1:250 000 GEOLOGICAL SERIES—EXPLANATORY NOTES

LAGRANGE

WESTERN AUSTRALIA

SHEET SE/51-10 INTERNATIONAL INDEX

DEPARTMENT OF RESOURCES & ENERGY
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

DEPARTMENT OF MINES, WESTERN AUSTRALIA
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COMPILED BY D. L. GIBSON

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Explanatory Notes on the Lagrange 1:250 000 Geological Sheet

Compiled by D. L. Gibson

The Lagrange 1:250 000 Sheet area lies in northern Western Australia between latitudes 18°S and 19°S, and longitudes 121°30'E and 123°E. The onshore part of the Sheet area contains scattered outcrops of Mesozoic rocks of the Canning Basin with a widespread cover of Cainozoic aeolian sand of the Great Sandy Desert. The Indian Ocean occupies the northwest third of the Sheet area.

Frazier Downs and Thangoo homesteads, Lagrange Mission, and a small pearling station at Port Smith are the only permanent centres of population. Cattle-grazing is confined mainly to coastal areas.

Access in the Sheet area is by the Great Northern Highway, which runs roughly parallel to and up to 23 km from the coast. Station roads and tracks provide reasonable access between the highway and coast, but, east of the highway, access is limited to petroleum exploration tracks, and a track leading to Dampier Downs station, in the adjoining Mount Anderson Sheet area. Light-plane landing strips service the homesteads and mission.

The climate is hot and seasonally wet. Average annual rainfall ranges from about 550 mm in the north to 400 mm in the south; most of this falls from December to March. Normal daily maximum and minimum temperatures are about 35° and 25°C in January, and 28° and 13°C in July. Average annual evaporation is about 2500 mm. All climate figures have been estimated from Bureau of Meteorology contour maps.

Vegetation of the dunes and sand sheet of the Great Sandy Desert is characterised by spinifex hummock grass, with scattered shrubs (*Acacia, Grevillea,* and *Hakea* predominate). Vegetation along the coastal strip is characterised by pindan, which is essentially a grassland wooded by a sparse upper layer of trees and a dense thicket-forming middle layer of phylloidal acacias (Beard, 1967). The latter layer is frequently destroyed by fire, but regenerates from seed. Supratidal mudflats are sparsely covered with halophytic shrubs and groundcover, and mangroves fringe bays and inlets.

History of investigations

The first explorer to pass through the Sheet area was Alexander Forrest in 1879; Fenton Hill, a geologist, was a member of his party (Feeken & others, 1970). Among the first recorded geological observations were those of Teichert (1939, 1941, 1942), who recognised Jurassic fossils from water-bores drilled at Broome, 4 km north of the Sheet area.

WAPET (West Australian Petroleum Pty Ltd) carried out geological surveys in the Sheet area in the early 1950s. The Sheet area was included in a Bureau of Mineral Resources (BMR) synopsis of the geology of the Canning Basin, which included a geological map at a scale of 20 miles to 1 inch (1:1 267 200), by Veevers & Wells (1961). In an appendix to this publication, J. M. Dickins (BMR) identified some of the fossils collected by WAPET.

The earliest geophysical survey in the Sheet area was a regional gravity traverse carried out along the Great Northern Highway by BMR in 1953 (Dooley, 1963);

this was followed by a regional aeromagnetic survey in 1954 (Quilty, 1960) and some detailed seismic work in the Lagrange Mission area in 1955 (Smith, 1960). The aeromagnetic survey indicated depth to basement of less than 3000 m in the Sheet area, and the seismic survey indicated sedimentary rocks possibly as thick as 2400 m. BMR also carried out several reconnaissance gravity surveys in and around the area in the period 1953–62; results of these are discussed by Flavelle & Goodspeed (1962) and Flavelle (1974).

WAPET carried out an aeromagnetic and several gravity and seismic surveys between 1955 and 1959 (WAPET 1956a, 1956c, 1958b, 1959, 1960), and drilled the petroleum exploration wells WAPET Roebuck Bay 1 (WAPET, 1956b) and WAPET Goldwyer 1 (WAPET, 1958a) concurrently with this early geophysical work. A show of free oil was encountered in Ordovician rocks in WAPET Goldwyer 1.

After the introduction of the Commonwealth Petroleum Search Subsidy Acts in 1959, copies of reports of geophysical and drilling projects which were entitled to subsidy were lodged with BMR and put on open file. The first of these in the Sheet area was the completion report for the wells WAPET Thangoo 1 and 1A (WAPET, 1961c), which encountered small amounts of free oil at several levels. Subsequent onshore geophysical surveys in the Sheet area (see below) delineated several structures too small to be shown on the simplified geology sketch on the accompanying map sheet; two were unsuccessfully tested by drilling the wells WAPET Parda 1 and WAPET Thangoo 2.

The Parda Seismic Survey (WAPET, 1964b) delineated a structure suitable as a petroleum trap, which was subsequently drilled by WAPET Parda 1 (WAPET, 1965a); minor oil stains and fluorescence were found in the Ordovician rocks in this well. The Marrin Seismic Project (WAPET, 1966a) showed that the regional dip in the northwest onshore part of the Sheet area is to the west. The Willara Hill Seismic Project (WAPET, 1966b) gave some information on the general structure of the southern part of the Sheet area. The Roebuck Seismic Survey (WAPET, 1966c) in the area between WAPET Goldwyer 1 and WAPET Roebuck Bay 1 wells delineated several structures thought to be favourable for hydrocarbon accumulation, but no drilling followed. The reflection seismic and magnetometer survey of the Lower Fitzroy Project (Gewerkschaft Elwerath Inc., 1966) extended into the northeast part of the Sheet area.

The Broome-Samphire Seismic Survey (WAPET, 1970a) provided regional reconnaissance control over the western half of the Sheet area. Following on from this, the North Broome Seismic Survey (WAPET, 1971) delineated two prospective structural anomalies south of WAPET Thangoo 1 and 1A, and the North Broome D-2 Seismic Survey (WAPET, 1972b) provided more detailed information on these features. The well WAPET Thangoo 2 (WAPET, 1973) was subsequently drilled on one of these anomalies, a faulted low-relief anticline; cores taken at several levels in the well showed fluorescence and gave instant cut (solvent staining).

Several offshore geophysical surveys have been carried out in and around the Sheet area (WAPET, 1965c, 1969, 1970b; BOCAL, 1968, 1969; Hematite Petroleum, 1972).

BMR carried out offshore geological reconnaissance (dredge sampling, seismic reflection, and seafloor photography) in 1967 (Jones, 1968, 1973), and a detailed offshore geophysical survey (seismic, gravity, and magnetics) in 1968 (Whitworth, 1969) in and around the Sheet area.

In 1973, BMR began a detailed study of the petroleum geology of the Canning Basin, the results of which are reported by Gorter & others (1979) and Forman & Wales (1981).

Several geophysical surveys have been carried out in the Sheet area since 1973. Most results are confidential, but data from offshore surveys which come under the Petroleum (Submerged Lands) Act are available at BMR and the Western Australian Department of Mines, generally five years after completion.

Aerial photographs and base maps. Vertical airphotos at a nominal scale of 1:85 000 (RC-9 series) were flown by the RAAF in 1967; 1:50 000 scale photos (K-17 series) were flown in 1949. The Royal Australian Survey Corps prepared a 1:250 000 topographic map in 1964 from the 1949 photos, and six 1:100 000 contoured topographic maps in 1971 from the 1967 photos.

Latest investigations. The map and these explanatory notes are based on fieldwork carried out by a combined BMR/GSWA (Geological Survey of Western Australia) team in 1977 as part of a project to map the entire Canning Basin at a scale of 1:250 000 (Towner & Gibson, 1980, 1983). Vehicle and helicopter traverses were made in the Sheet area during the survey.

PHYSIOGRAPHY

Most of the land in the Sheet area is made up of a gently undulating aeolian sand plain rising to over 200 m in the southeast (Fig. 1). Small rocky oucrops are

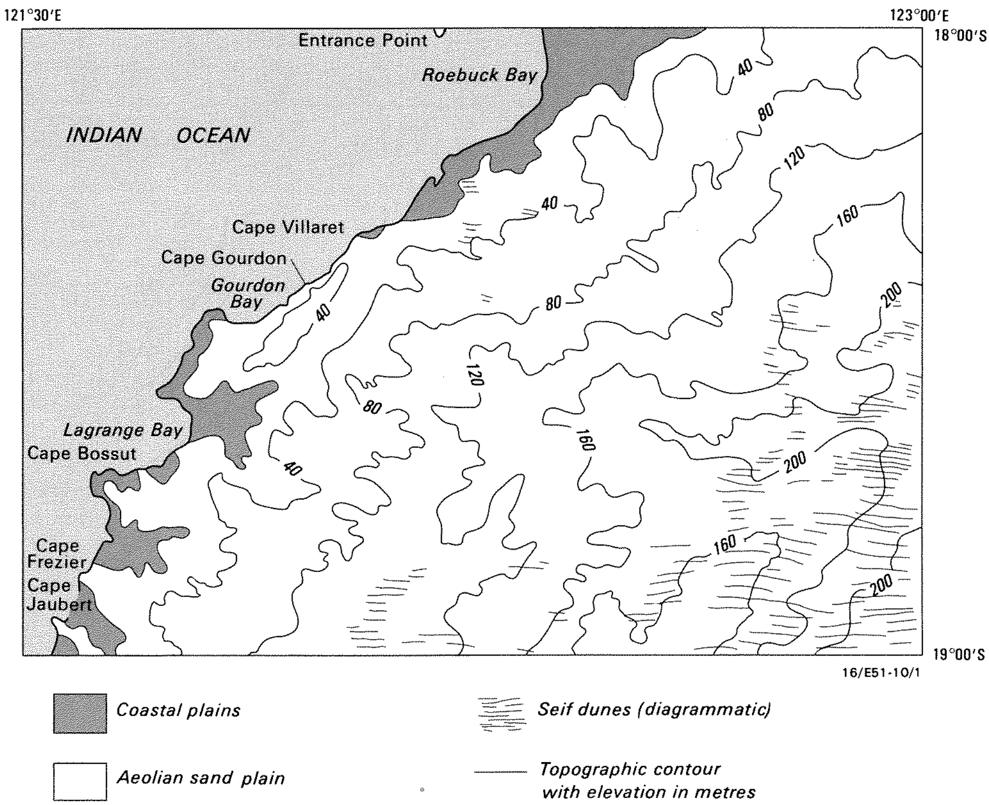


Fig. 1. Physiography.

