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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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The Geology and Mineral Occurrences of Bathurst Island, Melville Island, and Cobourg Peninsula, Northern Territory

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ABSTRACT

Lower Proterozoic sedimentary, metamorphic, and igneous rocks of the Pine Creek Geosyncline and Nimbuwah Complex form the basement rocks of the Bathurst Terrace. To the west of the Bathurst Terrace, along the eastern edge of the adjoining Bonaparte Gulf Basin, Phanerozoic sedimentation commenced in the Early Permian and led to the accumulation of a conformable sequence comprising the Kulshill, Hyland Bay, and Mount Goodwin Formations, and an unnamed Middle to Upper Triassic formation. It was not until the Late Jurassic that the sea transgressed onto the Bathurst Terrace to deposit the Petrel Formation, followed by the Bathurst Island Formation in the Cretaceous, and the Van Diemen Sandstone in the Early Tertiary. In the Late Cretaceous and Tertiary, chemical weathering produced an extensive cover of laterite.

Mineral sands containing ilmenite, zircon, and rutile occur along the northern and western coasts of Bathurst and Melville Islands. Uneconomical deposits of bauxite crop out on the northern headlands of Cobourg Peninsula and Croker Island. In addition, uneconomical deposits of uranium, manganese, phosphate, limestone, clay, and hydrocarbons have been found in the area. Subartesian water is available on Bathurst and Melville Islands from aquifers in the Van Diemen Sandstone, and artesian water was discovered in the Marligur Member of the Bathurst Island Formation in the southern Cobourg Peninsula Sheet area.

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CONTENTS

APPENDICES

TABLES

FIGURES

PLATES

SUMMARY

The Bureau of Mineral Resources carried out reconnaissance geological mapping of Bathurst and Melville Islands and Cobourg Peninsula in 1972-73.

Basement comprises Lower Proterozoic sedimentary, metamorphic, and igneous rocks of the Pine Creek Geosyncline and Nimbuwah Complex. On southern Cobourg Peninsula basement rocks are unconformably overlain by the nearly horizontal Carpentarian Kombolgie Formation.

A conformable Permo-Triassic sequence consisting of the Kulshill, Hyland Bay, and Mount Goodwin Formations, and an unnamed Middle to Upper Triassic formation is restricted to the western margin of the Bathurst Island Sheet area where it pinches out against the eastern edge of the Bonaparte Gulf Basin.

Late Jurassic paralic to fluvial conditions over much of the area led to the deposition of sand and silt (Petrel Formation and Tinganoo Bay Beds). Periodic transgressions and regressions followed in the Cretaceous during which sand and mud of the Bathurst Island Formation accumulated; four distinctive members are recognized within the Bathurst Island Formation: Darwin, Marligur, Wangarlu Mudstone and Moonkinu Members.

By the Early Tertiary, terrestrial conditions were dominant and chemical weathering had produced an extensive cover of laterite. Earth movements in the early Tertiary resulted in the northwest tilting of the landsurface. On Cobourg Peninsula this caused renewed erosion of the laterite and, ultimately, the formation of bauxite. At about the same time the Van Diemen Sandstone was deposited over much of Bathurst and Melville Islands Sheet areas.

Submarine terraces and notches, ancient strandlines, and stranded beach deposits are evidence of both higher and lower sea levels in the Quaternary.

Beach sands along the northern and western coasts of Bathurst and Melville Islands contain concentrations of ilmenite, zircon, and rutile, which warrant further investigation. Bauxite deposits up to 4 m thick on the northern headlands of Cobourg Peninsula assay 35 to 45 percent Al_2O_3. However, most of the silica is reactive, and this together with the scattered distribution and small size of the deposits limits the economic potential of the bauxite. Uneconomical deposits of uranium, manganese, phosphate, limestone, and clay have been found in the area.

Several onshore and offshore petroleum exploration wells have been drilled in the area but no commercial hydrocarbons have been found.

Subartesian water is available on Bathurst and Melville Islands from aquifers within the Van Diemen Sandstone, and in the southern Cobourg Peninsula Sheet area artesian water has been found in the Marligur Member. Elsewhere, Quaternary sand and laterite form unconfined aquifers from which unreliable supplies of domestic and stock water are obtained.

INTRODUCTION

This report covers the area between latitudes 11° and 12°30'S and longitudes 129° and 133°30'E, comprising the Bathurst Island, Melville Island, and Cobourg Peninsula 1:250 000 Sheet areas. Here the rocks of the North Australian Orogenic Province form a stable cratonic block upon which a thin sequence of platform cover sediments accumulated during the Mesozoic and Cainozoic. More or less continuous subsidence throughout the Mesozoic and Cainozoic resulted in the development of the Money Shoal and Bonaparte Gulf Basins to the north and west of the cratonic block respectively.

Fieldwork

A reconnaissance geological survey of the Sheet areas was made by the Bureau of Mineral Resources (BMR) between June and October, 1972 (Hughes & Senior, 1973). In 1973 further geological mapping was carried out on Melville Island and five stratigraphic drill holes were drilled on Cobourg Peninsula (Hughes, 1973).

Location and settlements

The islands lie about 60 km north of Darwin. Melville Island, 5700 km^2 in area, is separated from Bathurst Island, 2200 km^2, by Apsley Strait. Cobourg Peninsula is northeast of Darwin and is separated from Melville Island by Dundas Strait. The area is sparsely populated. The Aboriginals now live in Government and church-controlled welfare settlements established at Garden Point, Snake Bay, Paru Village, Bathurst Island Mission, Croker Island Mission, and South Goulburn Island Mission (Fig. 1). Each settlement has a population of less than 1000. The Department of Forestry, Darwin, maintains small settlements at Pickertaramoor and Murgenella for the development of cypress pine plantations and culling of the natural forests on Melville Island and in the Murgenella Wildlife Reserve. The Cobourg Peninsula Flora and Fauna Reserve is controlled by a ranger with headquarters at Black Point, Port Essington. A culture-pearl oyster farm has been established at Knocker Bay, and at Cape Don on the western tip of the Peninsula a small resident staff operates the Cape Don lighthouse.

