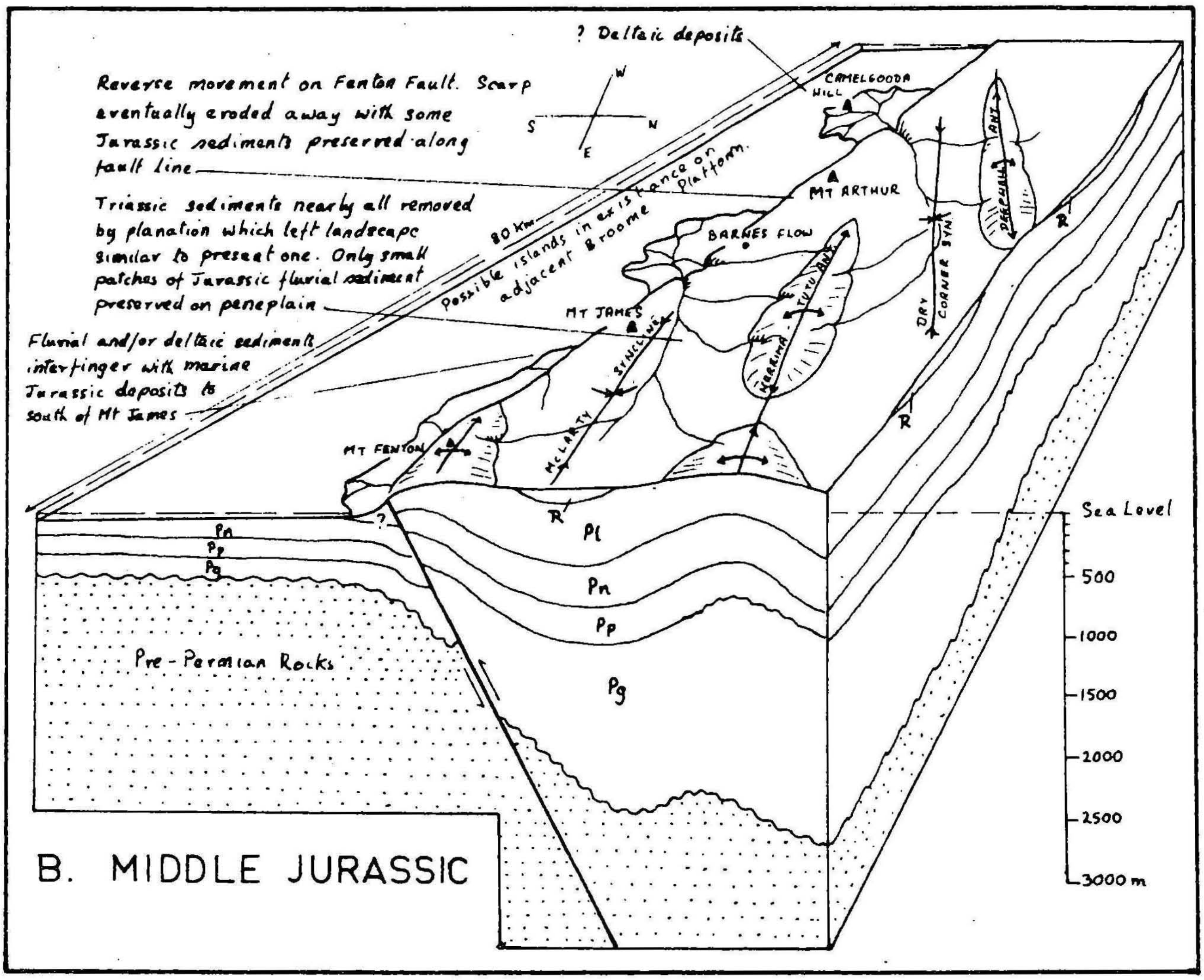
JURASSIC TO CRETACEOUS

After deposition in the Early and Middle Triassic, the area is thought to have remained stable until the Early or Middle Jurassic when a phase of tectonism began. This tectonism was caused by compressional movement of the northern Kimberley Block against the southern Canning Basin (Fig. 6). The result of the right-lateral wrench movement together with complementary lateral movement (Rattigan, 1967; Smith, 1968) in the area was that the previously normal movement of the Fenton Fault was reversed, and the sediments in the Fitzroy Trough were folded into large anticlines and synclines. The tensional stresses caused by the folding formed a large number of mainly north-trending normal faults, particularly in the axial areas of the folds. The sediments in areas adjacent to the Fitzroy Trough were only slightly tilted. Intrusion of the Fitzroy Lamproite may have occurred during the Jurassic and it is inferred to have been related to the Jurassic phase of tectonism.

The result of this tectonism was that the areas north of the Fenton Fault in eastern MOUNT ANDERSON and the eastern half of DERBY were uplifted relative to the remaining areas. The Fenton Fault, in eastern MOUNT ANDERSON, is thought to have formed a south-facing scarp or slope which acted as a barrier to the transgressing Jurassic sea (Fig. 14B). Farther westwards, in western MOUNT ANDERSON, there appears to have been little reverse movement on the fault and the Jurassic sea transgressed it.

Only two local facies of the oldest Jurassic Formation crop out. They indicate that deposition probably started in a continental environment with rivers flowing westwards (Mudjalla Sandstone 'Member') and possibly southwards (Barbwire Sandstone) from the uplifted structures in the Fitzroy Trough. On the plain that is thought to have existed, south of the Fenton Fault, sand dunes formed (Jurgurra Sandstone 'Member') and these may be of the coastal type as there are reports of rare marine fossils in the unit (Brunnschweiler, 1954).

Fig. 14 (cont.)



B. MIDDLE JURASSIC

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The Jurassic sea then transgressed these deposits and laid down tidal deposits in an open shallow-water marine environment (Alexander Formation). As the transgression continued the water depth is thought to have increased and suspension deposits of the Jarlemai Siltstone were laid down. At the same time, the channels that were depositing the Barbwire Sandstone along the Fenton Fault are inferred to have debouched into the sea and formed possible deltas (Camelgooda Hill sequence; Fig. 15). Farther south, on the Broome Platform, there is evidence to suggest that the Jurassic sea was lapping onto old valleys in the Edgar Ranges/Matches Springs area.

While the sea was depositing sediment in the southern and western parts of the area, the remaining parts of the Fitzroy Trough and Lennard Shelf were experiencing continental conditions. The Meda Formation which is interpreted to be fluviatile is thought to have been laid down on this landsurface although its exact age and correlations are unknown.

Deposition in the Jurassic sea may have been slow. This is suggested by the apparent compression of palynological zones in the Jarlemai Siltstone and it would explain the general absence of bedding structures, thought to be due to intense organic reworking. Towards the end of deposition of the Jarlemai Siltstone, the water is thought to have become shallower in southeastern MOUNT ANDERSON. This is inferred to have marked the beginning of the regression which probably occurred in the southern part of the area in the Late Jurassic. However, it appears that the same regression did not occur until later in the northern part of the area.

As the sea regressed from the southern part, deltas are thought to have built out into it, at least in the eastern Edgar Ranges area. These deltaic deposits may have been continuous with deposits that were laid down earlier adjacent to the Fenton Fault (Fig. 15) but erosion has since separated the sequences.

In the northwestern part of the area the start of the Jurassic regression is represented by the Jowlaenga Formation which is interpreted as a tidal deposit. The final phase of this regression is marked by the occurrence of the beach facies of the Melligo Sandstone

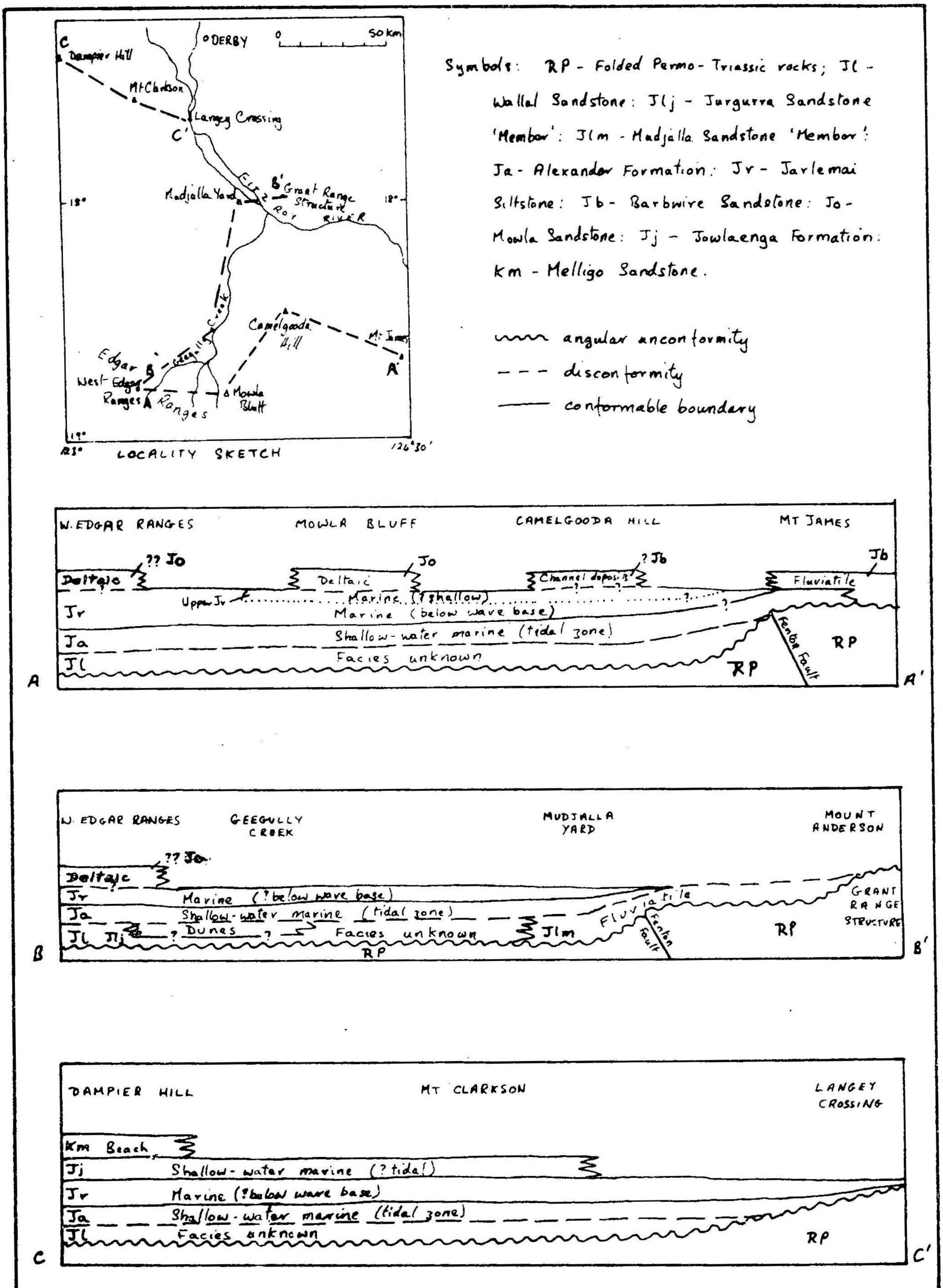

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Fig. 15 Interpreted facies correlations of the Jurassic sequence.

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at the top of the sequence along the western margin of the area (Fig. 15). The interfingering relation between the Jowlaenga Formation and the Melligo Sandstone at Dampier Hill implies that the shoreline oscillated as it moved westwards.

The Late Cretaceous history of the area is unknown as there are no deposits of this age preserved. It can be assumed, however, that the area experienced a continental environment and it may be that the present major drainage lines started developing in the Late Cretaceous (see van de Graaff and others, 1977). Minor post-Mesozoic tectonism (Early Tertiary) is then thought to have been responsible for modifying the drainage patterns and producing the landscape that is largely present today.

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BIBLIOGRAPHY

AQUITAINE (Australian Aquitaine Petroleum Pty Ltd), 1969 - Wilson Cliffs No. 1, well completion report. Bureau Mineral Resources Australia file 68/2011 (unpublished).

AFO (ASSOCIATED FRENEY OILFIELDS N.L.), 1955 - Nerrima No. 1, well completion report. (Unpublished company report).

AFO (ASSOCIATED FRENEY OILFIELDS N.L.), 1956 - Myroodah No. 1, well completion report. (Unpublished company report).

AFO (ASSOCIATED FRENEY OILFIELDS N.L.), 1957 - The Sisters No. 1, well completion report. (Unpublished company report).

BALME, B.E., 1961 - Palynological examination of samples from WAPET Samphire Marsh No. 1. Bureau of Mineral Resources Australia Petroleum Search Subsidy Acts Publication 5, 22-6

BALME, B.E., 1962 - Palynological Examination of samples from WAPET Meda No. 1. Bureau of Mineral Resources Australia, Petroleum Search Subsidy Acts Publication 7, Appendix A, p 23-4.

BALME, B.E., 1963 - Plant fossils from the Lower Triassic of Western Australia. Palaeontology, 6, 12-40.

BALME, B.E., 1964 - The palynological record of Australian pre-Tertiary floras. In CRANWELL, L. (Ed.) - ANCIENT PACIFIC FLORAS: Honolulu, University of Hawaii Press, 49-80.

BALME, B.E., 1967 - Palynological examination of samples from WAPET Blackstone No. 1. In WAPET (1967b).

BALME, B.E., 1969 - The Triassic System in Western Australia. The APEA Journal, 9 (2), 67-78.

BALME, B.E., & HELBY, R., 1973 - Floral modification at the Permian-Triassic boundary in Australia. In LOGAN & HILLS (Eds.), 1973, 433-44.

BLATCHFORD, T., 1927 - The Geology of portions of the Kimberley Division, with special reference to the Fitzroy Basin and the possibilities of the occurrence of mineral oil. Geological Survey of Western Australia, Bulletin 23.

BRUNNSCHWEILER, R.O., 1951 - Notes on the geology of Dampier Land, northwestern Australia. Australian Journal of Science, 14, 6-8.

BRUNNSCHWEILER, R.O., 1954 - Mesozoic stratigraphy and history of the Canning Desert and Fitzroy Valley, Western Australia. Journal of the Geological Society of Australia, 1, 35-54.

BRUNNSCHWEILER, R.O., 1957 - The geology of the Dampier Peninsula, Western Australia. Bureau of Mineral Resources Australia, Report 13.

BRUNNSCHWEILER, R.O., 1960 - Marine fossils from the Upper Jurassic and Lower Cretaceous of Dampier Peninsula, Western Australia. Bureau of Mineral Resources Australia, Bulletin 59.

BURNE, R.V., & CROWE, R.W.A., 1977 - Jurassic eolianites in the Jurgurra Sandstone at Geegully Creek, Mount Anderson Sheet area, W.A. BMR Journal of Australian Geology and Geophysics, 12(4), 314-17.

CASEY, J.N., 1958 - Mount Anderson - 4-Mile Geological Series. Bureau of Mineral Resources Australia, Explanatory Notes SE/51-11.

COLEMAN, P.J., 1957 - Permian Productacea of Western Australia. Bureau of Mineral Resources Australia, Bulletin 40.

CONEYBEARE, C.E.B., & CROOK, K.A.W., 1968 - Manual of sedimentary structures. Bureau of Mineral Resources Australia, Bulletin 102.

COSGRIFF, J.W., 1965 - A new genus of Temnospondyli from the Triassic of Western Australia. Journal of the Royal Society of Western Australia, 48, 65-90.

COSGRIFF, J.W., 1969 - Blinasaurus, a brachyopod genus from Western Australia and New South Wales. Journal of the Royal Society of Western Australia, 52, 65-88.

COSGRIFF, J.W., 1974 - Lower Triassic Temnospondyli of Tasmania. Geological Society of America, Special Paper 149, 1-134.

CROCKFORD, J., 1957 - Permian Bryozoa from the Fitzroy Basin, Western Australia. Bureau of Mineral Resources Australia, Bulletin 34.

CROWE, R.W.A., & TOWNER, R.R., 1976a - Permian stratigraphic nomenclature, Noonkanbah 1:250 000 Sheet, Western Australia. Geological Survey of Western Australia, Annual Report 1975.

CROWE, R.W.A., & TOWNER, R.R., 1976b - Environmental interpretation of the Permian Nura Nura Member of the Poole Sandstone, Noonkanbah Sheet area, Canning Basin: a gradation between fluviatile and shallow-water marine facies. Geological Survey of Western Australia, Annual Report 1975.

CROWE, R.W.A., & TOWNER, R.R., 1976c - Permian depositional history of the Noonkanbah 1:250 000 Sheet area, W.A. Bureau of Mineral Resources Australia, Record 1976/24 (unpublished).

CROWE, R.W.A., & TOWNER, R.R., in prep. - Noonkanbah, W.A. - 1: 250 000 Geological Series. Bureau of Mineral Resources Australia, Explanatory Notes SE/51-12.

CROWE, R.W.A, & TOWNER, R.R., in press - Definitions of some new and revised rock units in the Canning Basin. Geological Survey of Western Australia, Annual Report 1977.

DICKINS, J.M., 1963 - Permian pelecypods and gastropods from Western Australia. Bureau of Mineral Resources Australia, Bulletin 63.

DICKINS, J.M., TOWNER, R.R., & CROWE, R.W.A., in press - A Permian cold water marine fauna in the Grant Formation of the Canning Basin, Western Australia. In Yuri A. Orlov Memorial Volume: Palaeontological Society of India.

DOLBY, J.H., & BALME, B.E., 1976 - Triassic palynology of the Carnarvon Basin of Western Australia. Review of Palaeobotany and Palynology, 22(1976), 105-108.

EDWARDS, A.B., 1953 - An oolitic iron formation from northwestern Western Australia. Commonwealth Scientific and Industrial Research Organization (Melbourne), Mineragraphic Investigation Report 540. (unpublished).

EVANS, P.R., 1966 - Contribution to the palynology of northern Queensland and Papua. Bureau of Mineral Resources Australia, Record 1966/198 (unpublished).

FINDLAY, W.A., 1942 - Geological report Northwestern Fitzroy Basin, Kimberley District, W.A. West Australian Petroleum Pty Ltd, Company Report (unpublished).

GALLOWAY, M.C., & HOWELL, D.J., 1975 - Relinquishment report of TR 5851H to 5896H, 5878H to 5880H, Fitzroy Trough, Western Australia. Company Report, Esso Exploration and Production Aust. Inc. and Dampier Mining Co. (unpublished).

GIBSON, D.L., & CROWE, R.W.A., in prep. - Mount Anderson, W.A. - 1:250 000 Geological Series. Bureau of Mineral Resources Australia, Explanatory Notes SE/51-11.

GLENISTER, B.F., & FURNISH, W.M., 1961 - The Permian ammonoids of Australia. Journal of Palaeontology, 35, 673-736.

GORTER, J.D., in prep. - Permian. In Wales, D.W. (Editor) - Canning Basin Atlas. Bureau of Mineral Resources Australia.

GUPPY, D.J., CUTHBERT, J.O., & LINDNER, A.W., 1950 - Geology of the Nerrima Dome, Kimberley Division, Western Australia. Bureau of Mineral Resources Australia, Report 4.

GUPPY, D.J., LINDNER, A.W., RATTIGAN, J.H., & CASEY, J.N., 1952 - The stratigraphy of the Mesozoic and Permian sediments of the Desert Basin, Western Australia. 19th International Geological Congress, Algeirs, 1950, Symposium Series de Gondwana, 107-114.

GUPPY, D.J., LINDNER, A.W., RATTIGAN, J.H., & CASEY, J.N., 1958 - Geology of the Fitzroy Basin, Western Australia. Bureau of Mineral Resources Australia, Bulletin 36.

HELBY, R.J., 1973 - Review of the Late Permian and Triassic palynology of New South Wales. The Geological Society of Australia, Special Publication 4, 141-155.

HENDERSON, S.D., CONDON, M.A., & BASTIAN, L.V., 1963 - Stratigraphic drilling, Canning Basin, Western Australia. Bureau of Mineral Resources Australia, Report 60.

INGRAM, R.L., 1954 - Terminology for the thickness of stratification and parting units in sedimentary rocks. Bulletin of the Geological Society of America, 65, 937-38.

JOHNSTONE, M.H., 1961 - Samphire Marsh No. 1, well completion report. Bureau of Mineral Resources Australia, Petroleum Search Subsidy Acts Publication 5.

KAPLAN, G., FAURE, D., ELLOY, R., & HEILAMMER, R., 1967 - Contribution a l'etude de l'origine des lamproites. Centre Recherches Pau-SNPA, 1, 153-59.

KRAUS, P.S., 1941 - Geologic and stratigraphic reconnaissance, northwest portion Caltex Concession 7-H, Kimberley Division, Western Australia. Caltex (Australia) Oil Development Pty Ltd, Company Report (unpublished).

LENNARD OIL, 1970 - Napier No. 2, well completion report. Bureau of Mineral Resources Australia, file 69/2031 (unpublished).

LENNARD OIL, 1971 - Napier No. 5, well completion report. Bureau of Mineral Resources, Australia, file 70/750 (unpublished)

LOGAN, A., & HILLS, L.V., (Editors), 1973 - The Permian and Triassic Systems and their mutual boundary. Canadian Society of Petroleum Geologists, Memoir 2, 433-44.

McKENZIE, K.G., 1961 - Vertebrate localities in the Triassic Blina Shale of the Canning Basin, Western Australia. Journal of the Royal Society of Western Australia, 44, 69-76.

McWHAE, J.R.H., PLAYFORD, P.E., LINDNER, A.W., GLENISTER, B.F., & BALME, B.E., 1958 - The stratigraphy of Western Australia. Journal of the Geological Society of Australia, 4(2), 1-161.

PASSMORE, V.L., in prep. - Jurassic-Cretaceous. In Wales, D.W. (Editor) - Canning Basin Atlas. Bureau of Mineral Resources Australia.

PLAYFORD, P.E., 1957 - Report on the Derby Town, Myalls, and Broome water bores. West Australian Petroleum Pty Ltd, Company Report (unpublished).

PLAYFORD,,P.E., COPE, R.N., LOW, G.H., COCKBAIN, A.E., & LOWRY, D.C., 1975 - GEOLOGY OF WESTERN AUSTRALIA. Geological Survey of Western Australia, Memoir 2.

PORRENGA, D.H., 1967 - Glauconite and chamosite as depth indicators in the marine environment. Marine Geology, 5, 495-501.

POTTER, P.E., & PETTIJOHN, F.J., 1963 - PALAEOCURRENTS AND BASIN ANALYSIS. Berlin, Springer-Verlag.

PRIDER, R.T., 1960 - The leucite lamproites of the Fitzroy Basin, Western Australia. Journal of the Geological Society of Australia, 6, 71-118.

QUINTON, R.S., 1974 - Report on geological investigations within Temporary Reserves 5679H and 5693H, Canning Basin, Western Australia. Unpublished report for Conzinc Riotinto of Australia Pty Ltd.

RATTIGAN, J.H., & ELLIOTT, R.M.L., 1954 - Canning Basin, geological survey of the Fraser River area. West Australian Petroleum Pty Ltd, Company Report (unpublished).

RATTIGAN, J.H., 1967 - Fold and fracture patterns resulting from basement wrenching in the Fitzroy Depression, Western Australia. Proceedings of the Australasian Institute of Mining and Metallurgy. 223, 17-22.

REEVES, F., 1951 - Australian oil possibilities. Bulletin of the American Association of Petroleum Geologists, 35, 2479-2525.

REINECK, H.E., & SINGH, I.B., 1973 - DEPOSITIONAL SEDIMENTARY ENVIRONMENTS, WITH REFERENCE TO TERRIGENOUS CLASTICS. Heidelberg, Springer-Verlag.

REINECK, H.E., & WUNDERLICH, F., 1968 - Classification and origin of flaser and lenticular bedding. Sedimentology, 11, 99-104.

RUSSELL, R.T., 1966a - Report on exploration: temporary reserves for phosphate nos. 3563H and 3579H. Period: 15th April 1966 to 15th July 1966. Mines Exploration Pty Ltd, Company Report 1966/17 (unpublished).

RUSSELL, R.T., 1966b - Report on exploration temporary reserve for phosphate no. 3817H, Derby, W.A. Mines Exploration Pty Ltd, Company Report 1966/22 (unpublished).

SCRUTON, P.C., 1960 - Delta building and the deltaic sequence. In SHEPHARD, F.P., PHLEGER, F.B., & ANDEL, T.H. van (Eds.) - RECENT SEDIMENTS, NORTHWEST GULF OF MEXICO. American Association of Petroleum Geologists, Tulsa Oklahoma, 82-102.

SELLEY, R.C., 1970 - ANCIENT SEDIMENTARY ENVIRONMENTS. London, Chapman & Hall.

SKWARKO, S.K., 1970 - Aptian (Lower Cretaceous) 'Apiotrigonia' from the Melligo Quartzite, Dampier Peninsula, Western Australia. Bureau of Mineral Resources Australia, Bulletin 108, 227-35.

SMITH, J.G., 1968 - Tectonics of the Fitzroy Wrench Trough, Western Australia. American Journal of Science, 266, 766-76.

SMITH, D.N., & WILLIAMS, F.B., 1955 - The geology of Edgar Ranges-Matches Springs area. West Australian Petroleum Pty Ltd, Company Report (unpublished).

SMITH, D.N., & WILLIAMS, F.B., 1956 - The geology of the northwest coast of Dampier Land, West Australian Petroleum Pty Ltd, Company Report (unpublished).

STEVENS, G.R., 1965 - The Jurassic and Cretaceous belemnites of New Zealand and a review of the Jurassic and Cretaceous belemnites of the Indo-Pacific region. New Zealand Geological Survey, Palaeontology Bulletin 36.

TEICHERT, C., 1950 - Some recent additions to stratigraphy of Western Australia. American Association Petroleum Geologists, Bulletin 34(9), 1787-1794.

THOMAS, G.A., 1954 - Report on the Permian brachiopods from the Fitzroy Basin, Western Australia. Bureau of Mineral Resources Australia, Record 1954/9 (unpublished).

THOMAS, G.A., 1958a - Permian Orthotetacea from Western Australia. Bureau of Mineral Resources Australia, Bulletin 39.

THOMAS, G.A., 1958b - Noonkanbah, W.A. - 4-mile Geological Series. Bureau of Mineral Resources Australia, Explanatory Notes SE/51-12.

THOMAS, G.A., & DICKINS, J.M., 1954 - Correlation and age of the Permian Formations of Western Australia. Australian Journal of Science, 16, 219-33.

TOTAL (TOTAL EXPLORATION AUSTRALIA), 1968 - Edgar Range No. 1, well completion report. Bureau of Mineral Resources Australia, File 68/2041 (unpublished.

TOTAL (TOTAL EXPLORATION AUSTRALIA), 1969 - Mowla No. 1, well completion report. Bureau of Mineral Resources Australia, File 69/2039 (unpublished).

TOTAL (TOTAL EXPLORATION AUSTRALIA), 1970 - Matches Springs No. 1, well completion report. Bureau of Mineral Resources Australia, File 69/2023 (unpublished).

TOWNER, R.R., & GIBSON, D.L., in prep. - Derby, W.A. - 1:250 000 Geological Series. Bureau of Mineral Resources Australia, Explanatory Notes SE/51-7.

TOWNER, R.R., CROWE, R.W.A., & YEATES, A.N., 1976 - Notes on the geology of the South Canning Basin. Bureau of Mineral Resources Australia, Record 1976/95 (unpublished).

VAN DE GRAAFF, W.J.E., CROWE, R.W.A., BUNTING, J.A., & JACKSON, M.J., 1977 - Relict Early Cainozoic drainages in arid Western Australia, Zeitschrift fur Geomorphologie, 21(4), 379-400.

VEEVERS, J.J., 1958 - Lennard River, W.A. - 4-mile Geological Series. Bureau of Mineral Resources Australia, Explanatory Notes SE/51-8.