TABLE 1. STRATIGRAPHY OF THE LAGRANGE 1:250 000 SHEET AREA

Age	*Rock unit*	*Maximum thickness (m)*	*Lithology*
QUATERNARY	Qa	5?	Sand, silt, clay, minor gravel
	Qs	5?	Sand, silt, minor gravel
	Qz	15?	Fine to medium red sand, minc silt
	Qcs	5?	Clay, silt, sand, minor salt
	Qci	5?	Silty clay, black organic clay
	Qcd	30?	Calcareous sand, partly oolitic
	Bossut Formation (Qpb)	20?	Fine to coarse calcareous an quartzose sandstone, calcilutit oolite; cross-bedded in part
CAINOZOIC	Czl	5?	Pisolitic and massive laterite
EARLY CRETACEOUS	Frezier Sandstone (Kf)	30?	Fine to coarse poorly sorte sandstone, minor conglomerate mudstone; cross-bedded; biotu bated in part; commonly ferru ginous in outcrop
	Parda Formation (Kp)	30?	Mudstone, minor fine sandstone thin-bedded or massive
	Melligo Sandstone (Km)	5?	Fine to medium well-sorted thin bedded to laminated sandstone
	Broome Sandstone (Kb)	192 in Parda 1	Fine to very coarse sandstone some mudstone, minor conglo merate; ripple-marked, cross bedded; bioturbated in part
LATE JURASSIC TO EARLY CRETACEOUS?	Jarlemai Siltstone (JKr)	106 in Thangoo 2	Siltstone, claystone, sandstone glauconitic; ferruginous (phos phatic?) in part
LATE JURASSIC	Alexander Formation (Ja)	81 in Parda 1 and Thangoo 1	Fine to coarse sandstone, inter bedded mudstone; pyritic, glau conitic in part
EARLY? TO LATE JURASSIC	Wallal Sandstone (Jl)	229 in Parda 1	Sandstone; minor siltstone, con glomerate, shale, lignite
EARLY PERMIAN	Noonkanbah Formation (Pn)	76 in Roebuck Bay 1	Calcareous mudstone; fine sand stone, limestone interbeds
	Poole Sandstone (Pp)	71 in Roebuck Bay 1	Very fine to fine sandstone, inter-bedded mudstone; minor limestone at base
	Grant Group (Pg)	398 in Roebuck Bay 1	Fine to coarse sandstone, mud-stone, minor conglomerate
EARLY CARBONIFEROUS	Anderson Formation (Ca)	2500? (2551 in Yulleroo 1 to the north)	Fine to coarse sandstone, silt-stone, shale; minor limestone, dolomite, anhydrite

Stratigraphic relationships	*Fossils*	*Comments*
Superficial deposit		Alluvial and lacustrine
Superficial deposit		Mixed alluvial and aeolian
Superficial deposit		Aeolian; seif dunes and sand sheets
Superficial deposit		Supratidal mudflat
Superficial deposit		Tidal flat and mangrove swamp
Superficial deposit		Coastal aeolian dune sand; includes reworked Qpb
Unconformably overlies Kb, Km, Kp	Bivalves, gastropods, forams	Coastal; includes beach ridges
Derived from Kp, Kf		Pedogenic
Disconformably overlies Kp, Km, Kb; top eroded	Bivalves	Fluvial to deltaic
Disconformably overlies Km, Kb; disconformably overlain by Kf	Unidentified bivalves outside Sheet area	Lagoonal or shallow marine
Conformably overlies Kb; disconformably overlain by Kp, Kf	Belemnites, bivalves outside Sheet area	Regressive beach
Conformably overlies JKr; overlain conformably by Km, disconformably by Kf, Kp	Plant fossils, microfossils, dinosaur footprints, bivalves outside Sheet area	Shallow regressive marine (tidal)
Conformable between Ja and Kb	Microfossils. Bivalves, gastropods, ammonites, ostracods, belemnites outside Sheet area	Shallow marine (subtidal)
Conformable between Jl and JKr	Belemnites, bivalves. A wide range of shelly fossils known from outside Sheet area	Shallow transgressive marine (tidal)
Unconformably overlies Pn, Pp, Pg; conformably overlain by Ja	Microfossils, plant fossils	Continental to shallow-water marine
Conformably overlies Pp; unconformably overlain by Jl	A wide range of fossils known outside Sheet area	Shallow marine (unrestricted); warm water
Unconformably? overlies Pg; overlain conformably by Pn, unconformably by Jl	Brachiopods, bryozoans, ammonoids, molluscs, conodonts, crinoids, ostracods, plant fossils, microfossils	Shallow marine to lagoonal; warm water
Unconformably overlies Ca, DC, Sc, On, Oo; overlain unconformably? by Pp, unconformably by Jl	A wide range of fossils known from outside Sheet area	Marine (partly glacial marine)
Conformably overlies DC; unconformably overlain by Pg	Bivalves, microfossils outside Sheet area	Marine and continental. Inferred to be present in far north of Sheet area

Age	*Rock unit*	*Maximum thickness (m)*	*Lithology*
EARLY DEVONIAN TO EARLY CARBO-NIFEROUS	DC	94 in Roebuck Bay 1 (1163 in Yulleroo 1 to the north)	Limestone, dolomite, shale, si stone, fine sandstone
LATE ORDOVICIAN? TO EARLY DEVONIAN	Carribuddy Formation (Sc)	184 in Parda 1	Multicoloured claystone, silty ar sandy in part; anhydrite; min limestone near base
EARLY TO MIDDLE ORDOVICIAN	Nita Formation (On)	106 in Parda 1	Limestone, dolomite, interbedde shale
	Goldwyer Formation (Oo)	229 in Goldyer 1	Black fossiliferous calcareou pyritic shale; interbedded lim stone, dolomite; minor siltstor lenses
	Willara Formation (Ow)	454 in Thangoo 2	Fossiliferous, dolomitic limeston interbedded shale and siltstone
	Nambeet Formation (Ot)	71 in Thangoo 2	Grey to green shale; fine sanc stone; dolomite and limeston interbeds
PRECAMBRIAN	p-Є		Igneous, metamorphic, and sed: mentary rocks

present mainly in the south. In the southeast, the plain is characterised by west-trending aeolian seif dunes of simple type (term of Crowe, 1975) averaging 6–9 m high; elsewhere an aeolian sand sheet predominates. The dunes were formed by easterly winds, but are now inactive and mainly stabilised by vegetation. Some small ephemeral watercourses are present, but the plain is predominantly without organised drainage.

Coastal plains are characterised by aeolian dunes parallel to the shoreline, beach ridges, extensive intertidal and supratidal mudflats bordering inlets and bays (especially at Roebuck Bay, where supratidal flats of the Roebuck Plains extend 30 km inland), and platforms of lithified coastal deposits. Low cliffs back narrow beaches between Cape Villaret and Cape Du Boulay.

Offshore, the sea floor slopes gently to the west-northwest to a maximum depth in the Sheet area of about 60 m; a narrow west-northwest-trending tidal channel over 100 m deep (the Roebuck Deep) is present 2 km offshore in the far north of the Sheet area. Tidal range is up to 10 m.

STRATIGRAPHY

The onshore stratigraphy of the Sheet area is summarised in Table 1 and briefly described below. Map units beneath the Lower Cretaceous Broome Sandstone occur only in the subsurface. All but the Lower Carboniferous Anderson Formation have been penetrated in petroleum wells in the Sheet area; this formation has been penetrated in WAPET Barlee 1 (WAPET, 1961a) and Gewerkschaft Elwerath Yulleroo 1 (Gewerkshaft Elwerath Inc., 1967) respectively 21 and 16

Stratigraphic relationships	*Fossils*	*Comments*
Unconformably overlies Sc?, On; overlain conformably by Ca, unconformably by Pg	Conodonts, ostracods, fish scales, microfossils	Includes Thangoo Calcarenite, and possibly Fairfield Group and Luluigui Formation; marine
Unconformably overlies On; unconformably overlain by Pg, DC?	Microfossils, conodonts, fish scales outside Sheet area	Present in south of Sheet area, and possibly in far north; marine, partly evaporitic
Conformably overlies Oo; unconformably overlain by Sc, DC, Pg	Conodonts, microfossils, molluscs. Brachiopods, crinoids, acritarchs, ?conulariids outside Sheet area	Includes 'Roebuck Dolomite' in WAPET Roebuck Bay 1; shallow marine
Conformably overlies Ow; overlain conformably by On, unconformably by Pg	Microfossils, conodonts, graptolites, ostracods, trilobites, brachiopods, chitinozoans, nautiloids	Shallow marine
Overlies p€ unconformably, Ot conformably; overlain conformably by Oo	Conodonts, brachiopods, gastropods, nautiloids, trilobites, graptolites, sponge spicules, bryozoa, ostracods	Shallow marine
Unconformably overlies p€; conformably overlain by Ow	A wide variety of fossils known from outside Sheet area	Shallow marine
Unconformably underlies Ow, Ot		Basement to Canning Basin

km north of the Sheet area. Estimates of depths to the tops of map units in wells in and around the Sheet area are shown in Table 2.

