1:250 000 GEOLOGICAL SERIES—EXPLANATORY NOTES

BROOME
WESTERN AUSTRALIA

SHEET SE/51-6, INTERNATIONAL INDEX

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

DEPARTMENT OF MINES, FUEL & ENERGY, WESTERN AUSTRALIA
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

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COMPILED BY D. L. GIBSON

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Explanatory Notes on the Broome Geological Sheet

Compiled by D. L. Gibson

The Broome 1:250 000 Sheet area lies in northern Western Australia between latitudes 17° and 18°S, and longitudes 121°30′ and 123°E (Fig. 1). The eastern half of the area is land, the remainder is part of the Indian Ocean. Geologically, the Sheet area lies in the northern Canning Basin.

Broome, the only town, is well known as a tourist centre, and for its meat export and now declining pearling industries. There are several cattle stations in the Sheet area, but it is mostly undeveloped.

Access to the Sheet area is by the Great Northern Highway; a bitumen road connects this highway with Broome. A formed natural-surface road links Broome with Beagle Bay and Lombadina Missions to the north (Pender Sheet area), and station tracks provide limited access within the Sheet area. All unsealed roads are impassable after heavy rain. There are landing strips at Country Downs homestead and Beagle Bay Mission (just north of the Sheet area), and Broome has a large airport with regular airline services.

Aerial photographs and base maps

Vertical aerial photographs at a nominal scale of 1:85 000 (RC-9 series) were flown by the RAAF in 1967; 1:50 000 scale aerial photographs (K-17 series) were flown in 1949. The Royal Australian Survey Corps prepared a 1:250 000 topographic map from the 1949 airphotos in 1963, and four 1:100 000 contoured topographic maps in 1971 from the 1:85 000 airphotos.

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 from the Sheet area were those of Teichert (1941, 1942) who recognised Jurassic fossils from water bores drilled at Broome. Systematic geological mapping commenced in 1948 when the Bureau of Mineral Resources (BMR) began field operations in the area. Preliminary work was reported by Guppy & Lindner (1949), and a more exhaustive survey in 1950 was reported by Brunnschweiler (1951a, 1957). Brunnschweiler was accompanied by Hampton Smith, consulting geologist for Ampol Petroleum Ltd which held a petroleum exploration lease in the area from 1947 to 1952 (Smith, 1951). Reeves (1949, 1951) also reported on some aspects of the geology of the Sheet area. Rattigan & Elliott (1954) reported on a survey in the Fraser River area carried out for West Australian Petroleum Pty Ltd (WAPET), which had acquired a petroleum exploration lease over the area in 1953, and Smith & Williams (1956) reported on a WAPET survey of the northwest coast of the Dampier Peninsula.

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

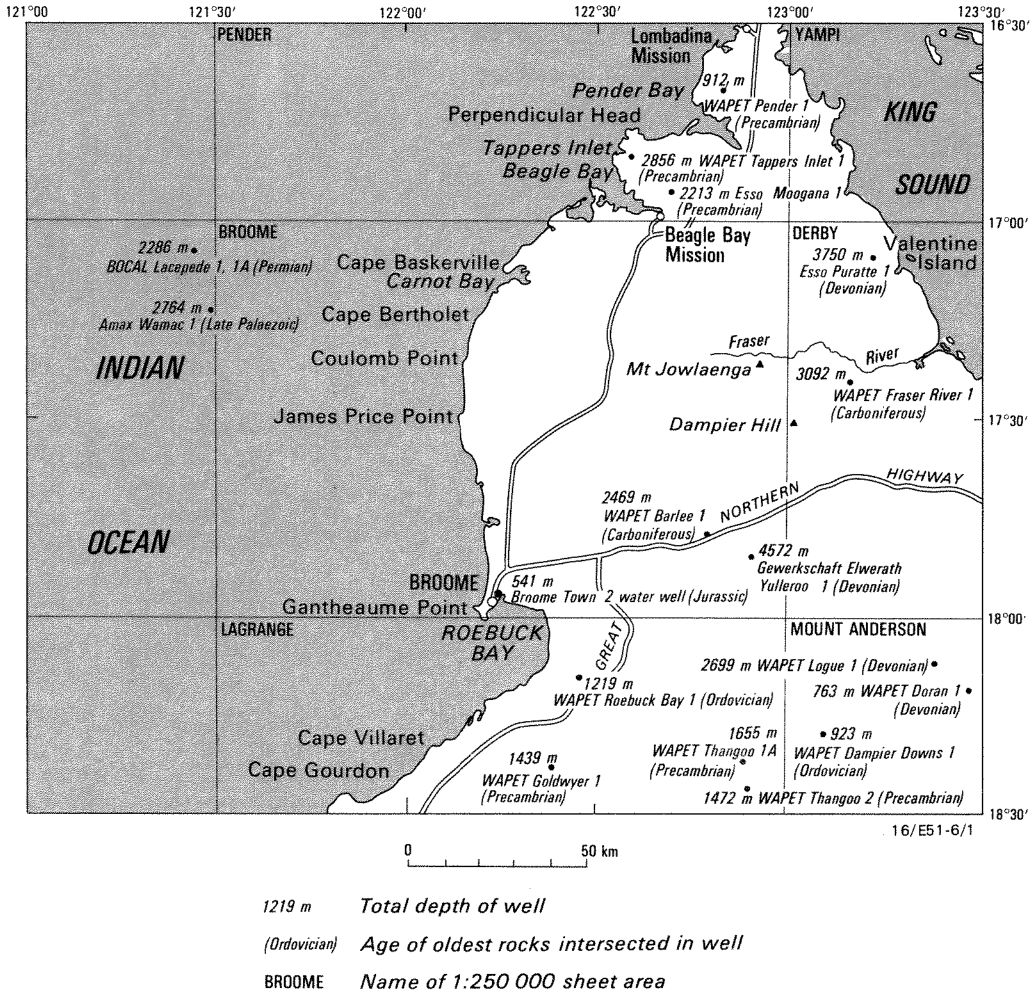

Fig. 1. Topographic features and deep wells in and around the BROOME 1:250 000 Sheet area.

This was followed by a regional aeromagnetic survey in 1954 (Quilty, 1960) and some detailed seismic work in the Broome area in 1954 and 1955 (Vale & Williams, 1955; Smith, 1961). The aeromagnetic survey showed that a considerable thickness of sediments overlies basement rocks in the Dampier Peninsula, and the seismic work indicated a considerable thickness of folded sediments. BMR also carried out several gravity surveys in and around the area in the period 1952-62; results of these are given by Flavelle & Goodspeed (1962), and Flavelle (1974).

WAPET carried out an aeromagnetic survey, and several gravity and seismic surveys in the area in the period 1955-59. These included the Roebuck East Refraction Profile A (WAPET, 1956a), the Dampier Downs, Roebuck Bay East, and Townshend Seismograph Surveys (WAPET, 1959), and the Broome Platform and McHugh Seismic Projects (WAPET, 1960).

Following 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. The first of these reports involving the Sheet area was the Barlee Gravity Survey carried out in 1959 (WAPET, 1964) which confirmed the presence of the Barlee Anticline in the southern part of the Sheet area, and indicated that there is no appreciable salt intrusion in this structure. The well WAPET Barlee 1 (WAPET, 1961a) was subsequently drilled on this structure. Some gas shows were encountered in the thick Carboniferous sequence in which the well bottomed at a depth of 2469 m.

The Dampierland Seismic Survey (WAPET, 1966a) was carried out mainly to the north of the Sheet area, but gave limited information in the northeastern corner. Meanwhile, the Lower Fitzroy Seismic and Magnetometer Survey (Gewerkschaft Elwerath Inc., 1966) delineated a small closed anticlinal structure (not shown on the map) south of the Barlee Anticline. This structure was subsequently drilled by the well Gewerkschaft Elwerath Yulleroo 1 (Gewerkschaft Elwerath Inc., 1967), which penetrated the thick Carboniferous sequence found in WAPET Barlee 1, and bottomed in Late Devonian rocks at a depth of 4572 m; very strong gas shows were encountered in the Carboniferous rocks. WAPET (1968) conducted the Baskerville Seismic Survey in the northern part of the Sheet area, to check a structural high suggested by aeromagnetic and gravity surveys. Reflection quality was poor, but two local anticlines (not shown on the map) were outlined.