VEEVERS, J.J., & WELLS, A.T., 1961 - The geology of the Canning Basin, Western Australia. Bureau of Mineral Resources Australia Bulletin 60.

VISHER, G.S., 1965 - Use of vertical profile in environmental reconstruction. Bulletin of the American Association of Petroleum Geologists, 49(1), 41-61.

WADE, A., 1938 - The geological succession in the West Kimberley district of Western Australia. Australian and New Zealand Association of the Advancement of Science, Report 23, 93-96.

WAPET (WEST AUSTRALIAN PETROLEUM PTY LTD), 1956a - Grant Range No. 1, well completion report. West Australian Petroleum Pty Ltd, Company Report (unpublished).

WAPET (WEST AUSTRALIAN PETROLEUM PTY LTD), 1956b - Fraser River No. 1, well completion report. West Australian Petroleum Pty Ltd, Company Report (unpublished).

WAPET (WEST AUSTRALIAN PETROLEUM PTY LTD), 1957 - Dampier Downs No. 1, well completion report. West Australian Petroleum Pty Ltd, Company Report (unpublished).

WAPET (WEST AUSTRALIAN PETROLEUM PTY LTD), 1962a - Meda No. 1, well completion report. Bureau of Mineral Resources Australia, Petroleum Search Subsidy Acts Publication 7.

WAPET (WEST AUSTRALIAN PETROLEUM PTY LTD), 1962b - Frome Rocks No. 1 and No. 2, well completion report. Bureau of Mineral Resources Australia, Petroleum Search Subsidy Acts Publication 8.

WAPET (WEST AUSTRALIAN PETROLEUM PTY LTD), 1962c - Hawkstone Peak No. 1, well completion report. Bureau of Mineral Resources Australia, File 62/1093 (unpublished).

WAPET (WEST AUSTRALIAN PETROLEUM PTY LTD), 1963 - Langoora No. 1, well completion report. Bureau of Mineral Resources Australia, File 62/1094 (unpublished).

WAPET (WEST AUSTRALIAN PETROLEUM PTY LTD), 1966a - Babrongan No. 1, Langoora No. 1, Hawkstone Peak No. 1, well completion report. Bureau of Mineral Resources Australia, Petroleum Search Subsidy Acts Publication 48.

WAPET (WEST AUSTRALIAN PETROLEUM PTY LTD), 1966b - Sahara No. 1, well completion report. Bureau of Mineral Resources Australia, Petroleum Search Subsidy Acts Publication 80.

WAPET (WEST AUSTRALIAN PETROLEUM PTY LTD), 1967a - May River No. 1, well completion report. Bureau of Mineral Resources Australia, File 67/4252 (unpublished).

WAPET (WEST AUSTRALIAN PETROLEUM PTY LTD), 1967b - Blackstone No. 1, well completion report. Bureau of Mineral Resources Australia, File 67/4262 (unpublished).

WAPET (WEST AUSTRALIAN PETROLEUM PTY LTD), 1968a - Doran No. 1, well completion report. Bureau of Mineral Resources Australia, File 68/2033 (unpublished).

WAPET (WEST AUSTRALIAN PETROLEUM PTY LTD), 1968b - Logue No.1, well completion report. Bureau of Mineral Resources Australia, File 68/2034 (unpublished).

WAPET (WEST AUSTRALIAN PETROLEUM PTY LTD), 1973 - Hardman No. 1, well completion report. Bureau of Mineral Resources Australia, File 73/259 (unpublished).

WATERFORD, L.M., 1941 - Resume of oil drilling operations conducted in the west Kimberley district of W.A. West Australian Petroleum Pty Ltd, Company Report (unpublished).

WELLMAN, P., 1973 - Early Miocene potassium-argon age for the Fitzroy lamproites of Western Australia. Journal of the Geological Society of Australia, 19, 471-74.

WHITE, M.E., & YEATES, A.N., 1976 - Plant fossils from the north-eastern part of the Canning Basin, Western Australia. Bureau of Mineral Resources Australia, Record 1976/18 (unpublished).

WILLIAMS, F.B., & McKELLAR, M.G., 1958 - Fenton Fault Project. Unpublished WAPET report.

WILLIAMS, H., TURNER, F.J., & GILBERT, C.M., 1958 - PETROGRAPHY - an introduction to the study of rocks in thin sections. San Francisco, Freeman.

WRIGHT, R.L., 1964 - Geomorphology of the West Kimberley area. Scientific Industrial Research Organisation, Melbourne, Land Research Series 9, 103-118.

YEATES, A.N., CROWE, R.W.A., TOWNER, R.R., WYBORN, L.A.I., & PASSMORE, V.L., 1975a - New and revised stratigraphic nomenclature northeast Canning Basin, Western Australia. Geological Survey of Western Australia, Annual Report for 1974.

YEATES, A.N., CROWE, R.W.A., TOWNER, R.R., WYBORN, L.A.I., & PASSMORE, V.L., 1975b - Notes on the geology of the Gregory Sub-basin and adjacent areas of the Canning Basin, Western Australia. Bureau of Mineral Resources Australia, Record 1975/77 (unpublished).

APPENDIX 1 - MEASURED SECTIONS

Figure 16 shows the locations of the measured sections. The sections were measured using the 'height-to-eyes' technique for predominantly vertical sections and the tape-and-compass method for mainly horizontal ones. The sections are all shown at the same scale for comparative purposes.

Table 28 - Measured sections

Section number	Name of section	Stratigraphic units
1	Central Grant Range	Carolyn Formation
2	Southeast Grant Range	Poole Sandstone
3	Liveringa Ridge	Noonkanbah, Lightjack, and Hardman Formations
4	Erskine Range	Blina Shale and Erskine Sandstone
5	Mount Alexander	Jurgurra Sandstone and Alexander Formation
6	Mount Jarlemai	Alexander Formation and Jarlemai Siltstone
7	Mowla Bluff	Jarlemai Siltstone and Mowla Sandstone
8	Dampier Hill	Jowlaenga Formation and Melligo Sandstone

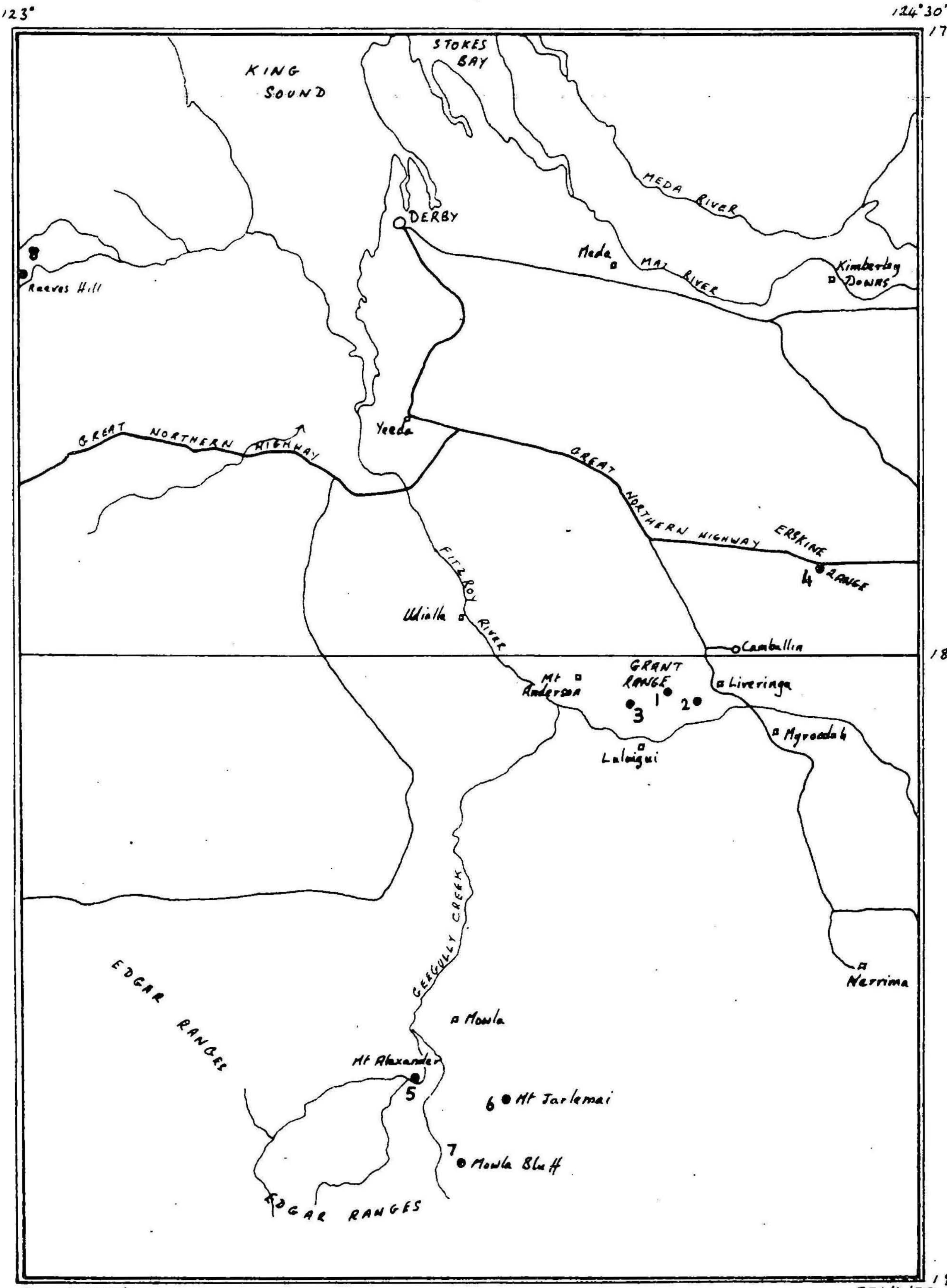

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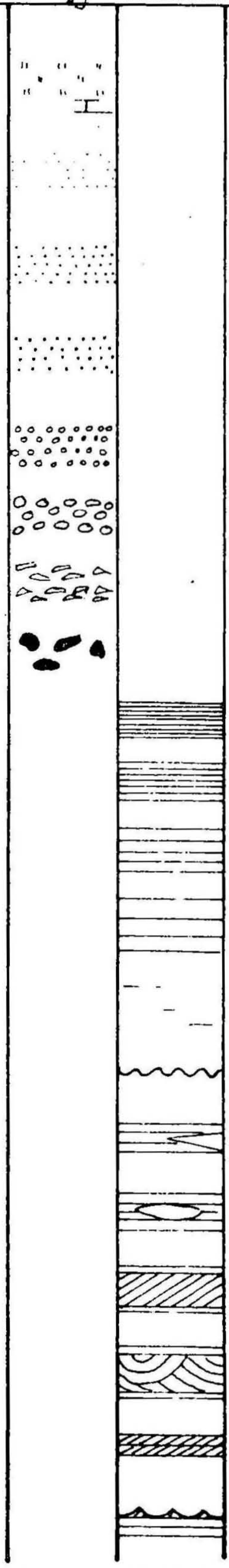
Fig. 16 Sketch map of DERBY and MT ANDERSON showing locations of sections in Appendix 1. Scale; 1:1 000 000

REFERENCE FOR MEASURED SECTIONS

Lithology | Sedimentary Structures



Mudstone – calcareous

Fine-grained sandstone

Medium-grained sandstone

Coarse-grained sandstone

Granule conglomerate

Pebble conglomerate

Clay-pellet conglomerate (intraformational)

Glacial dropstones

Laminated

Thin bedded

Medium bedded

Thick bedded

Poorly bedded or massive

Erosional boundary

Wedge-shaped bed

Lens

Planar cross-bedding } Large scale

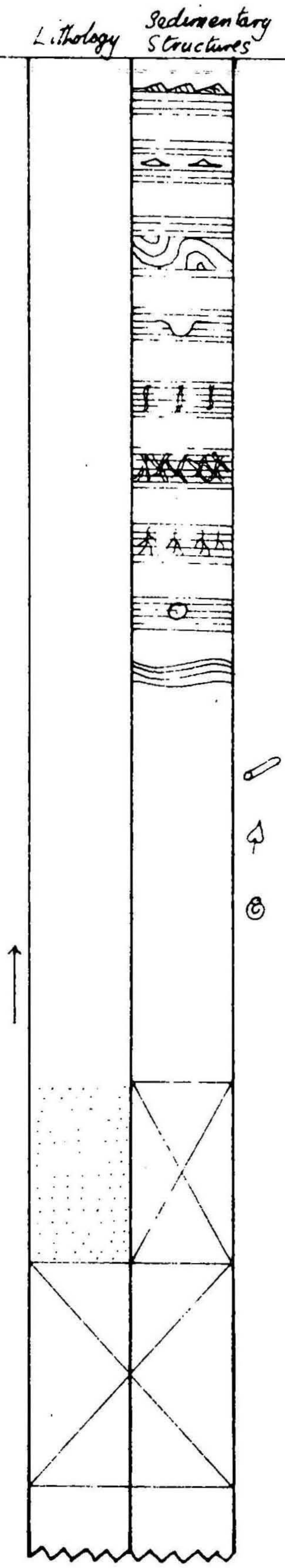
Trough cross-bedding } (greater than 5 cm thick)

Small-scale cross-bedding (less than 5 cm thick)

Symmetrical ripple marks

CONTINUED

REFERENCE FOR MEASURED SECTIONS (CONTINUED)



Asymmetrical ripple marks

Floser and/or lenticular bedding

Slump

Scour-and-fill structure

Burrows

Bioturbation

Fossil roots

Concretion

Wavy bedding

Fossil wood

Plant fossils

Marine macrofossils

Arrow indicates fining-upwards sequence.
Length of arrow indicates thickness of sequence.

Section partly obscured by scree. Bedding not seen.

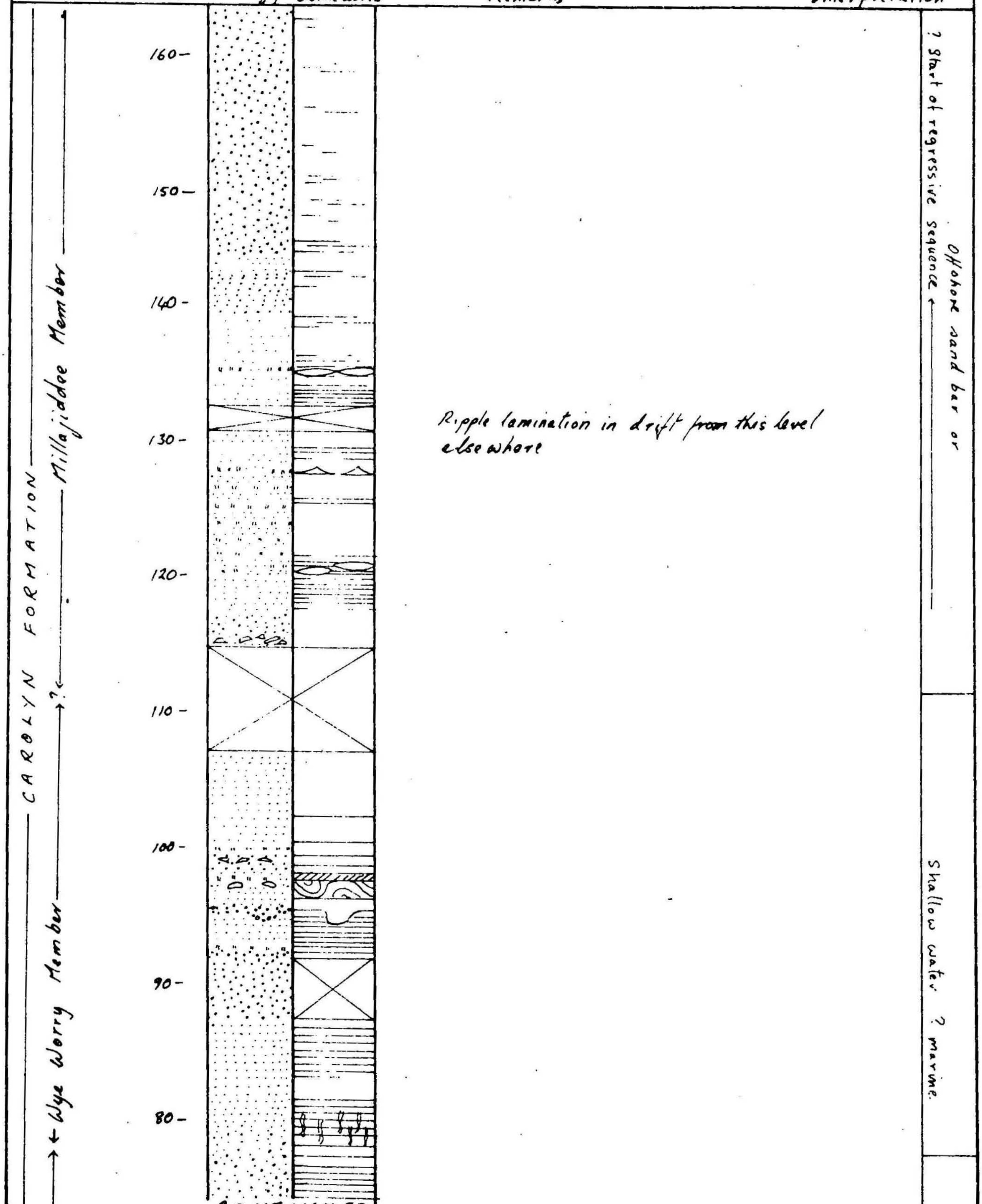
Section not exposed

Base of section.

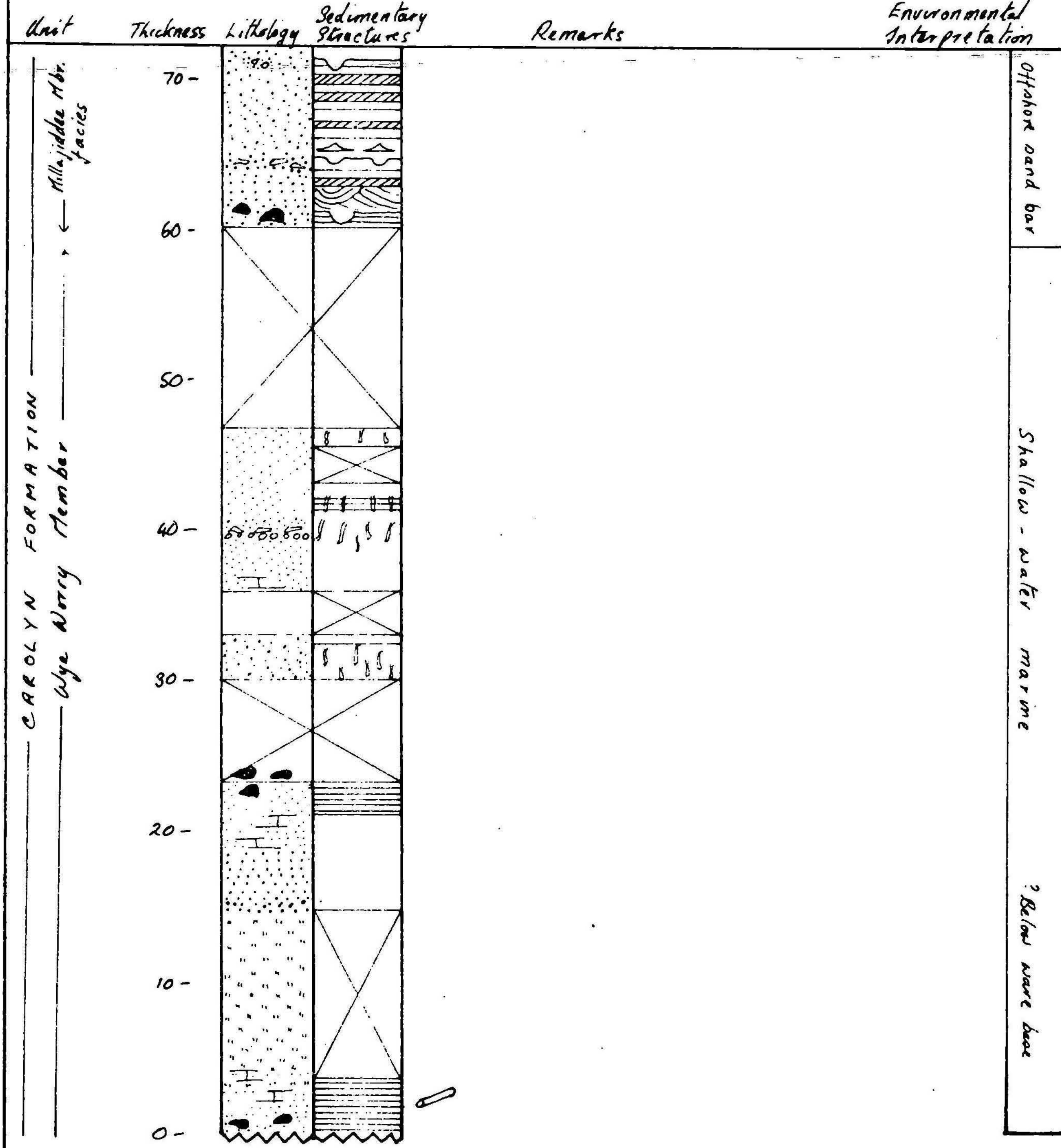
NAME CENTRAL GRANT RANGE SECTION NO. 1

LOCATION LAT. 18° 02' 45" S, LONG. 124° 04' 50" E

Unit	Thickness	Lithology	Sedimentary Structures	Remarks	Environmental Interpretation