Access

On Bathurst Island access is restricted to a track along the south coast from Bathurst Island Mission to Cape Fourcroy where there is an automatic lighthouse and meteorological station. A disused overgrown track runs north from the central southern coast to Interview Point. Graded and formed roads provide good access to western and central Melville Island. Four-wheel-drive vehicle tracks allow access to the southern and northern coasts, but there is no access by land to the eastern side of the island. Western Cobourg Peninsula is also inaccessible by land. Access to Cobourg Peninsula from Darwin is by bitumen road to Mount Bundey (Darwin Sheet area) and then by a graded gravel road via Oenpelli (Alligator River Sheet area). In the Cobourg Peninsula Sheet area itself, access is along graded and rough ungraded tracks which vary considerably according to the terrain they cross; they are impassable during the monsoon season.

Two helicopters were used for traverses in the three northern Sheet areas (total flying time 170 hours). Two boats were used to enable distant groups of islands, and parts of the coastlines inaccessible by helicopter or vehicle to be mapped. MV *Bali Hai* was used from 19 to 22 June 1972 and MV *Arandel* from 25 August to 14 September 1972.

Climate and vegetation

The climate is tropical with warm to hot, dry winters and hot wet summers. The average annual rainfall is 1600 mm, most of which falls between December and April under the influence of the northwest monsoons.

Temperatures range from a mean maximum of 35°C to a mean minimum of 21°C in summer, and in winter from 26°C maximum to 18°C minimum. The vegetation consists of tropical eucalypt and acacia forests, with paperbarks along the watercourses. Mangroves grow extensively on the tidal flats and pandanus palms fringe the coastline.

Acknowledgments

The permission of Australian Aquitaine Petroleum Pty Ltd to incorporate information from their unsubsidized exploration wells Newby No. 1, Bougainville No. 1, and Flat Top No. 1 is gratefully acknowledged; and Arco Australia Ltd for wells Tern No. 1 and Penguin No. 1.

Previous investigations

Geological. The first recorded geological observations in the area were made by Captain King (1827) during his survey of 1818 to 1822. He noted the ferruginous character of the sedimentary rocks on Cobourg Peninsula and described Sims Island and Bottle Rock as coarse granular quartzose sandstone (Kombolgie Formation). Stokes (1846) visited Vic-

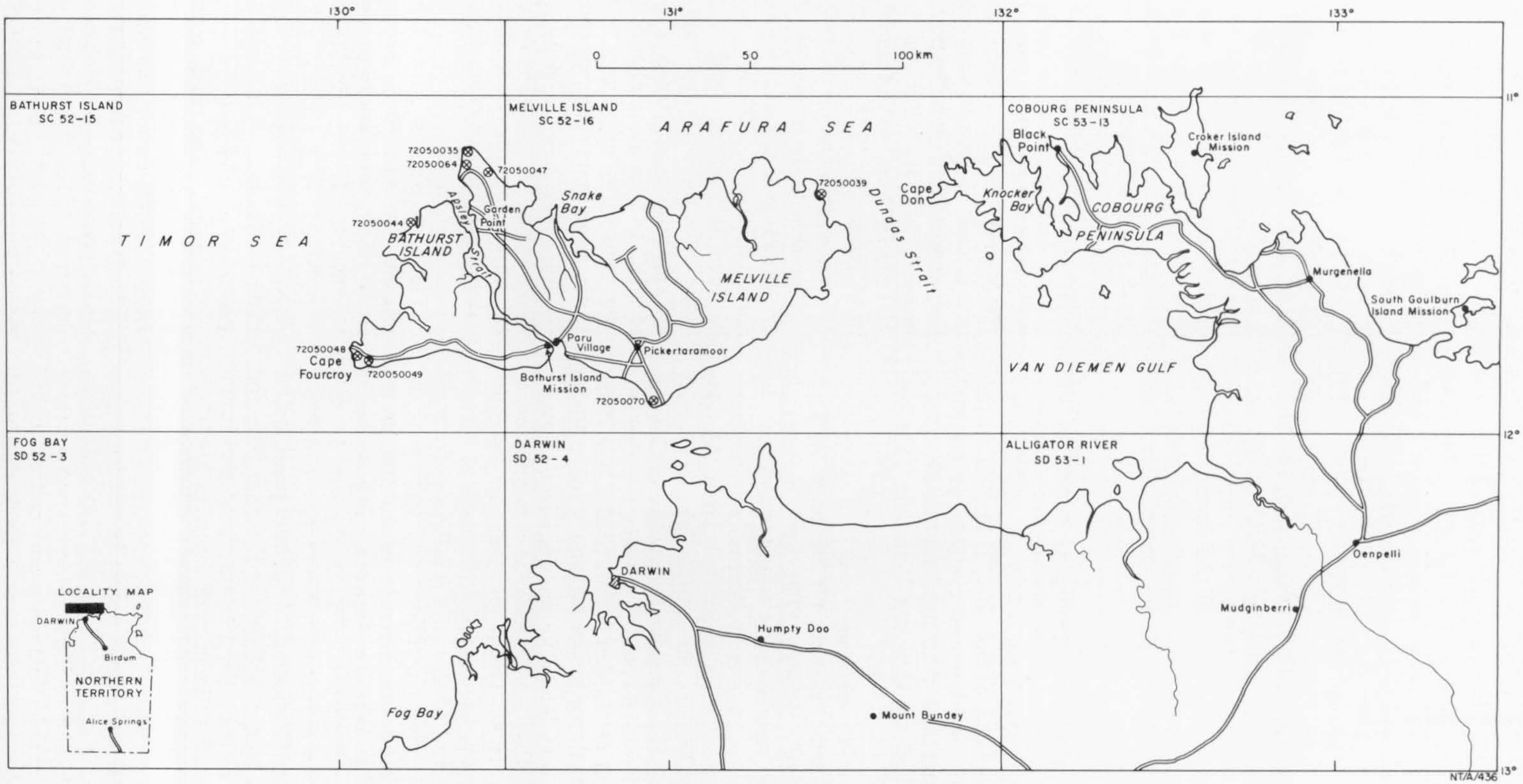

Fig. 1. Locality map, Sheet index, and location of heavy-mineral samples.