Several subsidised offshore geophysical surveys have been carried out in and around the Sheet area. These include the Rowley Shoals, Scott Reef, and Sahul Banks Aeromagnetic Survey (Mid-Eastern Oil, 1963), the Offshore Canning Aeromagnetic Survey (WAPET, 1965), the Montebello-Mermaid Marine Seismic Survey (BOCAL, 1965), the Offshore Canning-Seringapatam Marine Seismic Survey (BOCAL, 1968), the Legendre-Marie Marine Seismic Survey (BOCAL, 1969a), the Bedout Marine Seismic Survey (WAPET, 1969), the Adele-Scott Marine Seismic Survey (BOCAL, 1969b) and the Canning Marine Seismic Survey (WAPET, 1970a). These gave general information on structure in the west of the Sheet area, and led to the drilling of the offshore petroleum wells, BOCAL Lacepede 1 and 1A in 1970 (BOCAL, 1970) and Amax Wamac 1 in 1973 (Amax, 1973), respectively 5 km and 1 km west of the northern part of the Sheet area.

BMR carried out an offshore geological reconnaissance program (dredge sampling, seismic reflection, and sea-floor photography) in 1967, which provided information on the thickness of Late Tertiary sediments and the lithology of sediments exposed on the sea floor over part of the Sheet area (Jones, 1968, 1973). A detailed BMR offshore geophysical survey carried out in 1969 measured gravity, magnetics, and seismic refraction velocities over part of the Sheet area (Whitworth, 1969).

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 of these are confidential, but raw data from offshore surveys which come under the Petroleum (Submerged Lands) Act are available at BMR.

These Explanatory Notes and accompanying map are based on field mapping 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 1:250 000 scale (Towner & Gibson, 1980, 1983). Vehicle and helicopter traverses were made in the Sheet area during the survey. The section on the map is partly based on information from Gorter & others (1979) and Forman & Wales (1981).

PHYSIOGRAPHY

The climate is hot and seasonally wet. Average annual rainfall is about 600 mm, and most of this falls from December to March. Normal daily maximum and minimum temperatures are about 32° and 26°C in January, and 28° and 14°C in July. Potential average annual evaporation is about 2300 mm. All climate figures are estimated from Bureau of Meteorology contour maps.

The physiography of the land part of the Sheet area is summarised in Figure 2. It is characterised by a gently domed, well-vegetated plain which rises to more than 240 m above sea level. Watercourses are usually poorly defined on this plain, and are choked with sand. To the east and northwest of the updomed

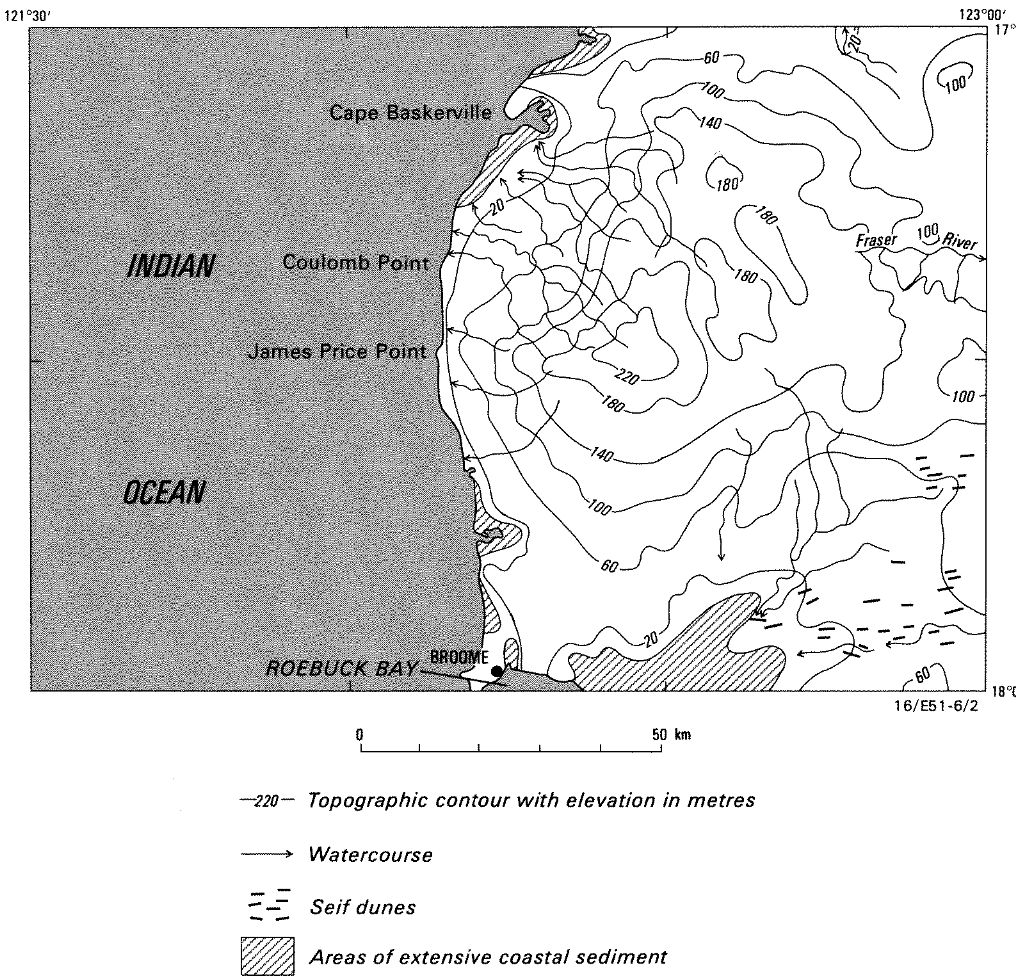

Fig. 2. Topography of the onshore portion of the BROOME 1:250 000 Sheet area.

area, the Fraser River, and streams reaching the coast between Coulomb Point and Cape Baskerville, have eroded the plain, causing slightly more rugged topography. West-trending seif dunes are present in the southeastern part of the Sheet area. These dunes are an extension of the dune fields and sand sheets developed to the southeast in the Great Sandy Desert. The dunes in the Sheet area are of simple type (term of Crowe, 1975), and were deposited by easterly winds.

Coastal areas are characterised by aeolian dunes (parallel with the coast), extensive intertidal and supratidal mud flats bordering inlets and bays (especially east of Roebuck Bay where supratidal mud flats extend 30 km inland), platforms of lithified coastal sediments, and narrow beaches. Cliffs up to 20 m high back a narrow beach between James Price and Coulomb Points.

Offshore, the sea floor slopes gently to the west where it reaches a maximum depth of about 80 m in the Sheet area; a narrow, deep (up to 105 m) northwest-trending tidal channel is present 2 km southwest of Gantheaume Point. Tidal range varies between 1 and 10 m.

Vegetation of the Sheet area is characterised by Pindan. This 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.

STRATIGRAPHY

The stratigraphy of the Sheet area is summarised in Table 1 and briefly described below. Onshore, units older than the Early Cretaceous Broome Sandstone are not known to crop out in the Sheet area; some have been penetrated in petroleum exploration wells in the Sheet area, and the remainder are inferred to be present from the results of the petroleum exploration wells Esso Moogana 1 (Esso, written communication, 1980) 7 km north, WAPET Tappers Inlet 1 (WAPET, 1971) 15 km north, and WAPET Roebuck Bay 1 (WAPET, 1956c) 13 km south of the Sheet area. Stratigraphic relationships and estimates of thicknesses of units not intersected or with incomplete sections in wells in the Sheet area are based on well information outside the Sheet area. An insight into the stratigraphy offshore is given by BOCAL Lacepede 1 and 1A (BOCAL, 1970) and Amax Wamac 1 (Amax, 1973). The well locations and total depths, and the age of the oldest rocks penetrated in these and other wells in and around the Sheet area, are shown in Figure 1.