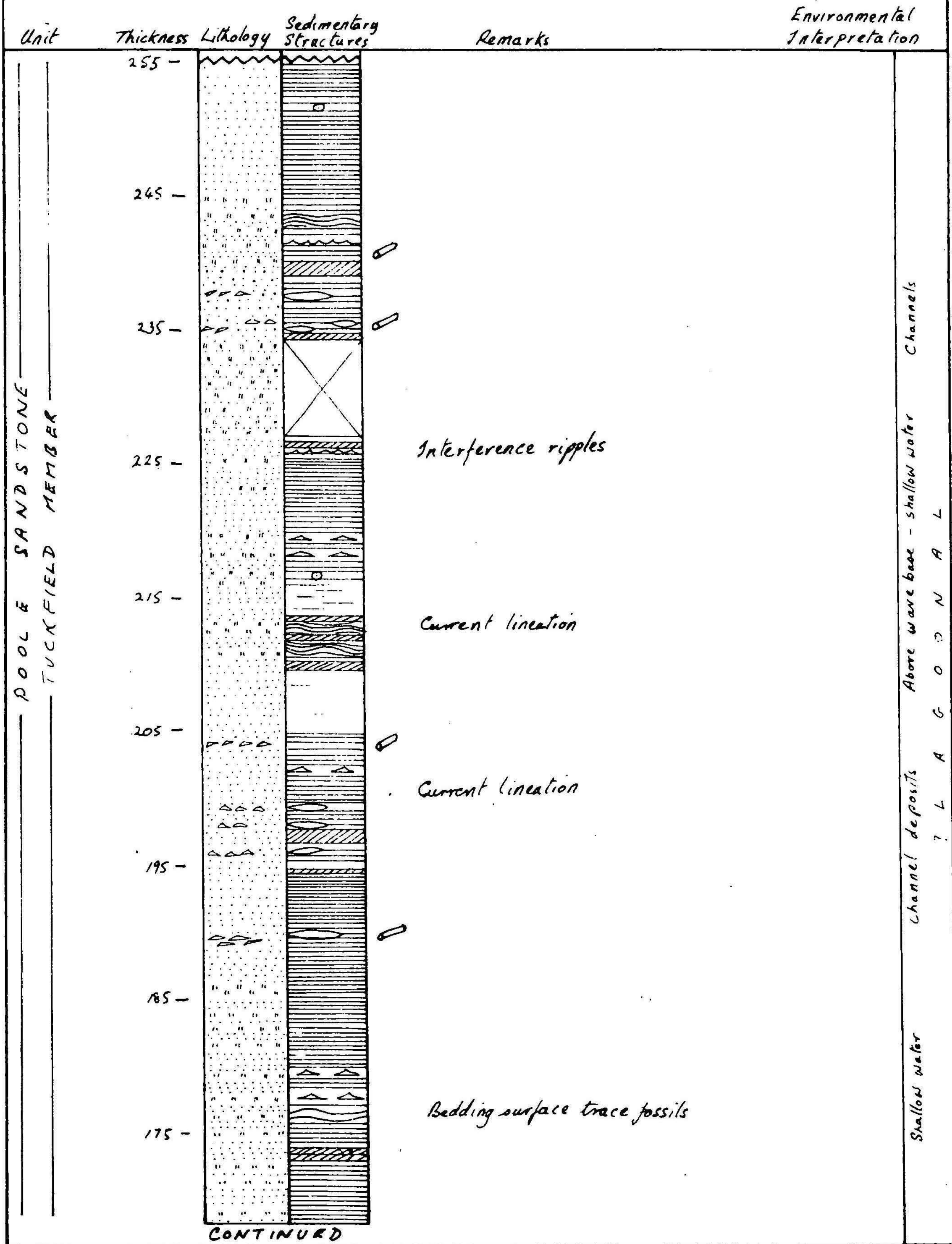
SECTION NO. 1
CONTINUED

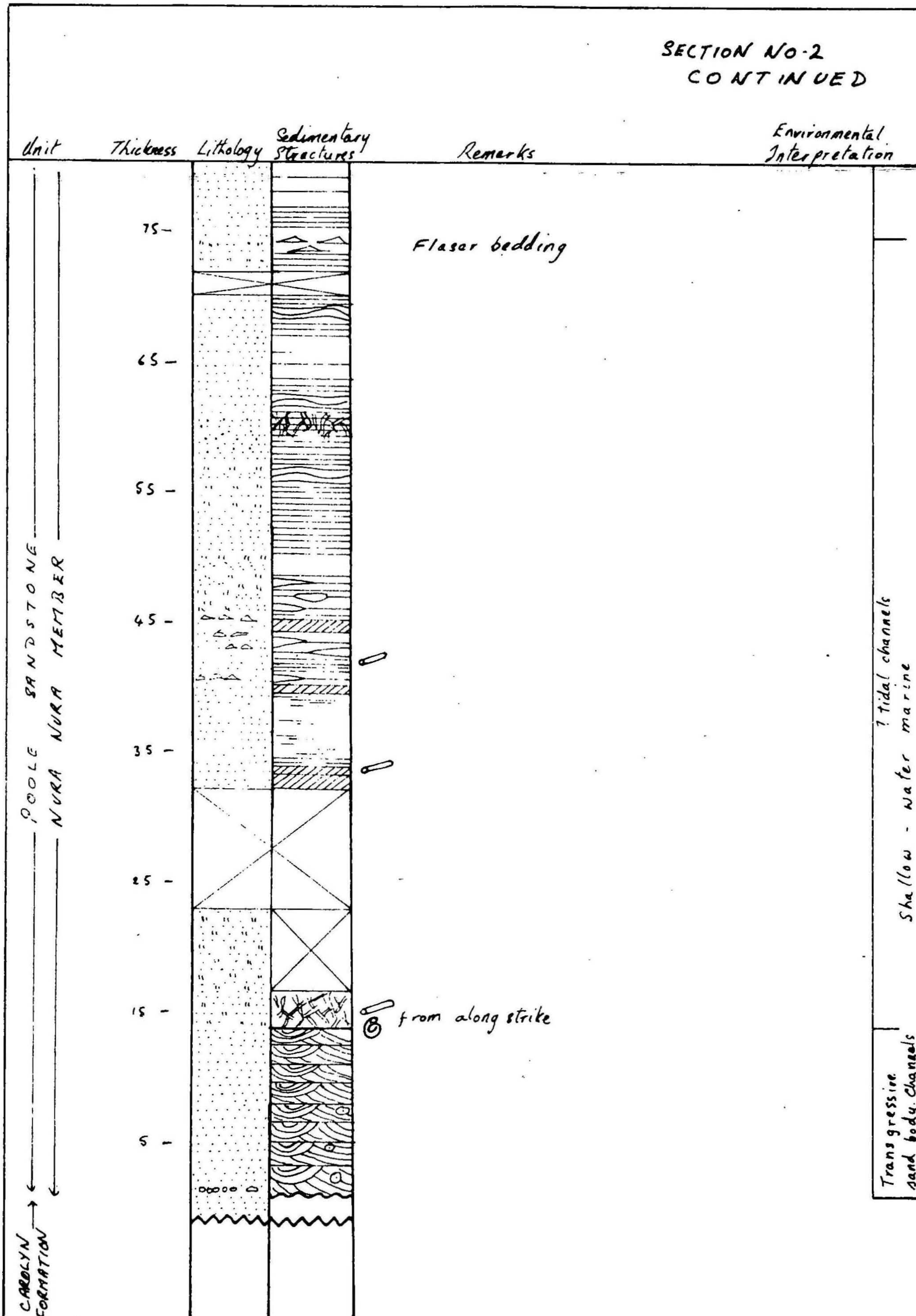


NAME SOUTHEAST GRANT RANGE, POOLE SANDSTONE COMPOSITE

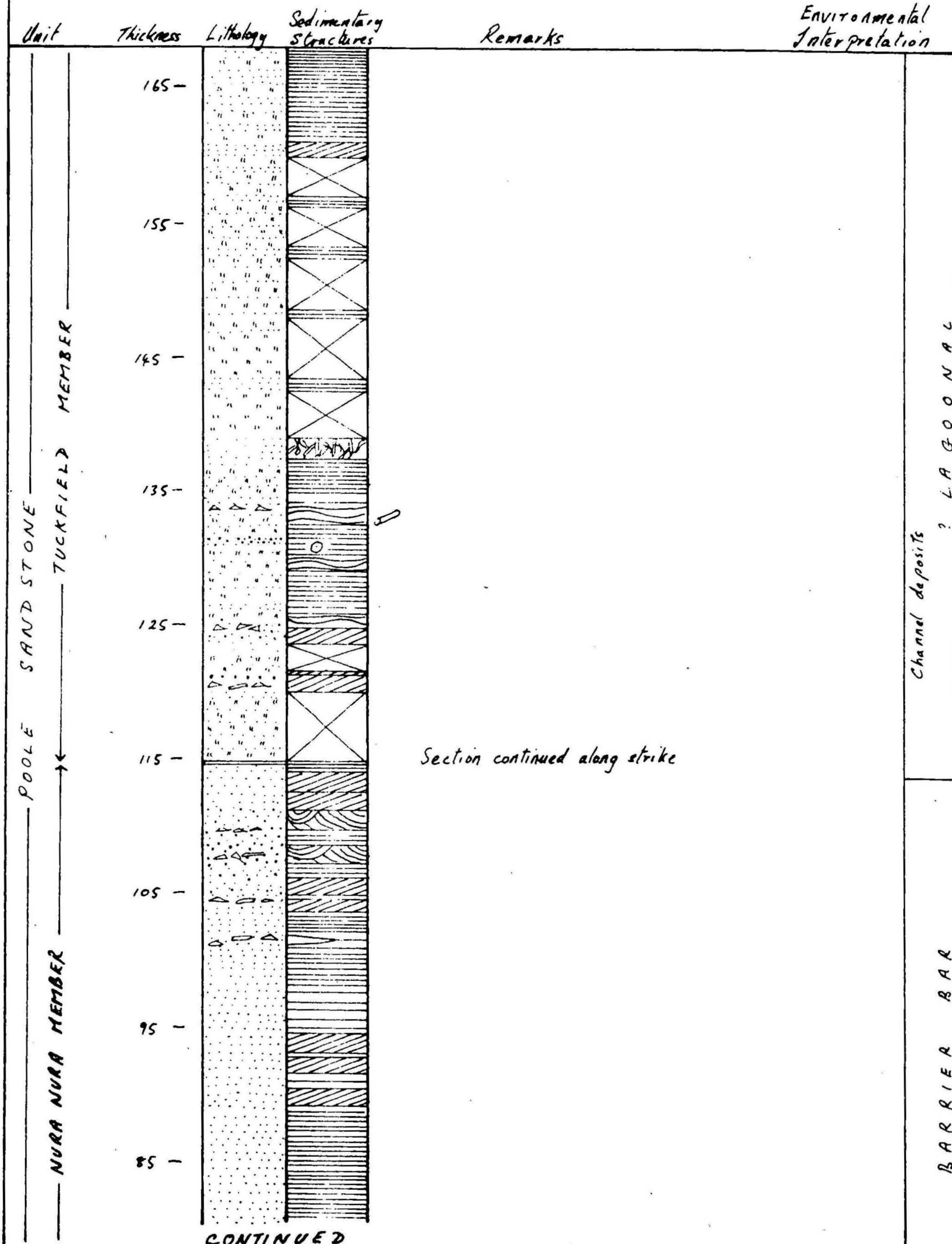
SECTION No 2

LOCATION LAT. 18°04'30"S, LONG. 124°08'30"E




SECTION NO.2
CONTINUED
Unit
Thickness
Lithology
Sedimentary Structures
Remarks
Environmental Interpretation
75 –
65 –
55 –
45 –
35 –
25 –
15 –
5 –
Flaser bedding
from along strike
POOLE SANDSTONE
NURA NURA MEMBER
CAROLYN FORMATION
? tidal channels
Shallow - water marine
Transgressive sand body. Channels

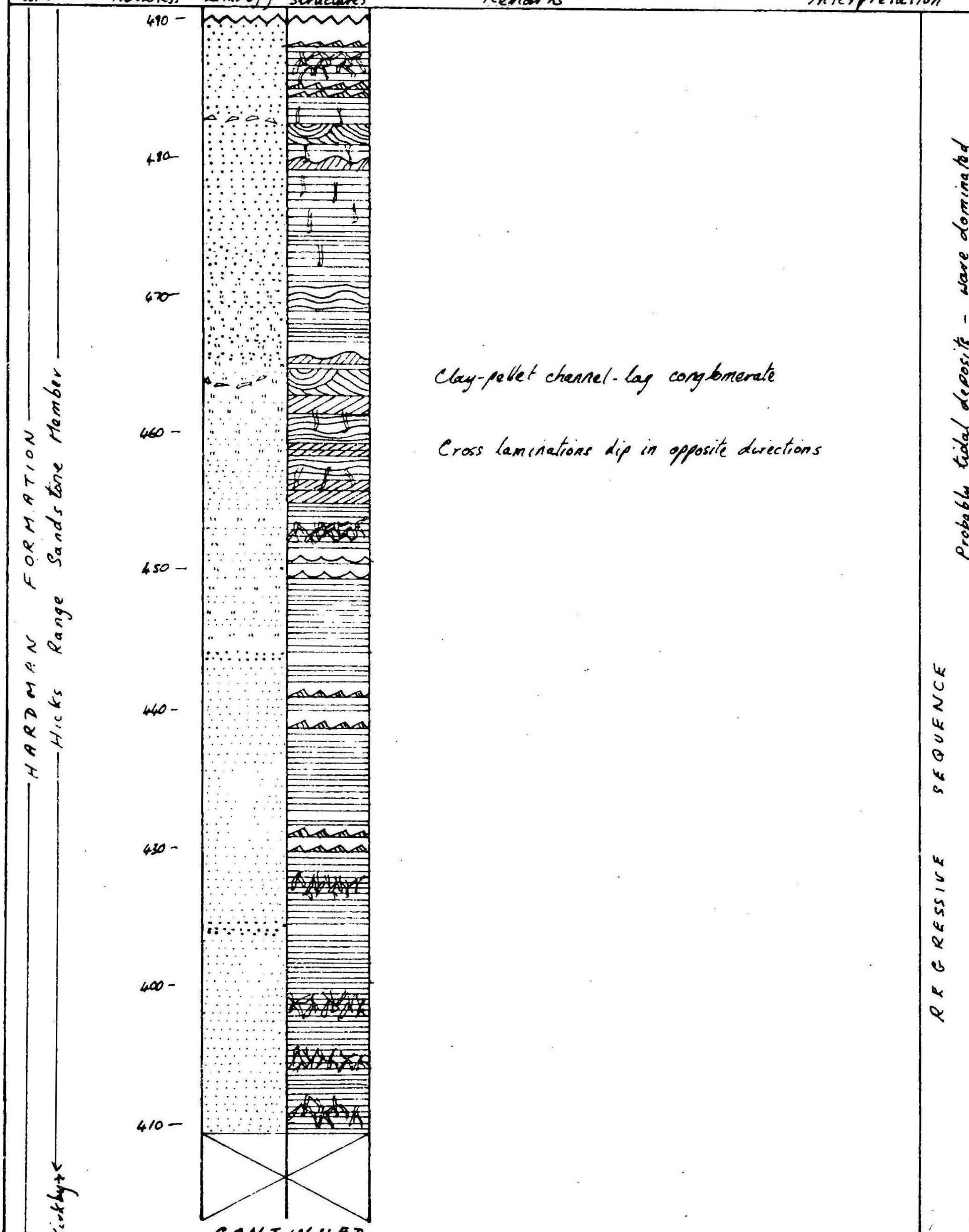
SECTION NO 2
CONTINUED

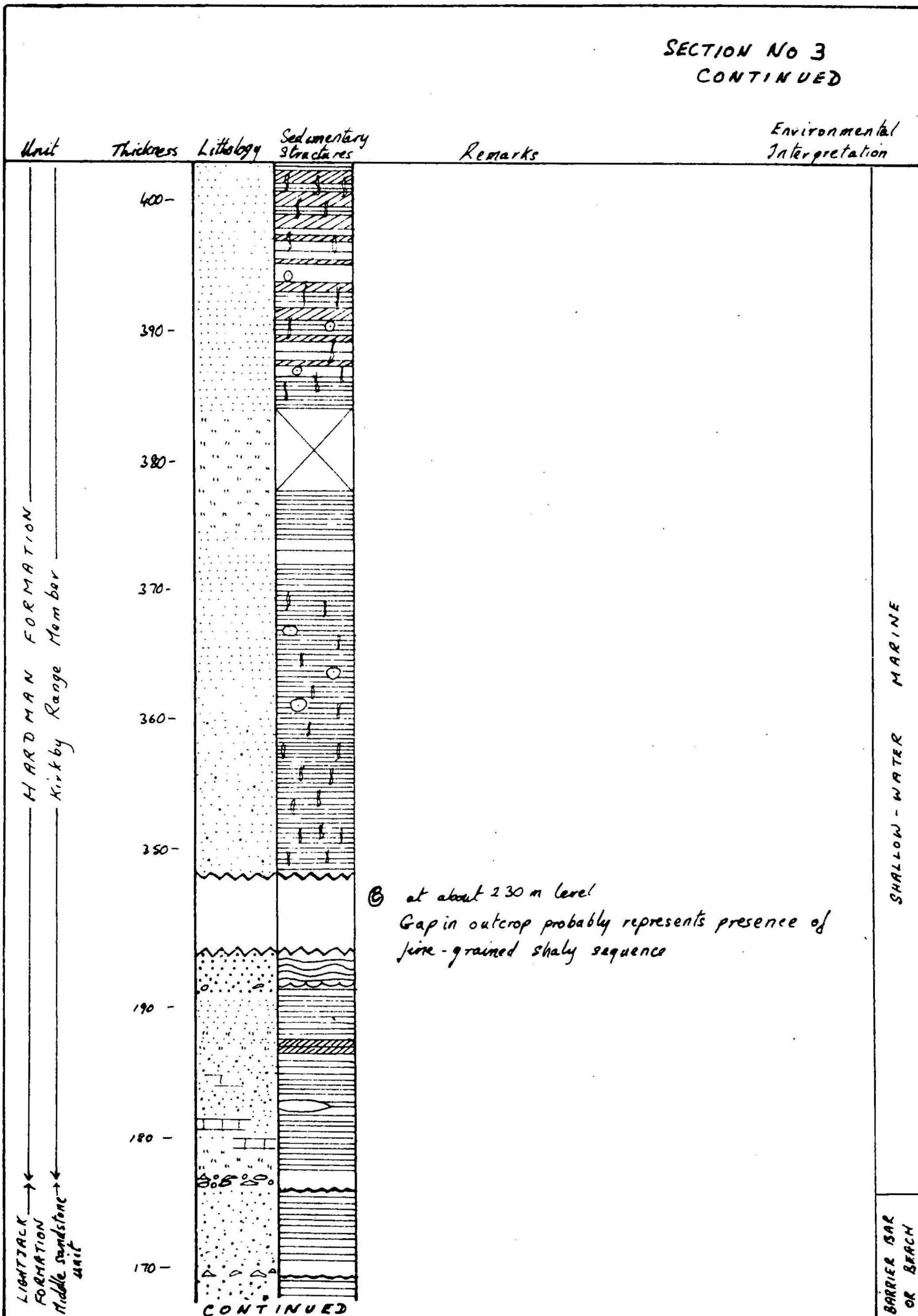


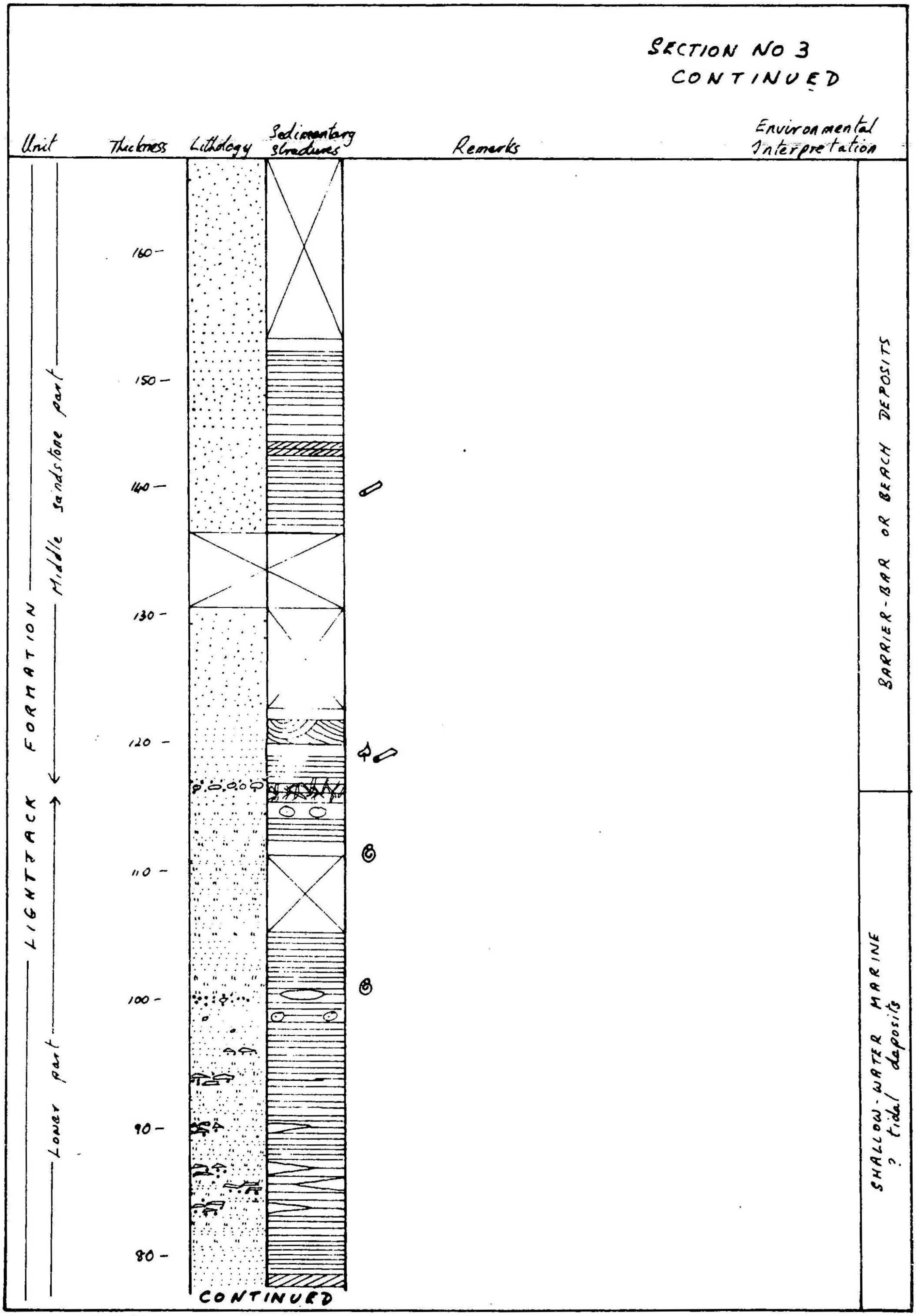
NAME LIVERINGA RIDGE SECTION No 3

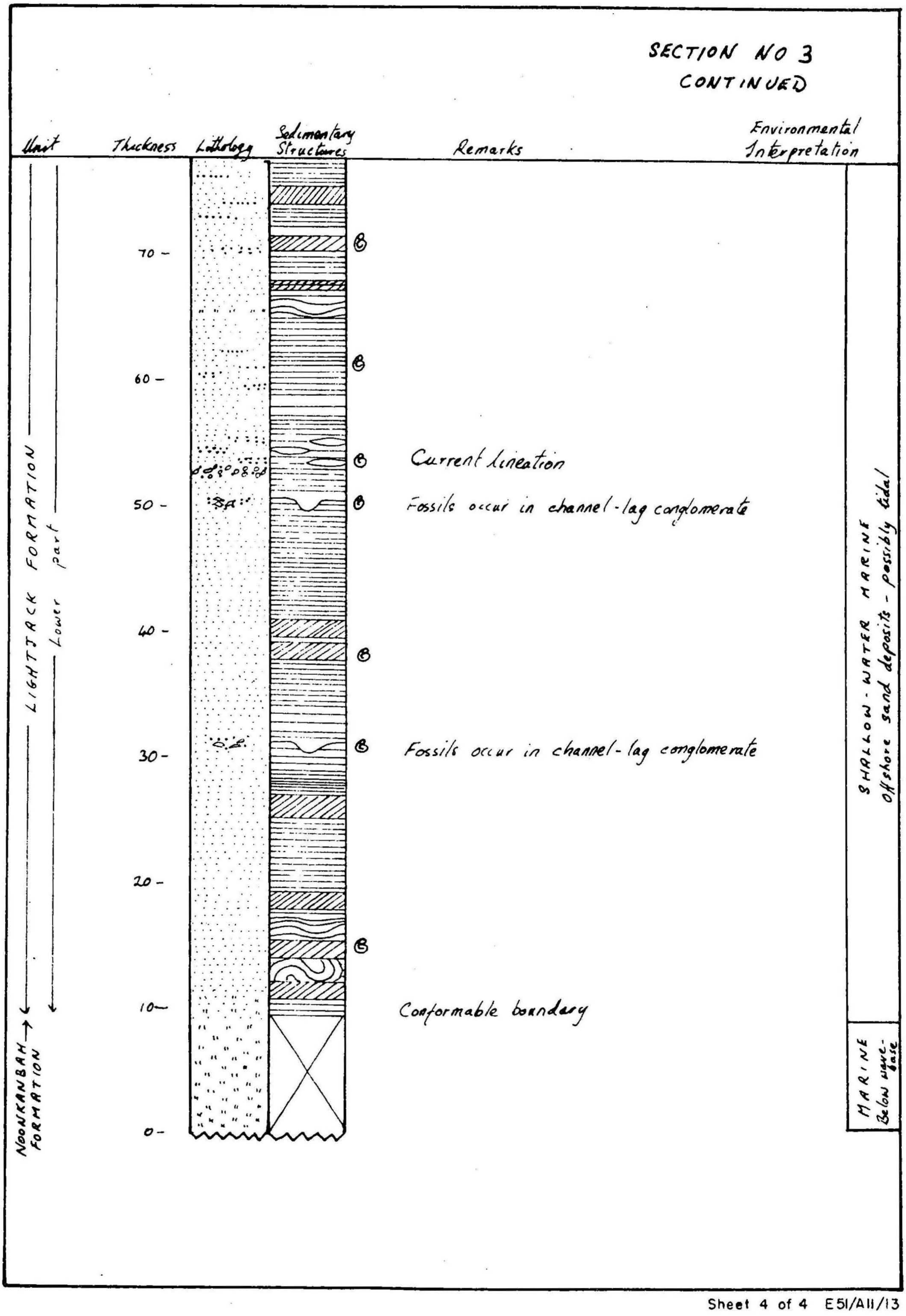
LOCATION LAT. 18° 04' 40"S, LONG. 124° 03' 00"E

Unit	Thickness	Lithology	Sedimentary Structures	Remarks	Environmental Interpretation




SECTION No 3
CONTINUED
Unit
Thickness
Lithology
Sedimentary Structures
Remarks
Environmental Interpretation
HARDMAN FORMATION
Kirkby Range Member
LIGHTJACK FORMATION
Middle sandstone unit
400-
390-
380-
370-
360-
350-
190 -
180 -
170 -
Ⓑ at about 230 m level
Gap in outcrop probably represents presence of fine-grained shaly sequence
SHALLOW-WATER MARINE
BARRIER BAR OR BEACH
CONTINUED

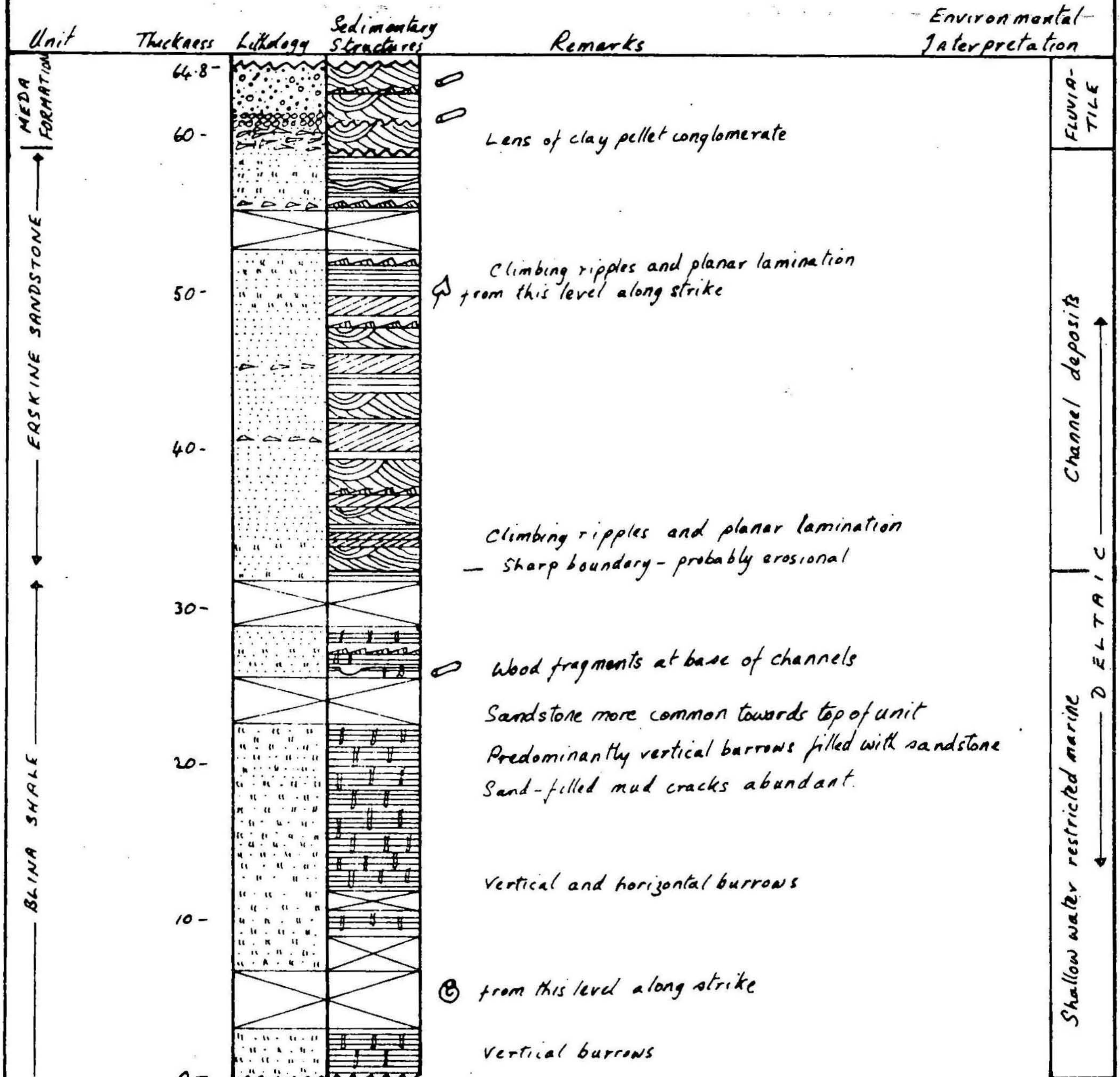

SECTION NO 3
CONTINUED
Unit
Thickness
Lithology
Sedimentary structures
Remarks
Environmental Interpretation
LIGHTJACK FORMATION
Middle sandstone part
Lower part
160 –
150 –
140 –
130 –
120 –
110 –
100 –
90 –
80 –
CONTINUED
BARRIER-BAR OR BEACH DEPOSITS
SHALLOW-WATER MARINE
? tidal deposits

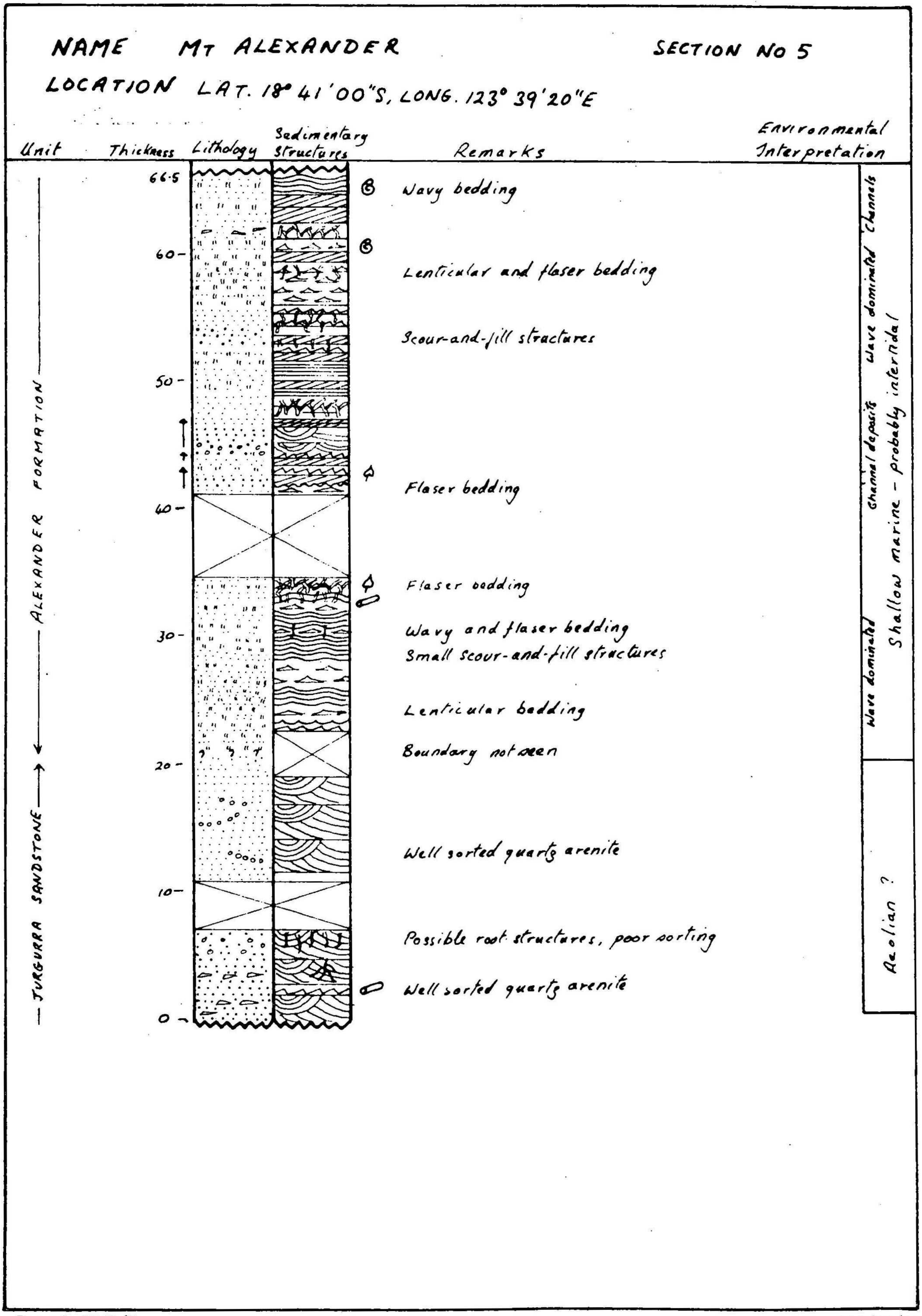

SECTION NO 3
CONTINUED
Unit
Thickness
Lithology
Sedimentary Structures
Remarks
Environmental Interpretation
70 -
60 -
50 -
40 -
30 -
20 -
10 -
0 -
Current lineation
Fossils occur in channel-lag conglomerate
Fossils occur in channel-lag conglomerate
Conformable boundary
LIGHTJACK FORMATION
Lower part
NOONKANBAH FORMATION
SHALLOW-WATER MARINE
Offshore sand deposits - possibly tidal
MARINE
Below wave-base

NAME ERSKINE RANGE

SECTION NO 4

LOCATION LAT. 17°51'30"S, LONG. 124°21'10"E





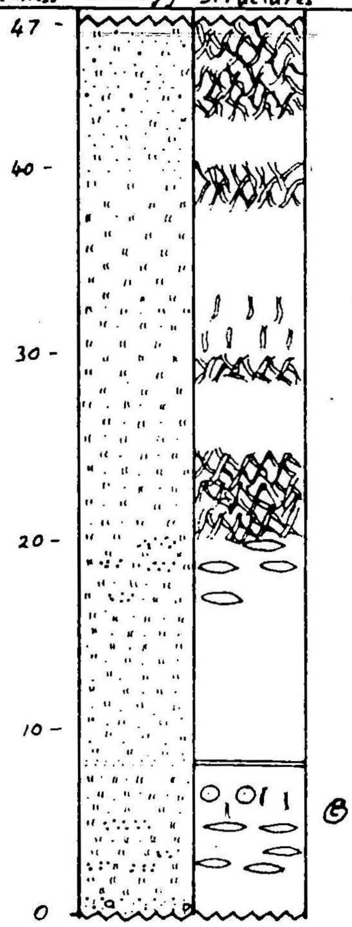
NAME Mt ALEXANDER
SECTION No 5
LOCATION LAT. 18° 41' 00"S, LONG. 123° 39' 20"E
Unit
Thickness
Lithology
Sedimentary Structures
Remarks
Environmental Interpretation
ALEXANDER FORMATION
JURGURRA SANDSTONE
66·5
60
50
40
30
20
10
0
Wavy bedding
Lenticular and flaser bedding
Scour-and-fill structures
Flaser bedding
Flaser bedding
Wavy and flaser bedding
Small scour-and-fill structures
Lenticular bedding
Boundary not seen
Well sorted quartz arenite
Possible root structures, poor sorting
Well sorted quartz arenite
Wave dominated Channels
Channel deposits
Shallow marine - probably intertidal
Wave dominated
Aeolian ?