toria, Port Essington and observed magnetic iron oxides in the rocks around Port Essington. He described the cliffs of the harbour as consisting of a 'light coloured marl, but the formation is chiefly of arenaceous rocks'. Leichhardt (1847) completed his overland expedition at Victoria having travelled from Moreton Bay, Queensland. He described the low hills in the neck of the peninsula as composed of 'clayey ironstone' and 'indurated, shaley grey coloured rock' (Wangarlu Mudstone Member).

The first known visit of a geologist was that by Brown (1906) to the south coast of Melville Island. He collected Cretaceous ammonites from the horizontally bedded rocks near Cape Gambier. During a geological reconnaissance from Darwin to the McArthur River, Brown (1908) made several landings on Cobourg Peninsula to examine bauxitic laterite. The discovery of bauxite on Cobourg Peninsula has resulted in several evaluation investigations by both exploration companies and the Government (Owen, 1949, 1954; Matheson, 1957; Kidd, 1961; Larsen, 1965; Swiss Aluminium, 1969).

Woolnough (1932) made an aerial photographic survey of Bathurst and Melville Islands to delineate broad structural features suitable for the concentration and retention of petroleum.

Daily (1955) was the first to attempt a regional study of Bathurst and Melville Islands. He described the stratigraphy of the cliffs sections along the southern coasts of both islands and briefly visited the inland outcrops of Cretaceous and Tertiary rocks. Geological mapping by Brunnschweiler (1956) along the southern coasts and Apsley Strait confirmed Daily's findings.

Systematic descriptions for 16 species of ammonites collected from Bathurst Island by Daily (1955) were published by Wright (1963). Skwarko (1966) discussed the outcrops of Cretaceous strata on Bathurst Island and listed the known macrofossils. A palynological examination of Cretaceous samples from Bathurst Island is reported by Norvick & Burger (1976). White (Appendix 2) described plant fossils collected from the Van Diemen Sandstone on Melville Island.

Geologists of the Water Resources Branch, Darwin, have examined the Tertiary and Cretaceous sediments in connexion with the development of a water supply for the various settlements in the area (Dunn, 1962; Barclay, 1964; Laws, 1967; Lau, 1972). Heavy-mineral beach sands along the coasts of Bathurst Island, Melville Island, and Cobourg Peninsula have been investigated by BMR and private companies (Mackay, 1956; Ward, 1961; Murphy, 1970).

Geophysical (Table 1). A reconnaissance gravity survey was made by Santos Ltd (Hare & Associates, 1962) on Melville and Bathurst Islands between 1956 and 1959. In 1967 BMR made a helicopter gravity survey across the area (Whitworth, 1970). In the Arafura and Timor Seas, gravity readings were taken by the Netherlands Geodetic Commission using pendulum equipment in submarines (Vening Meinesz, 1948), and by Helfer et al. (1962) who operated a marine surface gravity meter west of Bathurst Island. The western Bathurst Island Sheet area was surveyed by BMR in 1967 (Jones, 1969). The results of these surveys have been integrated to produce the Bouguer anomaly contouring shown in Plate 1.

Aeromagnetic surveys have been flown over most of the area and total magnetic intensity maps have been produced (Adastra, 1964; Faessler, 1964; Prior, 1965; CGG, 1969; Horsfall & Wilkes, 1975).

A short refraction survey of five lines was made on Bathurst Island in 1962 (Tinline & Fife, 1962) and a high-speed refractor assumed to represent the top of Proterozoic basement was found at depths ranging from 300 m in the east to 1000 m in the west. No other land surveys have been made in the area. The first marine seismic work was the Dundas Strait survey carried out in 1965 by Anacapa (Prastka & Polyniak, 1965). Shell Development made four seismic surveys in the Arafura Sea to the north of the area mapped (Table 1). Compilation of the seismic data has shown that the thickness of Mesozoic and Cainozoic sediments is about 1100 m along the northern edge of the Melville Island Sheet area, increasing to more than 4500 m in the northwestern Arafura Sea. A strong seismic event which can be correlated with the base of the Mesozoic has been observed throughout the Arafura Sea region.

In 1967 BMR (Jones, 1969) conducted a gravity, magnetic, and seismic survey in the Timor Sea including the area west of Bathurst Island.