PRECAMBRIAN

Rocks of Precambrian age (p€) most probably underlie the Canning Basin sequence in the Sheet area. Precambrian metabasalt was intersected in WAPET Tappers Inlet 1, and Precambrian interbedded graphitic shale and metadolerite in Esso Moogana 1, both wells being north of the Sheet area. Other wells near the Sheet area intersected Precambrian schist, granite, phyllite, gneiss, and quartzite (Gorter & others, 1979).

EARLY TO MIDDLE ORDOVICIAN

Early to middle Ordovician rocks (O) are probably present at the base of the Canning Basin sequence (see McTavish & Legg, 1976). To the north of the Sheet area, shale with interbedded limestone and fine sandstone of the Early Ordovician

TABLE 1. SUMMARY OF STRATIGRAPHY

Age	*Rock unit and map symbol*	*Estimated thickness (m)*	*Lithology*
QUATERNARY	Qa	10?	Sand, silt, clay, minor gravel
	Qb	5?	Clay, silt
	Qs	10?	Sand, silt, minor gravel
	Qz	10?	Fine to medium red sand, minor silt
	Qcs	5?	Clay, silt, sand, minor salt
	Qci	5?	Silty clay, black organic clay
	Qcd	20?	Calcareous sand, partly oolitic
	Bossut Formation (Qpb)	20?	Fine to coarse calcareous and quartzose sandstone; calcilutite, oolite; cross-bedded in part
TERTIARY TO QUATERNARY	Czl	2?	Pisolitic and massive laterite
EARLY CRETACEOUS	Emeriau Sandstone (Kr)	30?	Fine to coarse poorly-sorted sandstone; minor conglomerate; cross-bedded; commonly ferruginous in outcrop
	Melligo Sandstone (Km)	30?	Fine to medium, well-sorted, thin-bedded to laminated sandstone; pebbly in places; contains heavy minerals; partly silicified
	Broome Sandstone (Kb)	280 in Broome Water Bore 2, top eroded	Fine to very coarse sandstone; some mudstone; minor conglomerate; ripple-marked, cross-bedded; bioturbated in part
LATE JURASSIC TO EARLY CRETACEOUS(?)	Jarlemai Siltstone (JKr)	259 in WAPET Barlee 1	Siltstone, claystone, sandstone; glauconitic, ferruginous (phosphatic?) in part
LATE JURASSIC	Alexander Formation (Ja)	21 in WAPET Barlee 1	Interbedded fine to coarse sandstone and mudstone; pyritic, glauconitic in part
EARLY(?) TO LATE JURASSIC	Wallal Sandstone (Jl)	364 in WAPET Barlee 1	Sandstone; minor siltstone, conglomerate, lignite
EARLY TRIASSIC	Blina Shale (Rb)	60? (77.5 in Esso Moogana 1, 7 km north of Sheet area)	Mudstone, sandy in places
PERMIAN(?) TO TRIASSIC	d	100?	Dolerite
EARLY TO LATE PERMIAN	Liveringa Group (Pl)	200? (207 in Esso Moogana 1)	Sandstone, mudstone; minor conglomerate, limestone, coal

Stratigraphic relationships	*Fossils*	*Remarks*
Superficial deposit		Alluvial and lacustrine
Superficial deposit		'Black soil' of alluvial and lacustrine origin
Superficial deposit		Mixed aeolian and alluvial
Superficial deposit		Aeolian: seif dunes and sand sheets
Superficial deposit		Supratidal mud flat
Superficial deposit		Tidal flat and mangrove swamp
Superficial deposit		Coastal aeolian dune sand; includes reworked Qpb
Unconformably overlies Kb	Bivalves, gastropods, forams	Coastal; includes beach ridges
Superficial deposit		Pedogenic
Disconformably overlies Kb; top eroded		Fluvial to deltaic; probably equivalent to Aptian Frezier Sandstone of southwest Canning Basin
Conformably to disconformably overlies Kb; top eroded	Belemnites, bivalves	Regressive beach
Conformably overlies JKr; conformably to disconformably overlain by Km; disconformably overlain by Kr	Plant fossils, microfossils, dinosaur footprints; bivalves outside Sheet area	Includes 'Jowlaenga Formation' of Brunnschweiler (1957); regressive shallow-marine (tidal); oldest unit to crop out in Sheet area
Conformable between Ja and Kb	Bivalves, gastropods, ammonites, microfossils, ostracods, belemnites	Shallow-marine (subtidal)
Conformable between Jl and JKr	A wide range of shelly fossils known from outside Sheet area	Shallow-marine (tidal) transgressive deposit
Unconforambly overlies Rb, Pl, Pn, Pp, Pg, and Ca; conformably overlain by Ja	Microfossils, plant fossils	Continental to shallow-marine
Unconformable between Pl and Jl	Ostracods, brachiopods, vertebrates known from ouside Sheet area	Shallow restricted marine; inferred to be present in the Sheet area
Dykes and sills; intrudes Ca and older units in WAPET Barlee 1 area; probably intrudes late Palaeozoic rocks offshore		Intersected only in WAPET Barlee 1 in the Sheet area; sills up to 104 m intersected in Amax Wamac 1, 1 km west of Sheet area
Conformably overlies Pn; unconformably overlain by Rb and Jl	Bivalves, gastropods, brachiopods, ammonoids, plant fossils, microfossils known from outside Sheet area	Shallow-marine to deltaic; inferred to be present in the Sheet area

TABLE 1. SUMMARY OF STRATIGRAPHY *(continued)*

Age	*Rock unit and map symbol*	*Estimated thickness (m)*	*Lithology*
EARLY PERMIAN	Noonkanbah Formation (Pn)	200? (198 in Esso Moogana 1)	Calcareous mudstone, fine sandstone, limestone
	Poole Sandstone (Pp)	50? (49 in Esso Moogana 1)	Very fine to fine sandstone; mudstone; minor limestone at base
	Grant Group (Pg)	800? (824 in Esso Moogana 1)	Fine to coarse sandstone; mudstone in middle part; minor conglomerate
EARLY CARBONIFEROUS	Anderson Formation (Ca)	2551 in Gewerkschaft Elwerath Yulleroo 1 (partly eroded); probably 4000 maximum	Fine to coarse sandstone, siltstone, shale; minor limestone, dolomite, anhydrite
MIDDLE DEVONIAN(?) TO EARLY CARBONIFEROUS	DC	2000? (incomplete section of 1163 m in Gewerkschaft Elwerath Yulleroo 1)	Dolomite, limestone, shale, siltstone, fine sandstone
EARLY TO MIDDLE ORDOVICIAN	O	800? (817 in WAPET Tappers Inlet 1, 15 km north of Sheet area)	Shale, limestone, dolomite, siltstone, fine sandstone
PRECAMBRIAN	p€		Igneous, metamorphic, and sedimentary rocks

Nambeet Formation (Johnstone *in* WAPET, 1961b) rests unconformably on Precambrian basement, and is conformably overlain by partly dolomitic limestone with interbedded shale and siltstone of the Early Ordovician Willara Formation (McTavish *in* Playford & others, 1975). To the south, dolomite of the Middle Ordovician Nita Formation (McTavish *in* Playford & others, 1975), originally called the Roebuck Dolomite (McWhae & others, 1958), is the only Ordovician unit penetrated by WAPET Roebuck Bay 1, but its base was not reached. South of this, WAPET Goldwyer 1 (WAPET, 1958) is interpreted to have penetrated Willara Formation resting on basement, conformably overlain by calcareous shale and minor limestone of the Middle Ordovician Goldwyer Formation (Elliott *in* WAPET, 1961c). It is probable that all these units extend into the Broome Sheet area.

Middle Devonian(?) to Early Carboniferous

Gewerkschaft Elwerath Yulleroo 1 (Gewerkschaft Elwerath Inc., 1967) penetrated 1163 m of rocks of Late Devonian to Early Carboniferous age, but did not reach their base. To the south of the Sheet area, WAPET Roebuck Bay 1 intersected the Early Devonian Thangoo Calcarenite (McTavish & Legg, 1976), but as this is a unit of limited distribution, it is probable that it does not extend into the Sheet area. However, it is possible that the sequence in the Sheet area extends down into the Middle Devonian.