NAME Mt JARLEMAI

SECTION NO 6

LOCATION LAT. 18° 42'55"S, LONG. 123° 48'40"E

Unit	Thickness	Lithology	Sedimentary Structures	Remarks	Environmental Interpretation
JARLEMAI SILTSTONE	47 – 0				MARINE
ALEXANDER FORMATION					



Remarks (top to bottom):

Sand content increases towards top

Bedding may all be destroyed by bioturbation

Thin vertical and thick horizontal burrows

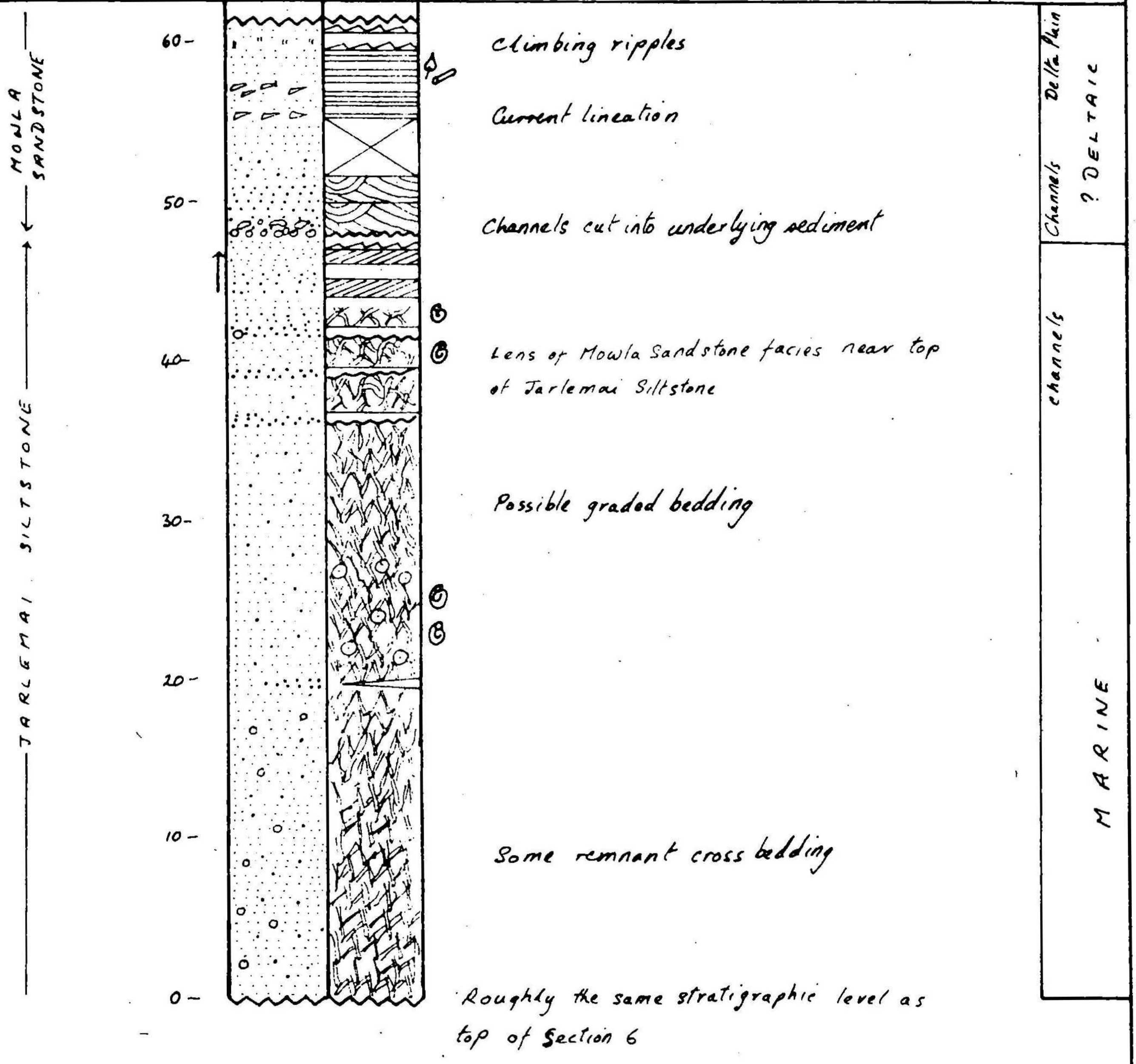
Rare lenses of coarse-grained quartz wacke

Very ferruginized

NAME MOWLA BLUFF SECTION NO. 7

LOCATION LAT. 18° 49' 20" S, LONG. 123° 38' 50" E

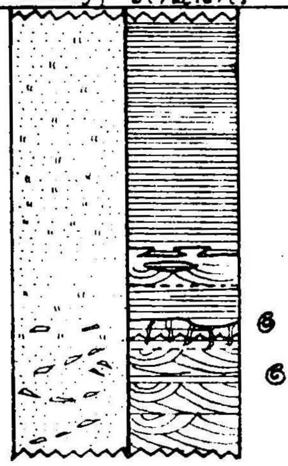
Unit	Thickness	Lithology	Sedimentary Structures	Remarks	Environmental Interpretation



NAME DAMPIER HILL SECTION NO 8

LOCATION LAT. 17°28'30"S, LONG. 123°02'00"E

Unit	Thickness	Lithology	Sedimentary Structures	Remarks	Environmental Interpretation
MELLIGO SANDSTONE	24.5 – 20 – 10			Current lineation	BEACH
				Sand volcanoe structures interpreted at contact	
JOWLAENGA FORMATION	10 – 0			Current lineation	Beach INTERTIDAL

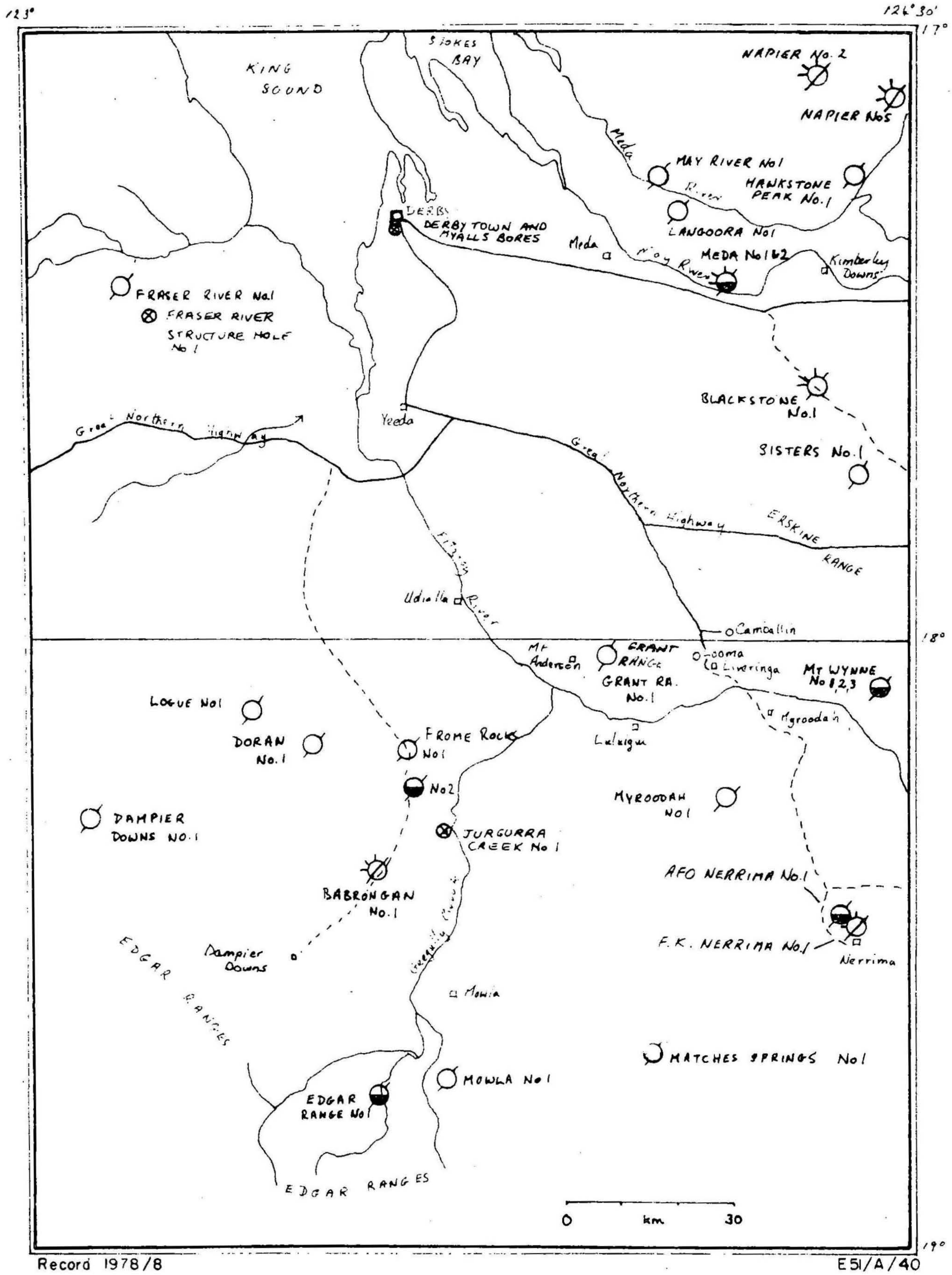


Rest of section covered by vegetation and scree

APPENDIX II - WELL SECTIONS

The positions of the wells are shown in Figure 17.

		Latitudes	Longitude	Principal Reference
1.	Babrongan No.1	18°23'23"S	123°35'37"E	WAPET (1966a)
2.	Blackstone No.1	17°35'14"S	124°21'01"E	WAPET (1967b)
3.	Dampier Downs No.1	18°18'00"S	123°06'00"E	WAPET (1957)
4.	Derby Town Bore	17°19'00"S	123°38'30"E	PLAYFORD (1957)
5.	Doran No. 1	18°10'56"S	123°29'06"E	WAPET (1968a)
6.	Edgar Range No.1	18°45'26"S	123°35'33"E	Total (1968)
7.	Fraser River No.1	17°25'04"S	123°09'39"E	WAPET (1956b)
8.	Frome Rocks No.1	18°11'48"S	123°38'42"E	WAPET (1962b)
9.	Frome Rocks No.2	18°15'15"S	123°39'35"E	WAPET (1962b)
10.	Grant Range No.1	18°01'00"S	124°00'02"S	WAPET (1956a)
11.	Hawkstone Peak No.1	17°14'45"S	124°24'26"E	WAPET (1966a)
12.	Jurgurra Creek No.1	18°19'49"S	123°42'45"E	Henderson and Others (1963)
13.	Langoora No.1	17°18'07"S	124°06'48"E	WAPET (1966a)
14.	Logue No.1	18°07'33"S	123°23'24"E	WAPET (1968b)
15.	Matches Springs No.1	18°41'28"S	124°03'11"E	Total (1970)
16.	May River No.1	17°14'50"S	124°05'01"E	WAPET (1967a)
17.	Meda No.1	17°24'00"	124°11'30"E	WAPET (1962a)
18.	Meda No.2	17°24'36"S	124°11'23"E	
19.	Mount Wynne No.3	18°06'00"S	124°27'00"E	Blatchford (1927)
20.	Mowla No.1	18°43'50"S	123°42'35"E	Total (1969)
21.	Myalls Bore	17°21'00"S	123°40'00"E	Playford (1957)
22.	Myroodah No.1	18°16'15"S	124°11'27"E	AFO (1956)
23.	Napier No.2	17°04'55"S	124°21'20"E	Lennard Oil (1970)
24.	Napier No.5	17°06'30'S	124°28'06"E	Lennard Oil (1971)
25.	Nerrima No.1 (AFO)	18°26'55"S	124°22'17"E	AFO (1955)
26.	Sisters No.1	17°43'31"S	124°25'09"E	AFO (1957)



Record 1978/8 E51/A/40

Fig. 17 Sketch map of DERBY and MT ANDERSON showing location of deep wells

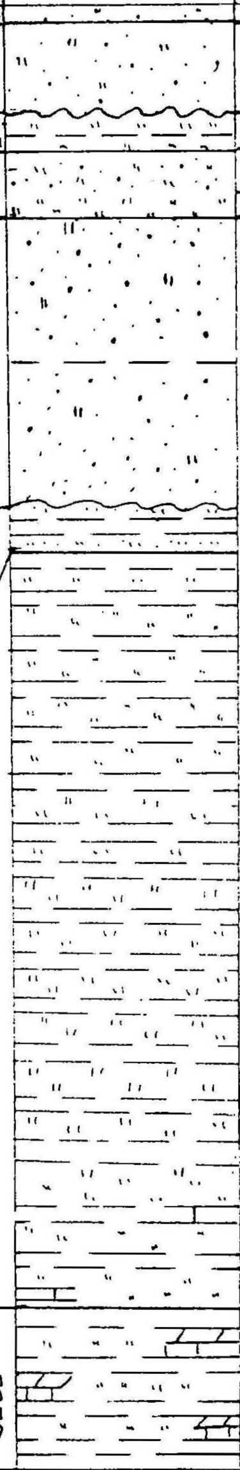
Petroleum exploration wells:

- Dry well, abandoned
- Abandoned well; show of oil
- Abandoned well. Show of oil and gas
- Abandoned well; show of gas

Other deep wells:

Fig 1 WAPET Babrongan No 1

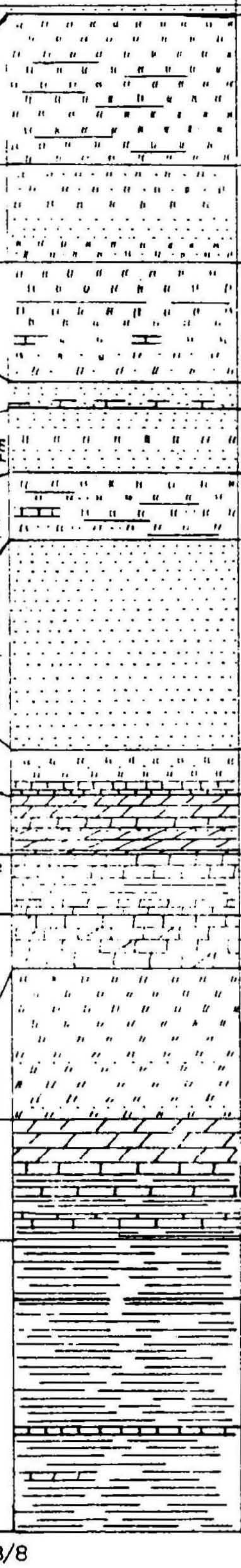
Scale : 10mm = 100m



AGE		UNIT	GRAPHIC LOG	DEPTH	THICKNESS	LITHOLOGY	DATING
JURASSIC		ALEXANDER FMN		23	14	Interbedded fine to coarse-grained quartzose sandstone and micaceous siltstone. Base of Alexander Formation picked from gamma ray log.	
JURASSIC		WALLAL SST		143	120		
EARLY PERMIAN	ARTINSKIAN	NOONKANBAH FMN		186	43	Interbedded shale and siltstone	
EARLY PERMIAN	ARTINSKIAN	POOLE SST		247 279	93	Interbedded siltstone and fine to coarse grained quartzose sandstone; siltstone below 247m (Nura Nura Member)	
EARLY PERMIAN	SAKMARIAN	GRANT GROUP		470 669	390	Fine to coarse-grained quartzose sandstone with thin beds of siltstone. 7m shale bed at 470m is probably Winifred Fmn	
LATE DEVONIAN	FAMMENIAN	LULUIGUI FMN.		724	55	Calcareous siltstone with interbedded shale and fine to medium-grained sandstone	mid - late Fammenian
LATE DEVONIAN	FAMMENIAN	CLANMEYER SILTSTONE		1616 1736	1012	Calcareous, greyish green siltstone and shale. Some limestone below 1616m.	mid-late Fammenian
LATE DEVONIAN	FAMMENIAN	BABRONGAN BEDS		1949	213	Shale and siltstone interbedded with dolomite and dolomitic limestone	

Fig 2 WAPET BLACKSTONE No 1

Scale : 10mm = 150m.



AGE	UNIT	DEPTH (m)	THICKNESS (m)	LITHOLOGY	DATING
TRIASSIC	ERSKINE SST.	9	9	Very fine to fine sandstone, micaceous; lateritised	
TRIASSIC	BLINA SHALE	320	311	Interbedded siltstone and shale, finely mi., fissile, pyritic. Traces of fine sandstone	* Palynology * Early Triassic
PERMIAN	[illegible] GP	511	191	Siltstone, sandy, mi, slightly pyrite, carbonaceous; Sandstone, fine to medium, calcareous in parts, well-sorted, micaceous.	* Palynology L. Permian; Palynology * Artinskian to Kungurian
PERMIAN — ARTINSKIAN	NOONKANBAH FM	747	236	Siltstone, grey, brown, clayey, sandy, micaceous, minor shale with pyritic nodules. Sandstone, fine, calcareous; fossiliferous limestone	* Palynology * Artiniskian
PERMIAN — ARTINSKIAN	Poole Sst	795	48	Sandstone, fine to medium, minor siltstone; sandy, fossiliferous limestone at base Nura Nura Mbr.	* Palynology - Artinskian
PERMIAN — SAKMARIAN	[illegible] — Carolyn Fm	930	135	Interbedded fine to medium, micaceous, partly calcareous sandstone and siltstone.	▸ Sakmarian * Palynology
PERMIAN — SAKMARIAN	[illegible] — Winifred Fm	1065	135	Siltstone, shale, grey, fissile, micaceous; minor sandstone.	
LATE CARBONIFEROUS – EARLY PERMIAN	GRANT — BETTY FM.	1486	421	Interbedded fine- to coarse sandstone, moderate to well-sorted; partly pyritic and feldspathic	
[illegible] CARBONIFEROUS	Laurel Fm.	1579	93	Siltstone, minor sandstone; Interbedded limestone, sandstone, siltstone	Ostracods, conodont, brachiopod.
[illegible]	Yellow Drum Sst	1699	120	Dolomite; minor limestone, shale, siltstone, sandstone	
DEVONIAN	Gumhole Fm.	1811	112	Limestone, fine to medium, with thin interbeds of shale.	Bryozoans, crinoids, ostracods.
DEVONIAN	REEF COMPLEX	1919	103	Limestone, partly dolomitic	
DEVONIAN	[illegible] FM	2220	306	Siltstone, micaceous, [illegible] sandy, with thin interbeds and lenses of sandstone; minor shale. Traces of dolomite.	* Palynology Mid-Devonian
ORDOVICIAN	NITA FM	2460	240	Dolomite, finely crystalline, minor shales; Interbedded fossiliferous limestone and shale. Thin-bedded, partly dolomitic	* gastropods, * brachiopods
ORDOVICIAN	GOLDWYER FORMATION	3050	590	Shale, grey, fissile, finely micaceous, thin-bedded to laminated, partly calcareous; Limestone, microcrystalline, silty; Shale, silty, calcareous.	* graptolites, * brachiopods; * graptolites

Record 1978/8 E51/A7/10

Interpretation by BMR Basin Study Group, Druce & Radke (in prep.) and the authors.

Fig 3 WAPET DAMPIER DOWNS No 1

Scale: 10 mm = 50 m

AGE	UNIT	GRAPHIC LOG	DEPTH (m)	THICKNESS (m)	LITHOLOGY	DATING
LATE JURASSIC	JARLEMAI SILTSTONE		92	87	Siltstone, with lenses of coarse to fine-grained sandstone	
LATE JURASSIC	ALEXANDER FMN		148	56	Poorly sorted, ~~sandstone~~ fine to coarse-grained sandstone with interbedded siltstone	
MIDDLE? TO LATE JURASSIC	WALLAL SANDSTONE		249 316	168	Poorly sorted fine to coarse-grained sandstone with siltstone interbeds to 249 m. Fine to very fine coarse-grained sandstone with stringers of coal below 249 m	
PERMIAN – ARTINSKIAN	NOONKANBAH FORMATION		416	100	Interbedded fine-grained poorly sorted sandstone and siltstone	* Palynology ?Artinskian * "
PERMIAN – ARTINSKIAN	POOLE SST		469 482	66	Interbedded fine-grained poorly sorted sandstone and siltstone to 469 m, then interbedded sandstone, siltstone, and calcarenite	* " * "
PERMIAN	CAROLYN FORMATION		594	112	Fine- to coarse-grained (?conglomeratic) sandstone, and siltstone	
PERMIAN – SAKMARIAN	WINIFRED FMN		661	67	Siltstone and sandstone	
PERMIAN – SAKMARIAN	BETTY FORMATION		800	139	Fine to coarse-grained conglomeratic sandstone with interbedded siltstone. Some thin beds of limestone at the base	
ORDOVICIAN?	ROEBUCK DOLOMITE		923	123	Fine to coarse-grained crystalline dolomite with numerous interconnecting vugs.	* Conodonts Ordovician, but possibly reworked

Record 1978/8 E51/A11/18

Interpretation by BMR Basin Studies Group and the authors

Fig 4 DERBY TOWN BORE

Scale :- 10mm = 40m

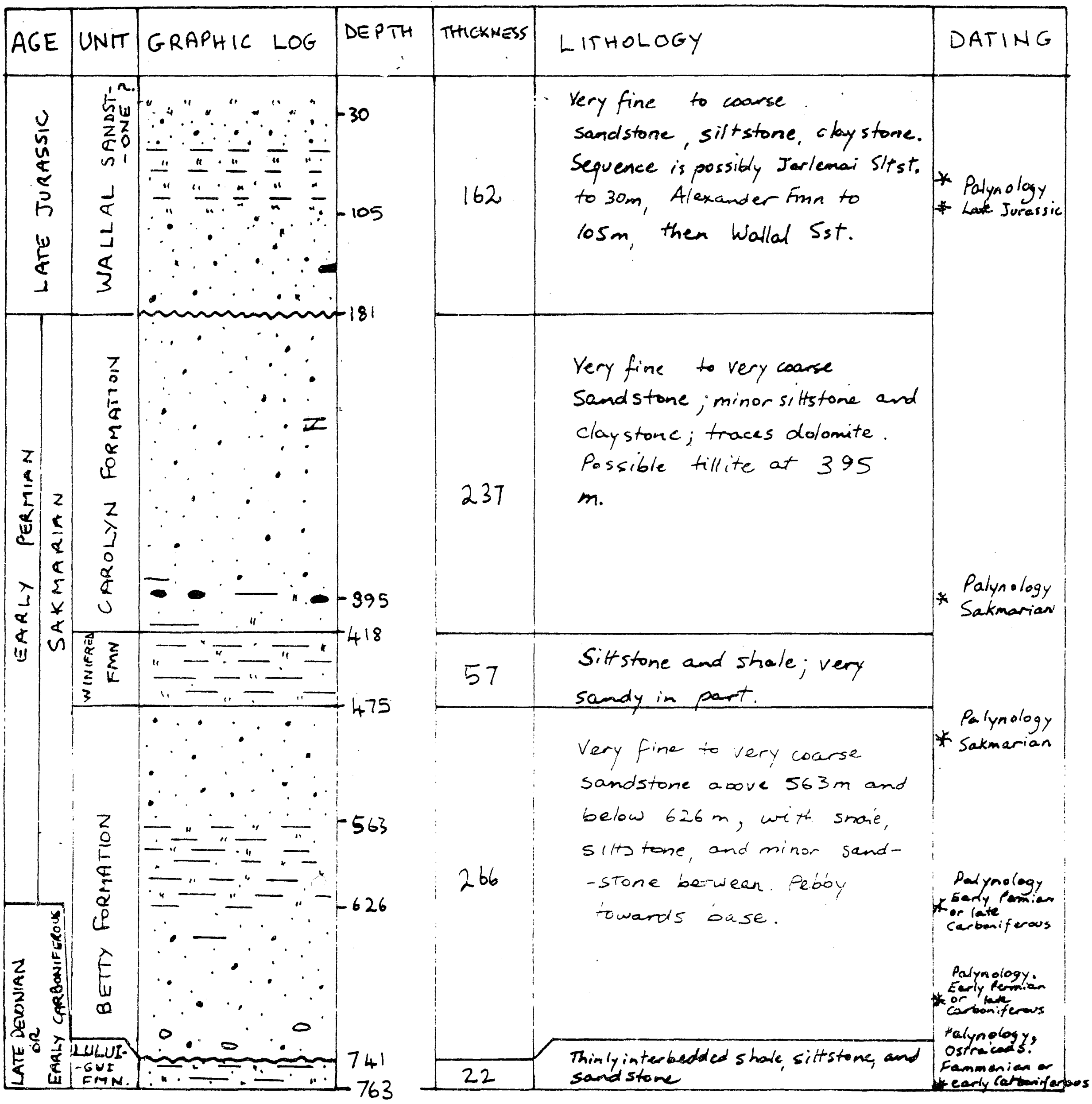
AGE		UNIT	GRAPHIC LOG	DEPTH	THICKNESS	LITHOLOGY*	DATING
TRIASSIC	EARLY TO MIDDLE TRIASSIC	ERSKINE SANDSTONE		260	255	Poorly to thin bedded, micaceous, very fine silty quartz sandstone, with minor siltstone increasing with depth	Palynology Early Triassic
TRIASSIC	SCYTHIAN	BLINA SHALE		536	276	Bedded and unbedded claystone, siltstone, and very fine grained quartz sandstone.	Micropal. and Palynology. Early Triassic
EARLY PERMIAN	KUNGURIAN	LIGHTJACK FORMATION		701 723	187	Interbedded silty very fine grained poorly sorted, angular, micaceous quartz sandstone, and sandy and clayey micaceous siltstone. Dark reddish brown ironstone at 701m : oolites of chamosite in matrix of limonite, silt, and fine to very fine quartz sand.	Brachiopods, micropal., palynology. Early Permian

Record 1978/8 E51/A7/11

* Based on driller's log and unlabelled samples. Interpretation by Playford (1957).