PRECAMBRIAN

Rocks of Precambrian age (p€) underlie the Canning Basin—granite in WAPET Goldwyer 1, phyllite in WAPET Thangoo 1A, and gneiss in WAPET Thangoo 2 and WAPET Parda 1 (Forman & Wales, 1981).

EARLY TO MIDDLE ORDOVICIAN

Lower to middle Ordovician rocks are present at the base of the Canning Basin sequence: the lower Arenig *Nambeet Formation* (Ot; Johnstone *in* WAPET, 1961b); the middle to upper Arenig (McTavish & Legg, 1976) *Willara Formation* (Ow; McTavish *in* Playford & others, 1975); the Arenig to Llanvirn *Goldwyer Formation* (Oo; Elliott *in* WAPET, 1961c), which has its type section in WAPET Thangoo 1A; and the Llanvirn *Nita Formation* (On; McTavish *in* Playford & others, 1975), which has its type section in WAPET Parda 1 and—following the usage of McTavish & Legg (1976)—includes the 'Roebuck Dolomite' (McWhae & others, 1958) intersected in WAPET Roebuck Bay 1.

LATE ORDOVICIAN? TO EARLY DEVONIAN

The *Carribuddy Formation* (Sc; Koop, 1966; WAPET, 1966e) is poorly dated: McTavish & Legg (1976) considered that it is possibly Early Devonian, but other

TABLE 2. ESTIMATES OF DEPTHS (IN METRES) TO THE TOPS OF MAP UNITS IN PETROLEUM EXPLORATION WELLS

Map unit	*Gewerkschaft Elwerath Yulleroo 1**	*WAPET Roebuck Bay 1*	*WAPET Thangoo 1*	*WAPET Thangoo 1A*	*WAPET Goldwyer 1*	*WAPET Thangoo 2*	*WAPET Parda 1*	*WAPET Willara 1†*
Parda Formation	—	—	—	—	—	—	5	—
Melligo Sandstone	—	—	—	—	—	—	—	—
Broome Sandstone	10	9	12	12	12	12	18	21
Jarlemai Siltstone	66	152	68	72	162	77	210	134
Alexander Formation	266	241	167	173	259	183	302	216
Wallal Sandstone	287	296	248	252	318	248	383	265
Noonkanbah Formation	—	478	—	—	—	—	—	—
Poole Sandstone	—	553	421	428	—	—	—	—
Grant Group	561	624	455	468	553	422	612	492
Anderson Formation	858	—	—	—	—	—	—	—
DC	3409	1022	—	—	—	—	—	—
Carribuddy Formation	—	—	—	—	—	—	980	1264
Nita Formation	—	1116	—	—	—	—	1165	1736
Goldwyer Formation	—	—	826	848	848	788	1271	1874
Willara Formation	—	—	1029	1060	1078	913	1492	2610
Nambeet Formation	—	—	—	1506	—	1367	—	3142
pЄ	—	—	—	1555	1420	1438	1777	—
Total Depth	4572	1219	1059	1655	1439	1472	1907	3903

* 17°51′S, 122°54′E—16 km north of Sheet area

† 19°11′S, 122°04′E—20 km south of Sheet area

authors (e.g., Glover, 1973) have suggested that it may extend down into the Late Ordovician. Koop (1966) reported a Late Ordovician age for what he recognised as the lower part of the formation in WAPET Parda 1, but these rocks have now been assigned to the Nita Formation by McTavish & Legg (1976).

In WAPET Parda 1, the only well to intersect the formation in the Sheet area, it consists of claystone with minor anhydrite overlying dolomitic limestone (WAPET, 1965a). Elsewhere it contains large thicknesses of evaporites—for example, in Total McLarty 1, 80 km southeast of the Sheet area (Total, 1968; Towner & Gibson, 1980). Burne *in* Forman & Wales (1981) considered that the formation was deposited in a desiccating marine basin. Glover (1973) described several sedimentary facies within the unit.

Early Devonian to Early Carboniferous

Lower Devonian dolomitic limestone 94 m thick in WAPET Roebuck Bay 1 has not been differentiated in the Sheet area, but has been included in map unit *DC*. McWhae & others (1958) proposed the name Thangoo Calcarenite for the dolomitic limestone, which overlies rocks formerly assigned to the Roebuck Dolomite (now part of the Nita Formation). The Thangoo Calcarenite yielded no fossils of stratigraphic value until McTavish & Legg (1976) reported an Early Devonian fish scale from the unit. In the meantime, Elliott (*in* WAPET, 1961c) had proposed the name 'Thangoo Limestone' to cover the Thangoo Calcarenite plus the Roebuck Dolomite in WAPET Roebuck Bay 1, and had nominated a type section in WAPET Thangoo 1A. However, Playford & others (1975) showed that this type section is of Early Ordovician age, and that it occupies a lower stratigraphic position than the Thangoo Calcarenite and Roebuck Dolomite. The rocks in this type section are now referred to the Willara Formation (McTavish *in* Playford & others, 1975), and the term 'Thangoo Limestone' has been abandoned, but the name Thangoo Calcarenite is still valid for the rocks overlying the Nita Formation in WAPET Roebuck Bay 1.

No other deposits of Devonian or Early Carboniferous age (excluding the Carribuddy Formation—see above) have been recognised in petroleum exploration wells in the Sheet area. However, Gewerkschaft Elwerath Yulleroo 1 (Gewerkschaft Elwerath Inc., 1967), 16 km north of the Sheet area, is interpreted to have penetrated the Upper Devonian to Lower Carboniferous Fairfield Group, overlying the Devonian Luluigui Formation (Druce & Radke, 1979; Gorter & others, 1979). These units probably extend into the far northern part of the Sheet area, and have been incorporated with the Thangoo Calcarenite into unit DC.

In Gewerkschaft Elwerath Yulleroo 1, the Fairfield Group is conformably overlain by the Lower Carboniferous *Anderson Formation* (Ca; McWhae & others, 1958). This unit is known only from the Fitzroy Trough (see 'STRUCTURE' below) and adjacent structural units, and marks an episode of rapid subsidence. In Gewerkschaft Elwerath Yulleroo 1, it is about 2500 m thick; fossil evidence shows that the bottom 1000 m is marine, and the rest is continental (Gewerkschaft Elwerath Inc., 1967). It probably is present in the far north of the Sheet area.

Permian

The *Grant Group* (Pg; Guppy & others, 1958; Crowe & Towner, 1976) is thought to be present over the entire Sheet area. No attempt has been made on the map section to distinguish the lower, sandy Betty Formation, the middle, shaly

Winifred Formation, and the upper, sandy Carolyn Formation, as they are too thin to show at this scale. However, they have been recognised in some of the petroleum exploration wells in the Sheet area (Towner & Gibson, 1980). The Betty and Carolyn Formations are thought to have been deposited in a cold-water marine or glacial-marine environment. The Grant Group is generally regarded as being Sakmarian (Early Permian) in age, although it extends down into the Late Carboniferous north of the Sheet area in WAPET Pender 1 (WAPET, 1972a).

The Sakmarian to Artinskian *Poole Sandstone* (Pp; Wade, 1938; Guppy & others, 1952) is present in at least the northeastern part of the Sheet area, where it overlies the Grant Group; Crowe & others (1978) have shown that the boundary is an angular unconformity in the Grant Range (Mount Anderson and Derby Sheet areas to the east and northeast). No attempt has been made on the map to show the lower, calcareous Nura Nura Member (Guppy & others, 1958) and the upper, sandy Tuckfield Member (Crowe & Towner, 1976), which are too thin to show at this scale.

The Artinskian *Noonkanbah Formation* (Pn; Wade, 1938; Guppy & others, 1952) has been intersected only in WAPET Roebuck Bay 1 in the Sheet area. It is made up of fine-grained shallow-marine deposits.

JURASSIC TO CRETACEOUS

The *Wallal Sandstone* (Jl; McWhae *in* WAPET, 1961b) is probably present over all the Sheet area. It has been dated in the Sheet area as Middle to Late Jurassic (Oxfordian) in WAPET Parda 1 (Balme *in* WAPET, 1965a), although there are indications that it may extend down into the Early Jurassic in the southwest Canning Basin (Towner & Gibson, 1980).

The Alexander Formation (Ja; Brunnschweiler, 1954), which is probably present over all the Sheet area, is a thin unit of glauconitic sandstone and mudstone that represents the beginnings of a Jurassic-Cretaceous regional marine transgression in the area. It has been dated as Oxfordian and possibly Kimmeridgian outside the Sheet area.

The *Jarlemai Siltstone* (JKr; Brunnschweiler, 1954) has been dated as possibly Oxfordian or Kimmeridgian to Tithonian, but there are indications that it extends up into the earliest Cretaceous in WAPET Parda 1 (Balme, *in* WAPET, 1965a). It was deposited at the height of the Jurassic-Cretaceous transgression in the Canning Basin.

The *Broome Sandstone* (Kb; Reeves, 1951; Brunnschweiler, 1957; Towner & Gibson, 1980; Gibson, 1983) is poorly dated. It contains a Neocomian microflora, Late Jurassic or Early Cretaceous plant fossils (Playford & others, 1975), shelly fossils identified as Late Jurassic and Early Cretaceous (Gibson, 1983), and, at Gantheaume Point (2 km north of the Sheet area near Broome), dinosaur footprints (Glauert, 1952; Colbert & Merilees, 1967); it conformably underlies the Aptian Melligo Sandstone (see below). It is here considered to have been deposited as the Late Jurassic-Early Cretaceous sea shallowed owing to regression. It is probably time transgressive, and is the oldest unit to crop out in the Sheet area.