Druce & Radke (1979) have interpreted the presence of the Late Devonian to Early Carboniferous Fairfield Group between 3963 m and 3409 m in Gewerk-

Stratigraphic relationships	*Fossils*	*Remarks*
Conformably overlies Pp; conformably overlain by Pl; unconformably overlain by Jl	Brachiopods, bryozoans, corals, crinoids, bivalves, gastropods, ostracods and microfossils known from outside Sheet area	Unrestricted shallow-marine; inferred to be present in the Sheet area
Unconformably(?) overlies Pg; conformably overlain by Pn; unconformably overlain by Jl	Brachiopods, bryozoans, ammonoids, molluscs, conodonts, crinoids, ostracods, plant fossils, microfossils known from outside Sheet area	Shallow-marine to lagoonal; inferred to be present in the Sheet area
Unconformably overlies Ca, DC, and O; unconformably(?) overlain by Pp; unconformably overlain by Jl	Bivalves, gastropods, brachiopods, bryozoans, crinoids, fossil wood, microfossils known from outside Sheet area	Marine; partly glacial-marine
Conformably overlies DC; unconformably overlain by Pg and Jl	Bivalves, microfossils	Marine and continental
Unconformably overlies O; conformably overlain by Ca; unconformably overlain by Pg	Conodonts, ostracods, microfossils	Includes Fairfield Group, Luluigui Formation, and other units not penetrated in the Sheet area; marine
Unconformably overlies p€; unconformably overlain by DC and Pg	A wide variety of fossils known from outside Sheet area	Probably includes Nita, Goldwyer, Willara, and Nambeet Formations; shallow-marine
Unconformably overlain by O		Basement to the Canning Basin

schaft Elwerath Yulleroo 1, and Gorter & others (1979) interpret this to be conformably underlain by the Late Devonian Luluigui Formation (Willmott *in* WAPET, 1966c).

As there is only one intersection of these rocks in the Sheet area, and the distribution of formations of this age varies widely, no attempt has been made to show the recognised units on the map section, and they have been combined into one map unit (DC) of undifferentiated Middle Devonian(?) to Early Carboniferous rocks.

These rocks are conformably overlain by the Early Carboniferous *Anderson Formation* (Ca) (McWhae & others, 1958), which may reach a thickness of over 4000 m in the Sheet area. This unit is known only from the Fitzroy Trough, a graben which is present over most of the Sheet area (see section on Structure), and its close environs, and was deposited during a time of rapid subsidence. In Gewerkschaft Elwerath Yulleroo 1, it is 2551 m thick. Fossil evidence shows that the bottom 1000 m here is marine, and the rest continental (Gewerkschaft Elwerath Inc., 1967).

PERMIAN

The Anderson Formation is unconformably overlain by the *Grant Group* (Pg) (Guppy & others, 1958; Crowe & Towner, 1976). No attempt is made here to distinguish the basal, sandy Betty Formation, the shaly Winifred Formation, and the upper, sandy Carolyn Formation which have been identified in WAPET Roebuck Bay 1 to the south and WAPET Tappers Inlet 1 to the north (Towner

& Gibson, 1980). Most or all (as in WAPET Barlee 1) of the Group is interpreted to have been removed by post Permian-pre Early(?) Jurassic erosion where drilled in petroleum exploration wells in the Sheet area (Towner & Gibson, 1980). The Betty and Carolyn Formations are thought to have been deposited under cold water or glacial marine conditions (see Dickins & others, 1977). 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).

Well data from outside the Sheet area and seismic data suggest that younger Permian units overlie the Grant Group in the Sheet area; if so these have been eroded in WAPET Barlee 1 and Gewerkschaft Elwerath Yulleroo 1 areas. The following units are probably present over much of the Sheet area.

The *Poole Sandstone* (Pp) (Guppy & others, 1952) overlies the Grant Group. Crowe & others (1978) showed that the contact is an angular unconformity in the Grant Range (Mount Anderson and Derby 1:250 000 Sheet areas to the southeast and east). No attempt has been made to show the lower calcareous Nura Nura Member (Guppy & others, 1958) and the upper sandy Tuckfield Member (Crowe & Towner, 1976) on the map; if present, these units would be too thin to show individually. The Poole Sandstone is of Sakmarian to Artinskian age, and is probably of marine to lagoonal origin.

The conformably overlying *Noonkanbah Formation* (Pn) (Wade, 1938; Guppy & others, 1952) is of Artinskian age, and is made up of fine-grained shallow-marine deposits.

The Noonkanbah Formation is conformably overlain by the *Liveringa Group* (Pl) (Guppy & others, 1952; Yeates & others, 1975), which was intersected in Esso Moogana 1 to the north of the Sheet area. No attempt has been made to divide the Group into its constituent formations and their members. It is a shallow-marine to deltaic deposit, and is of Kungurian to Tatarian age.

PALAEOZOIC ROCKS OFFSHORE

The Palaeozoic sequence in the west of the Sheet area could be as thick as 6000 m, as magnetic surveys show that basement may reach a depth of 8000 m, and Forman & Wales (1981) show the base of the Mesozoic sequence to reach a depth of about 2000 m. The Palaeozoic sequence could include Ordovician, Devonian, Carboniferous, and Permian rocks. Amax Wamac 1 intersected 800 m of Palaeozoic rocks and intruded dolerite (see 'INTRUSIVE ROCKS' below). The sedimentary rocks intersected included sandstone, claystone, shale, and siltstone, with minor coal, dolomite, and limestone. The sequence could not be adequately dated, as microfossils were intensely carbonised; ages ranging from Early Carboniferous to Early Permian were speculatively assigned to the sequence by Amax (1973).

Gorter & others (1979) recognise Carboniferous rocks in BOCAL Lacepede 1A, apparently on the basis of lithology. However, Late Permian palynomorphs have been recognised in sidewall cores (BOCAL, 1970). The Palaeozoic rocks intersected were 186 m of very fine to fine sandstone, grading into siltstone with minor shale, overlain by 87 m of siltstone, and in turn overlain by 15 m of shale. These rocks are of non-marine origin (BOCAL, 1970), and they could be equivalent to part of the Liveringa Group.

TRIASSIC

The *Blina Shale* (Rb) (Reeves, 1951; Brunnschweiler, 1954) is of Early Triassic age, and was deposited in a shallow sea. It was intersected in Esso Moogana 1 to the north of the Sheet area, and is most probably present in the northeastern part of the Sheet area. The deltaic to fluvial Erskine Sandstone was probably deposited over the Blina Shale in this area, but was eroded prior to Jurassic deposition (see Gorter, 1978).

Triassic rocks are not known offshore in the Sheet area.

JURASSIC TO EARLY CRETACEOUS

The *Wallal Sandstone* (Jl) (McWhae *in* WAPET, 1961b) is made up of sandstone with minor siltstone, conglomerate, and lignite. It is probably of continental to shallow-marine origin. It has not been dated in the Sheet area, but is probably of Middle to Late Jurassic (Oxfordian) age (Playford & others, 1975), although there are indications that it may extend down into the Early Jurassic in the southwest Canning Basin (Towner & Gibson, 1980).

The overlying *Alexander Formation* (Ja) (Brunnschweiler, 1954) is a thin unit of glauconitic sandstone and mudstone that represents the beginnings of the Jurassic-Cretaceous 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, outside the Sheet area, but may extend up into the Early Cretaceous (Crowe & others, 1978). This unit was deposited at the height of the Jurassic-Cretaceous marine transgression in the Canning Basin.

The *Broome Sandstone* (Kb) (Reeves, 1951; Brunnschweiler, 1957) was originally defined to cover sandstone cropping out along the west coast of the Dampier Peninsula near Broome, and overlying what is now identified as the Jarlemai Siltstone in water bores at Broome. Brunnschweiler (1957) introduced the term 'Jowlaenga Formation' (amended by McWhae & others (1958) to 'Jowlaenga Sandstone') for sandstone underlying the Melligo Sandstone (see below) in the Fraser River area and along the east coast of the Dampier Peninsula north from Valentine Island.