Fig 5 WAPET Doran Corehole No 1

Scale : 10 mm = 50 m

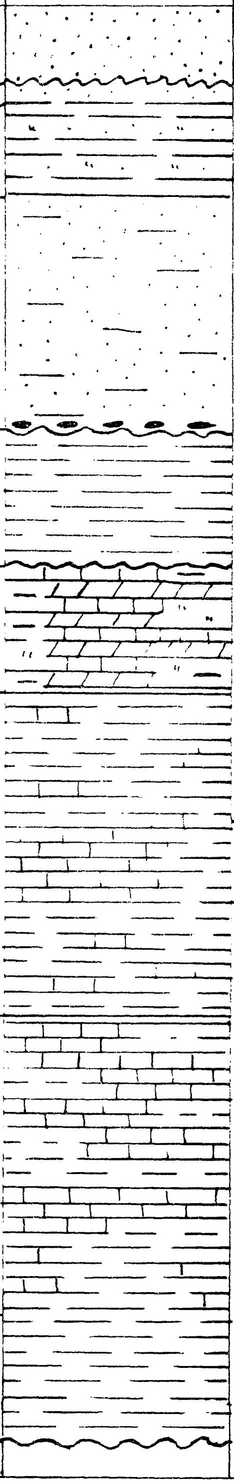


Record 1978/8

E51/A11/19

Fig 6 TOTAL EDGAR RANGE No 1

Scale : 10 mm = 100 m



AGE	UNIT	DEPTH (m)	THICKNESS (m)	LITHOLOGY	DATING
JURASSIC	WALLAL SST	113	104	Coarse-grained sandstone with interbedded fine sandstone predominating between 21 and 75m	
PERMIAN SAKMARIAN	CAROLYN FMN	128	15	Clayey and silty fine-grained sandstone	* Palynology Sakmarian
	WINIFRED FMN	262	134	Shale, with interbeds of siltstone and fine to medium-grained sandstone	
	BETTY FMN	572	310	Fine- to medium-grained sandstone, with interbedded silty shale. Conglomerate in basal 7m	
LATE SILURIAN TO EARLY DEVONIAN	CARRIBUDDY FMN	750	178	Red brown and mottled grey shale becoming dark grey towards base.	
ORDOVICIAN	NITA FMN	922	172	Dolomite and limestone, interbedded dark grey shale and siltstone	* Palynology Llandeilian
	GOLDWYER FMN	1088 1201 1353	431	Dark grey shale with limestone interbeds. Limestone predominates between 1098 and 1201m	* Palynology Llandeilian Macrofossils Llanvirnian * Macrofossils Llanvirnian
	WILLARA FMN	1754	401	Fine-grained limestone with thin shale interbeds to 1647 m, then grey to black shale with thin interbeds of limestone	* Conodonts mid-Ordovician * Conodonts mid-Ordovician
	NAMBEET FMN	1916	162	Grey to black fissile shale	
PRE-CAMBRIAN	BASEMENT	1968	52	quartz-muscovite-biotite schist.	

Record 1978/8 E51/A11/20

Interpretation by BMR Basin Studies Group and the authors

Fig 7 WAPET Fraser River No 1

Scale: 10 mm = 150 m

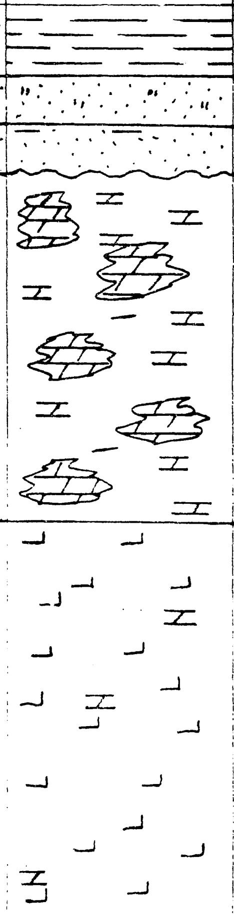
AGE	UNIT	GRAPHIC LOG	DEPTH	THICKNESS	LITHOLOGY	DATING
JURASSIC	JARLEMAI SILTSTONE		72	60	Clay and siltstone	
JURASSIC	WALLAL SANDSTONE AND ALEXANDER FMN (UNDIFF)		192, 424	352	Siltstone and sandstone to ?192 m then fine to medium sandstone, minor shale. Upper and lower boundaries uncertain	Palynology * Mesozoic
PERMIAN – JARTINSKIAN	POOLE SANDSTONE		680	256	Fine to medium sandstone, very minor shale	
PERMIAN – SAKMARIAN	CAROLYN FORMATION		922	242	Fine to medium sandstone, shale, 'fontainebleau' sandstone, some conglomerate near base	
SAKMARIAN / LATE CARBONIFEROUS TO EARLY PERMIAN	WINIFRED FMN		1038	116	Siltstone, claystone	
LATE CARBONIFEROUS TO EARLY PERMIAN	BETTY FORMATION		1381	343	Sandstone, siltstone, claystone; conglomeratic near base	
CARBONIFEROUS	ANDERSON FORMATION		2437	1056	Sandstone interbedded siltstone.	
CARBONIFEROUS / PRE-CAMBRIAN	LAUREL FMN.		3062	625	Siltstone and claystone, minor sandstone	
PRE-CAMBRIAN	BASEMENT		3092	30	Gabbro	

Record 1978/8 E51/A7/12

Interpretation by BMR Basin Studies Group and the authors, from composite well and gamma logs. Dating by Crespin (1955) is now considered inaccurate, and is not shown.

Fig 8 WAPET FROME ROCKS No 1

Scale :- 10 mm = 100 m



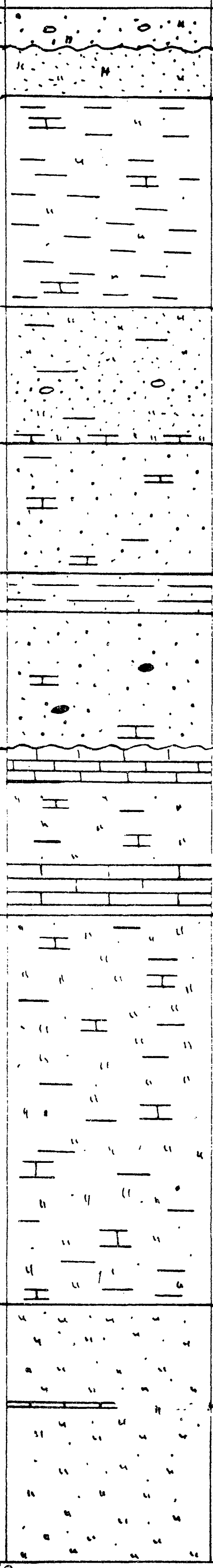
AGE	UNIT	GRAPHIC LOG	DEPTH	THICKNESS	LITHOLOGY	DATING
LATE JURASSIC	JARLEMAI SLTST.		94	82	Pyritic and glauconitic clay. Weathered down to 60 m	
LATE JURASSIC	ALEXANDER FMN.		155	61	Thin bedded very fine to medium sandstone with interbedded siltstone	* Palynology Mid-Late Jurassic
JURASSIC	WALLAL SST		224	69	Pyritic fine and medium grained sandstone, some shale near top of unit	* Palynology Early-Mid Jurassic ?
CARBONIFEROUS OR OLDER	CAP ROCK		688	464	Dolomite breccia - fragments of dolomite, minor quartz and anhydrite in matrix of friable fine granular dolomite with minor clay and authigenic quartz	
CARBONIFEROUS OR OLDER	SALT DOME		1220	532	Translucent grey, pink, brown and white salt, with scattered small fragments of dolomite and anhydrite. Several beds of dolomite breccia.	* Conodonts Fish Plates. Dolomite late Devonian or early Carboniferous.

Record 1978/8 E51/A11/21

Interpretation by BMR Basin Studies Group and the authors.

Fig 9 WAPET FROME ROCKS No 2

Scale:- 10mm = 100m



AGE	UNIT	DEPTH	THICKNESS	LITHOLOGY	DATING
Jurassic	Wallal Sst.	63	54	Medium-grained sandstone, with fine and coarse beds, and siltstone and conglomerate lenses	
Early Permian – Kungurian	Lightjack Fmn	133	70	Very finegrained, slightly calcareous, pyritic sandstone; interbedded siltstone	
Early Permian – Artinskian	Noonkanbah Formation	441	308	Micaceous, pyritic, gypseous shale, with lenses of siltstone grading to very fine grained sandstone. Occasional thin beds of limestone	* Palynology Artinskian * Palynology Artinskian * Palynology Early Permian
Early Permian – Artinskian	Poole Sandstone	643	202	very fine to fine grained micaceous, pyritic ?glauconitic sandstone, with beds of siltstone and shale. 536-579m coarse to very coarse sandstone with clay pellet conglomerate. Siltstone, calcilutite, and sandy limestone in basal 8m	* Palynology Artinskian
Early Permian – Sakmarian	Carolyn Formation	831	188	Poorly sorted, fine to coarse grained feldspathic sandstone, with beds of conglomerate and 'fontainebleu' sandstone; Minor shale	
Early Permian – Sakmarian	Winnifred Fmn.	886	55	Shale, with sandstone interbeds	
Early Permian – Sakmarian	Betty Formation	1078	192	Well to poorly sorted, fine- to coarse-grained feldspathic to arkosic pebbly sandstone. Numerous beds of 'Fontainbleu' sandstone, particularly near base of unit	* Palynology latest Permian
Late Devonian – Fammenian	Gumhole Fmn	1338	260	Interbedded limestone, siltstone, shale, and sandstone	* Palynology ?Fammenian * Palynology Fammenian
Late Devonian – Fammenian	Luluigui Formation	1909	571	Siltstone, with interbedded shale, limestone and fine sandstone	* Palynology Fammenian * Palynology Fammenian * Palynology Fammenian or slightly older
Late Devonian	Clanmeyer Siltstone	2064 2287	378	Thin bedded micaceous (biotite) grey siltstone, some beds slightly calcareous; some thin beds of very fine grained calcareous micaceous (biotite) sandstone. Limestone bed at 2064m.	* Palynology Fammenian or Frasnian * Ammonoid Fammenian

Record 1978/8 E51/A11/22

Interpretation by BMR Basin Studies Group, Druce + Radke (in prep.), and the authors.

Fig 10 WAPET Grant Range No 1

Scale : 10mm = 200 m

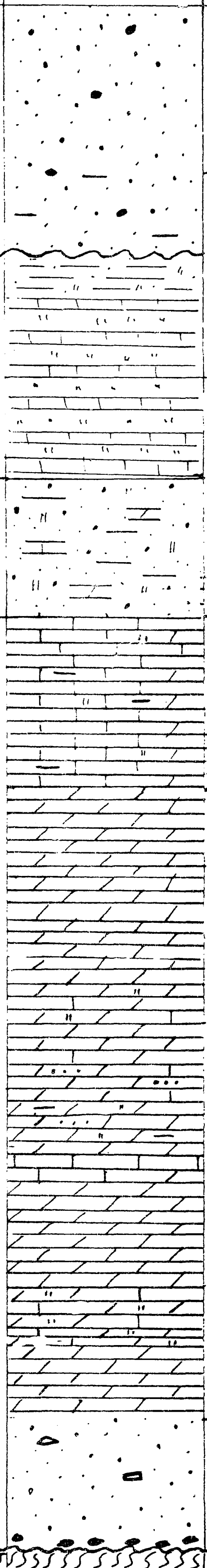
AGE		UNIT	GRAPHIC LOG	DEPTH	THICKNESS	LITHOLOGY	DATING
PERMIAN	?SAKMARIAN	Carolyn Fmn.		30	21	Very fine to medium sandstone	
		Winifred Fmn.		142	112	Interbedded shale, siltstone, and fine grained sandstone.	
LATE CARBONIFEROUS to EARLY PERMIAN	?STEPHANIAN - SAKMARIAN	Betty Formation		1856	1714	Sandstone, coarse to very fine grained; some siltstone, shale; minor conglomerate, limestone	
CARBONIFEROUS		Anderson Formation		3936	2080	Interbedded shale, siltstone, sandstone; minor limestone.	*Palynology Visean

Record 1978/8 E51/A11/23

Interpretation by BMR Basin Studies Group and the authors

Fig 11 WAPET HAWKSTONE PEAK No 1

Scale: 10mm = 50m



AGE	UNIT	DEPTH	THICKNESS	LITHOLOGY	DATING
PERMIAN SAKMARIAN	BETTY FMN	128 186	171	Fine-to coarse-grained sandstone with thin pebble beds; thin beds of claystone below 128m	
LATE DEVONIAN TO EARLY CARBONIFEROUS	LAUREL FMN	354	168	Shale, siltstone, sandstone in top 30m, then interbedded limestone and siltstone.	Palynology, Macrofossils * Early Carboniferous or late Devonian Palynology * Late Devonian or early Carboniferous
	YELLOW DRUM SST	463	109	Interbedded coarse-to fine-grained sandstone, siltstone, and shale, dolomite, and minor limestone.	Palynology * Fammenian
DEVONIAN FRASNIAN TO FAMMENIAN	REEF COMPLEX	591 1074 1175	714	Massive limestone to 591m, then Dolomite, with interbedded siltstone, shale, limestone, sandstone to 1074m Fine-to coarse-grained micaceous sandstone with clay pebbles, and basal conglomerate below 1074m	Palynology * Famenian Microfossils, Palynology * ?Fammenian or Frasnian
PRE-CAMBRIAN	BASEMENT	1188	13	Quartzite with schistose partings	

Record 1978/8

Interpretation by BMR Basin Studies Group, Druce + Radke (in prep.), and the authors

E51/A7/13

Fig 12. BMR No 1 Jurgurra Creek

Scale :- 10mm = 25m

AGE	UNIT	GRAPHIC LOG	DEPTH	THICKNESS	LITHOLOGY	DATING
EARLY PERMIAN — ARTINSKIAN	NOONKANBAH FORMATION		15	317	Pink very fine-grained calcareous quartz wacke to 15m Light to dark grey laminated and thin bedded micaceous carbon-aceous siltstone, with dissem-inated pyrite; shelly fossils and micro fossils; minor inter-calated pale grey laminated to thin bedded very fine to fine-grained micaceoos, and in places carbonaceoos and calcar-eous quartz wacke	* Micropal. marine Permian * Micropal. marine Permian * Bryzoa Corals Brachiopods Permian
			197		Interbedded friable grey laminated fine to very fine-grained micaceoos, and hard pale grey fine to medium-grained calcar-eous quartz wacke, and dark grey laminated micac-eous carbonaceous siltstone with shelly fossils and diss-eminated pyrite	
?	POOLE SANDSTONE		319	60	Pale grey friable laminated and cross laminated medium, fine, and coarse-grained carbonaceous quartz sandstone; minor grey lamin-ated very fine to medium grained quarto wacka and dark grey laminated siltstone.	
SAKMARIAN	CAROLYN FORMATION		379	133	Friable, grey, laminated to thin-bedded medium-grained (with coarse and fine-grained laminae and scattered grains) quartz wacke, hard dolomitic(?) grey medium grained quartz wacke with coarse grains and pebbles, and hard light green-ish grey sandy micaceous siltstone; larger grains include quartz, quartzite, slate, jasper, and limestone	
			512			

Record 1978/8

E51/A11/24

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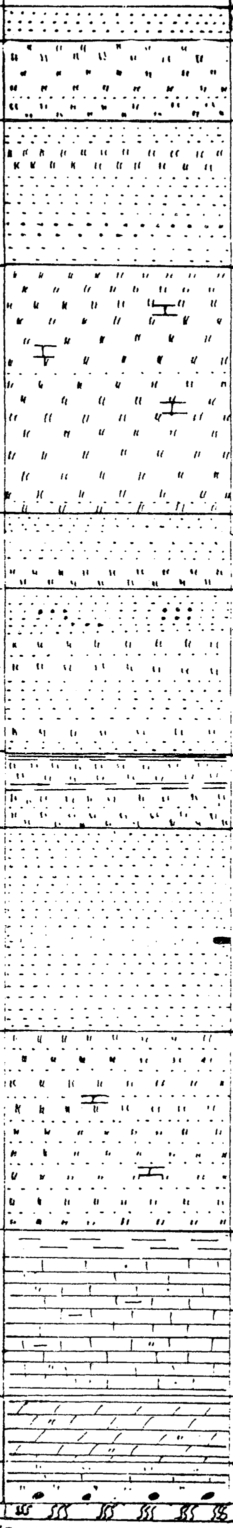
Fig 13 WAPET LANGOOKA No 1

Scale :- 10mm = 80m



Age	Unit	Depth	Thickness	LITHOLOGY	DATING
	Alluvium	32	29	Sandstone, fine to coarse, poorly sorted	
Early Triassic	Blina Shale	127	95	Siltstone, grey, micaceous, carbonaceous, fossiliferous; minor fine sandstone	
PERMIAN	Liveringa Group	276	149	Sandstone, very fine to fine Siltstone, micaceous to carbonaceous. Sandstone, v. fine to medium, poorly sorted,	
PERMIAN	Noonkanbah Formation	539	263	Siltstone, dark grey to black, micaceous, pyritic, fossiliferous; minor interbeds of limestone, very fine to fine sandstone.	
PERMIAN	Poole Sst	565 622	83	Sandstone, fine to medium, moderately sorted, to 565m (Tuckfield Mbr.), then Siltstone, grey, sandy, rare fossils (Nura Nura Mbr).	Palynology * U. Sakmarian
PERMIAN	Grant Group: Carolyn Formation	799	177	Sandstone, fine to medium, locally coarse, subangular to subrounded, micaceous; minor interbeds of sandy, micaceous siltstone; minor carbonaceous shale, and lignite	
PERMIAN	Grant Group: Winifred Fm	876	77	Siltstone, grey, sandy, micaceous, carbonaceous minor interbeds of shale, and very fine sandstone	
PERMIAN	Grant Formation: Betty	1094	218	Sandstone, very fine to medium, angular to subrounded, poor sorting; occasional thin beds of carbonaceous material.	x Palynology Permian
CARBONIFEROUS	Anderson Formation	1308	214	Interbedded fine to coarse, slightly calcareous massive, moderately sorted sandstone, and grey, sandy, soft siltstone.	Palynology * U. Carboniferous
CARBONIFEROUS	Laurel Fmn	1484	176	Limestone; minor shale, siltstone, sandstone.	* Palynology ? L. Carboniferous
DEVONIAN TO PRECAMBRIAN	Yellow Drum Sst	1551	67	Dolomite, minor siltstone	* Forams U. Devonian
DEVONIAN TO PRECAMBRIAN	Gumhole Fmn	1597	46	Limestone and siltstone, basal conglomerate	
PRECAMBRIAN		1615	18	Basement: biotite schist.	

Interpretation by BMR Basin Studies Group, Druce & Radke (in prep.), and the authors.

Fig 14 WAPET Logue No 1

Scale: 10 mm = 120 m

AGE		UNIT	GRAPHIC LOG	DEPTH	THICKNESS	LITHOLOGY	DATING
JURASSIC		WALLAL SST		165	154	Medium to coarse grained sandstone, minor siltstone, coal.	
PERMIAN	ARTINSKIAN	NOONKANBAH FMN		405	240	Siltstone, claystone, and minor fine to medium sandstone	* Palynology Artinskian
		POOLE SST.		512	107	Sandstone, very fine to coarse grained, and siltstone. Basal 12m (Nura Nura Mbr.) is sandy limestone.	* Palynology Sakmarian
	SAKMARIAN	CAROLYN FMN		927	415	Very fine to very coarse sandstone, minor shale.	* Palynology Sakmarian
		WINIFRED FMN		1009	82	Shale and claystone, minor sandstone.	* Palynology Sakmarian
		BETTY FORMATION		1359 1563	554	Very fine to very coarse sand-stone, siltstone, shale, above 1359m, then shale, claystone, sandstone, with minor limestone and dolomite. Interpretation is by BMR Basin Studies Group. Section below 1359m may be Luluigui Fmn, defined from Frome Rocks No 1, but Palynology does not support this interpretation	* Palynology Carboniferous * Palynology Carboniferous (Visean)
LATE DEVONIAN		CLANMEYER SILTSTONE			1067	Siltstone, with minor very fine sandstone and claystone	* Palynology Upper Famennian * " * " * " * " * " * "
		BABRONGAN BEDS		2630 2699	69	Reddish-brown siltstone	* "

Record 1978/8

E51/A11/25

Interpretation by BMR Basin Studies Group and the authors.

Fig 15 TOTAL MATCHES SPRINGS No 1

Scale :- 10 mm = 120 m

AGE	UNIT	GRAPHIC LOG	DEPTH	THICKNESS	LITHOLOGY	DATING
JURASSIC	ALEXANDER FMN		22	17	Very fine to medium-grained sandstone; siltstone bed at base	
	WALLAL SST		123	101	Very fine to medium-grained sandstone with siltstone interbeds	
PERMIAN SAKMARIAN	BETTY FMN		490 547	424	Fine- to medium-grained sandstone with minor interbedded shale and pebbly bands. Sandstone pebbly below 490 m.	
LATE DEVONIAN	REEF FACIES CARBONATES		1502 1706	1159	Vuggy microcrystalline to finely crystalline dolomite, argillaceous in part, to 1163 m, then dolomite and dolomitic limestone with common interbeds of dark grey shale above 1502 m.	* Palynology Frasnian * Palynology, Conodonts Frasnian * Micropal. Famennian
DEVONIAN	TANDALGOO RED BEDS		1778	72	Very fine to fine grained sandstone with lenses of red and gray-green shale	* Palynology Mid Devonian
LATE ORDOVICIAN TO (?) EARLY DEVONIAN	CARRIBUDDY FMN		2019	241	Dolomitic shale, dolomite, sandstone, minor limestone. Shale silty near base	
	NITA FMN		2269	240	Dolomite, shaley towards the top, to 2108 m, then finely crystalline in part dolomitic limestone with occasional shale interbeds	
ORDOVICIAN	GOLDWYER FMN		2407 2468 2835	566	Interbedded shale and limestone; limestone dominant between 2407 and 2468 m.	

Record 1978/8

Interpretation by BMR Basin Studies Group and the authors

E51/A11/26

Fig 16 WAPET MAY RIVER No 1

Scale :- 10mm = 100m.

AGE	UNIT	GRAPHIC LOG	DEPTH (m)	THICKNESS (m)	LITHOLOGY	DATING
	Alluvium		20		Laterite.	
Triassic	Blina Shale		37		Siltstone, sandy; minor fine sandstone.	
	Liveringa Group		163	126	Sandstone, fine to medium, micaceous, lignitic, minor siltstone, grey, carbonaceous, sandy	
PERMIAN — Artinskian	Noonkanbah Fm		439	276	Siltstone, grey, soft, finely micaceous, lignitic, pyritic, sandy; minor sandstone grey, fine, calcareous. Limestone, coquinoidal.	bryzoans, brachiopods
PERMIAN — Sakmarian	Poole Sst		521	82	Sandstone, fine to medium; Limestone, fossiliferous, sandy (Nura Nura Mbr)	bryzoa, brachiopods
	Grant Group — Carolyn Fm		680	159	Interbedded sandy, grey siltstone and fine well sorted sandstone, Medium - coarse, pebbly sandstone	
	Grant Group — Winifred Fm		786	106	Shale, grey, fissile, finely micaceous; minor sandy siltstones very fine sandstone.	
LATE CARBONIFEROUS TO EARLY PERMIAN	Grant — Betty Fm.		969	183	Sandstone, fine-medium to v. coarse, poor sorting, calcareous in places; minor siltstone, shale; slightly lignitic.	
CARBONIFEROUS	Anderson Fm.		1172	203	Interbedded sandstone and siltstone: sandstone - coarse to very coarse, mod. well sorted, massive siltstone - multi coloured, micaceous, carbonaceous, sandy.	
	Laurel Fm		1402	230	Interbedded siltstone and fine, silty, mi sandstone; minor sandy limestone. Interbedded grey, fossiliferous limestone, and grey sandstone; minor black, micaceous siltstone and shale	brachiopods, pelecypods *polynology Early Carbonaceous
DEVONIAN	Yellow Drum Sst.		1503	101	Interbedded fine to coarse, friable sandstone and microcrystalline dolomite c̄ quartz grains	* rare spores.
	Gum-hole Fm.		1579	76	Limestone, dolomite, and minor shale	x rare fossils
	Reef Complex		1642	63	Interbedded and interlaminated dolomitic sandstone, siltstone, shale	
Precambrian	Basement		1678	36	Schist	

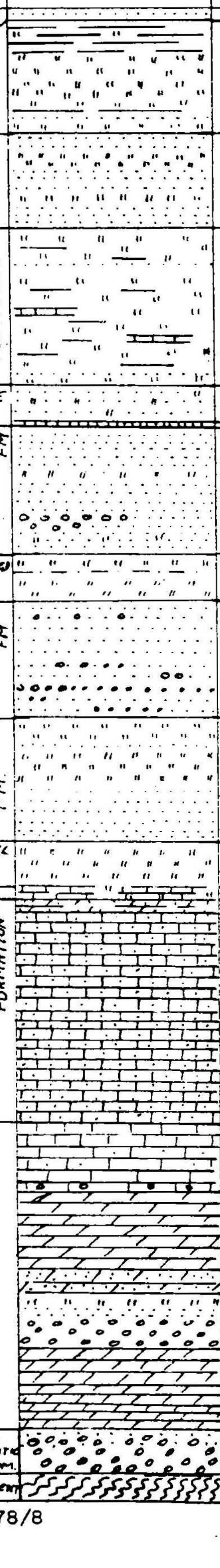
Record 1978/8

E51/A7/15

Interpretation by BMR Basin Study Group, Druce & Radke (in prep), and the authors.

Fig 17 WAPET Meda No 1

Scale : 10mm. = 120 m.