The Hyland seismic survey (Amberg, 1967), the West Bathurst marine seismic survey (Namco Geophysical Co., 1967) and the Parry Shoal seismic survey (United Geophysical Corp., 1969) have all demonstrated the existence of a sedimentary sequence west of Bathurst Island varying from 700 m in the

TABLE 1. GEOPHYSICAL SURVEYS IN THE BATHURST ISLAND, MELVILLE ISLAND, AND COBOURG PENINSULA SHEET AREAS

Survey	*Year*	*Abbreviated Title*	*Reference*
Seismic surveys	1962	Bathurst Island refraction survey	Tinline & Fife, 1962
	1965	Dundas Strait marine seismic survey	Prastka & Polyniak, 1965
	1965	Arafura Sea seismic survey	Shell Development, 1965
	1966	Money Shoal sparker survey	Shell Development, 1966
	1967	Hyland seismic survey	Amberg, 1967
	1967	West Bathurst marine seismic survey	Namco Geophysical Co., 1967
	1967	Lynedoch Bank seismic survey	Shell Development (Ley, 1967)
	1967	Timor Sea gravity, magnetic, and seismic survey	Jones, 1969
	1968	New Year Island seismic survey	CGG, 1968
	1969	Arafura Sea marine seismic survey	Shell Development (Spicher, 1969)
	1969	Parry Shoal marine seismic survey	United Geophysical Corporation, 1969
	1972	Northwest Australia marine seismic survey	B.O.C. of Australia Ltd, 1972
Gravity surveys	1948	Gravity expeditions at sea, Vol. IV	Vening Meinesz, 1948
	1956	Bathurst and Melville Islands gravity survey	Hare & Associates, 1962
	1962	Gravity measurements in the Pacific and Indian Oceans	Helfer et al., 1962
	1967	Arnhem Land and Kimberleys reconnaissance gravity surveys	Whitworth, 1970
	1967	Timor Sea gravity, magnetic, and seismic survey	Jones, 1969
Aeromagnetic surveys	1963	Anson Bay aeromagnetic survey	Adastra, 1965
	1964	Melville Island aeromagnetic survey	Faessler, 1964
	1965	Arafura Sea airborne magnetometer survey	Prior, 1965
	1967	Timor Sea gravity, magnetic, and seismic survey	Jones, 1969
	1969	Van Diemen Gulf aeromagnetic survey	CGG, 1969
	1972	Aeromagnetic and radiometric survey of Cobourg Peninsula and Mount Evelyn 1:250 000 Sheet areas	Horsfall & Wilkes, 1975

south to 2000 m in the northwest corner of the Sheet area.

Drilling (Table 2). In 1960-61 Alliance Oil N.L. drilled two unsubsidized exploration wells, Bathurst Island Nos. 1 and 2 (Hare & Associates, 1961, 1962), on Bathurst Island to prove sufficient thickness of prospective sediments to justify seismic exploration. Flinders Petroleum N.L. and Pexa Oil N.L. (Pemberton, 1971) drilled Tinganoo Bay No. 1 on Melville Island to obtain detailed stratigraphic information at a location where geophysical data had indicated a sedimentary section more than 1000 m thick. The only offshore petroleum exploration well, Newby No. 1, was drilled in 1969 by Australian Aquitaine after an examination of the seismic data from the Hyland seismic survey (Amberg, 1967) had shown horizons characteristic of Permian and Triassic sandstones, pinching out near Newby Shoal. In 1973 BMR drilled five shallow stratigraphic holes in the Cobourg Peninsula Sheet area (Hughes, 1973). Numerous shallow waterbores put down by Water Resources Branch, Darwin, are summarized in Table 7. The locations of the exploration wells, waterbores, and BMR drill holes are shown in Plate 1.

Physiography

Both Bathurst and Melville Islands are of low relief with undulating laterite rises and dissected low plateaux up to 100 m above sea level. Cobourg Peninsula is a northwesterly-trending peninsula of low undulating relief connected to the mainland by a narrow isthmus near Mountnorris Bay. The southern Cobourg Peninsula Sheet area is also of low relief except in the southeast where steeply rising scarps, up to 250 m high, and plateaux form the Wellington Range.

The area reviewed may be divided into four physiographic units: Wellington Range Plateau, low dissected plateaux and undulating laterite rises, northern and inland sandplains, and coastal plains.

TABLE 2. SUMMARY OF PETROLEUM EXPLORATION WELLS AND BMR SHALLOW STRATIGRAPHIC DRILL HOLES

Name of well	*Company or organization*	*Year drilled*	*Total depth (m)*	*Sheet area*	*Status*	*Reference*
Bathurst Island No. 1	Alliance Oil	1960	252	Bathurst Island	Abandoned	Hare & Associates, 1961
Bathurst Island No. 2	Alliance Oil	1961	312	Bathurst Island	Abandoned	Hare & Associates, 1962
Newby No. 1	Australian Aquitaine	1969	1160	Bathurst Island	Abandoned	Australian Aquitaine, 1970
Tinganoo Bay No. 1	Flinders Petroleum and Pexa Oil	1971	583	Melville Island	Abandoned	Pemberton, 1971
Cobourg Peninsula No. 1	BMR	1973	67.5	Cobourg Peninsula	Abandoned	Hughes, 1973
Cobourg Peninsula No. 2	BMR	1973	134	Cobourg Peninsula	Abandoned	Hughes, 1973
Cobourg Peninsula No. 3	BMR	1973	290.5	Cobourg Peninsula	Abandoned	Hughes, 1973
Cobourg Peninsula No. 4	BMR	1973	138.5	Cobourg Peninsula	Abandoned	Hughes, 1973
Cobourg Peninsula No. 5	BMR	1973	276	Cobourg Peninsula	Abandoned	Hughes, 1973

Wellington Range Plateau. Resistant Upper Proterozoic sandstone rises steeply out of sandplains in the southern Cobourg Peninsula Sheet area to form the Wellington Range Plateau; the plateau is deeply dissected along joints and faults to form deep youthful gorges drained by narrow streams. The concordant summit heights of the plateaux and hills of the Wellington Range suggest that they are remnants of an old erosion surface which forms the Arnhem Land Plateau in the south.

Low dissected plateaux and undulating laterite rises. The low plateaux and laterite-capped hills of northern Cobourg Peninsula are remnants of a younger erosion surface which developed by the chemical weathering and erosion of Cretaceous sediments. This surface is also present on Bathurst and Melville Islands, but it is only in the Maxwell Creek and Cape Gambier areas on Melville Island and central Bathurst Island that it forms the present land surface. Elsewhere on the islands it is unconformably overlain by Tertiary sandstone which forms the plateaux and areas of higher relief.