The *Melligo Sandstone* (Km; Brunnschweiler, 1957; McWhae & others, 1958), which Brunnschweiler described as a silicified unit, crops out as an unsilicified sandstone in the Cape Villaret-Cape Gourdon area, where Towner & Gibson (1980) identified it from its sedimentary structures, rock fabric, and stratigraphic position. The good sorting and rounding of the constituent grains (some of which are heavy minerals), thin bedding, flat bedding to low-angle cross-bedding, and parting lineation indicate that it is a beach deposit. The age of the Melligo Sandstone to the north of the Sheet area is well documented as it contains the key Aptian bivalve, *Fissilunula clarkei.*

The disconformity below the *Parda Formation* (Kp; Lindner & Drew *in* McWhae & others, 1958) probably represents only a short period of non-deposition. At Cape Gourdon, the Parda Formation occupies a 5 m deep and 10–15 m wide channel cut into the Melligo Sandstone (Towner & Gibson, 1980). It is probably of Aptian age, as it lies between the Aptian Melligo Sandstone and the Aptian? Frezier Sandstone. Its present distribution is roughly shown on the simplified geology map on the accompanying map sheet.

The disconformity below the *Frezier Sandstone* (Kf; Lindner & Drew *in* McWhae & others, 1958) also probably represents only a short period of non-deposition. Typical outcrops of this unit are ferruginised, and bedding has been largely obliterated by the ferruginisation. It has been dated as probably Aptian by Dickins (*in* Veevers & Wells, 1961, p. 283) near Lagrange Mission; this is the only age determination from this unit. Its present distribution is roughly shown on the simplified geology sketch. The Frezier Sandstone may be a partial facies equivalent of the Parda Formation in areas where the latter was not deposited.

Late Cretaceous rocks are probably present in the offshore northwest of the Sheet area (Gorter & others, 1979; Forman & Wales, 1981). These unconformably overlie the Lower Cretaceous rocks, and most probably consist of siltstone, marl, and claystone; these lithologies were encountered in the petroleum exploration wells Amax Wamac 1 (Amax, 1973) and BOCAL Lacepede 1A (BOCAL, 1970), respectively 85 km and 100 km north of the Sheet area.

Cainozoic

Laterite (Czl) overlying the Parda Formation and Frezier Sandstone is exposed on some low ridges in the Sheet area. It may be of late Tertiary or younger age (Towner & Gibson, 1980).

The *Bossut Formation* (Qpb; Traves & others, 1956; Lindner *in* WAPET, 1961b) is considered to be of Quaternary age because of its occurrence at or close to the present-day shoreline, and because it is in part poorly cemented.

Coastal aeolian sand deposits (Qcd) form high dunes along much of the coastline. The dunes are now inactive, and many are well vegetated.

Tidal flat and mangrove swamp deposits (Qci) up to 2 km wide flank inlets and tidal creeks.

Supratidal mudflat deposits (Qcs) are usually present landward of the tidal deposits, and may extend inland for many kilometres, for example at Roebuck Bay.

Aeolian deposits (Qz) occur over most of the Sheet area as sand sheets and seif dunes. These are a part of the aeolian deposits of the Great Sandy Desert.

Small deposits of *sand and silt* (Qs) are probably of mixed aeolian and alluvial origin.

Alluvial and lacustrine sediments (Qa) are limited to small watercourses draining into the coastal mudflats, and associated claypans.

Offshore, the Cainozoic is represented by a wedge of carbonates thickening to the west (Gorter & others, 1979; Forman & Wales, 1981). Rocks present are likely to be of late Miocene to Recent age, and probably consist predominantly of detrital carbonates and glauconitic sandstone.

STRUCTURE

Structural interpretation is wholly based on the results of geophysical surveys and drilling in and around the Sheet area, as the onshore part of the area is covered by a veneer of undeformed Mesozoic rocks. The structure across the Sheet area is shown in the section and simplified geology sketch on the accompanying map sheet. The Canning Basin is divided into four structural subdivisions in the Sheet area; these subdivisions are based on basement morphology.

The *Fitzroy Trough* (Fitzroy Basin of Reeves, 1951) is a northwest-trending graben, part of which occupies the far central north of the Sheet area. It was initiated in the Middle Devonian when movement started along its bounding faults; the Fenton Fault System forms the southern boundary of the trough in the Sheet area. Further movement along the Fenton Fault System during deposition in the Devonian and Early Carboniferous resulted in much larger thicknesses of sediment being laid down in the trough than in the adjacent areas. Limited seismic information in the Sheet area suggests that downthrow along the Fenton Fault System is in the order of 3000 m.

Many east-west-trending en-echelon folds are present in the Triassic and older rocks of the Fitzroy Trough (although there are probably none of these folds in the Sheet area), and it has been suggested that these were generated probably in the Late Triassic or Early Jurassic by right-lateral shear along the bounding faults of the trough (Rattigan, 1967; Smith, 1968; Rixon, 1978).

The *Jurgurra Terrace* (Playford & Johnstone, 1959) is an area of intermediate basement depth at the southern margin of the Fitzroy Trough; part of it occurs in the northeast of the Sheet area, where it is bounded to the south by the Dampier Fault. It was affected by some subsidence in the Middle to Late Devonian, but received little, if any, of the great thickness of sediment laid down in the trough to the north during the Carboniferous. Depths to basement on the terrace are probably in the order of 3000 m in the Sheet area.

The *Broome Arch,* south of the terrace and trough, has depths to basement generally between 1500 and 2500 m, and may be an area which did not subside as quickly as the trough and terrace to the north and the Willara Sub-basin to the south; alternatively it may be an uplifted area marginal to the Fitzroy Trough, similar to the uplifts marginal to rift zones in the northwest Africa-Red Sea area. The southern boundary of the Broome Arch in the Sheet area is the Admiral Bay Fault, on which the throw may be up to 2000 m (down to the south) in the Munro Sheet area to the south (Towner, 1982b); most movement on this fault occurred in pre-Permian times.

The *Willara Sub-basin,* south of the Admiral Bay Fault, is a downwarped area with a maximum depth to basement of about 4500 m to the south of the Sheet area. It started to subside during the Ordovician, and became the depocentre for greater thicknesses of sediment (Ordovician units and Carribuddy Formation) than in the areas to the north and south.

GEOLOGICAL HISTORY

In Precambrian times, sediments were laid down, igneous rocks intruded them, and metamorphism took place. These rocks, basement to the Canning Basin, were eroded till the Early Ordovician, when a shallow sea transgressed the Sheet area. Carbonates, mud, and sand (Nambeet, Willara, Goldwyer, and Nita Formations) were deposited in this sea.

Emergence and minor erosion followed until carbonates, mud, evaporites, and sand (Carribuddy Formation) were deposited in an evaporating sea which extended across the southern part of the Sheet area in Late Ordovician? to Early Devonian times. Further erosion followed. In the north of the Sheet area, carbonate and clastic sediments (DC and Anderson Formation) were deposited in marine and finally continental environments in and around the newly formed Fitzroy Trough. Emergence in the Carboniferous resulted in erosion of the Carboniferous and older rocks.

The sea again transgressed the Sheet area in Early Permian time, and sand and mud (Grant Group) were deposited in a cold marine or glacial-marine environment. A short period of emergence and erosion may have followed before sand and mud (Poole Sandstone) were deposited once more, but in a warm sea or lagoon system. As the transgression continued, open-marine mud and carbonate (Noonkanbah Formation) accumulated.

Emergence and erosion followed. During a major period of tectonism in the Late Triassic or Early Jurassic, right-lateral shearing occurred along the Fenton Fault System.

After further erosion had peneplaned all structural highs, sedimentation resumed, possibly in the Early Jurassic, when continental to shallow-marine sand and minor silt, gravel, and clay (Wallal Sandstone) were deposited. A regional transgression in the Late Jurassic led to deposition of sand and mud in a marine environment (Alexander Formation and Jarlemai Siltstone).

Regression in Early Cretaceous time resulted in deposition of sand and mud (Broome Sandstone) in a shallow sea. During Aptian time, the sea withdrew, leaving beach sands (Melligo Sandstone) in its wake. After probably only a short depositional hiatus a shallow sea or lagoon spread across much of the Sheet area, and mud and fine sand (Parda Formation) were deposited in its calm waters. After a further, probably short hiatus, sand and minor gravel and mud (Frezier Sandstone) accumulated in a fluvial to deltaic environment.

Erosion and weathering followed. Laterite formed probably in late Tertiary time, and, in the Quaternary, a variety of thin sediments of shoreline, aeolian, alluvial, and lacustrine origin accumulated onshore. Offshore, detrital carbonates and sand were probably deposited during the late Tertiary and Quaternary in a marine environment.

MINERAL RESOURCES

Petroleum

All the petroleum exploration wells in the Sheet area encountered petroleum shows in the form of oil stain or fluorescent core or cuttings. Small amounts of free oil were encountered in WAPET Goldwyer 1 and WAPET Thangoo 1 and 1A; these shows occurred in the Grant Group and the Goldwyer and Willara Formations. A fluorescent interval in the Grant Group in WAPET Thangoo 2 was calculated to have 76 percent water saturation (WAPET, 1973).

Burne & Kantsler (1977) concluded that the zone of oil generation in the Canning Basin lies between the 50° and 75°C isotherms; this relatively low-temperature range reflects the prolonged burial of the Palaeozoic rocks. They showed that rocks of Ordovician to Permian age in the Sheet area lie within this temperature window at present, and that this is probably the maximum temperature reached by these rocks.