Towner & Gibson (1980) found that the Broome Sandstone near Reeves' type section at Gantheaume Point contains a wide variety of sandstone lithologies and sedimentary structures consistent with deposition in a shallow-marine (tidal) environment, and also identified outcrops previously mapped as Jowlaenga Sandstone at Dampier Hill (outside the Sheet area—see Fig. 1) and along the west coast of the Dampier Peninsula with the Broome Sandstone, and at Mount Jowlaenga with the Melligo Sandstone. Mount Jowlaenga was Brunnschweiler's type locality for the Jowlaenga Formation, but his coordinates and map give different locations for what he designated to be the type locality, and neither coincide with the current gazetted position of Mount Jowlaenga. Towner & Gibson's usage is continued here.

The Broome Sandstone is poorly dated. It contains a Neocomian microflora and Late Jurassic to Early Cretaceous plant fossils (Playford & others, 1975), it conformably to disconformably underlies the Aptian Melligo Sandstone, and it contains both Late Jurassic and Early Cretaceous shelly fossils, identified from the 'Jowlaenga Sandstone' (see: Skwarko, 1970; Brunnschweiler, 1960) and from the 'Leveque Sandstone', also considered to be part of the Broome Sandstone (see: Gibson, in press a; Brunnschweiler, 1960). Dinosaur footprints are present at Gantheaume Point near Broome (Colbert & Merilees, 1967). The Broome Sandstone is here considered to be a unit deposited in shallow water as the Early Cretaceous sea regressed.

The *Melligo Sandstone* (Km) (Brunnschweiler, 1957; McWhae & others, 1958) conformably to disconformably overlies the Broome Sandstone. Brunnschweiler used silicification as a requisite for recognising this unit, but unsilicified Melligo Sandstone has been recognised in the Mount Jowlaenga area (Towner & Gibson, 1980) on the basis of sedimentary structures and fabric.

The good sorting and rounding of the constituent grains, which include heavy minerals, coupled with thin bedding, flat to low-angle cross bedding, and parting lineation indicate that it is a beach deposit, laid down as the sea in which the Broome Sandstone was deposited regressed.

The age of the Melligo Sandstone is well documented as it contains the key Aptian bivalve, *Fissilunula clarkei.*

The *Emeriau Sandstone* (Kr) (Brunnschweiler, 1957) disconformably overlies the Broome Sandstone where the contact is exposed at Emeriau Point, 25 km north of the Sheet area. Towner & Gibson (1980) equated this unit with the Aptian Frezier Sandstone of the western Canning Basin on lithological and stratigraphic grounds, in preference to giving it a Tertiary age as did Brunnschweiler (the 'Pender Bay Conglomerate', considered by Brunnschweiler to be a lateral equivalent of the Emeriau Sandstone, was found by Towner & Gibson to be a thin Cainozoic lag gravel of clasts of ferruginised Emeriau Sandstone, and is not considered a mappable unit at the scale of the accompanying map).

Mesozoic Rocks Offshore

Offshore, Jurassic to Cretaceous rocks are most probably everywhere present in the Sheet area. BOCAL Lacepede 1A (BOCAL, 1970) intersected 1695 m of Jurassic to Cretaceous rocks. The basal part of the sequence consists of 658 m of non-marine sandstone with interbedded shale and minor coal of Early Jurassic to Oxfordian age, overlain by 67 m of Oxfordian to Tithonian marine sandstone with interbedded shale. This is overlain, probably with minor disconformity, by a sequence of 187 m of claystone (open-marine at base, grading up to nearshore-marine) of Tithonian age, overlain by 181 m of nearshore-marine sandstone and siltstone of Tithonian to Neocomian age. Another probably minor disconformity separates this from 523 m of marine, grading up to nearshore-marine, sandstone, siltstone, and claystone of Neocomian to Aptian age.

A major break separates this from a sequence of 78 m of Late Cretaceous siltstone, marl, and claystone, which is unconformably overlain by Tertiary carbonates.

The lowermost disconformity may correspond to the 'breakup' unconformity, a major break encountered in offshore wells in the Canning, Browse, and Carnarvon Basins. It marks a change from predominantly continental deposition and erosion to marine deposition which commenced with the breakup of Australia from a landmass to the northwest (see Powell, 1976). This unconformity has not been recognised onshore in the Canning Basin, but it probably corresponds to the boundary between the Wallal Sandstone and the Alexander Formation.

Cainozoic

Laterite (Czl) overlying Broome Sandstone is exposed in the headwaters of some of the creeks reaching the coast between Coulomb Point and Carnot Bay. It may be as old as Early Tertiary (Towner & Gibson, 1980).

The *Bossut Formation* (Qpb) (Traves & others, 1956; Lindner *in* WAPET, 1961a) as used here includes the 'North Head Limestone' of Brunnschweiler (1957), which was considered by Towner & Gibson (1980) to be a local facies variant of the Bossut Formation. The Bossut Formation 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 mud flat deposits (Qcs) usually occur landward of the tidal deposits.

Aeolian deposits (Qz) occur as sand sheets and seif dunes mainly in the south of the Sheet area. These are a peripheral part of the aeolian deposits of the Great Sandy Desert to the south.

Most of the land in the Sheet area is veneered with a cover of *sand and silt* (Qs) which is probably of mixed aeolian and alluvial origin.

Alluvial and lacustrine sediments consist of sandy alluvium (Qa) and clay-rich 'black soil' (Qb).

Cainozoic Rocks Offshore

Offshore, the Cainozoic is represented by a wedge of carbonates thickening to the west (Gorter & others, 1979; Forman & Wales, 1981). BOCAL Lacepede 1A intersected 235 m of Cainozoic rocks, but no samples were obtained, except for the basal 3 m (dolomite), because of lost circulation (BOCAL, 1920).

Amax Wamac 1 intersected 272 m of Cainozoic rocks, but no samples were obtained during drilling; dolomite and glauconitic sandstone recovered while drilling at deeper depths are thought to be cavings of Cainozoic rocks (Amax, 1973).

The offshore Cainozoic sequence can be regionally divided into an early Tertiary sequence of carbonates and clastics, unconformably overlain by a late Tertiary (Upper Miocene to Recent) sequence of carbonates, but it is probable that the lower sequence is not present in the Sheet area (Gorter & others, 1979; Forman & Wales, 1981).

Intrusive Rocks

Dolerite (d) intrudes the Anderson Formation in WAPET Barlee 1 and the Palaeozoic sequence in Amax Wamac 1. The dolerite in WAPET Barlee 1 is present between 2385 and 2394 m, and has been dated at 196 m.y. (Harding, 1966; Prider, 1969), placing it in the Triassic. Glover (*in* WAPET, 1961a) believes that the dolerite is comagmatic with that encountered in WAPET Fraser River 1 (WAPET, 1956b), 64 km to the northeast. However, this dolerite has been dated at 830 m.y., i.e. Precambrian (White, 1962), although this age is controversial; Playford & others (1975) believe that the main igneous body in WAPET Fraser River 1 is intrusive into the Anderson Formation, and is of Triassic age.

Dolerite in Amax Wamac 1 is present as probable sills up to 104 m thick. It has been dated by the K-Ar method at 228 m.y., or Early Triassic; this is a minimum age, and the dolerite here is most probably Permian (Amax, 1973).

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 virtually undeformed Mesozoic and Cainozoic rocks. Some idea of structure in pre-Permian rocks onshore is given by the Lower Fitzroy Seismic Survey (Gewerkschaft Elwerath Inc., 1966); offshore, there is no seismic information on horizons below the Permian. A simplified presentation of structure within the Sheet area is given in the section and simplified geology sketch on the accompanying map. In the Sheet area the Canning Basin is divided into three structural subdivisions based on basement morphology.

The *Fitzroy Trough* is a northwest-trending graben which is present over most of the Sheet area. It was initiated in the Middle Devonian when movement started along its bounding faults; only the southern boundary of the trough, the Fenton Fault System, occurs in the Sheet area. Further movement along the Fenton Fault System during deposition in the Late 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 about 4000 m.