AGE	UNIT	DEPTH	THICKNESS	LITHOLOGY	DATING
TRIASSIC	Alluvium	18		Sand	
TRIASSIC	BLINA SHALE	218	200	Shale, grey, micaceous, pyritic, laminated Siltstone, c quartz grains, fossils; minor fine sandstone, glauconitic.	* Palynology basal Triassic
PERMIAN	LIVERINGA GROUP	397	179	Sandstone, grey, fine, poor to well sorted; interbedded with siltstone, micaceous, carbonaceous, pyritic. ? 350 - 397 maybe equiv. to Lightjack Fm.	* Palynology U. Permian.
PERMIAN – ARTINSKIAN	NOONKANBAH FORMATION	678	281	Thinly interbedded siltstone, and shale, black, micaceous, calcareous; minor fine sandstone, and limestone beds with fossils. Coquinite.	* Palynology Artinskian; Palynology * Artinskian
PERMIAN – ARTINSKIAN	POOLE SST	738	60	Sandstone, fine, well sorted; micaceous siltstone; Fossiliferous sandy limestone - Nura Nura Mbr	* Palynology
PERMIAN – SAKMARIAN	GRANT GROUP – CAROLYN FM	986	148	Fine to medium sandstone, well sorted, minor siltstone with plant remains; conglomerate with pebbles of quartzite, granite.	* Palynology; * Palynology
PERMIAN – SAKMARIAN	WINIFRED FM.	1068	82	Massive, grey, sandy siltstone, interbedded with micaceous claystone.	
LATE CARBONIFEROUS to EARLY PERMIAN	GRANT – BETTY FM	1280	212	Sandstone, fine to coarse; beds of pebble conglomerate, poorly sorted, with minor calcareous cement.	
EARLY CARBONIFEROUS	ANDERSON FM.	1504	224	Siltstone, multicoloured, micaceous, lignitic, sandy in parts; poorly laminated. Sandstone, fine, well sorted, micaceous, carbonaceous, plant remains; thin-bedded.	
EARLY CARBONIFEROUS	LAUREL FM	1623		Siltstone, thinly laminated, fissile, micaceous, carbonaceous; interbedded with calcareous sandstone. Limestone with quartz grains	Conodonts, Ostracode, brachiopode.
	?	1649			
DEVONIAN	YELLOW DRUM SST		26	Interbedded sandstone and sandy dolomite	
DEVONIAN	GUMHOLE FORMATION	2018	369	Limestone, grey-brown, in part oolitic, with clear calcite; fine quartz sand grains abundant	Ostracods, conodonts. Latest Devonian
DEVONIAN	REEF COMPLEX	2548	530	Limestone, recrystallized, fine to coarse, minor siltstone, quartz pebble conglomerate. Dolomite, recrystallized, fine, silty. Sandy dolomite with pyrite. Interbedded fine to coarse sandstone and siltstone. Pebble, boulder conglomerate with calcareous sandstone matrix. Dolomite, grey, fine, crystalline, calcite veins	
DEVONIAN	BASAL CHLORITE CONGLOM.	2640	92	Conglomerate, dolomitic, quartzite, schist pebbles; dolomitic sandstone	
PRE-CAMBRIAN	BASEMENT	2684	44	Schist - basement	

Record 1978/8 E51/A7/16

Interpretation by BMR Basin Study Group; Druce & Radke (in prep.); and the authors

Fig 18 WAPET Meda No. 2

Scale: 10mm = 100m.

AGE	UNIT	DEPTH	THICKNESS	LITHOLOGY	DATING
TRIASSIC		21		Sand	
TRIASSIC	BLINA SHALE	254	233	Shale and siltstone.	
PERMIAN	LIVERINGA GROUP	435	181	Siltstone and sandstone	
PERMIAN – ARTINSKIAN	NOONKANBAH FM.	723	288	Siltstone and shale	
PERMIAN – SAKMARIAN	POOLE SST	799	76	Sandstone, calcareous at base	
PERMIAN – SAKMARIAN	CAROLYN FMN	1037	238	Sandstone minor siltstone.	
LATE CARBONIFEROUS to EARLY PERMIAN	WINIFRED FMN	1119	82	Sandy siltstone	
LATE CARBONIFEROUS to EARLY PERMIAN	BETTY FMN	1317	198	Sandstone, siltstone, minor conglom.	
EARLY CARBONIFEROUS	ANDERSON FORMATION	1551	134	Multicolored siltstone, and fine sandstone interbeds.	
LATE DEVONIAN to EARLY CARBONIFEROUS	FAIRFIELD GROUP	2018	467	Siltstone, limestone and sandstone includes Laurel Fmn, Yellow Drum Sst and Gumhole Fmn.	
DEVONIAN	REEF COMPLEX	2325	307	Dolomite, minor siltstone, sandstone and limestone.	

Record 1978/8

E51/A7/17

Interpretation by BMR Basin Study Group

Fig 19 FKO Mt. Wynne No 3

Scale : 10mm = 40m

AGE		UNIT	GRAPHIC LOG	DEPTH	THICKNESS	LITHOLOGY	DATING
EARLY PERMIAN	SAKMARIAN	CAROLYN FORMATION		277	272	Fine to coarse grained sandstone; minor shale, conglomerate.	
		WINIFRED FMN.		340	63	Claystone	
LATE CARBONIFEROUS TO EARLY PERMIAN		BETTY FORMATION		657	217	Fine to medium grained sandstone; minor shale, conglomerate beds near base of well.	

Record 1978/8

E51/A11/27

Interpretation by BMR Basin Studies Group and the authors.

Fig 20 TOTAL Mowla No 1

Scale: 10mm = 50m

AGE	UNIT	GRAPHIC LOG	DEPTH	THICKNESS	LITHOLOGY	DATING
LATE JURASSIC	JARLEMAI SILTSTONE		118	113	Mudstone, siltstone	* 3 cuttings samples,
	ALEXANDER FMN ?		158	40	Medium to coarse Sandstone, mudstone, some coal. Lower boundary uncertain.	* Micropal. and Palynology,
	WALLAL SANDSTONE		274	116	Medium to coarse grained Sandstone, with some mudstone and common coal.	Oxfordian or * Kimmeridgian
LATE CARBONIFEROUS OR EARLY PERMIAN	BETTY FORMATION		379 417 473	199	Interbedded mudstone and Sandstone to 379m, then conglomeratic sandstone and Siltstone to 417m, then dolomitic siltstone and fine sandstone. This unit is tentatively assigned to the Grant Group, but it may be older	* 4 cuttings samples, Palynology. * Late Carboniferous or Early * Permian *
MIDDLE TO LATE DEVONIAN	REEF DEPOSITS		762	289	Calcareous dolomite, Shale	Palynology, Conodonts. ? Middle or Late Devonian *

Record 1978/8

E51/A11/28

Interpretation by the authors and BMR Basin Studies Group. Jurassic dating by Backhouse (written communication), Carboniferous or Permian dating by Kemp (written communication).

Fig 21 MYALLS BORE

Scale : 10mm = 20m

AGE		UNIT	GRAPHIC LOG	DEPTH	THICKNESS	LITHOLOGY *	DATING
TRIASSIC	EARLY TO MIDDLE TRIASSIC	ERSKINE SANDSTONE		269	269	Micaceous silty very fine grained sandstone with beds of siltstone and claystone	microfauna probable Early Triassic
	SCYTHIAN	BLINA SHALE		322	53	Siltstone, mudstone	Macrofossils Early Triassic

Record 1978/8 E51/A7/18

* Based on driller's log and cores. Interpretation by Playford (1957)

Fig 22 AFO Myroodah No 1

Scale: 10mm = 100m

AGE	UNIT	GRAPHIC LOG	DEPTH	THICKNESS	LITHOLOGY	DATING
PERMIAN – ARTINSKIAN TO ?TATARIAN	LIVERINGA GROUP		434	431	Sandstone, shale, siltstone.	
PERMIAN – ARTINSKIAN	NOONKANBAH FORMATION		828	394	Shale, minor siltstone and Sandstone	
PERMIAN – ?	POOLE SANDSTONE		1073 1151	323	Sandstone with some shale to 1073m (?Tuckfield Mbr.), then Sandstone and shale (?Nura Nura Mbr.)	
PERMIAN – SAKMARIAN	CAROLYN FMN		? 1390	239	Sandstone, minor shale	
PERMIAN – SAKMARIAN	WINIFRED FMN		? 1635	245	Sandstone, siltstone, shale Boundaries uncertain	
LATE CARBONIFEROUS TO EARLY PERMIAN	BETTY FMN		1829	194	Sandstone, minor shale	

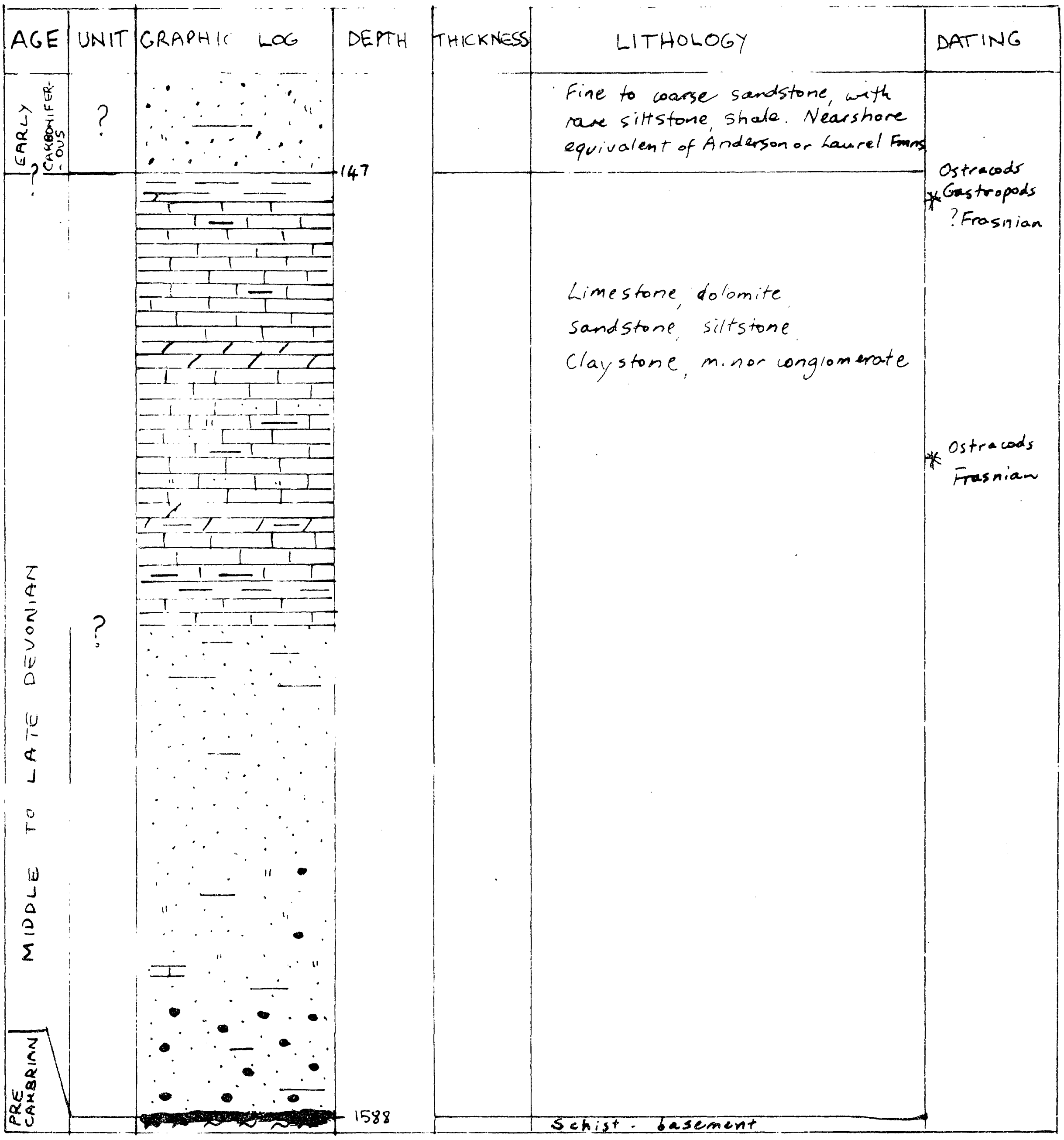
Record 1978/8

E51/A11/29

Interpretation by BMR Basin Studies Group and the authors

Fig 23 LENNARD Napier No 2

Scale: 10mm = 100m

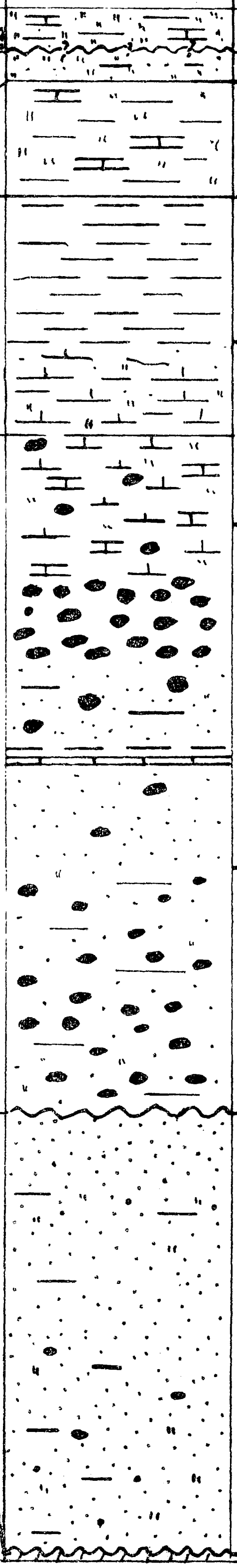


Record 1978/8 E51/A7/19

Interpretation by BMR Basin Studies Group, Druce & Radke (in prep.), and the authors

Fig 24. LENNARD Napier No 5

Scale : 10 mm = 80m



AGE	UNIT	DEPTH	THICKNESS	LITHOLOGY	DATING
LATE DEVONIAN TO EARLY CARBONIFEROUS	ANDERSON FMN	49	45	Siltstone, shale, limestone, sandstone.	
	YELLOW DRUM SST	77	28	Siltstone, Shale, sandstone.	
	GUMHOLE FMN	198	121	Fossiliferous shale, limestone, and siltstone	
	NAPIER FMN	358 361	263	Claystone to 358m then marl, with interbedded shale, siltstone, and sandstone Lower boundary uncertain	
	? VAN EMERICK CONGLOMERATE	555 918 1190	719	Marl, arkose, limestone, Shale, siltstone. Limestone conglomerates to 918m, then conglomerates with 'hard rock' clasts. Gypsum bed at 555m	ostracods * Famennian
EARLY TO MIDDLE DEVONIAN	POULTON FORMATION	1649	469	Sandstone, siltstone, shale, in part pebbly	
PRE-CAMBRIAN	LAMBOO COMPLEX	1657	8	Granite gneiss	

Record 1978/8

E51/A7/20

Interpretation by BMR Basin Studies Group, Druce + Radke (in prep.), and the authors.

Fig 25 AFO Nerrima No 1

Scale : 10mm = 120m

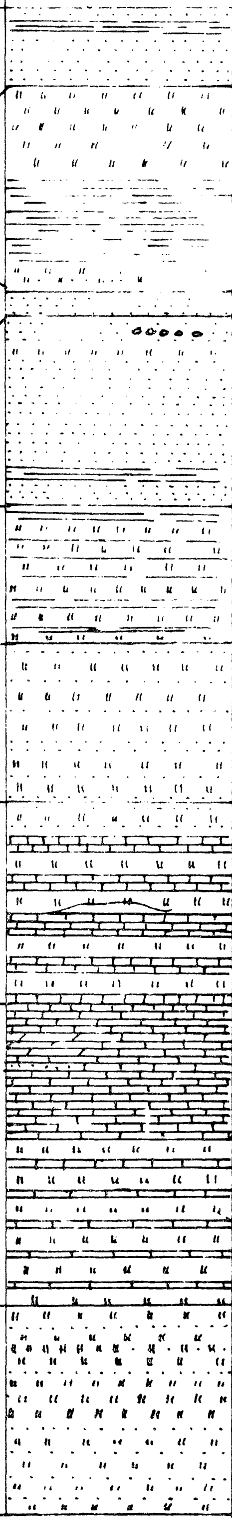
AGE		UNIT	GRAPHIC LOG	DEPTH	THICKNESS	LITHOLOGY	DATING
EARLY PERMIAN	ARTINSKIAN	NOONKANBAH FORMATION		69 120 244 259 308	294	Shale, siltstone, minor sandstone. BMR Basin Studies Group interpret Fitzroy Lamproite at 69-120m and 244-259m	
		POOLE SANDSTONE		579 658	350	Sandstone, some siltstone, shale to 579 m (Tuckfield Mbr.), then siltstone with some shale and sandstone (Nura Nura mbr.).	
	SAKMARIAN	CAROLYN FORMATION		843	185	Fine to medium grained sandstone, siltstone, shale	
		WINNIFRED FMN		962	119	Shale, siltstone, sandstone	
LATE CARBONIFEROUS (?) TO EARLY PERMIAN		BETTY FORMATION		2441	1479	Fine to medium grained sandstone, siltstone, shale	
[redacted]		ANDERSON FMN		2765	234	Very fine to medium sandstone, shale.	

Interpretation by BMR Basin Studies Group and the authors

Log of FKO Nerrima No 1 is difficult to interpret, but it appears to have intersected the same formations as above at similar depths. It bottomed in the Betty Formation at 1302m.

Fig 26 AFO Sisters No. 1

Scale :- 10mm = 150m



AGE	UNIT	DEPTH (m)	THICKNESS (m)	LITHOLOGY	DATING
PERMIAN	LIVERINGA GROUP	158	158	Sandstone, quartzose, fine to coarse, subangular to subrounded grains; Shale, silty, micaceous, black, poorly laminated.	
	NOONKANBAH FORMATION	568	410	Siltstone, black, poorly laminated, micaceous, slightly sandy Shale: grey, black, micaceous, laminated Interbeds, shale, siltstone and fine, calcareous sandstone.	
	Poole Sst.	619	51	Sandstone, fine, well sorted.	
	CAROLYN FORMATION	985	366	Sandstone, fine to medium, well sorted, micaceous, minor conglomerate, and siltstone, poorly bedded. Interbed sandstone and shale, grey	
	WINIFRED FM	1263	278	Interbedded Shale, siltstone, sandy siltstone and minor fine sandstone.	
LATE CARBONIFEROUS EARLY PERMIAN	BETTY FORMATION	1580	317	Interbedded sandstone, fine to coarse, subangular to subrounded, and siltstone, grey, micaceous, sandy, pyritic	
EARLY CARBONIFEROUS	LAUREL FORMATION	1975	395	Interbedded sandstone, medium, mi. and siltstone, light brown, micaceous; minor microcrystalline limestone. Interbedded grey, microcrystalline, fossiliferous limestone and calcareous siltstone; minor silty sandstone.	
LATE DEVONIAN	LULUIGUI FORMATION	2576	601	Limestone, grey-brown, crystalline, hard, silty, pyritic, fossiliferous; minor fissile siltstone, and fine sandstone. Interbedded limestone, grey, soft, silty fossiliferous and siltstone, grey, fissile, carbonaceous, micaceous, pyritic	
	CLANMEYER SILTSTONE	2996	420	Siltstone, grey, fissile, micaceous, carbonaceous, fossiliferous, minor interbeds of sandstone and limestone. Interbeds, siltstone, dark grey, fissile, and sandstone, grey, fine-grained, silty, micaceous, rare fossils	

Record 1978/8 E51/A7/21

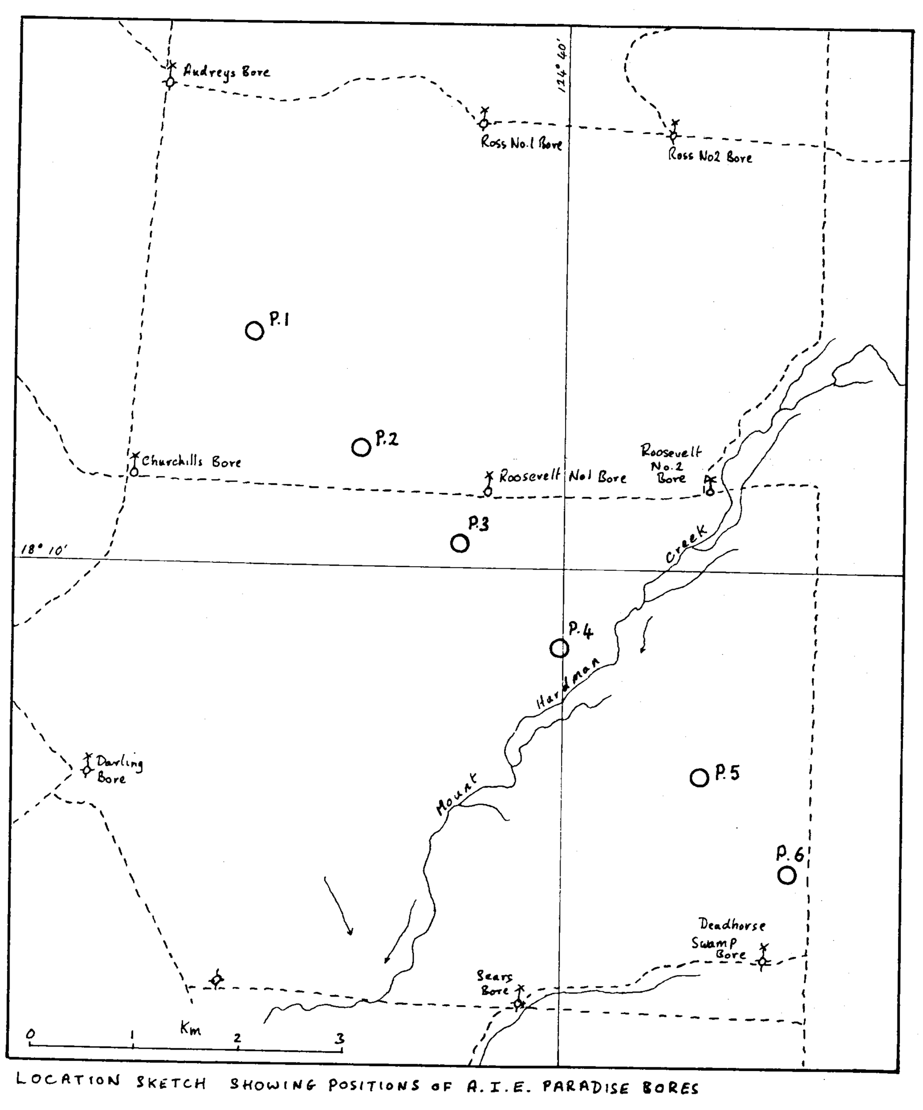
Interpretation by BMR Basin Study Group.

ENCLOSURE NO. 1

AUSTRALIAN INLAND EXPLORATION PARADISE BOREHOLES
COMPOSITE LOG OF LIVERINGA GROUP

REFERENCE

- Sandstone
- Mudstone
- Conglomerate
- Coal
- Ripples
- Large-scale cross-bedding
- Calcareous
- end of section
- Mudcracks
- Burrows
- Bioturbated
- Graded bedding
- M Micaceous
- Fossil roots
- Fossil leaves
- Marine macrofossils
- USA Palynology sampling point with palynological zone



LOCATION SKETCH SHOWING POSITIONS OF A.I.E. PARADISE BORES

ACKNOWLEDGEMENTS

Bores drilled by; Australian Inland Exploration in 1971 (continuous coreholes)

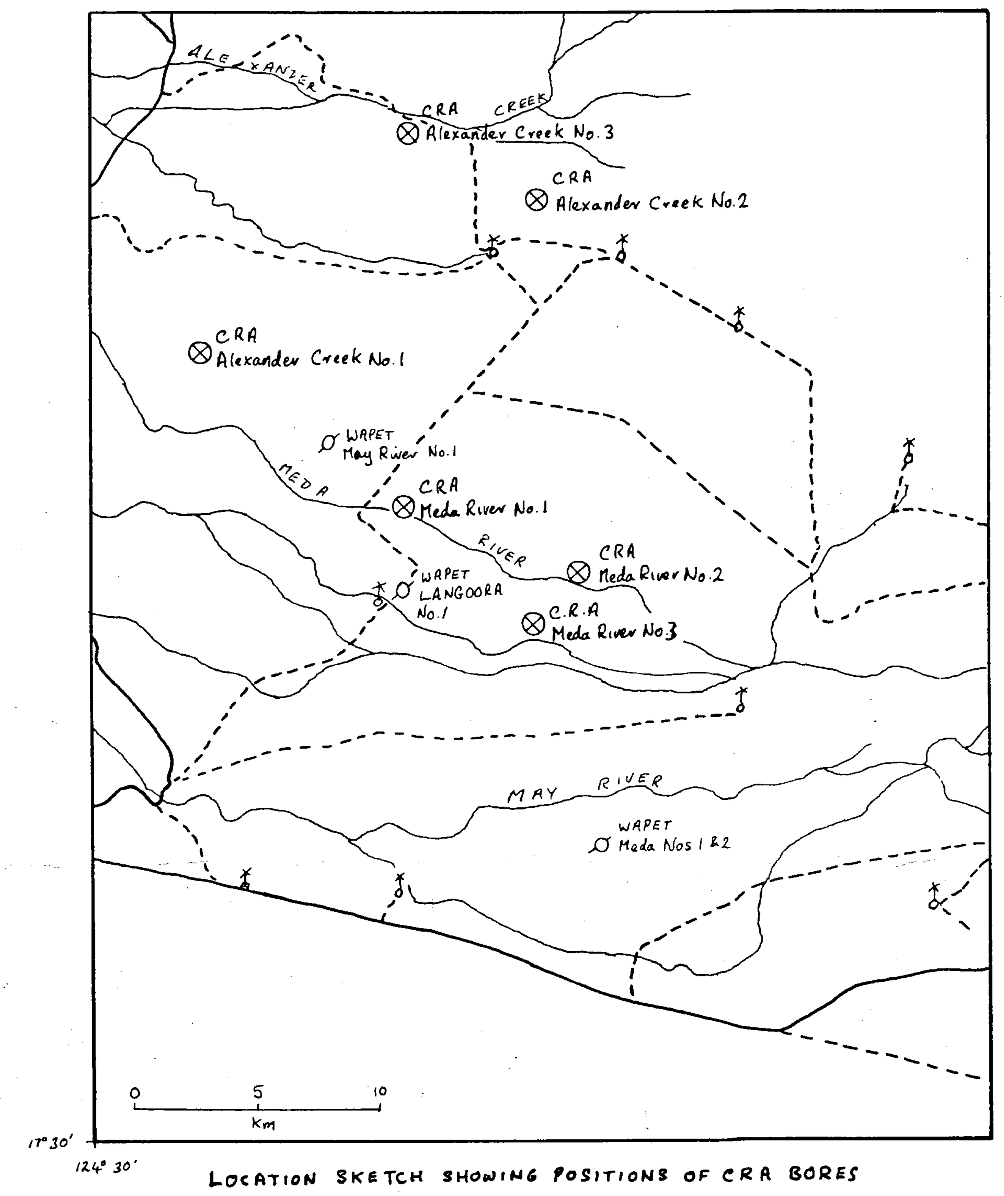
Lithological logs by; Esso in 1974 (Galloway & Howell, 1975).

Electric logs by; Australian Inland Exploration and Esso.

Palynology by; R. Paten and P. Price of Mines Administration Pty Ltd (pers. comm) and R. Helby for Esso (in Galloway & Howell, 1975).