Northern and inland sandplains. The plateaux are fringed by colluvium, and extensive red-yellow sandplains have built up over the northern part of the islands as a result of the dissection of the Tertiary sandstone. A large alluvial plain has been deposited by Murgenella Creek to form the Murgenella Plains in the central Cobourg Peninsula Sheet area. The floodplain is characterized by meandering channels, lagoons, swamp depressions, and cut-off meanders.

Coastal plains. Beach and littoral sands have accumulated on the western and northern coasts of the islands and emerged former strandlines are preserved as low vegetated ridges in many areas. Sand dunes, which rise to more than 20 m above sea level and extend inland up to 1.5 km, occupy coastal strips on southwestern Bathurst Island, northwestern Melville Island, and south of De Courcy Head on Cobourg Peninsula. Large areas of estuarine plains have developed along the northern and western coastlines of the islands and Cobourg Peninsula by the drowning of ancient river valleys.

OUTLINE OF STRATIGRAPHY

Most of the area is underlain by thin Upper Jurassic to Tertiary clastics. These thicken to the west of the Van Diemen Rise (Pl. 1) and into the eastern part of the Bonaparte Gulf Basin where Permian and Triassic sedimentary rocks are also present. The Phanerozoic sequence has not been metamorphosed or intruded by igneous rocks; however, essentially

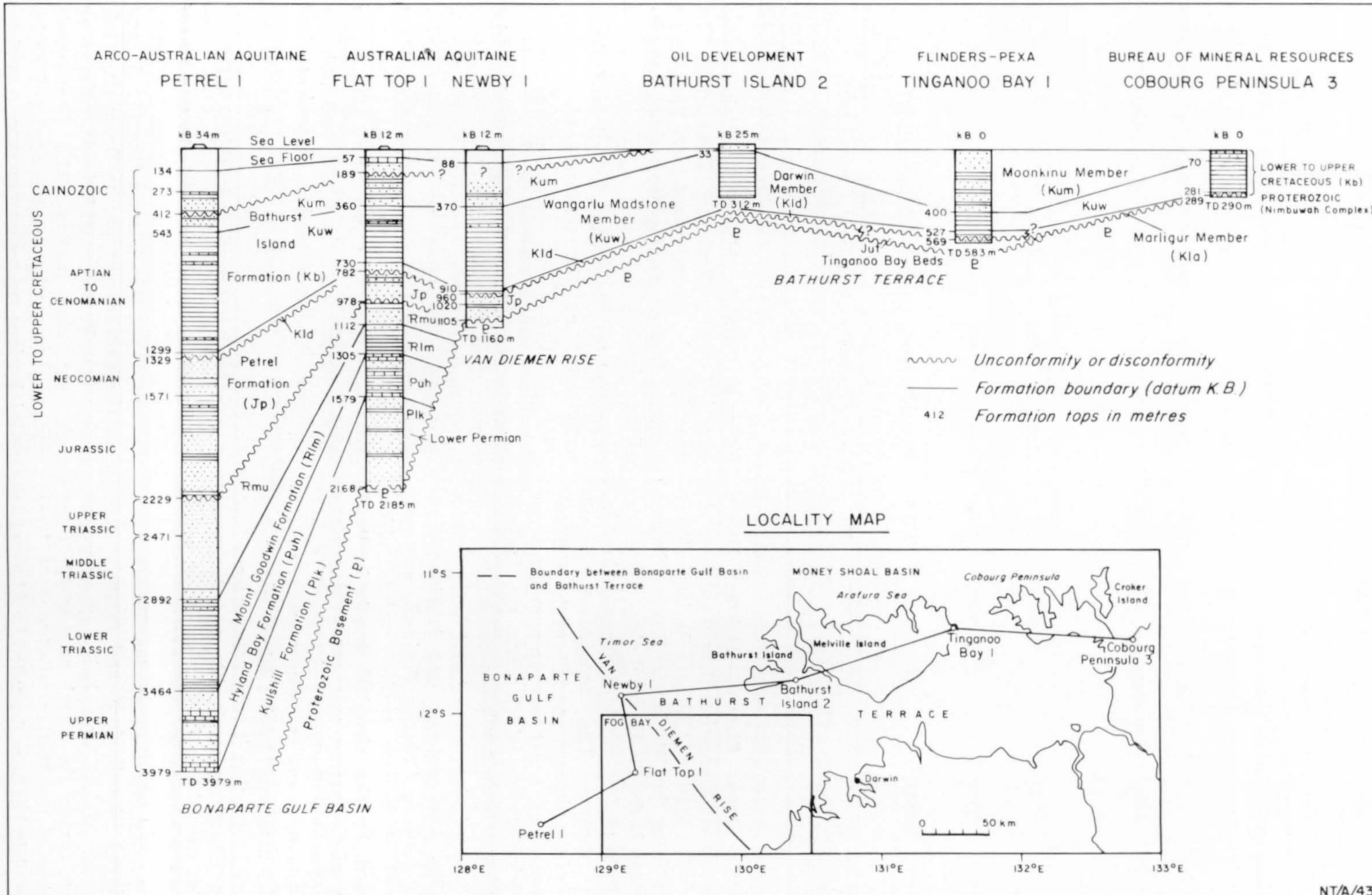

Fig. 2. Correlation of rock units from the eastern Bonaparte Gulf Basin across the Bathurst Terrace to Cobourg Peninsula.

vertical movements have resulted in several breaks in sedimentation.