Many east-west trending en-echelon folds are present in the Triassic and older rocks of the Fitzroy Trough, and it has been proposed 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 two major anticlines in the Sheet area, the Barlee Anticline and Baskerville Anticline, probably formed in this manner.

The presence of a broad domal structure, the 'Fraser River Structure', was proposed by workers in the late 1940s and early 1950s (e.g. Reeves 1949, 1951; Guppy & Lindner, 1949; Brunnschweiler, 1957) in the Sheet area on the basis of regional dips in the outcropping Mesozoic rocks and the elevation of the Melligo Sandstone. The presence of a broad anticlinal warp in the Mesozoic in the Sheet area is probable, as the top of the Broome Sandstone occurs near sea level 25 km to the north of the Sheet area in the Perpendicular Head area (Pender Sheet area), 35 km to the east at Valentine Island (Derby Sheet area), and 40 km south in the Cape Villaret-Cape Gordon area (Lagrange Sheet area). However, within the Sheet area, it occurs at about 120 m above sea level in the Mount Jowlaenga area, and above 100 m about 20 km east of Coulomb Point (where Broome Sandstone crops out at about 100 m above sea level). The area between Mount Jowlaenga and Coulomb Point is a relatively high, domed plain reaching over 240 m above sea level. This topography may be the result of relatively recent upwarping; steepening stream gradients to the west of this rising area may have led to incision of creeks draining to the sea. The upwarping may have also diverted the Fitzroy River from a previous possible course towards Roebuck Bay (Brunnschweiler, 1957).

The *Jurgurra Terrace* is an area of intermediate basement depth at the southern margin of the Fitzroy Trough, and is present in the southeastern corner of the Sheet area. This area 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 Fitzroy

Trough to the north during the Carboniferous. Basement depths on the Terrace are about 3000 m in the Sheet area.

To the south of the Jurgurra Terrace and Fitzroy Trough is the *Broome Arch*, with depths to basement of 1500-2500 m to the southeast of the Sheet area. The Broome Arch is only present offshore in the Sheet area, and no estimates of depth to basement are available in this area. It may be an area which did not downwarp as quickly as the Trough and Terrace to the north, and Willara and Kidson Sub-basins (Towner & Gibson, 1980) to the south, or may be an uplifted area marginal to the Fitzroy Trough, similar to marginal uplifts in the Red Sea-African Rift Zone area.

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 until Early Ordovician time, when it is likely that a shallow sea transgressed across the Sheet area, and mud, sand, and carbonate (Nambeet, Willara, Goldwyer, and Nita Formations) were deposited in it in Early to Middle Ordovician times. Regression followed.

No equivalents of the thick sequence of evaporites and related sediments (Carribuddy Formation) which were deposited in the southern Canning Basin, probably in the Silurian to Early Devonian, are known in the Sheet area, but they may have been deposited.

In Middle(?) Devonian times the sea entered the Sheet area, probably as a result of movement (down to the north) along the Fenton Fault System. Clastic sediments and carbonates were deposited in this sea (Devonian rocks intersected by Gewerkschaft Elwerath Yulleroo 1), and sedimentation continued into the Carboniferous (Anderson Formation). Emergence in Carboniferous times resulted in erosion of the Carboniferous and also the Devonian rocks.

The sea transgressed again across the Sheet area in latest Carboniferous or Early Permian times. Sand and mud (Grant Group) were then deposited under cold water conditions. A minor period of emergence and erosion may have followed, then sand and mud (Poole Sandstone) were deposited in a warmer sea. Transgression continued, and mud and carbonates (Noonkanbah Formation) were laid down. Regression in Early to Late Permian times resulted in deposition of shallow-marine to fluviatile sand and mud (Liveringa Group).

Emergence and minor erosion followed. Mud of the Blina Shale was deposited in the Early Triassic in a shallow sea which may have extended across the northern part of the Sheet area. As this sea regressed, deltaic sands were probably deposited (Erskine Sandstone).

During the Triassic, or possibly earlier, dolerite was intruded into some of the late Palaeozoic rocks.

In the Late Triassic or Early Jurassic, the area was subjected to a major period of tectonism and erosion. Right-lateral shear along the Fenton Fault System probably induced folding in the rocks of the Fitzroy Trough. Major erosion of the Triassic and Permian rocks followed.

Deposition recommenced, possibly as early as Early Jurassic times, when continental to shallow-marine sand and minor silt (Wallal Sandstone) were deposited. 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 times resulted in deposition of sand and mud in a shallow-marine environment (Broome Sandstone). By Aptian times, the sea had regressed from the land part of the Sheet area, beach sands (Melligo Sandstone) being deposited as this happened. Fluvial sand (Emeriau Sandstone) was then deposited. The sea regressed from the whole of the Sheet area by Albian times, and minor erosion followed.

The sea transgressed across the western part of the Sheet area in the Late Cretaceous, and fine-grained carbonates and mud were deposited. It then regressed entirely from the area, probably in latest Cretaceous times, and, again, minor erosion followed.

Tertiary (Miocene and younger) marine carbonates and minor sand were then deposited offshore over the western part of the Sheet area.

In the Cainozoic, lateritisation occurred and a variety of thin deposits of shoreline (including Bossut Formation), alluvial, lacustrine, aeolian, and mixed aeolian and alluvial origin were deposited on the onshore part of the Sheet area. Offshore, carbonates and sand continued to be deposited in a marine environment.

ECONOMIC GEOLOGY

Petroleum

Very strong gas shows were encountered in Gewerkschaft Elwerath Yulleroo 1 near the base of the Early Carboniferous Anderson Formation. More than 850 m^3 of gas was recovered in several tests, with a total flow estimated at 70 m^3/hour. The gas-producing zones were not made up of good reservoir rocks, as porosities ranged between 4.6% and 13.5%, with permeabilities between 0 and .65 mD. The source rock potential of the upper part of the Devonian to Early Carboniferous sequence (identified as Fairfield Group by Druce & Radke, 1979) and lower part of the Anderson Formation appeared to be good (Gewerkschaft Elwerath Inc., 1967).

Burne & Kantsler (1977) concluded that the zone of oil generation in the Canning Basin lies between the 50° and 75°C isotherms; these relatively low temperatures reflect the prolonged burial of the Palaeozoic rocks. They show that rocks of Devonian to Permian age in the Sheet area mostly lie within this temperature window at present; however, present temperatures of these rocks in major anticlines are less than temperatures reached in the past. Burne & others (1979) list the Fitzroy Trough and Jurgurra Terrace as being amongst the areas having greatest potential for the commercial discovery of hydrocarbons, and state that source rock analyses favour oil generation in the Fairfield Group and Anderson Formation. However, porosity in the Fairfield Group is very low, and potential reservoirs in the Anderson Formation generally lack seals.

Offshore, to the west of the Sheet area, BOCAL Lacepede 1A encountered minor gas shows in Permian and Jurassic rocks, and Amax Wamac 1 did not have any hydrocarbon shows. The Mesozoic sequence in Amax Wamac 1 is considered to contain reasonable source rocks, but is immature, and the Palaeozoic sequence is considered to contain overmature poor source rocks, and has low porosity and permeability (Amax, 1973). The offshore Mesozoic sequence probably has not reached the oil generative window in the Sheet area, so the petroleum potential over the whole Sheet area must be considered poor.

Coal

Lignite and black coal were encountered in the Wallal Sandstone in the petroleum exploration wells in the Sheet area. This is likely to have little economic significance.

Coal is also known from the Liveringa Group (see Explanatory Notes for the Derby (Towner, 1981) and Mount Anderson (Gibson & Crowe, 1982) Sheet areas), but the probable existence of the Group at depths of around 1000 m in this Sheet area (see section on the accompanying map) would make any coal present uneconomic.

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) report three bores at Broome yielding about 70 000 litres/hour, each from a depth of 30-60 m, i.e. in Broome Sandstone. Poor-quality artesian water is obtained from the Alexander Formation, Wallal Sandstone, and Jarlemai Siltstone at Broome, and it is expected that large quantities of this water would be present in these formations throughout the Sheet area.