Burne & others (1979) found that source rock analyses favour oil accumulation in the Ordovician on the Broome Arch, but noted that the most promising areas had been tested with no success because of tight Ordovician formations and lack of seal on possible Permian reservoir rocks. They also stated that the Fitzroy Trough and Jurgurra Terrace have potential for discovery of hydrocarbons, and that oil generation is favoured in the Fairfield Group and Anderson Formation; however, porosities there are also generally low, and potential reservoirs lack seals. They concluded that the slow rate of burial of the Canning Basin resulted in the loss of primary porosity before any petroleum migrated, and that extensive erosion and groundwater flushing have adversely affected prospectiveness.

Phosphate

Freas & Zimmerman (1965) reported phosphatic sideritic ironstone in the Jarlemai Siltstone, Alexander Formation, and Wallal Sandstone. A 122 m interval (depth not specified by Freas & Zimmerman) of the Jarlemai Siltstone in WAPET Barlee 1 (WAPET, 1961a), 21 km north of the Sheet area, contained an average of more than 1 percent P_2O_5; within this interval, the interval 158 to 168 m averaged 5.7 percent P_2O_5 and 23.4 percent Fe_2O_3. The Jarlemai Siltstone in WAPET Thangoo 1 (WAPET, 1961c) between 137 and 152 m averaged 4.3 percent P_2O_5.

Freas & Zimmerman considered that the Jurassic sequence is not favourable for economic phosphate occurrences, as clastic rocks predominate, and the phosphate present occurs in phosphatic ironstones.

Water

Claypans and watercourses in the Sheet area contain water after heavy rain in the wet season. Groundwater from Quaternary sediments and the Broome Sandstone is tapped by station wells and bores. Speck & others (1964) reported that three bores at Broome yield about 70 000 L/h each from the Broome Sandstone at depths of 30–60 m. Poor-quality artesian water has been drawn from the Alexander Formation, Wallal Sandstone, and Jarlemai Siltstone at Broome, and large quantities of water of varying quality are probably present in these formations in the Sheet area.

BIBLIOGRAPHY

ALBANI, A. D., & GEYSKES, R., 1969—A preliminary account of the distribution of Recent foraminifera on part of the N.W. Australian continental shelf. *Bureau of Mineral Resources, Australia, Record* 1969/15 (unpublished).

AMAX (AMAX PETROLEUM (AUSTRALIA) INC.), 1973—Well completion report, Wamac No. 1 well, northwest continental shelf, Western Australia. *Bureau of Mineral Resources, Australia,* File 73/246 (unpublished).

BEARD, J. S., 1967—Some vegetation types of tropical Australia. *Journal of Ecology,* 55, 271-280.

BEARD, J. S., 1969—The natural regions of the deserts of Western Australia. *Journal of Ecology,* 57, 677-711.

BEARD, J. S., & WEBB, M. J., 1974—Vegetation survey of Western Australia—Sheet 2, Great Sandy Desert. *1:1 000 000 Vegetation Series, Map and Explanatory Notes, University of Western Australia Press.*

BOCAL (BURMAH OIL COMPANY OF AUSTRALIA LTD), 1968—Offshore Canning-Seringapatam Reef Marine Seismic Survey, final report. *Bureau of Mineral Resources, Australia,* File 68/3027 (unpublished).

BOCAL, 1969—Adele-Scott Marine Seismic Survey, final report. *Bureau of Mineral Resources, Australia,* File 69/3038 (unpublished).

BOCAL, 1970—Lacepede No. 1 and 1A well completion report. *Bureau of Mineral Resources, Australia,* File 70/426 (unpublished).

BOUTAKOFF, N., 1963—Geology of the off-shore areas of north-western Australia. *APEA Journal,* 3(I), 10-18.

BRANSON, J. C., 1974—Structures of the western margin of the Australian continent. *Bureau of Mineral Resources, Australia, Record* 1974/64 (unpublished).

BROWN, G. A., 1959—Desert dune sands from the Canning Basin, Western Australia. *Bureau of Mineral Resources, Australia, Record* 1959/82 (unpublished).

BRUNNSCHWEILER, R. O., 1951a—Notes on the geology of Dampier Land, north-western Australia. *Australian Journal of Science,* 14(1), 6-8.

BRUNNSCHWEILER, R. O., 1951b—Discovery of the Late Jurassic genus *Calpionella* Lorenz (Oligotric Infusoria) in Australia. *Australian Journal of Science,* 14(3), 94.

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 the Dampier Peninsula, Western Australia. *Bureau of Mineral Resources, Australia, Bulletin* 59.

BURBIDGE, N. T., 1944—Ecological notes on the vegetation of 80-mile Beach. *Journal and Proceedings of the Royal Society of Western Australia,* 28, 157-164.

BURNE, R. V., & KANTSLER, A. J., 1977—Geothermal constraints on the hydrocarbon potential of the Canning Basin, Western Australia. *BMR Journal of Australian Geology & Geophysics,* 2, 271-288.

BURNE, R. V., GORTER, J. D., & SAXBY, J. D., 1979—Source rocks and hydrocarbon potential of the Palaeozoic in the onshore Canning Basin, Western Australia. *BMR Journal of Australian Geology & Geophysics,* 4, 125-133.

CARRIGY, M. A., & FAIRBRIDGE, R. W., 1954—Recent sedimentation, physiography and structure of the continental shelves of Western Australia. *Journal of the Royal Society of Western Australia,* 38, 65-95.

CASEY, J. N., 1958a—Mt. Anderson—4-mile Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes* SE/51-11.

CASEY, J. N., 1958b—Derby—4-Mile Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes* SE/51-7.

CHALLINOR, A., 1970—The geology of the offshore Canning Basin, Western Australia. *APEA Journal,* 10(II), 78-90.

CLAPP, F. G., 1926a—Oil prospects of the Desert Basin, Western Australia. *Bulletin of the American Association of Petroleum Geologists,* 10(11), 1118-1135.

CLAPP, F. G., 1926b—The oil problem in Western Australia. *Economic Geology,* 21, 409-430.

COLBERT, E. H., & MERILEES, D., 1967—Cretaceous dinosaur footprints from Western Australia. *Journal of the Royal Society of Western Australia,* 50, 21-25.

COOKSON, I. C., & EISENACK, A., 1958—Microplankton from Australian and New Guinea Upper Mesozoic sediments. *Proceedings of the Royal Society of Victoria,* 70(1), 19-78.

COOKSON, I. C., & EISENACK, A., 1960—Upper Mesozoic microplankton from Australia and New Guinea. *Palaeontology,* 2(2), 243-261.

CRESPIN, I., 1948—Micropalaeontological examination of samples from bores Nos. 1, 2, 3 and 4, Broome, and Derby Town bore, Western Australia. *Bureau of Mineral Resources, Australia, Record* 1948/60 (unpublished).

CRESPIN, I., 1956—Micropalaeontological examination of cores from Roebuck Bay No. 1 stratigraphic bore, Canning Basin, Western Australia. *Bureau of Mineral Resources, Australia, Record* 1956/90 (unpublished).

CRESPIN, I., & CONDON, M. A., 1956—Micropalaeontology and stratigraphy of Roebuck No. 1 bore, Canning Basin, Western Australia. *Bureau of Mineral Resources, Australia, Record* 1956/139 (unpublished).

CROWE, R. W. A., 1975—The classification, genesis and evolution of sand dunes in the Great Sandy Desert. *Geological Survey of Western Australia, Annual Report for 1974,* 46-49.

CROWE, R. W. A., & TOWNER, R. R., 1976—Definitions of some new and revised rock units in the Canning Basin. *Geological Survey of Western Australia, Record* 1976/24 (unpublished).

CROWE, R. W. A., TOWNER, R. R., & GIBSON, D. L., 1978—Permian and Mesozoic geology of the Derby and Mount Anderson 1:250 000 Sheet areas, Western Australia. *Bureau of Mineral Resources, Australia, Record* 1978/8 (unpublished).

DICKINS, J. M., TOWNER, R. R., & CROWE, R. W. A., 1977—A Permian cold water marine fauna in the Grant Formation of the Canning Basin, Western Australia. *Journal of the Palaeontological Society of India,* 20, 275-278.

DOOLEY, J. C., 1963—Onslow/Derby regional gravity traverse, W.A., 1953. *Bureau of Mineral Resources, Australia, Record* 1963/13 (unpublished).

DRUCE, E. C., & RADKE, B. M., 1979—The geology of the Fairfield Group, Canning Basin, Western Australia. *Bureau of Mineral Resources, Australia, Bulletin* 200.

FEEKEN, E. H. J., FEEKEN, G. E. E., & SPATE, D. H. K., 1970—THE DISCOVERY AND EXPLORATION OF AUSTRALIA. *Nelson, Sydney.*

FLAVELLE, A. J., 1974—Canning Basin gravity surveys, 1953-1962. *Bureau of Mineral Resources, Australia, Record* 1974/181 (unpublished).

FLAVELLE, A. J., & GOODSPEED, M. J., 1962—Fitzroy and Canning Basins, reconnaissance gravity surveys, Western Australia, 1952-60. *Bureau of Mineral Resources, Australia, Record* 1962/105 (unpublished).

FORMAN, D. J., & WALES, D. W. (Compilers), 1981—Geological evolution of the Canning Basin, Western Australia. *Bureau of Mineral Resources, Australia, Bulletin* 210.

FREAS, D. H., & ZIMMERMAN, D. O., 1965—Geological evaluation for phosphate exploration of the Canning, Ord River, and Bonaparte Gulf Basins of north-western Australia. *IMC Development Corporation, Report No.* 7 (unpublished).

GEWERKSCHAFT ELWERATH INC., 1966—Lower Fitzroy Reflection Seismic and Magnetometer Survey, final report. *Bureau of Mineral Resources, Australia,* File 66/11111 (unpublished).