Identifications and correlations by; Galloway & Howell (1975) and present authors

ENCLOSURE NO. 2



LOCATION SKETCH SHOWING POSITIONS OF CRA BORES

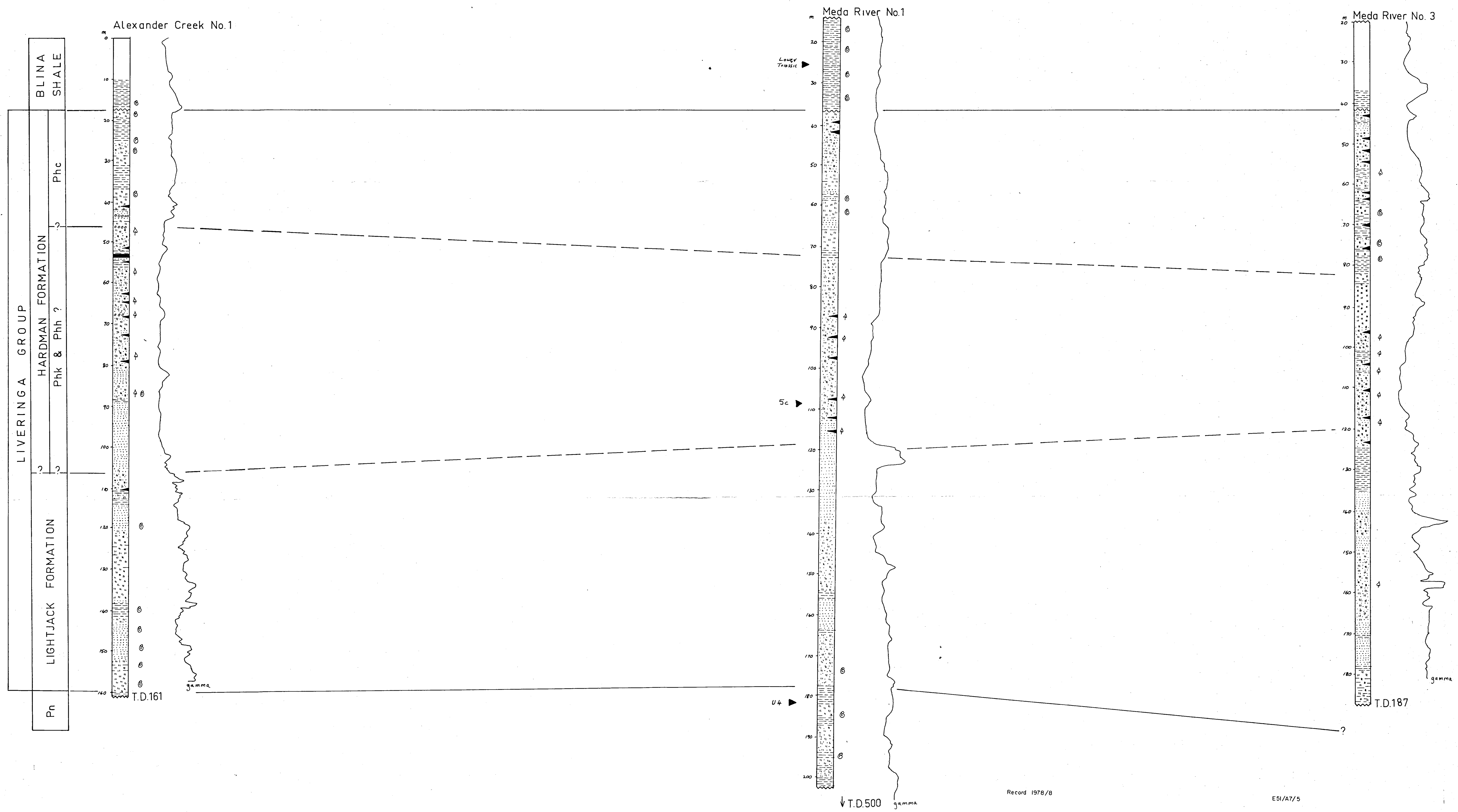
CONZINC RIOTINTO OF AUSTRALIA ALEXANDER CREEK & MEDA RIVER BORES
CORRELATION OF LIVERINGA GROUP

REFERENCE

- Sandstone
- Siltstone
- Shale
- Conglomerate
- Bed of coal / Trace of coal
- Marine fossils
- Plant fossils
- 5c ▶ Palynological sample and zone number

ACKNOWLEDGEMENTS

Bores drilled and logged by; CRA in 1973.
Palynology by; P. Price (in Quinton, 1974).
Identifications and correlations by; Quinton (1976) and present authors.

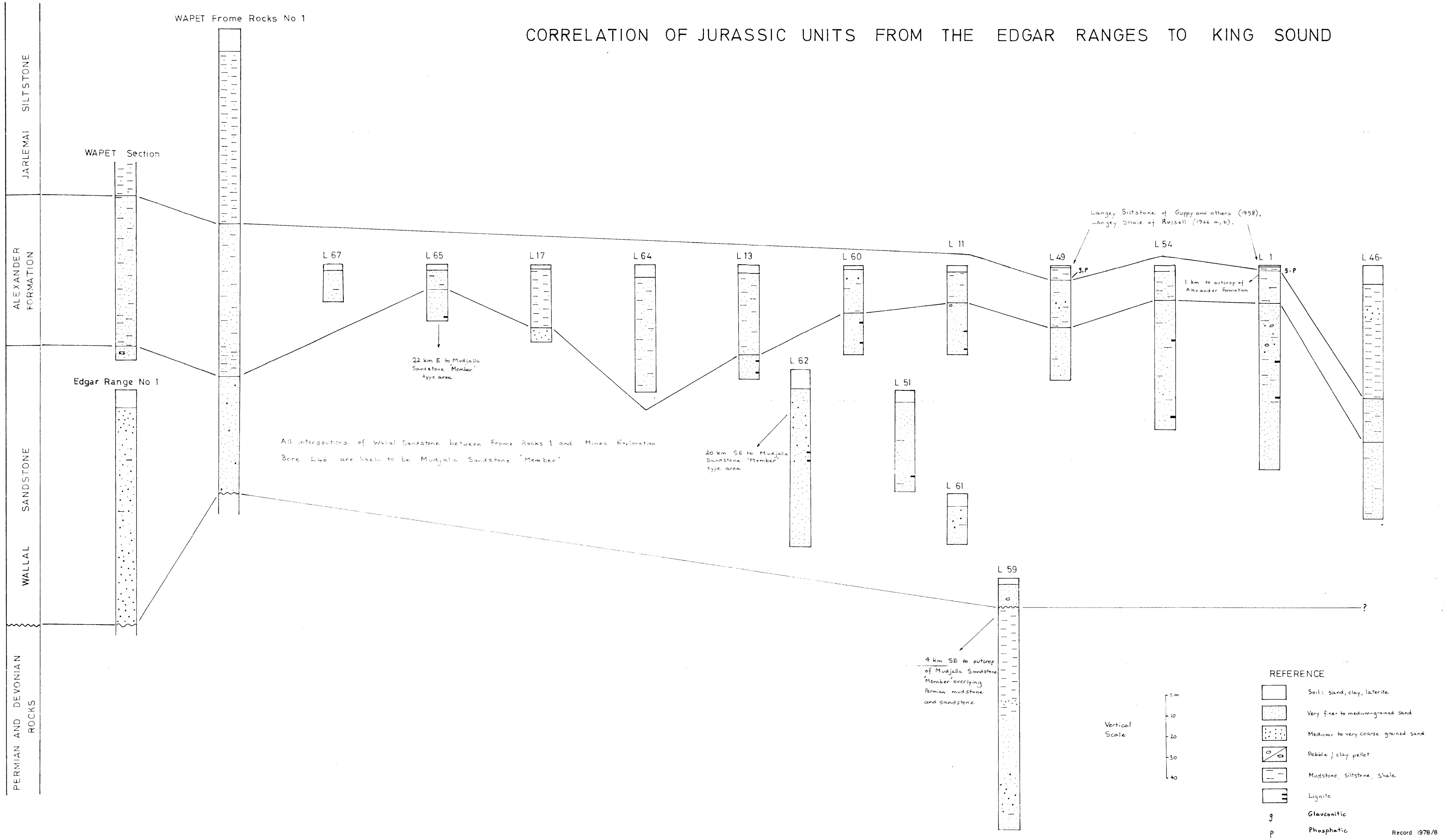


Record 1978/8

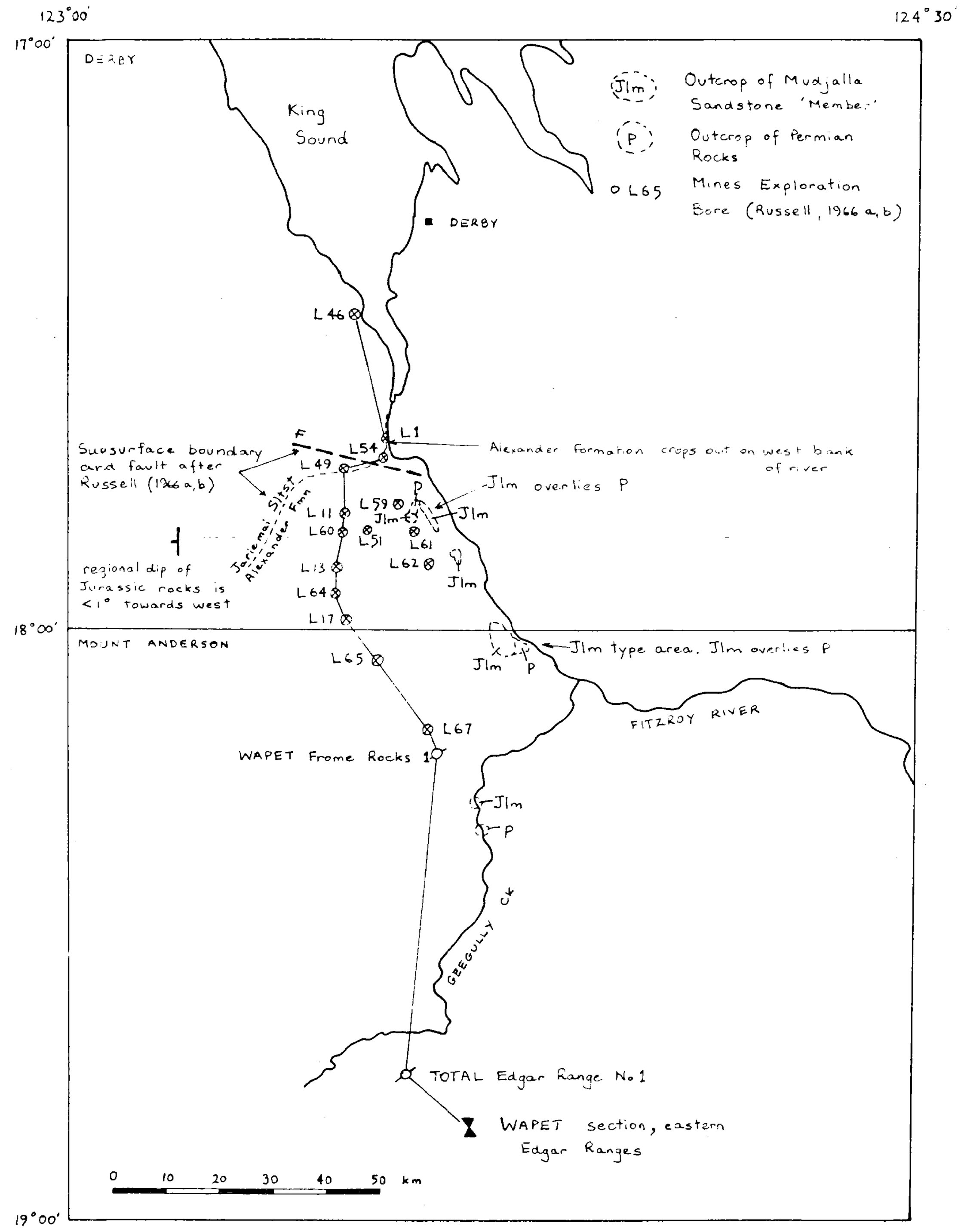
E51/A7/5

ENCLOSURE NO 3

CORRELATION OF JURASSIC UNITS FROM THE EDGAR RANGES TO KING SOUND



Record 1978/8



LOCATION SKETCH SHOWING POSITIONS OF BORES AND SECTION

E51/A/31

DERBY
WESTERN AUSTRALIA

AUSTRALIA 1:250,000 GEOLOGICAL SERIES

SHEET SE 51-7

Reference

- Geological boundary
- Facies change
- Fault
- Fault, showing relative horizontal movement
- Fault (D,U indicate relative movement down, up)

Where location of boundaries, folds and faults is approximate, line is broken; where inferred, queried; where concealed, boundaries and folds are dotted, faults are shown by short dashes

- Strike and dip of strata
- Strike and dip of strata, dip not measured
- Dip < 15° } airphoto interpretation
- Trend line } airphoto interpretation
- Lineament } airphoto interpretation

- Macrofossil locality
- Plant fossil locality
- Fossil wood locality

Petroleum Exploration Wells

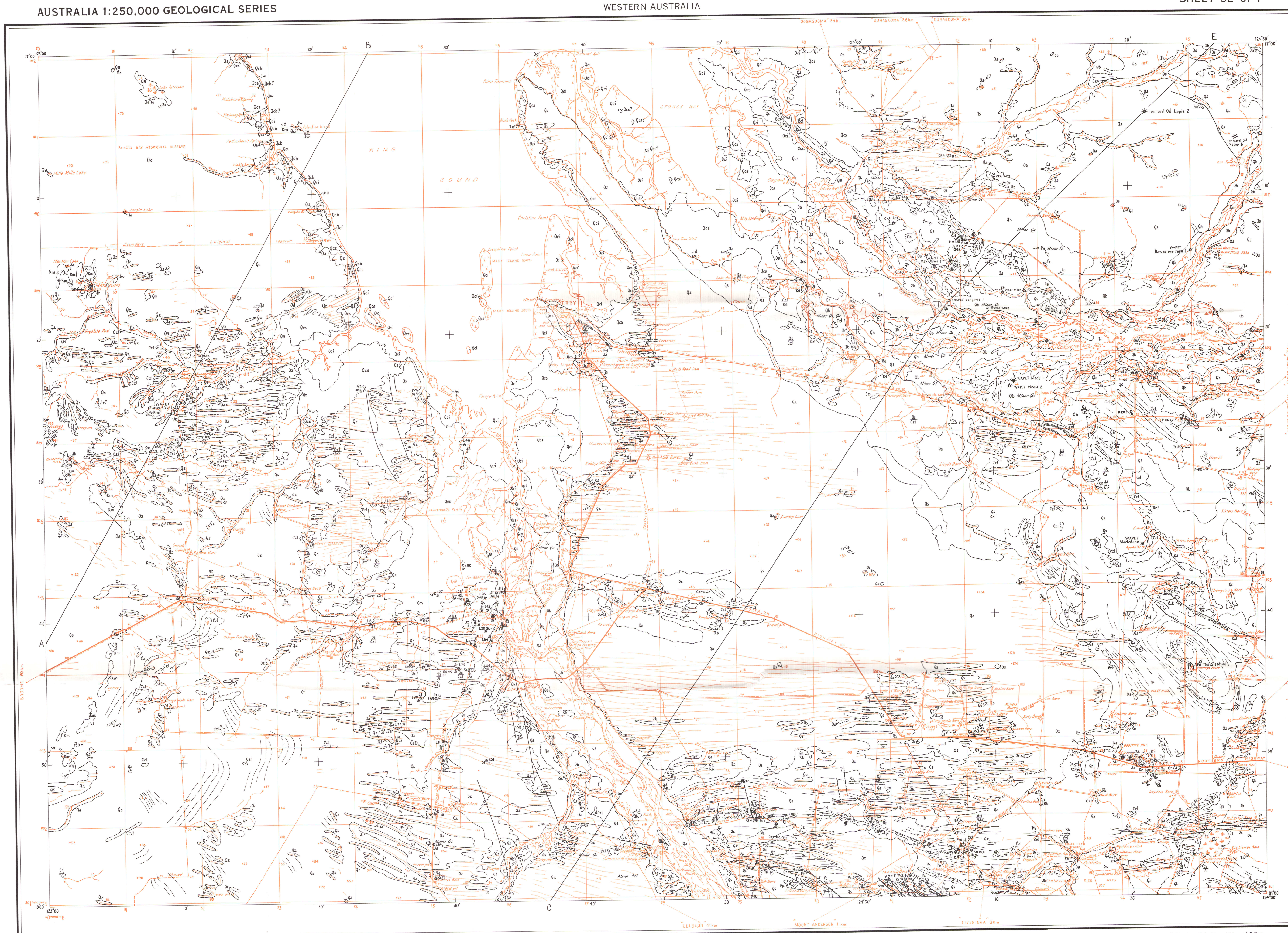
- Well-dry, abandoned
- Well with show of oil-abandoned
- Well with show of gas-abandoned
- Well with show of oil and gas-abandoned
- St Stratigraphic hole

CRA-AC - Conzinc Riotinto Australia - Alexander Creek
CRA-MR - Conzinc Riotinto Australia - May River
P-KH - Premier Mining - Kimberley Homestead
P-KD Premier Mining - Kimberley Downs
P-S Premier Mining - Savage
P-N Premier Mining - Nickels
P-H Premier Mining - Hunters
P-M Premier Mining - Meda
P-L Premier Mining - Liveringa
P-G Premier Mining - Goanna
T Theiss Bros Pty Ltd
L Mines Exploration Pty Ltd

- Bore
- Bore, abandoned
- Bore-salinity < 1500 ppm
- Bore-salinity 1500-2500 ppm
- Bore-salinity 2500-10 000 ppm
- Bore-salinity > 10 000 ppm
- Artesian bore, flowing
- Sub-artesian bore
- Well
- Windpump
- pe Equipped with pump engine
- T Water tank
- E Earth tank

- WH Waterhole
- Spring
- Swamp
- Mangroves

- Sand dunes
- Escarpment
- Levee or bank
- Quarry
- Gravel pit
- Highway
- Secondary road
- Minor road
- Vehicle track
- Fence
- Aboriginal reserve boundary
- Telephone line
- Landing ground
- "Kimberley Downs" Homestead
- Building
- Yd Yard
- Built up area
- Trigonometrical station
- •50 Elevation in metres, accurate
- •76 Elevation in metres, approximate
- abd Abandoned
- pa Position approximate

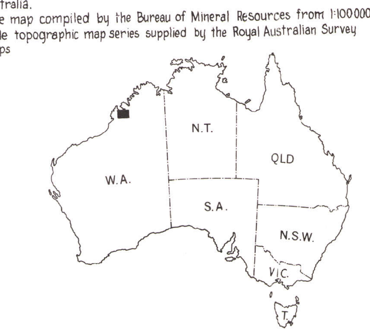


Reference

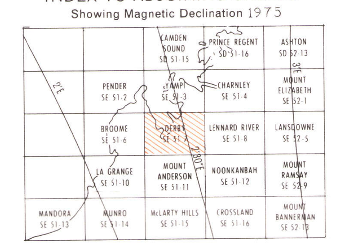
Era	Age	Unit	Symbol	Description
CAINOZOIC	QUATERNARY		Qa	Sand, silt, clay; minor gravel: alluvial and lacustrine
			Qs	Sand, silt; minor gravel: mixed alluvial and aeolian
			Qz	Red sand, fine to medium; minor silt: aeolian
			Qg	Gilgai soil
			Qb	Clay and silt: black soil
			Qcb	Quartzose sand, shelly in places: beach ridge
			Qcs	Clay, silt, sand; minor salt: supratidal mud flat deposits
			Qci	Silty clay, black organic clay; minor salt: tidal flat and mangrove swamp
			Czl	Laterite; pisolitic or massive: pedogenic
			Czk	Calcrete; minor chalcedony: evaporitic, pedogenic
	MESOZOIC OR TERTIARY	Fitzroy Lamproite	fv	Leucite lamproite
MESOZOIC	EARLY CRETACEOUS	Melligo Sandstone	Km	Sandstone, fine to medium, well-sorted, laminated to thin-bedded; upper part silicified: beach
	LATE JURASSIC TO EARLY CRETACEOUS	Jowlaenga Formation	Jw	Sandstone, fine to medium, well-sorted; mudstone interbeds; cross-bedded, bioturbated; minor conglomerate; fossiliferous: shallow marine
		Meda Formation	Jd	Sandstone, fine to coarse, granule to pebble conglomerate; poorly sorted; cross-bedded, ripple-marked: fluvial
	LATE JURASSIC	Jarlemai Siltstone	Jr	Mudstone, massive, bioturbated, sandy; glauconitic, phosphatic; minor limestone; fossiliferous: deep water marine
		Alexander Formation	Ja	Sandstone, fine to medium; interbedded mudstone; laminated to thin-bedded, lenticular bedding; ripple-marked cross-bedded; bioturbated; minor conglomerate lenses; fossiliferous: shallow water marine
	EARLY? TO LATE JURASSIC	Wallal Sandstone	Jl	Sandstone; minor siltstone, conglomerate, lignite *
		Mudjalla Sandstone Member†	Jlm	Sandstone, medium to coarse, poorly sorted, cross-bedded; siltstone, very fine sandstone, planar-bedded, ripple-marked: fluvial
	EARLY TO MIDDLE TRIASSIC	Erskine Sandstone	Re	Sandstone, very fine to fine; laminated to thin-bedded, cross-bedded, ripple-marks; minor clay pellet conglomerate; mudstone, plant fossils: deltaic
	EARLY TRIASSIC	Blina Shale	Rb	Mudstone, sandy mudstone, laminated to thin-bedded, ripple-marked, burrowed; minor fine sandstone; fossiliferous: brackish water
PALAEOZOIC	LATE PERMIAN	Liveringa Group	Pl	Sandstone, mudstone
		Hardman Formation	Ph	Sandstone, mudstone interbedded; thin-bedded
		Cherrabun Member	Phc	Mudstone, calcareous, fossiliferous; sandstone, cross-bedded; minor limestone: regressive marine
		Hicks Range Sandstone Member	Phh	Sandstone, fine to medium; thin-bedded, ripple-marked, cross-bedded, bioturbated; minor interbedded mudstone; plant fossils: lagoonal-fluviatile
		Kirkby Range Member	Phk	Mudstone, fine sandstone; calcareous, laminated to thin-bedded, ripple-marked; minor conglomerate lenses; cross-bedded in upper part; fossiliferous: regressive marine *
	EARLY TO LATE PERMIAN	Lightjack Formation	Pj	Mudstone, fine sandstone interbedded; clay pellet conglomerate; laminated to thin-bedded; ripple-marked, fossiliferous, bioturbated; medium sandstone, well-sorted, thin-bedded, plant fossils: regressive marine
	EARLY PERMIAN	Noonkanbah Formation	Pn	Mudstone, calcareous, micaceous; limestone, fine sandstone interbeds; minor granule conglomerate lenses; fossiliferous: marine
		Poole Sandstone	Pp	Sandstone, mudstone
		Tuckfield Member	Ppt	Sandstone, very fine to fine; minor mudstone; thin-bedded, ripple-marked, clay pellet conglomerate lenses, cross-bedded, flaser-bedded, plant fossils: lagoonal?
		Nura Nura Member	Ppn	Sandstone, fine; mudstone; thin-bedded, ripple-marked, wavy and flaser bedding, bioturbated, fossiliferous: marine
		Grant Group	Pg	Sandstone, mudstone; minor conglomerate *
		Millajiddee Member	Pcm	Sandstone, medium to fine; minor mudstone; ripple-marked, cross-bedded; minor flaser bedding: regressive marine
		Wye Worry Member	Pcw	Sandstone, fine to medium, mudstone, calcareous; facetted and striated dropstones; poorly bedded; minor conglomerate lenses: glacial marine
		Carolyn Formation	Pc	Sandstone, fine to coarse; massive to poorly bedded, cross-bedded, scour and fill structures; minor conglomerate
		Winifred Formation	Pw	Shale, carbonaceous, pyritic; minor siltstone, fine sandstone *
	LATE CARBONIFEROUS TO EARLY PERMIAN	Betty Formation	Pb	Sandstone, very fine to coarse; minor conglomerate *
	EARLY CARBONIFEROUS	Anderson Formation	Ca	Sandstone, siltstone, shale, minor limestone, dolomite, anhydrite *
	LATE DEVONIAN TO EARLY CARBONIFEROUS	Fairfield Group	DCf	Limestone, shale, siltstone; minor dolomite, sandstone *
		Laurel Formation	Cll	Limestone, shale, siltstone; sandstone: shallow marine *
		Yellow Drum Sandstone	Duy	Sandstone, calcareous; dolomite; minor shale, siltstone, limestone: fluviatile to intertidal *
	LATE DEVONIAN	Gumhole Formation	Dug	Limestone, siltstone, shale, sandstone; minor dolomite: marine *
	LATE DEVONIAN		D	Limestone, dolomite, siltstone, shale, fine sandstone: reef complex *
		Luluigui Formation	Dl	Interbedded siltstone, shale, limestone, fine sandstone *
		Clanmeyer Siltstone	Dc	Siltstone, shale; minor limestone *
		Babrongan Beds	Db	Shale, siltstone; partly calcareous; minor limestone and dolomite *
	MIDDLE DEVONIAN	Poulton Formation	Dp	Siltstone; minor shale, sandstone; traces of dolomite *
	EARLY DEVONIAN	Tandalgoo Red Beds	Dt	Sandstone, siltstone *
	LATE ORDOVICIAN? TO EARLY DEVONIAN	Carribuddy Formation	Sc	Siltstone, claystone, sandstone, dolomite, halite, anhydrite; minor limestone *
	ORDOVICIAN	Nita Formation	On	Dolomite, limestone, shale *
		Goldwyer Formation	Oo	Shale, limestone, dolomite, siltstone *
			O	Siltstone, sandstone, shale; minor dolomite, limestone *
PRECAMBRIAN		Undivided	p€	Igneous, metamorphic, sedimentary rocks *

* Not shown on face of Map
† Name not yet approved

Compiled by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development, in conjunction with the Geological Survey of Western Australia. Issued under the joint authority of the Minister for National Development and the Minister for Mines, Western Australia.
Base map compiled by the Bureau of Mineral Resources from 1:100 000 scale topographic map series supplied by the Royal Australian Survey Corps



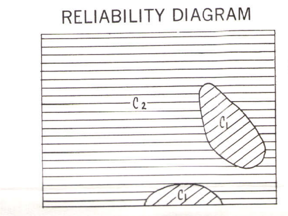
INDEX TO ADJOINING SHEETS
Showing Magnetic Declination 1975



Scale 1:250 000

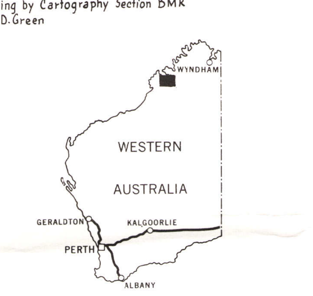
BROWN NUMBERED LINES ARE 10 000 METRE INTERVALS OF THE AUSTRALIAN MAP GRID ZONE 51
TRANSVERSE MERCATOR PROJECTION

RELIABILITY DIAGRAM

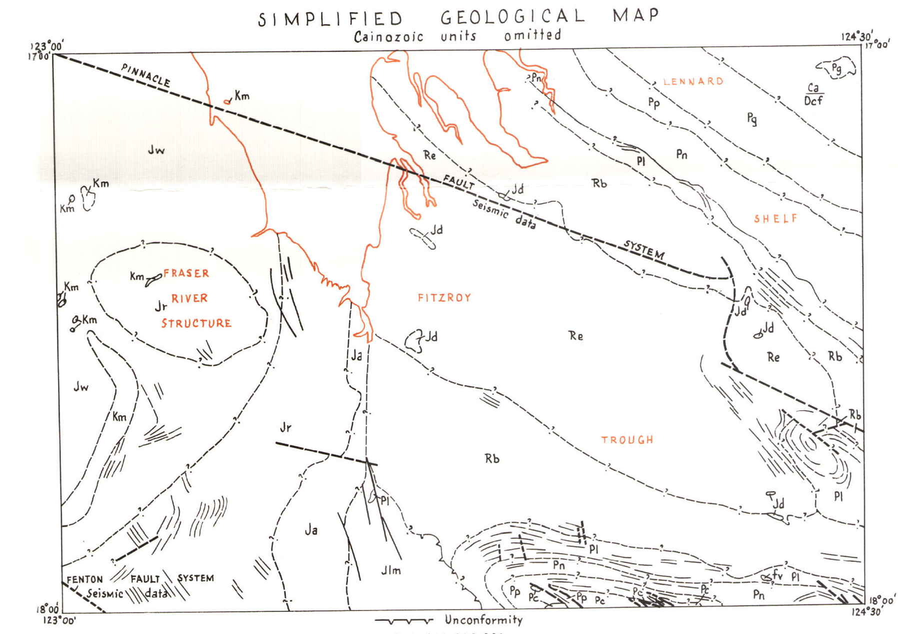


Geology C_1 General reconnaissance: many traverses, and airphoto interpretation
C_2 General reconnaissance: few traverses, mainly airphoto interpretation