Heavy minerals

Heavy-mineral concentrations in Recent sands along the coastline of the Sheet area have been reported by Simpson (1951), Brunnschweiler (1952, 1957), Stillwell (1953), Farrand (1965), and Towner & Gibson (1980). The results of the earlier reports have been incorporated in Baxter (1977) and Gardiner (1977).

The heavy minerals present are opaques (mainly magnetite and magnetite-ilmenite compounds), with zircon, and some rutile, tourmaline, andalusite, kyanite, and staurolite.

Greatest concentrations are in the James Price Point-Coulomb Point area. Between these Points is a beach about 14 km long and 18-36 m wide, overlying a platform cut into Broome Sandstone, at the foot of a cliff 6-12 m high truncating Broome Sandstone and red soil. Drilling carried out by Enterprise Exploration in their lease area in the early 1950s indicated 42 600 tonnes of mineral sands containing approximately 21 000 tonnes of heavy minerals. The principal concentrations, between 20% and 80%, occurred in sands generally thinner than 1.5 m (Baxter, 1977).

Brunnschweiler (1952) suggested that the source of the heavy minerals could be either Mesozoic sandstones exposed in the Dampier Peninsula, or the Precambrian Pilbara Block, 400-600 km to the southwest. He remarked that the sandstones of the Dampier Peninsula were composed almost entirely of quartz in thin-section, implying that these were unlikely to be the source.

However, Towner & Gibson (1980) showed that the topmost part of the Broome Sandstone, and the Melligo Sandstone contain heavy-mineral grains, and that the grains in the heavy-mineral sand samples examined were well to very well rounded, and most probably multicyclic (J. Colwell, BMR, written communication, 1979).

Hence it is quite possible that the heavy-mineral grains were derived from the top of the Broome Sandstone and the Melligo Sandstone, which were themselves deposited in nearshore and beach environments conducive to the concentration of heavy minerals. The heavy minerals may have originated in the Precambrian Kimberley Block to the northeast of the Canning Basin.

The concentrations are likely to have little economic significance.

Phosphate

Freas & Zimmerman (1965) report phosphatic sideritic ironstone in the Jarlemai Siltstone, Alexander Formation, and Wallal Sandstone in the Canning Basin. A 122 m interval (depth not specified by Freas & Zimmerman) of the Jarlemai Siltstone in WAPET Barlee 1 contained an average of more than 1% P_2O_5; within this, the interval 158 to 168 m averaged 5.7% P_2O_5 and 23.4% Fe_2O_3. The Jarlemai Siltstone in WAPET Thangoo 1 (WAPET, 1961c), 41 km south of the Sheet area, averaged 4.3% P_2O_5 between 137 and 152 m.

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

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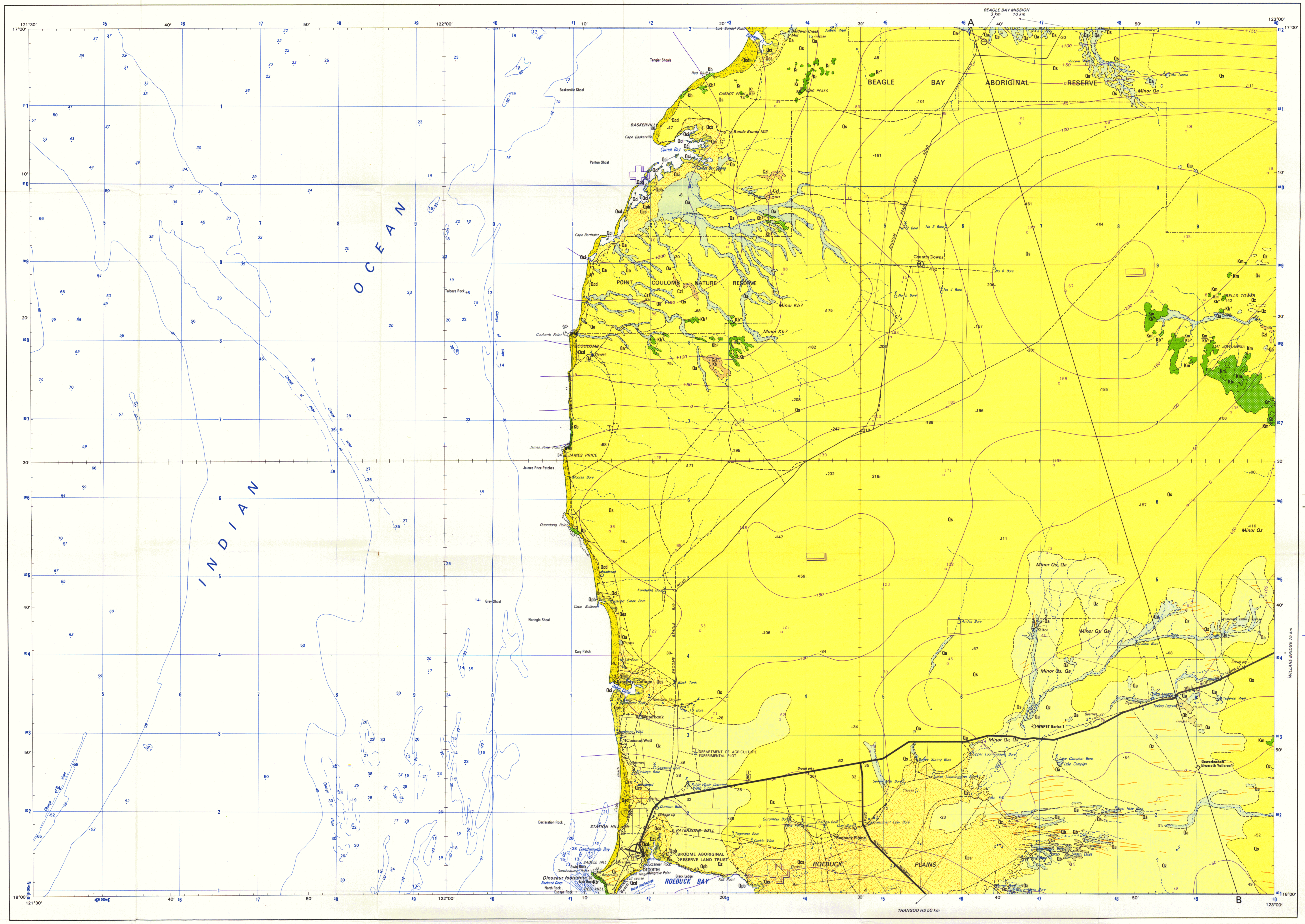
AUSTRALIA 1:250 000 GEOLOGICAL SERIES

BROOME

WESTERN AUSTRALIA

SHEET SE 51-6



AUSTRALIA

CAINOZOIC	QUATERNARY		Qa	Sand, silt, clay; minor gravel: alluvial and lacustrine
			Qb	Clay, silt: 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 dunes (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	Emeriau Sandstone	Kr	Sandstone, fine to coarse, poorly sorted; minor conglomerate; cross-bedded: fluvial to deltaic
		Melligo Sandstone	Km	Sandstone, fine to medium, well-sorted; laminated to thin-bedded; pebbly in places; silicified in part: beach
		Broome Sandstone	Kb	Sandstone, fine to very coarse; mudstone in part; minor conglomerate; ripple-marked, cross-bedded; partly bioturbated; plant fossils: 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, lignite: continental to shallow marine
	EARLY TRIASSIC	Blina Shale	Rb	Mudstone, sandy in places: shallow marine
	PERMIAN? TO TRIASSIC		d	Dolerite sills and dykes
PALAEOZOIC	EARLY TO LATE PERMIAN	Liveringa Group	Pl	Sandstone, mudstone; minor limestone, conglomerate, coal: shallow marine
	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
	MIDDLE DEVONIAN? TO EARLY CARBONIFEROUS		DC	Dolomite, limestone, shale, siltstone, fine sandstone: marine
	EARLY TO MIDDLE ORDOVICIAN		O	Shale, limestone, dolomite, siltstone, fine sandstone: shallow marine
PRECAMBRIAN			p€	Igneous, metamorphic, and sedimentary rocks