The stratigraphy of the area is summarized in Table 3 and the distribution of the rock units is shown in Figure 2. Petroleum exploration wells provide the only information for the sedimentary rock units older than Upper Cretaceous. The most valuable sources of subsurface information for the area are the completion reports of Australian Aquitaine Newby No. 1 and Flat Top No. 1, Alliance Oil Bathurst Island Nos. 1 and 2, Flinders Pexa Tinganoo Bay No. 1 and BMR Cobourg Peninsula Nos. 1 to 5.

The stratigraphic nomenclature in Table 2 follows Laws & Brown (1976) for the Permian to Jurassic units and Hughes & Senior (1974) for the Cretaceous and Tertiary units.

A list of abbreviations used in the Figures is given in Appendix 4.

Basement rocks

The nature of basement underlying Bathurst Island, Melville Island, and northwestern Cobourg Peninsula is poorly known. Newby No. 1 and Flat Top No. 1 intersected hard pink fine to medium quartzite believed to be Proterozoic on the basis of its similarity to Proterozoic quartzite outcropping in the Fog Bay Sheet area to the south (Senior & Hughes, 1976). Total magnetic intensity contours (Faessler, 1964; CGG, 1969; Horsfall & Wilkes, 1975) show pronounced northeast-trending anomaly axes under southeastern Melville Island and northwestern Cobourg Peninsula. These are thought to reflect well bedded, steeply dipping metamorphosed rocks. Elsewhere in the Sheet areas the contours are rounded and perhaps indicate the presence of basic igneous intrusives similar to those cutting the Pine Creek Geosyncline sediments in the Darwin area.

In the southern-central Cobourg Peninsula Sheet area two linear zones of high magnetic anomalies are interpreted by Horsfall & Wilkes (1975) as a northern extension of the Koolpin Formation which crops out in the Alligator River Sheet area. The talc-tremolite schist recovered from BMR Cobourg Peninsula No. 1, which was located close to one of the anomalies, is probably Koolpin Formation equivalent as defined by Smart et al. (1974).

The only outcrops of Lower Proterozoic rocks in the area mapped are igneous and metamorphic Nimbuwah Complex rocks on southern Cobourg Peninsula. The Complex may be divided into a granitoid core, migmatite zone, lit-par-lit gneiss zone, and transitional zone. Each zone is gradational into the adjacent zones and the metamorphic grade increases from lower amphibolite facies in the transitional zone to upper amphibolite or possibly lower granulite facies towards the granitoid core. The degree of migmatization also increases towards the core. The Nimbuwah Complex is known to extend in subsurface beneath the Murgenella Plains to the Mountnorris Fault (BMR Cobourg Peninsula Nos. 3 and 5; Hughes, 1973). However, northwest of this fault the nature of the basement is not known.

The Carpentarian Oenpelli Dolerite intrudes the Nimbuwah Complex and extends discontinuously across the southeastern corner of the Cobourg Peninsula Sheet area. Drilling by Union Carbide Australia Ltd (pers. comm.) at Black Rock has shown that the dolerite is 130 m thick. Ophitic dolerite, ophitic gabbro, and granophyric dolerite have been recognised in the Sheet area and according to Senior & Smart (1976) the mineralogy of these differentiated phases suggests that it was derived from an alkali basalt parent magma.

A medium to coarse quartzose sandstone and quartz pebble conglomerate known as the Kombolgie Formation unconformably overlies the Nimbuwah Complex (Pl. 2, fig. 1). It is Carpentarian and appears to be restricted to the southern Cobourg Peninsula Sheet area, the northernmost known occurrences being on Simms Island and at Anyiminali Point on South Goulburn Island.

Permian/Triassic

The Permian and Triassic rocks form a conformable sequence comprising the Kulshill, Hyland Bay, and Mount Goodwin Formations, and an unnamed Middle to Upper Triassic formation. All are restricted to the western margin of the Bathurst Island Sheet area; they do not crop out, but are known from drilling and seismic data to thin eastwards from Petrel No. 1 and to pinch out along the eastern edge of the Bonaparte Gulf Basin.

Australian Aquitaine Flat Top No. 1 (Australian Aquitaine, 1969) provides the only direct information about the Permian-Triassic sequence where it thins onto the eastern margin of the Bonaparte Gulf Basin. The interval between 1579 and 2168 m in Flat Top No. 1 is composed of Lower Permian fine to coarse friable sandstone with interbeds of dark grey shale and siltstone. The rocks of this interval are similar to those of the upper Kulshill Formation as mapped in the southeastern Bona-

TABLE 3. STRATIGRAPHY OF THE BATHURST ISLAND, MELVILLE ISLAND, AND COBOURG PENINSULA SHEET AREAS

	Age	*Formation (map symbol)*	*Lithology*	*Max. thickness in mapped area (m)*	*Depositional environment*	*References*
CAINOZOIC	QUATERNARY	Qa	Silt, fine sand, mud, minor gravel; alluvium	5	Fluvial, channel, and flood plain sediments	
		Qs	Red sandy, and mottled grey to yellow sandy soils	10	Colluvial and eluvial	
		Qc	Quartzose sand, shell, and coral debris, saliferous organic mud and silt; coastal sediments	20	Littoral, aeolian, intertidal deltaic, and estuarine	
	Pleistocene	Qp	Coquina, calcarenite, conglomerate	8	Littoral to shallow marine	
	TERTIARY	Czp	Ferruginous to bauxitic pisolitic laterite	5	Humid, terrestrial, mechanical and chemical reworking of parent laterite	
		Van Diemen Sandstone Czv	Friable, white to yellow, medium to coarse quartzose sandstone, minor lenses of siltstone and granular conglomerate	60	Fluvial and paralic	Hughes & Senior, 1974
			UNCONFORMITY			
MESOZOIC	UPPER CRETACEOUS (Cenomanian)	Moonkinu Member Kum	Fine to very fine sublabile sandstone interbedded with grey carbonaceous mudstone and siltstone. Calcareous and limonitic concretions	400	Shallow marine, deltaic	Hughes & Senior, 1974
	LOWER CRETACEOUS (Aptian)	Wangarlu Mudstone Member Kuw	Mudstone, siltstone, and minor sublabile sandstone, scattered nodular pyrite	550	Open marine	Hughes & Senior, 1974
		Marligur Member Kla	Fine to coarse quartzose sandstone interbedded with micaceous siltstone and mudstone in upper part	70	Paralic	Hughes & Senior, 1974
		Darwin Member Kld	Fine argillaceous sandstone, radiolarian siltstone, claystone, and minor conglomerate	50	Shallow marine	Noakes, 1949; this Report Table 8
			DISCONFORMITY			