GEWERKSCHAFT ELWERATH INC., 1967—Yulleroo No. 1, Western Australia, well completion report. *Bureau of Mineral Resources, Australia,* File 67/4249 (unpublished).

GIBSON, D. L., 1983—Broome, Western Australia—1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes* SE/51-6.

GIBSON, D. L., & CROWE, R. W. A., 1982—Mount Anderson, Western Australia—1:250 000 Geological Series, second edition. *Bureau of Mineral Resources, Australia, Explanatory Notes* SE/51-11.

GILBERT-TOMLINSON, J., 1960—Ordovician fossils from Goldwyer No. 1, Thangoo No. 1, and Thangoo No. 1A bores, Western Australia. *Bureau of Mineral Resources, Australia, Record* 1960/94 (unpublished).

GLAUERT, L., 1952—Dinosaur footprints near Broome. *Western Australian Naturalist,* 3, 82-83.

GLENISTER, B. F., & GLENISTER, A. T., 1958—Discovery of subsurface Ordovician strata, Broome area, Western Australia. *Australian Journal of Science,* 20(6), 183-184.

GLOVER, J. E., 1973—Petrology of the halite-bearing Carribuddy Formation, Canning Basin, Western Australia. *Journal of the Geological Society of Australia,* 20(3), 343-359.

GORTER, J. D., RASIDI, J. S., TUCKER, D. H., BURNE, R. V., PASSMORE, V. L., WALES, D. W., & FORMAN, D. J., 1979—Petroleum geology of the Canning Basin. *Bureau of Mineral Resources, Australia, Record* 1979/32 (unpublished).

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. *Nineteenth International Geological Congress, Algeria, Gondwana Symposium,* 101-114.

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

HEMATITE PETROLEUM, 1972—Bedout-Broome Swell Seismic and Magnetic Survey, final report. *Bureau of Mineral Resources, Australia, Petroleum Search Subsidy Acts,* File 72/2616 (unpublished).

HORSTMAN, E. L., LYONS, D. A., NOTT, S. A., & BROAD, D. S., 1976—Canning Basin, onshore. *In* LESLIE, R. B., EVANS, H. J., & KNIGHT, C. L. (Editors)—ECONOMIC GEOLOGY OF AUSTRALIA AND NEW GUINEA—3. PETROLEUM. *Australasian Institute of Mining and Metallurgy, Melbourne, Monograph Series,* 7, 170-184.

JONES, H. A., 1968—A preliminary account of the sediments and morphology of part of the north-west Australian continental shelf and upper continental slope. *Bureau of Mineral Resources, Australia, Record* 1968/84 (unpublished).

JONES, H. A., 1971—Late Cenozoic sedimentary forms on the northwest Australian continental shelf. *Marine Geology,* 10(4), M20-M26.

JONES, H. A., 1973—Marine geology of the northwest Australian continental shelf. *Bureau of Mineral Resources, Australia, Bulletin* 136.

KOOP, W. J., 1966—Recent contributions to Palaeozoic geology in the south Canning Basin, Western Australia. *APEA Journal,* 6(1), 105-109.

MAYNE, S. J., 1975—History of petroleum search in the Canning Basin, Western Australia, to 31 December 1974. *Bureau of Mineral Resources, Australia, Record* 1975/109 (unpublished).

MCTAVISH, R. A., & LEGG, D. P., 1976—The Ordovician of the Canning Basin, Western Australia. *In* BASSETT, M. G. (Editor)—THE ORDOVICIAN SYSTEM. *University of Wales Press and Natural Museum of Wales, Cardiff,* 447-478.

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).

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

PLAYFORD, P. E., 1967—Derby town, Myalls and Broome water bores, Canning Basin, Western Australia. *West Australian Petroleum Pty Ltd, Company Report* (unpublished).

PLAYFORD, P. E., COPE, R. N., COCKBAIN, A. E., LOW, G. H., & LOWRY, D. C., 1975—Canning Basin. *In* The geology of Western Australia. *Geological Survey of Western Australia, Memoir* 2, 319-368.

PLAYFORD, P. E., & JOHNSTONE, M. H., 1959—Oil exploration in Australia. *Bulletin of the American Association of Petroleum Geologists,* 43, 397-433.

POWELL, D. E., 1976—The geological evolution of the continental margin off northwest Australia. *APEA Journal,* 16, 13-23.

QUILTY, J. H., 1960—Canning Basin aeromagnetic reconnaissance survey, W.A., 1954. *Bureau of Mineral Resources, Australia, Record* 1960/11 (unpublished).

RAINE, M. J., 1970—Bibliography of the Canning Basin, Western Australia (to 31-12-69). *Bureau of Mineral Resources, Australia, Record* 1970/9 (unpublished).

RATTIGAN, J. H., 1967—Fold and structure 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., 1949—Geology and oil prospects of the Desert Basin, Western Australia. *Vacuum Oil Company, Company Report* (unpublished).

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

RIXON, L. K., 1978—Clay modelling of the Fitzroy Graben. *BMR Journal of Australian Geology & Geophysics,* 3(1), 71-76.

SKWARKO, S. K., 1970—Aptian (Lower Cretaceous) '*Apiotrigonia*' from the Melligo Quartzite, Dampier Peninsula, Western Australia. *Bureau of Mineral Resources, Australia, Bulletin* 108, 227-235.

SMITH, E. R., 1960—La Grange seismic reflection survey, W.A., 1955. *Bureau of Mineral Resources, Australia, Record* 1960/49 (unpublished).

SMITH, J. G., 1968—Tectonics of the Fitzroy Wrench Trough, Western Australia. *American Journal of Science,* 266, 766-776.

SPECK, N. H., WRIGHT, R. L., RUTHERFORD, G. K., FITZGERALD, K., THOMAS, F., ARNOLD, J. M., BASINSKI, J. J., FITZPATRICK, E. A., LAZARIDES, M., & PERRY, R. A., 1964—General report on the lands of the West Kimberley area, W.A. *CSIRO, Australia, Land Research Series* 9.

TEICHERT, C., 1939—The Mesozoic transgressions in Western Australia. *Australian Journal of Science,* 2(3), 84-86.

TEICHERT, C., 1941—Marine Jurassic of East Indian affinities at Broome, north-west Australia. *Journal of the Royal Society of Western Australia,* 26, 103-119.

TEICHERT, C., 1942—Marine Upper Jurassic near Derby, north-western Australia. *Australian Journal of Science,* 5(1), 33-34.

TOTAL (TOTAL EXPLORATION AUSTRALIA PTY LTD), 1968—McLarty No. 1 well completion report. *Bureau of Mineral Resources, Australia,* File 68/2009 (unpublished).

TOWNER, R. R., 1981—Derby, Western Australia—1:250 000 Geological Series, second edition. *Bureau of Mineral Resources, Australia, Explanatory Notes* SE/51-7.

TOWNER, R. R., 1982a—Mandora, Western Australia—1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes* SE/51-13.

TOWNER, R. R., 1982b—Munro, Western Australia—1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes* SE/51-14.

TOWNER, R. R., & GIBSON, D. L., 1980—Geology of Late Carboniferous and younger rocks of the onshore western Canning Basin, Western Australia. *Bureau of Mineral Resources, Australia, Record* 1980/30 (unpublished).

TOWNER, R. R., & GIBSON, D. L., 1983—Geology of the onshore Canning Basin, Western Australia. *Bureau of Mineral Resources, Australia, Bulletin* 215.

TRAVES, D. M., CASEY, J. N., & WELLS, A. T., 1956—The geology of the southwestern Canning Basin, Western Australia. *Bureau of Mineral Resources, Australia, Report* 29.

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 für Geomorphologie,* 21(4), 379-400.

VEEVERS, J. J., 1967—The Phanerozoic geological history of northwest Australia. *Journal of the Geological Society of Australia,* 14(2), 253-271.

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

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

WAPET (WEST AUSTRALIAN PETROLEUM PTY LTD), 1956a—Roebuck East Refraction Profile A. *West Australian Petroleum Pty Ltd, Company Report* (unpublished).

WAPET, 1956b—Roebuck Bay No. 1 well completion report. *West Australian Petroleum Pty Ltd, Company Report* (unpublished).

WAPET, 1956c—Lagrange Prospect (14) Refraction Profile 'D'. *West Australian Petroleum Pty Ltd, Company Report* (unpublished).

WAPET, 1958a—Goldwyer No. 1 well completion report. *West Australian Petroleum Pty Ltd, Company Report* (unpublished).

WAPET, 1958b—Seismograph survey of Roebuck Bay (11) and Lagrange East (14). *West Australian Petroleum Pty Ltd, Company Report* (unpublished).

WAPET, 1959—Dampier Downs, Roebuck Bay East, and Townshend Seismograph Surveys. *West Australian Petroleum Pty Ltd, Company Report* (unpublished).

WAPET, 1960—Broome Platform Refraction (49), Reflection (50), and McHugh (57) Projects. *West Australian Petroleum Pty Ltd, Company Report* (unpublished).

WAPET, 1961a—Barlee No. 1 well completion report, of West Australian Petroleum Pty Limited. *Bureau of Mineral Resources, Australia, Petroleum Search Subsidy Acts Publication* 16.

WAPET, 1961b—Samphire Marsh No. 1 well, Western Australia, of West Australian Petroleum Pty Ltd. *Bureau of Mineral Resources, Australia, Petroleum Search Subsidy Acts Publication* 5.

WAPET, 1961c—Thangoo No. 1 and No. 1A wells, Western Australia, of West Australian Petroleum Pty Ltd. *Bureau of Mineral Resources, Australia, Petroleum Search Subsidy Acts Publication* 14.