Section and rock relationship diagram only (JKr to p€)

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

Trace fossil locality

Unworked deposit; HM— Heavy mineral sands

Petroleum exploration well with show of gas, abandoned

Bore

Well

Windpump

Water storage

Bathymetric contour in metres; closed depression

Spot depth showing general level in metres, and change of grade

Spot depth on isolated feature in metres

Sand dunes, beach ridges

Rock ledge

Rock awash; rock submerged

Cliff

Principal road and highway

Minor road

Vehicle track

Airport; landing ground

Homestead

Building

Yard

Fence

Minor administrative boundary

Trigonometrical station

Elevation in metres

Selected gravity station with elevation in metres

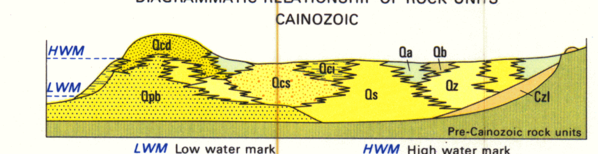
Bouguer anomaly contour (micrometres sec^{-2}), computer-plotter produced

Gravity anomaly — relative high

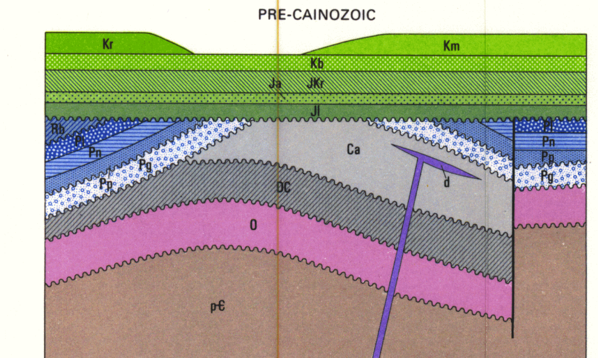
Gravity anomaly — relative low

DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS

CAINOZOIC



PRE-CAINOZOIC



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UNIVERSAL GRID REFERENCE

GRID ZONE DESIGNATION: 51K

100 000 METRE SQUARE IDENTIFICATION

UB	VB
UA	VA

IGNORE the SMALLER figures of any grid number; these are for finding the full co ordinates. Use ONLY the LARGER figures of the grid number; example: 350 000

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

SAMPLE POINT: Kilto

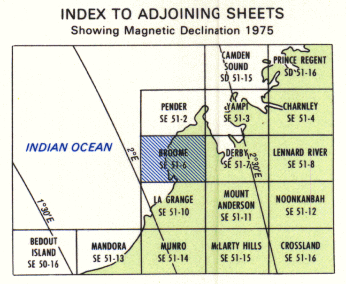
1 Read letters identifying 100 000 metre square in which the point lies: VA
2 Locate first VERTICAL grid line to LEFT of point and read LARGE figure labelling the line either in the top or bottom margin, or on the line itself: 6
3 Estimate tenths from grid line to point: 9
4 Locate first HORIZONTAL grid line BELOW point and read LARGE figure labelling the line in either the left or right margin, or on the line itself: 4
5 Estimate tenths from grid line to point: 4

SAMPLE REFERENCE: VA6944

If reporting beyond 18° in any direction, prefix Grid Zone Designation, as: 51KVA6944

INDEX TO ADJOINING SHEETS

Showing Magnetic Declination 1975



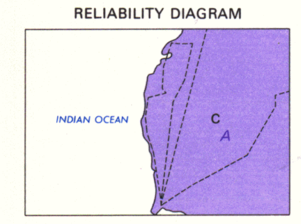
SCALE 1:250 000

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 airphoto interpretation

Helicopter traverse

Gravity A Detailed survey

Geology 1948 by D.J. Guppy, A.W. Lindner BMR
1950 by R. O. Brunnschweiler BMR
1977 by D.L. Gibson, R.R. Towner BMR; R.W.A. Crowe GSWA
Compiled 1978 by D.L. Gibson, D.G. Walton BMR
Edited 1981 by J. Mitchell, A.S. Mikolajczak
Gravimetry 1954-65 by BMR and private companies
Design by Cartography Section, BMR
Drawn by Capital Drafting Consultants Pty Ltd
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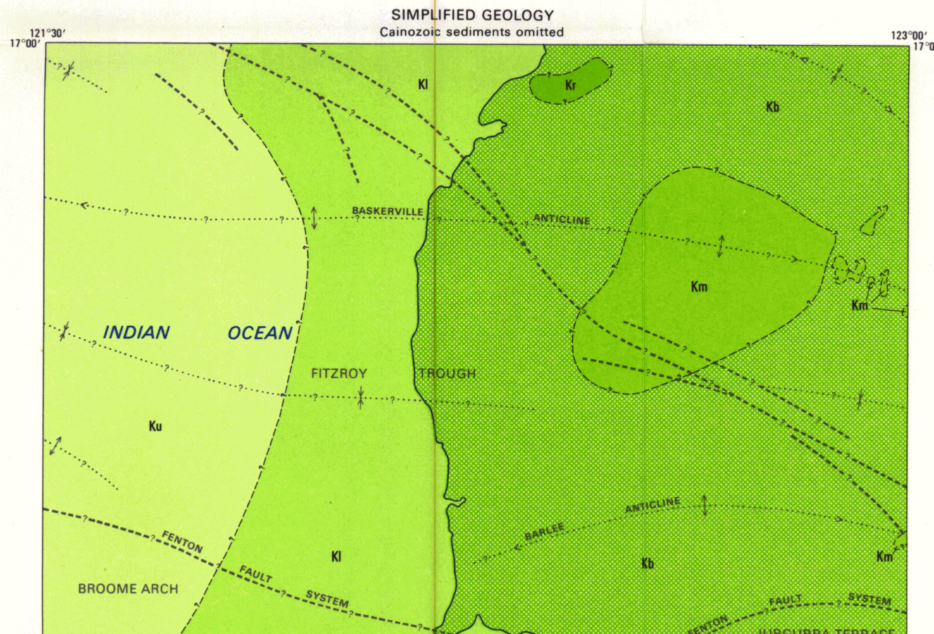
SIMPLIFIED GEOLOGY

Cainozoic sediments omitted



Scale 1:1 000 000

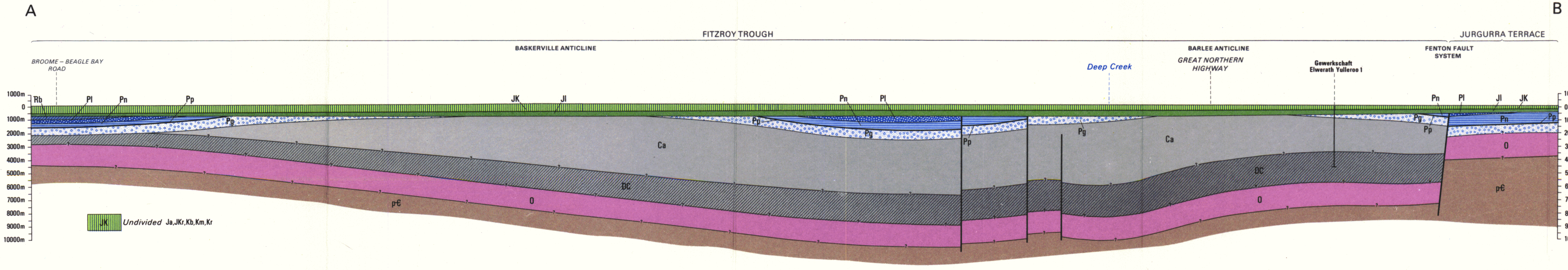
Ku	Undivided Late Cretaceous rocks; includes siltstone, marl, and claystone
Kl	Undivided Kb, Km, Kr

Anticline, showing trend of plunge; Syncline, showing trend of plunge; Fault — concealed and inferred (from seismic data)

SCHEMATIC SECTION

Cainozoic sediments omitted

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



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SHEET SE 51-6

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