Geology 1948-52 by D.J. Guppy, A.W. Lindner, J.H. Rattigan, J.N. Casey, A.B. Clarke
1949-50 by R.O. Brunnschweiler
1976 by R.R. Towner, D.L. Gibson BMR, R.W.A. Crowe GSWA
Compiled 1976 by R.R. Towner, D.L. Gibson, R.W.A. Crowe
Design and drafting by Cartography Section BMR
Drawn 1977 by D. Green

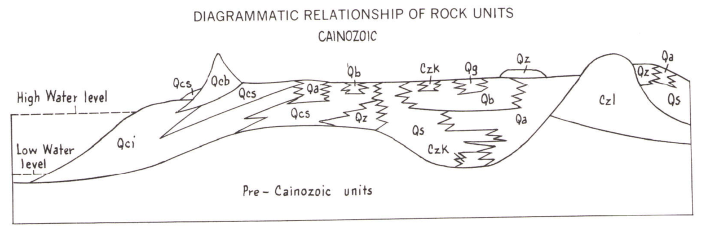


SIMPLIFIED GEOLOGICAL MAP
Cainozoic units omitted

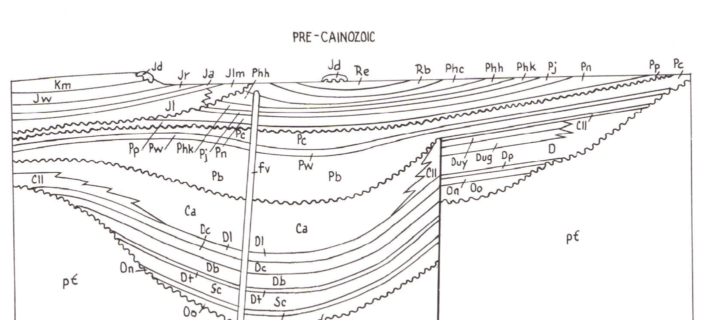


Unconformity
Scale 1:1 000 000

DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS
CAINOZOIC

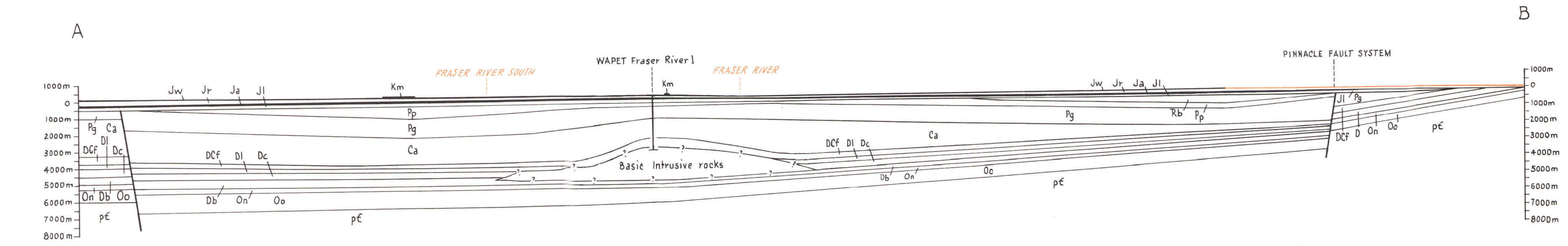


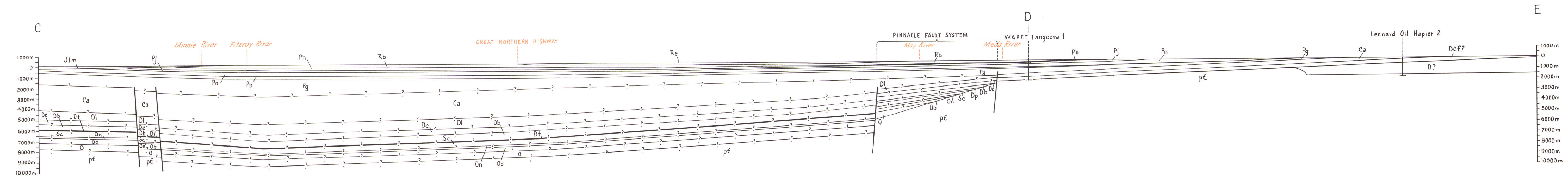
PRE-CAINOZOIC



Unconformity

Schematic Sections
Cainozoic sediments omitted
Scale: $\frac{V}{H} = 1$





DERBY
SHEET SE 51-7

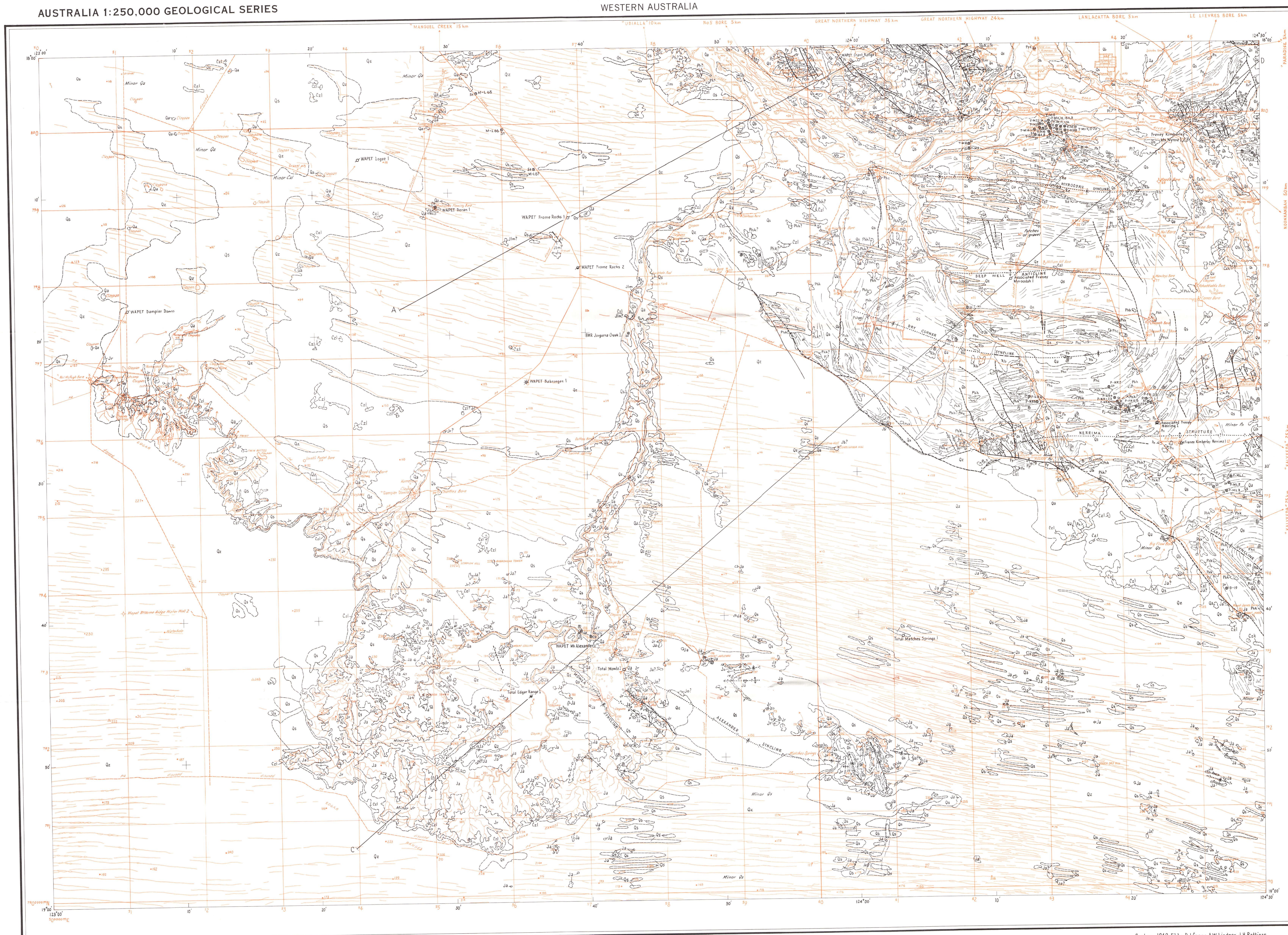
PRELIMINARY TO SECOND EDITION FEBRUARY 1978
SUBJECT TO AMENDMENT

MOUNT ANDERSON

WESTERN AUSTRALIA

AUSTRALIA 1:250 000 GEOLOGICAL SERIES

SHEET SE 51-11



Reference

- Geological boundary
- Facies change
- Anticline, showing plunge
- Syncline, showing plunge
- Fault
- Normal fault } Triangle indicates direction of dip
- High-angle reverse fault } Triangle indicates direction of dip
- Fault, inclined (70)
- Fault, showing relative horizontal movement
- Fault, (D, U indicate relative movement down, up)

Where location of boundaries, folds and faults is approximate, line is broken; where inferred, queried; where concealed, boundaries and folds are dotted, faults are shown by short dashes

- Strike and dip of strata (10)
- Strike and dip of strata, dip not measured
- Dip <5° } airphoto interpretation
- Dip 5°–15° } airphoto interpretation
- Trend line } airphoto interpretation
- Joint pattern } airphoto interpretation
- Lineament } airphoto interpretation

- Macrofossil locality
- Plant fossil locality
- Fossil wood locality
- Fossil vertebrate locality
- Palynomorph locality
- Type section locality

Petroleum Exploration Wells

- Well-dry, abandoned
- Well with show of oil-abandoned
- Well with show of gas - abandoned
- St: Stratigraphic hole
- CH: Core hole

T-M = Theiss - Myroodah
T-W = Theiss - Watson
P-NR = Premier Mining - Nerrima
P-FR = Premier Mining - Freney
P-ML = Premier Mining - McLarty
P-F = Premier Mining - Fitzroy
M-L = Mines Exploration - Langey
D = Dampier Mining

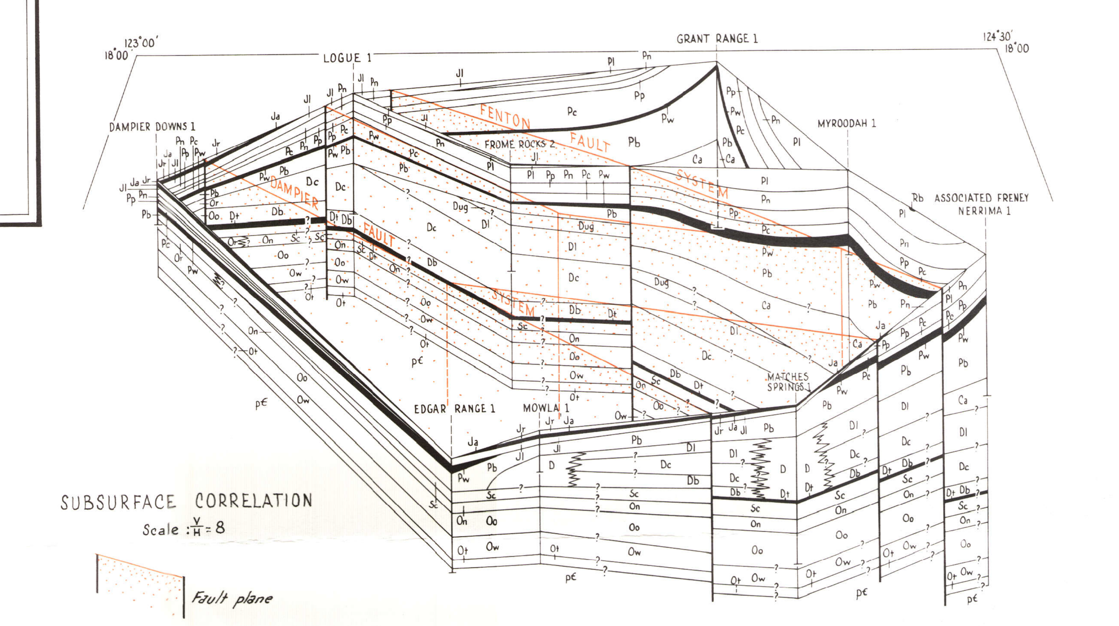
- Bore
- Bore, abandoned
- Bore-salinity < 1500 ppm
- Bore-salinity 1500-2500 ppm
- Bore-salinity 2500-10 000 ppm
- Artesian bore, flowing
- Well
- Windpump
- pe: Equipped with pump engine
- Well, abandoned
- T: Water tank
- E: Earth tank or dam
- WH: Waterhole
- Spring
- Swamp

- Sand dunes
- Escarpment
- Levee or bank
- Gravel pit
- Minor road
- Vehicle track
- Fence
- Landing ground
- "Dampier Downs": Homestead
- Building
- Yd: Yard
- 248: Trigonometrical station
- 52: Elevation in metres, accurate
- 65: Elevation in metres, approximate
- abd: Abandoned
- pa: Position approximate

Reference

Era	Age	Unit	Symbol	Description
CAINOZOIC	QUATERNARY		Qa	Sand, silt, clay; minor gravel: alluvial and lacustrine
			Qb	Clay, silt: black soil
			Qs	Sand, silt; minor gravel: mixed alluvial and aeolian
			Qz	Sand, fine to medium; minor silt: aeolian
		Warrimbah Conglomerate	Czh	Conglomerate, pebble and cobble; unconsolidated: fluvial
			Czk	Calcrete; minor chalcedony: pedogenic
			Czl	Laterite; pisolitic or massive: pedogenic
MESOZOIC			J	Undifferentiated Jurassic units *
	LATE JURASSIC TO EARLY CRETACEOUS?	Barbwire Sandstone	Jb	Sandstone, fine to coarse, conglomerate; minor mudstone; cross-bedded: fluvial
	LATE JURASSIC?	Mowla Sandstone	Jo	Sandstone, fine to coarse; minor mudstone; partly rippled, cross-bedded; some clay pellets, pebbles; basal conglomerate: deltaic
	LATE JURASSIC	Jarlemai Siltstone	Jr	Sandy mudstone with scattered granules, pebbles; bioturbated, massive; upper part mainly fine silty sandstone; glauconitic and partly phosphatic: marine
		Alexander Formation	Ja	Sandstone, fine to medium, mudstone; cross-bedded, rippled, bioturbated in part: shallow marine
	EARLY? TO LATE JURASSIC	Wallal Sandstone	Jl	Sandstone; minor siltstone, conglomerate, lignitic beds *
		Jurgurra Sandstone 'Member'†	Jlj	Sandstone, medium to coarse, cross-bedded, cross-laminated; minor mudstone, clay pellet conglomerate: aeolian
		Mudjalla Sandstone 'Member'†	Jlm	Sandstone, medium to coarse, cross-bedded; conglomerate lenses; minor siltstone; sandstone, very fine to medium, rippled: fluvial
	EARLY TO MIDDLE TRIASSIC	Erskine Sandstone	Re	Sandstone, very fine and fine, cross-bedded, rippled, laminated to thin-bedded; minor clay pellet conglomerate, mudstone: deltaic
	EARLY TRIASSIC	Blina Shale	Rb	Mudstone, sandy mudstone; minor very fine sandstone; rippled, burrowed, laminated to thin-bedded, pyritic, glauconitic; phosphatic bone beds near base: shallow restricted marine
		Millyit Sandstone	Rm	Sandstone, fine; minor mudstone; thin-bedded, cross-bedded, rippled, bioturbated; basal pebble conglomerate: continental
PALAEOZOIC	LATE PERMIAN	Liveringa Group	Pl	Sandstone, mudstone
		Hardman Formation	Ph	Sandstone, mudstone
		Cherrabun Member	Phc	Sandstone, fine to medium, cross-bedded in part; interbedded mudstone: marine
		Hicks Range Sandstone Member	Phh	Sandstone, fine to medium, mudstone; partly cross-bedded, bioturbated, rippled, thin-bedded, pebbly: lagoonal-fluvial
		Kirkby Range Member	Phk	Sandstone, fine, calcareous mudstone; partly cross-bedded, rippled; granule conglomerate lenses; fossiliferous: marine
	EARLY TO LATE PERMIAN	Lightjack Formation	Pj	Sandstone, fine and medium; partly cross-bedded, rippled; coal in upper part; fossiliferous: marine
	EARLY PERMIAN	Noonkanbah Formation	Pn	Mudstone, calcareous, pyritic; interbeds of limestone, sandstone, granule conglomerate; fossiliferous: marine
		Poole Sandstone	Pp	Sandstone, mudstone
		Tuckfield Member	Ppt	Sandstone, fine, thin-bedded, flaser-bedded, cross-bedded; interbedded mudstone; clay pellet conglomerate lenses: lagoonal?
		Nura Nura Member	Ppn	Sandstone, fine to medium, mudstone; partly cross-bedded, rippled; fine sandstone, well sorted, cross-bedded, at base: marine
		Grant Group	Pg	Sandstone, mudstone; minor conglomerate *
		Millajiddee Member	Pcm	Sandstone, medium; minor fine sandstone, mudstone; rippled, cross-bedded: marine
		Wye Worry Member	Pcw	Sandstone, fine to medium, mudstone; calcareous; rare facetted and striated dropstones: glacial
		Carolyn Formation	Pc	Sandstone, fine to coarse, poorly bedded, cross-bedded, scour and fill structures
		Winifred Formation	Pw	Shale, carbonaceous, pyritic; minor siltstone, fine sandstone *
	LATE CARBONIFEROUS TO EARLY PERMIAN	Betty Formation	Pb	Sandstone, very fine to coarse; minor conglomerate; Precambrian rock clasts may be glacial dropstones *
	CARBONIFEROUS	Anderson Formation	Ca	Sandstone, siltstone, shale; minor limestone, dolomite, anhydrite *
	DEVONIAN	Fairfield Group Gumhole Formation	Dug	Limestone, siltstone, shale, sandstone *
		Luluigui Formation	Dl	Siltstone, shale, limestone, fine sandstone *
		Clanmeyer Siltstone	Dc	Siltstone, shale; minor limestone *
		Babrongan Beds	Db	Shale, siltstone; partly calcareous; minor limestone and dolomite *
			D	Dolomite, dolomitic limestone, shale, fine sandstone: reef complex deposits *
		Tandalgoo Red Beds	Dt	Sandstone, shale; calcareous *
	LATE ORDOVICIAN? TO EARLY DEVONIAN		Sb	Breccia; dolomite fragments in fine dolomite matrix; minor quartz, anhydrite: salt dome caprock *
			Ss	Halite; minor dolomite, anhydrite, dolomite breccia: salt dome *
		Carribuddy Formation	Sc	Siltstone, claystone, sandstone, dolomite, halite, anhydrite, minor limestone *
	ORDOVICIAN	Roebuck Dolomite	Or	Dolomite; minor calcilutite *
		Nita Formation	On	Limestone; minor dolomite, shale *
		Goldwyer Formation	Oo	Shale, limestone, dolomite, siltstone *
		Willara Formation	Ow	Limestone; minor dolomite, shale, sandstone *
	ORDOVICIAN TO CAMBRIAN?	Nambeet Formation	Ot	Shale; minor limestone, sandstone *
PRECAMBRIAN			p€	Igneous, metamorphic, and sedimentary rocks *

† Name not yet approved * Not shown on face of Map



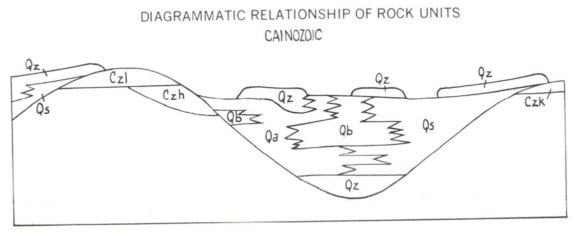
SUBSURFACE CORRELATION

Scale $\frac{V}{H} = 8$

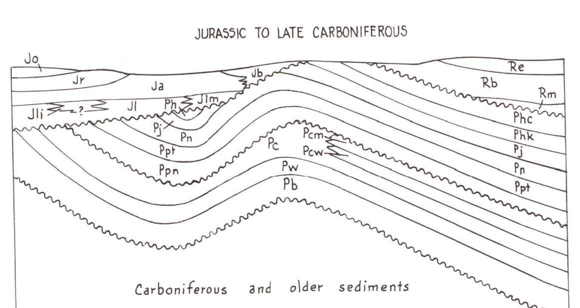
Fault plane

DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS

CAINOZOIC



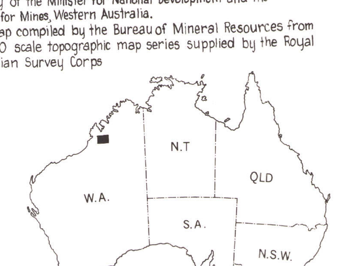
JURASSIC TO LATE CARBONIFEROUS



Carboniferous and older sediments

Unconformity

Compiled by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development, in conjunction with the Geological Survey of Western Australia. Issued under the joint authority of the Minister for National Development and the Minister for Mines, Western Australia.
Base map compiled by the Bureau of Mineral Resources from 1:100 000 scale topographic map series supplied by the Royal Australian Survey Corps



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Showing Magnetic Declination 1975

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	BROOME SE 51-6	DERBY SE 51-7	LENNARD RIVER SE 51-8	LANSDOWNE SE 52-5
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Scale 1:250 000

5 0 5 10 15 20 25 KILOMETRES

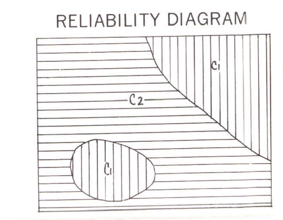
BROWN NUMBERED LINES ARE 10 000 METRE INTERVALS OF THE AUSTRALIAN MAP GRID ZONE 51
TRANSVERSE MERCATOR PROJECTION

Schematic Sections

Cainozoic sediments omitted

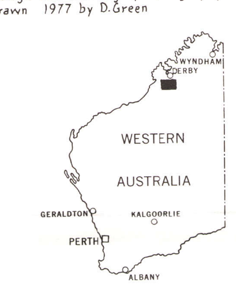
Scale: $\frac{V}{H} = 1$

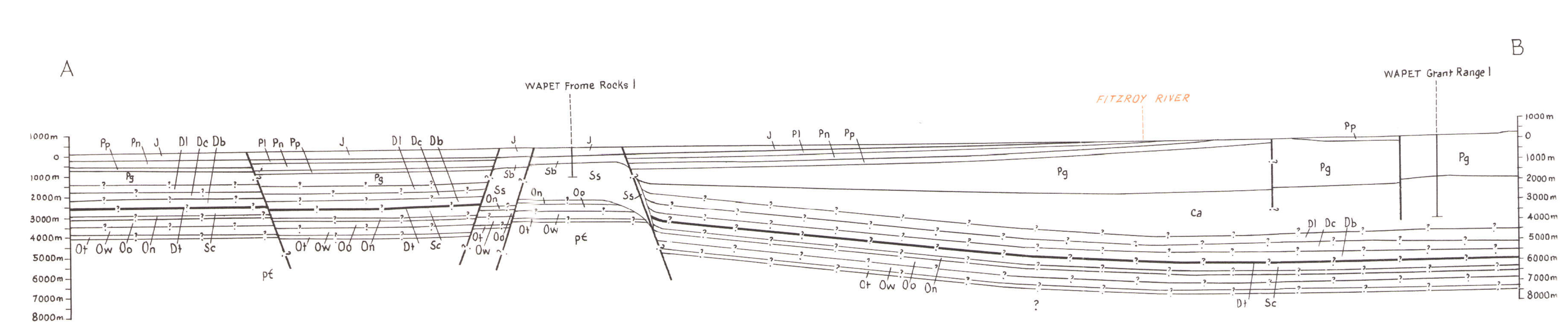
RELIABILITY DIAGRAM

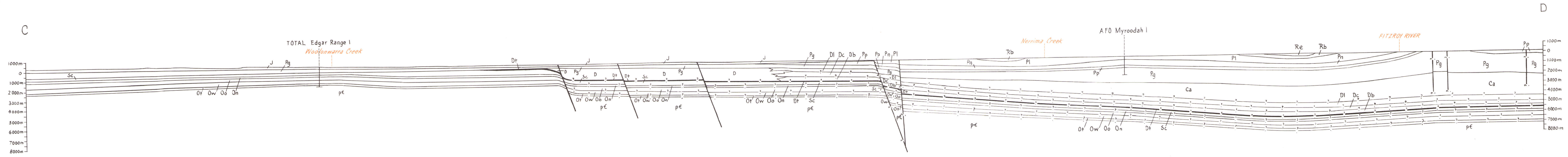


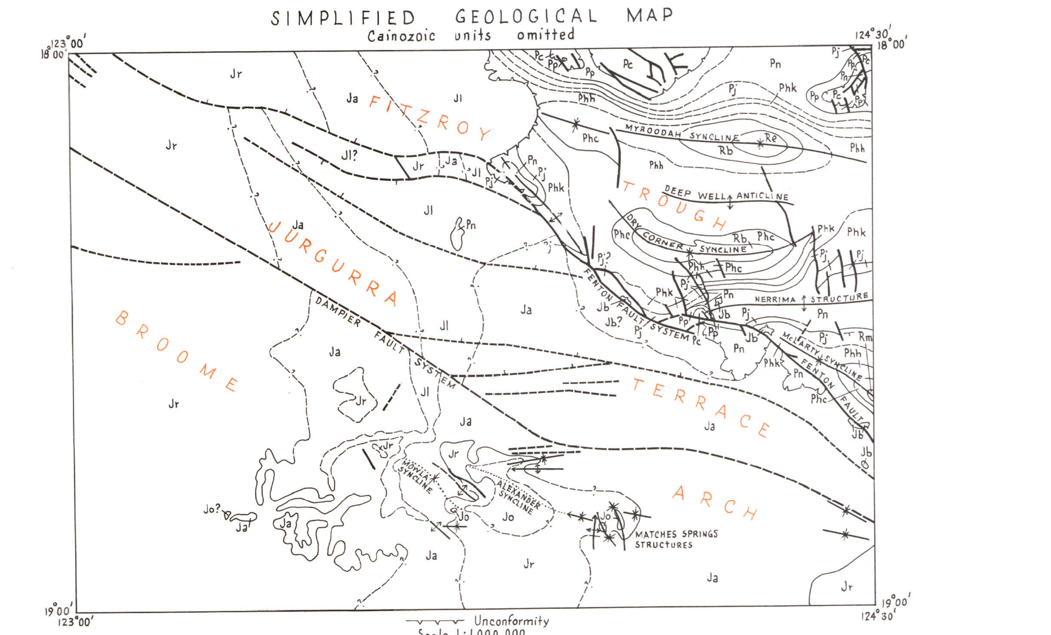
Geology C1 General reconnaissance: many traverses, and airphoto interpretation
C2 General reconnaissance: few traverses, mainly airphoto interpretation

Geology 1949-52 by D.J. Guppy, A.W. Lindner, J.H. Rattigan, J.N. Casey, R.O. Brunnschweiler BMR
1976 by R.W.A. Crowe GSWA, D.L. Gibson, R.R. Towner BMR
Compiled 1977 by D.L. Gibson, R.W.A. Crowe, R.R. Towner
Design and drafting by Cartography Section BMR
Drawn 1977 by D. Green









SIMPLIFIED GEOLOGICAL MAP

Cainozoic units omitted

Unconformity

Scale 1:1 000 000

MOUNT ANDERSON

SHEET SE 51-11

PRELIMINARY TO SECOND EDITION FEBRUARY 1978
SUBJECT TO AMENDMENT