TABLE 3. STRATIGRAPHY OF THE BATHURST ISLAND, MELVILLE ISLAND, AND COBOURG PENINSULA SHEET AREAS (*Cont.*)

	Age	*Formation (map symbol)*	*Lithology*	*Max. thickness in mapped area (m)*	*Depositional environment*	*References*
MESOZOIC	UPPER JURASSIC to Neocomian	Petrel Formation JKp	Friable fine to medium quartzose sandstone with interbedded brown to grey shale (section only)	250	Fluvial to shallow marine	Laws & Brown, 1976
		Tinganoo Bay Beds Jut	Coarse quartzose sandstone and conglomerate with angular to rounded pebbles of quartz and quartzite, minor fine micaceous sandstone (section only)	100	Non-marine	Hughes & Senior, 1974
			DISCONFORMITY			
	MIDDLE TO UPPER TRIASSIC	Rmu	Fine to coarse quartzose sandstone, red-brown micaceous shale, fine to very fine sandstone, and redbeds (section only)	150	Fluvial-terrestrial	Laws & Brown, 1976
	LOWER TRIASSIC	Mount Goodwin Formation Rlm	Hard micaceous and silty shale, thin interbeds of siltstone and very fine sandstone (section only)	120	Open marine	Laws & Brown, 1976
PALAEOZOIC	UPPER PERMIAN	Hyland Bay Formation Puh	Fine to coarse friable sandstone, bioclastic limestone, and dark grey to black shale (section only)	400	Shallow marine	Laws & Brown, 1976
	LOWER PERMIAN	Kulshill Formation Plk	Fine to coarse sandstone interbedded with shale and siltstone	500	Marginal marine	Australian Aquitaine, 1966; Caye, 1968
			UNCONFORMITY			
PROTEROZOIC	CARPENTARIAN	Kombolgie Formation Ɐhk	Medium to very coarse quartzose sandstone, siliceous. Basal conglomerate of quartzite and vein quartz clasts	250	?Fluviatile	Walpole et al., 1968
		Undifferentiated Lower Proterozoic and Archaean igneous, metamorphic, and sedimentary rocks	Including Nanambu Complex, Nimbuwah Complex, Oenpelli Dolerite, Fisher Creek Siltstone, Koolpin Formation equivalent, and Mount Partridge Formation			Smart et al., 1974