WAPET, 1964a—Barlee Gravity Survey, Western Australia, 1959, by West Australian Petroleum Pty Limited. *Bureau of Mineral Resources, Australia, Petroleum Search Subsidy Acts Publication* 38.

WAPET, 1964b—Parda Seismic Survey, final report. *Bureau of Mineral Resources, Australia,* File 64/4524 (unpublished).

WAPET, 1965a—Parda No. 1 well completion report. *Bureau of Mineral Resources, Australia,* File 65/4137 (unpublished).

WAPET, 1965b—Willara No. 1 well completion report. *Bureau of Mineral Resources, Australia,* File 65/4158 (unpublished).

WAPET, 1965c—Offshore Canning Aeromagnetic Survey, final report. *Bureau of Mineral Resources, Australia,* File 65/4614 (unpublished).

WAPET, 1966a—Reflection seismic survey by the 'Vibroseis' of the Marrin Seismic Project. *Bureau of Mineral Resources, Australia,* File 66/11067 (unpublished).

WAPET, 1966b—Reflection seismic survey by the 'Vibroseis' of the Willara Hill Seismic Project. *Bureau of Mineral Resources, Australia,* File 66/11081 (unpublished).

WAPET, 1966c—Roebuck Seismic Survey, final report. *Bureau of Mineral Resources, Australia,* File 66/11115 (unpublished).

WAPET, 1966d—Summary of data and results: Babrongan No. 1, Langoora No. 1, Hawkstone Peak No. 1, Canning Basin, Western Australia. *Bureau of Mineral Resources, Australia, Petroleum Search Subsidy Acts Publication* 48.

WAPET, 1966e—Summary of data and results: Sahara No. 1 well, Canning Basin, Western Australia. *Bureau of Mineral Resources, Australia, Petroleum Search Subsidy Acts Publication* 80.

WAPET, 1968—Willara Hill No. 1 well completion report. *Bureau of Mineral Resources, Australia,* File 68/2044 (unpublished).

WAPET, 1969—Bedout Marine Seismic Survey, final report. *Bureau of Mineral Resources, Australia,* File 69/3013 (unpublished).

WAPET, 1970a—Broome-Samphire Seismic Survey, final report. *Bureau of Mineral Resources, Australia,* File 70/857 (unpublished).

WAPET, 1970b—Canning Marine Seismic Survey, final report. *Bureau of Mineral Resources, Australia,* File 70/158 (unpublished).

WAPET, 1971—Final report, North Broome Seismic Survey. *Bureau of Mineral Resources, Australia,* File 71/252 (unpublished).

WAPET, 1972a—Pender No. 1 well completion report. *Bureau of Mineral Resources, Australia,* File 72/2000 (unpublished).

WAPET, 1972b—North Broome D-2 (333) Seismic Survey, final report. *Bureau of Mineral Resources, Australia,* File 72/961 (unpublished).

WAPET, 1972c—Liveringa Ridge (325) Seismic Survey, final report. *Bureau of Mineral Resources, Australia,* File 72/2938 (unpublished).

WAPET, 1973—Thangoo No. 2 well completion report. *Bureau of Mineral Resources, Australia,* File 73/218 (unpublished).

WARRIS, B. J., 1976—Canning Basin, off-shore. In LESLIE, R. B., EVANS, H. J., & KNIGHT, C. L. (Editors)—ECONOMIC GEOLOGY OF AUSTRALIA AND NEW GUINEA—3. PETROLEUM. *Australasian Institute of Mining and Metallurgy, Melbourne, Monograph Series,* 7, 185-188.

WEBBY, B. D., 1978—History of the Ordovician continental platform shelf margin of Australia. *Journal of the Geological Society of Australia,* 25(1), 41-63.

WHITWORTH, R., 1969—Marine geophysical survey of the north-west continental shelf, 1968. *Bureau of Mineral Resources, Australia, Record* 1969/99 (unpublished).

WOOLNOUGH, W. G., 1933—Report on aerial survey operations in Australia during 1932. *Parliamentary Paper 2164, Government Printer, Canberra.*

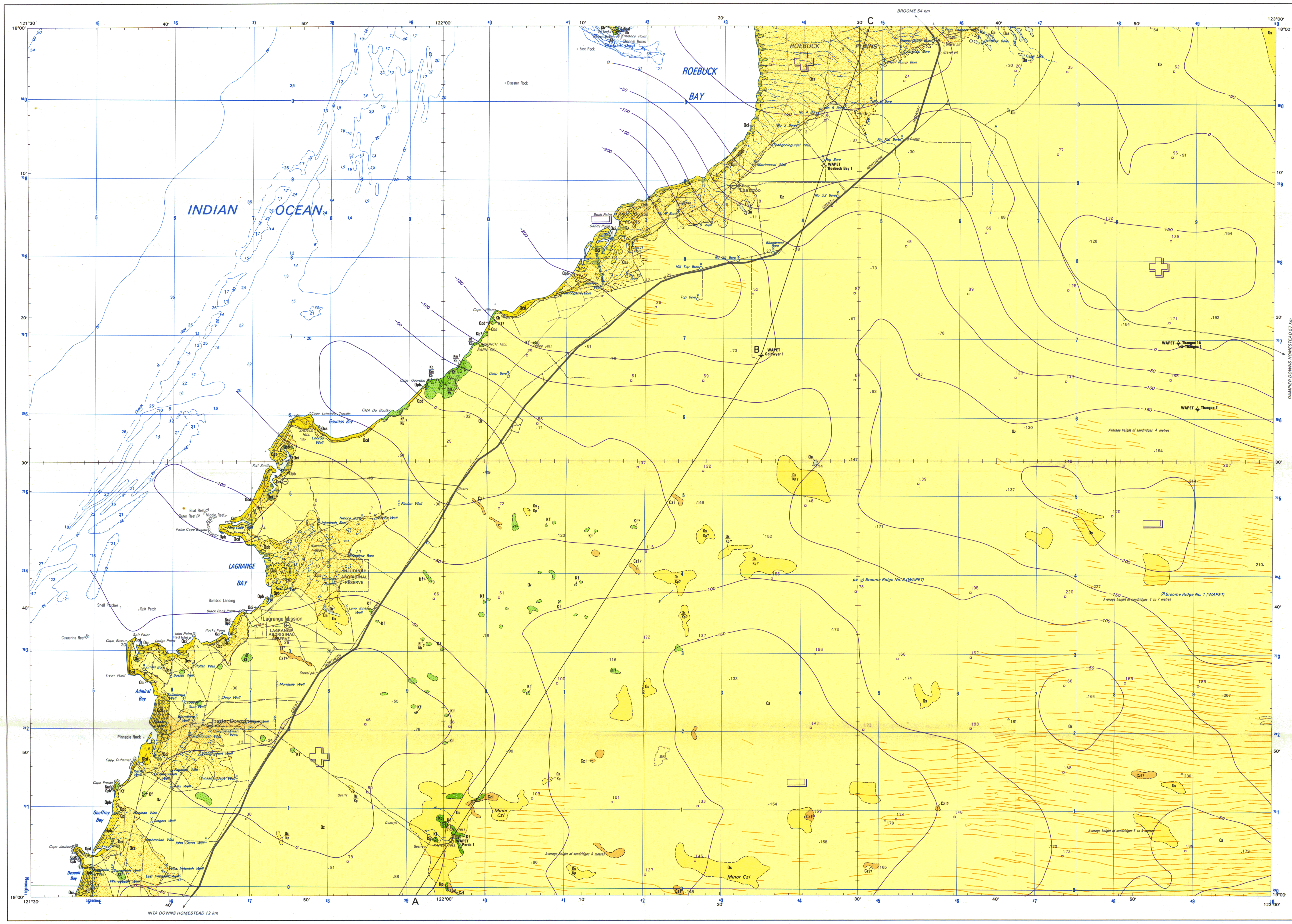
YEATES, A. N., CROWE, R. W. A., PASSMORE, V. L., TOWNER, R. R., & WYBORN, L. A. I., 1975—New and revised stratigraphic nomenclature, northeast Canning Basin, Western Australia. *Geological Survey of Western Australia, Annual Report for 1974,* 49-51.

AUSTRALIA 1:250 000 GEOLOGICAL SERIES

LAGRANGE

WESTERN AUSTRALIA

SHEET SE 51-10



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
			Qcs	Clay, silt, sand; minor salt: supratidal mud flat
			Qci	Silty clay, black organic clay: tidal flat and mangrove swamp
			Qcd	Calcareous sand, partly oolitic: coastal aeolian (includes reworked Qpb)
		Bossut Formation	Qpb	Calcareous and quartzose sandstone, fine to coarse; calcilutite, oolite; cross-bedded in part: coastal
			Czl	Laterite, pisolitic or massive: pedogenic
MESOZOIC	EARLY CRETACEOUS	Frezier Sandstone	Kf	Sandstone, fine to coarse, poorly sorted, poorly bedded, some relict cross-bedding; bioturbated in part; minor conglomerate, mudstone: fluvial to deltaic
		Parda Formation	Kp	Mudstone; minor fine sandstone lenses; thin bedded or massive: lagoonal or shallow marine
		Melligo Sandstone	Km	Sandstone, fine to medium; well-sorted, laminated to thin-bedded: beach
		Broome Sandstone	Kb	Sandstone, fine to very coarse; mudstone in part; minor conglomerate; ripple-marked, cross-bedded; bioturbated in part: shallow marine
	LATE JURASSIC TO EARLY CRETACEOUS?	Jarlemai Siltstone	JKr	Siltstone, claystone, sandstone: shallow marine
	LATE JURASSIC	Alexander Formation	Ja	Sandstone, fine to coarse; interbedded mudstone: shallow marine
	EARLY? TO LATE JURASSIC	Wallal Sandstone	Jl	Sandstone; minor siltstone, conglomerate, shale, lignite: continental to shallow marine
PALAEOZOIC	EARLY PERMIAN	Noonkanbah Formation	Pn	Mudstone, calcareous; fine sandstone, limestone interbeds: shallow marine
		Poole Sandstone	Pp	Sandstone, very fine to fine; interbedded mudstone; minor limestone at base: shallow marine to lagoonal
		Grant Group	Pg	Sandstone, fine to coarse; mudstone; minor conglomerate: marine, partly glacial marine
	EARLY CARBONIFEROUS	Anderson Formation	Ca	Sandstone, siltstone, shale; minor limestone, dolomite, anhydrite: marine and continental
	EARLY DEVONIAN TO EARLY CARBONIFEROUS		DC	Limestone, dolomite, shale, siltstone, fine sandstone: marine
	LATE ORDOVICIAN? TO EARLY DEVONIAN	Carribuddy Formation	Sc	Multicoloured claystone, silty and sandy in part; anhydrite; minor limestone near base: shallow marine, partly evaporite
	EARLY TO MIDDLE ORDOVICIAN	Nita Formation	On	Limestone, dolomite, interbedded shale: shallow marine
		Goldwyer Formation	Oo	Shale, black, fossiliferous, calcareous, pyritic; interbedded limestone, dolomite; minor siltstone lenses: shallow marine
		Willara Formation	Ow	Limestone, dolomitic, fossiliferous; interbedded shale and siltstone: shallow marine
		Nambeet Formation	Ot	Shale, grey to green; fine sandstone; interbedded dolomite, limestone: shallow marine
PRECAMBRIAN			p€	Igneous, metamorphic, and sedimentary rocks

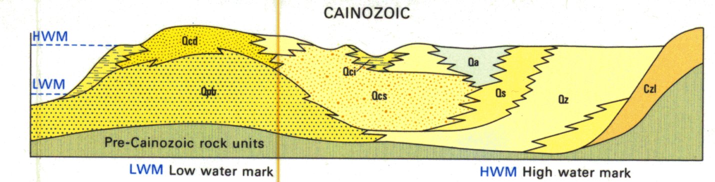
Section and rock relationship diagram only

Geological boundary
Fault
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.
Macrofossil locality
Plant fossil locality
Petroleum exploration well, dry, abandoned
Petroleum exploration well with show of oil, abandoned
Bore
Abandoned bore
Well
Windpump
Earth tank
Bathymetric contours in metres; closed depression
Submarine cliff
·80 Spot depth in metres showing general level and change of grade
·60 Spot depth in metres on isolated feature
Sand dunes, beach ridges
Rock ledge
Rock awash

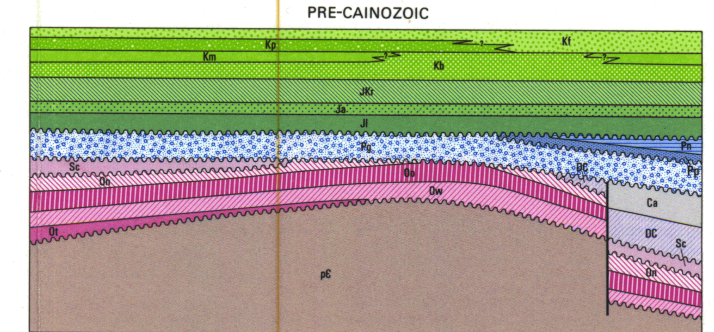
Escarpment, depression
Principal road and highway
Minor road
Vehicle track
Landing ground
Thangoo Homestead
Building
Yard
Fence
Minor administrative boundary
Trigonometrical station
·30 Elevation in metres
pa Position approximate
182 Selected gravity station with elevation in metres
Bouguer anomaly contour (micrometres sec^{-2}), computer-plotter produced
Gravity anomaly — relative high
Gravity anomaly — relative low

DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS

CAINOZOIC



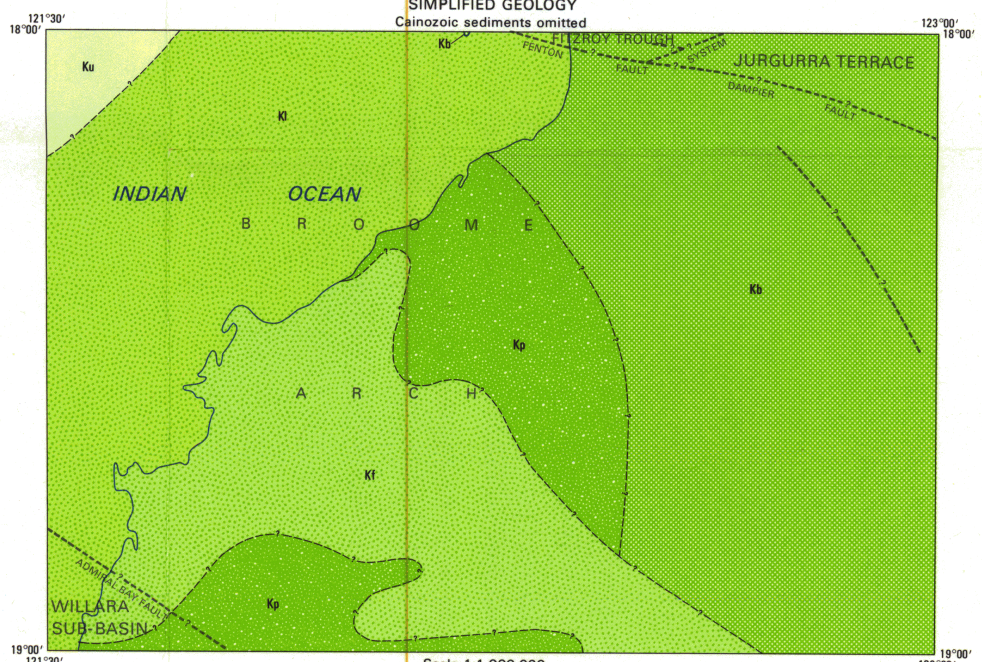
PRE-CAINOZOIC



Unconformity
Facies change

SIMPLIFIED GEOLOGY

Cainozoic sediments omitted



Scale 1:1 000 000

Ku — Undivided Late Cretaceous rocks; includes siltstone, marl, and claystone
Kl — Undivided Kb,Km,Kp,Kf
Fault, concealed and inferred (from seismic data)

Published by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development and Energy. Prepared in collaboration with the Geological Survey of Western Australia. Issued under the joint authority of the Minister for National Development and Energy and the Minister for Mines, WA. Base map supplied by the Division of National Mapping, topographic information shown is correct to 1979

UNIVERSAL GRID REFERENCE

GRID ZONE DESIGNATION: 51 K

100 000 METRE SQUARE IDENTIFICATION

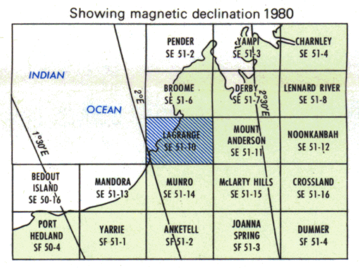
TO GIVE A STANDARD REFERENCE ON THIS SHEET TO NEAREST 1000 METRES

SAMPLE POINT: PARDA HILL ·127

1 Read letters identifying 100 000 metre square in which the point lies:
2 Locate first VERTICAL grid line to LEFT of point and read LARGE figure labelling the line either in the top or bottom margin, or on the line itself:
3 Estimate tenths from grid line to point:

INDEX TO ADJOINING SHEETS

Showing magnetic declination 1980



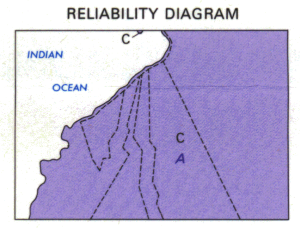
SCALE 1:250 000

5 0 5 10 15 20 25 Kilometres

BLUE NUMBERED LINES ARE 10 000 METRE INTERVALS OF THE AUSTRALIAN MAP GRID, ZONE 51

TRANSVERSE MERCATOR PROJECTION

RELIABILITY DIAGRAM



Geology C General reconnaissance: few traverses, mainly air photo interpretation

Helicopter traverse

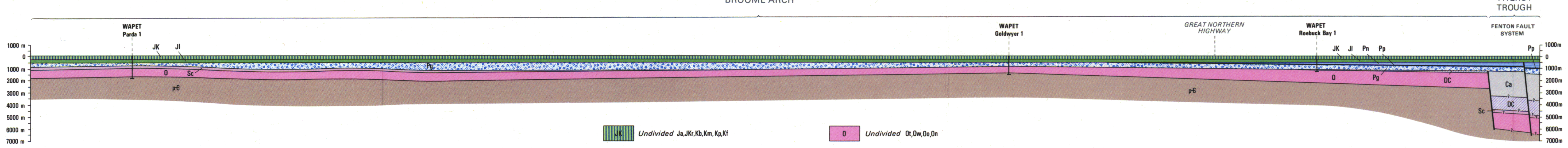
Gravity A Detailed survey

Geology 1977 by D.L. Gibson, R.R. Towner BMR; R.W.A. Crowe GSWA
Compiled 1978 by D.L. Gibson, A. Murray BMR
Edited 1981 by J. Mitchell, A.S. Mikolajczak
Gravimetry 1955-67 by BMR and private companies
Design by Cartography Section, BMR
Drawn by Capital Drafting Consultants Pty Ltd
Printed by Mercury-Walch, Hobart, Australia

SCHEMATIC SECTION

Cainozoic sediments omitted

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



JK — Undivided Ja,JKr,Kb,Km,Kp,Kf
O — Undivided Ot,Ow,Oo,On

LAGRANGE

SHEET SE 51-10

FIRST EDITION 1983