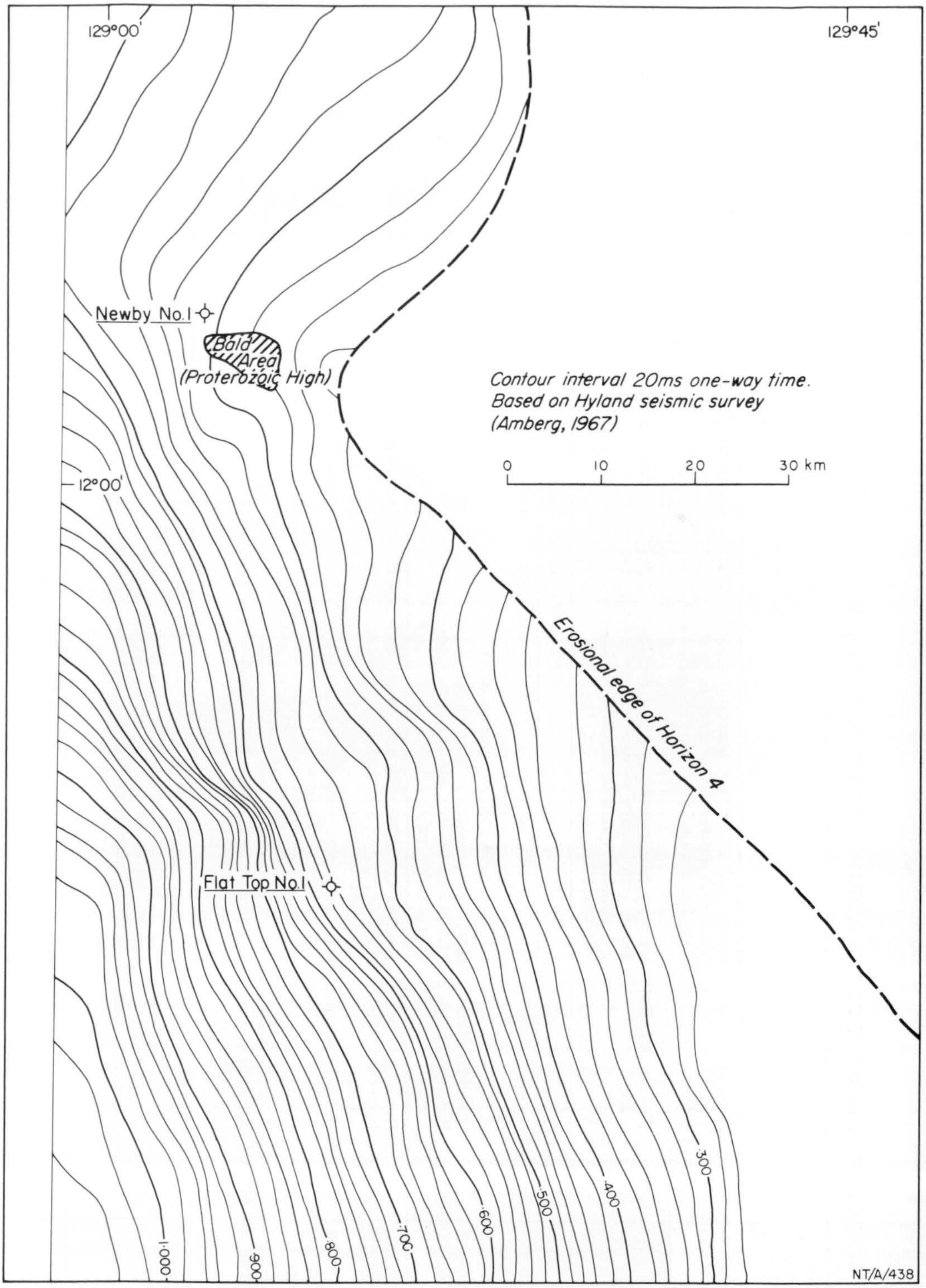

Fig. 3. Structural contour map of Horizon 4 (in milliseconds) at the top of the Hyland Bay Formation.

parte Gulf Basin (Caye, 1968), and thus may be correlated with it.

The Upper Permian Hyland Bay Formation succeeds the Kulshill Formation in Flat Top No. 1. It consists of fine to coarse friable sandstone interbedded with silty shale and three beds of biomicritic limestone containing abundant Bryozoa and a few echinoids. The limestone beds are seismic reflectors and have been used to map the distribution of the formation along the eastern margin of the Bonaparte Gulf Basin (Fig. 3). The Hyland Bay Formation is conformably overlain by thick dark grey to black shale with minor beds of sandy shale and very fine sandstone. This lithology is characteristic of the Lower Triassic Mount Goodwin Formation which is widespread throughout the southeastern Bonaparte Gulf Basin. It, in turn, is overlain by unnamed Middle to Upper Triassic unit consisting of two distinct members, both apparently non-marine. In Flat Top No. 1 the upper member covers the interval 978-1030 m and comprises a series of micaceous shale and minor very fine sandstone varying in colour from red-brown to green; the lower member (1030-1112 m) is a sequence of thinly bedded very fine to fine sandstone and shale with a basal bed of coarse micaceous sandstone.

Jurassic/Cretaceous

A major hiatus separates the Permo-Triassic from the Jurassic/lowermost Cretaceous (Neocomian) Petrel Formation in both Petrel No. 1 and Flat Top No. 1. A seismic reflector that can be correlated with the top of the Triassic sandstone in Petrel No. 1 allows the disconformity to be traced from Petrel No. 1 to the eastern edge of the Bonaparte Gulf Basin where it disappears against the Van Diemen Rise. In Newby No. 1 on the edge of the Rise, the Petrel Formation rests directly on Proterozoic basement.

In the deeper parts of the Bonaparte Gulf Basin the Petrel Formation shows a tripartite division with basal and upper arenaceous members and a middle shale member. However, towards the eastern margin of the basin the marine shale grades into fluvial to paralic sandstone, and in both Flat Top No. 1 and Newby No. 1 the dominant rock type is white friable fine to medium quartzose sandstone with a few interbeds of greyish brown shale. Rocks of Upper Jurassic/Neocomian age transgress over the Van Diemen Rise and extend eastward across the Bathurst Terrace as far east as Tinganoo Bay No. 1 (Burger, Appendix 1) where they have been mapped as the Tinganoo Bay Beds (Hughes & Senior, 1974), comprising 100 m of coarse clastics with minor beds of fine micaceous sandstone and a few shale laminae.

The Bathurst Island Formation disconformably overlies the Petrel Formation throughout the area except in the Cobourg Peninsula Sheet area where it rests directly on the Nimbuwah Complex (Fig. 2). Offshore, the Bathurst Island Formation ranges in age from Aptian to Cenomanian with no indication of any breaks in deposition. Howevery, palynological examination of the onshore Cretaceous sequences by Burger (Appendix 1) failed to recognise any Albian strata, suggesting a short hiatus at this time on the Bathurst Terrace.

The base of the Bathurst Island Formation can be readily distinguished on the electric logs of exploration wells, and a widespread seismic event generated by the sharp shale-sandstone interface at the boundary of the Petrel and Bathurst Island Formations allows the base of the Bathurst Island Formation to be mapped across the Van Diemen Rise and onto the Bathurst Terrace (Fig. 4). East of the Van Diemen Rise the Bathurst Island Formation crops out on Bathurst Island, Melville Island, and Cobourg Peninsula where it is divisible into four members, two of which are laterally equivalent.

The basal Marligur Member of the Bathurst Island Formation is Aptian and consists of fine to very coarse quartzose sandstone with thin beds of shale and siltstone in the upper part. It crops out extensively in the southern Cobourg Peninsula Sheet area to form thin ridges of weathered sandstone above the Proterozoic basement. It also crops out in the northeast Alligator River Sheet area and extends in the subsurface at least as far north as Cobourg Peninsula No. 3 (Hughes, 1973). The 1973 BMR drilling in the Alligator River region (Needham, 1976) has shown that in the northwestern East Alligator 1:1 000 000 Sheet area the Marligur Member interfingers with, and is replaced by, the Darwin Member (Fig. 5). The Darwin Member is also Aptian, and the change in lithology from an arenaceous unit to a more argillaceous unit represents a change in facies from paralic conditions in the east to open epicontinental sea conditions in the west.

The stratigraphic interval and lithology of the Darwin Member are equivalent to part of the Mullaman Beds, a name which has previously been used to describe all Mesozoic outcrops in the Northern Territory. A revision of

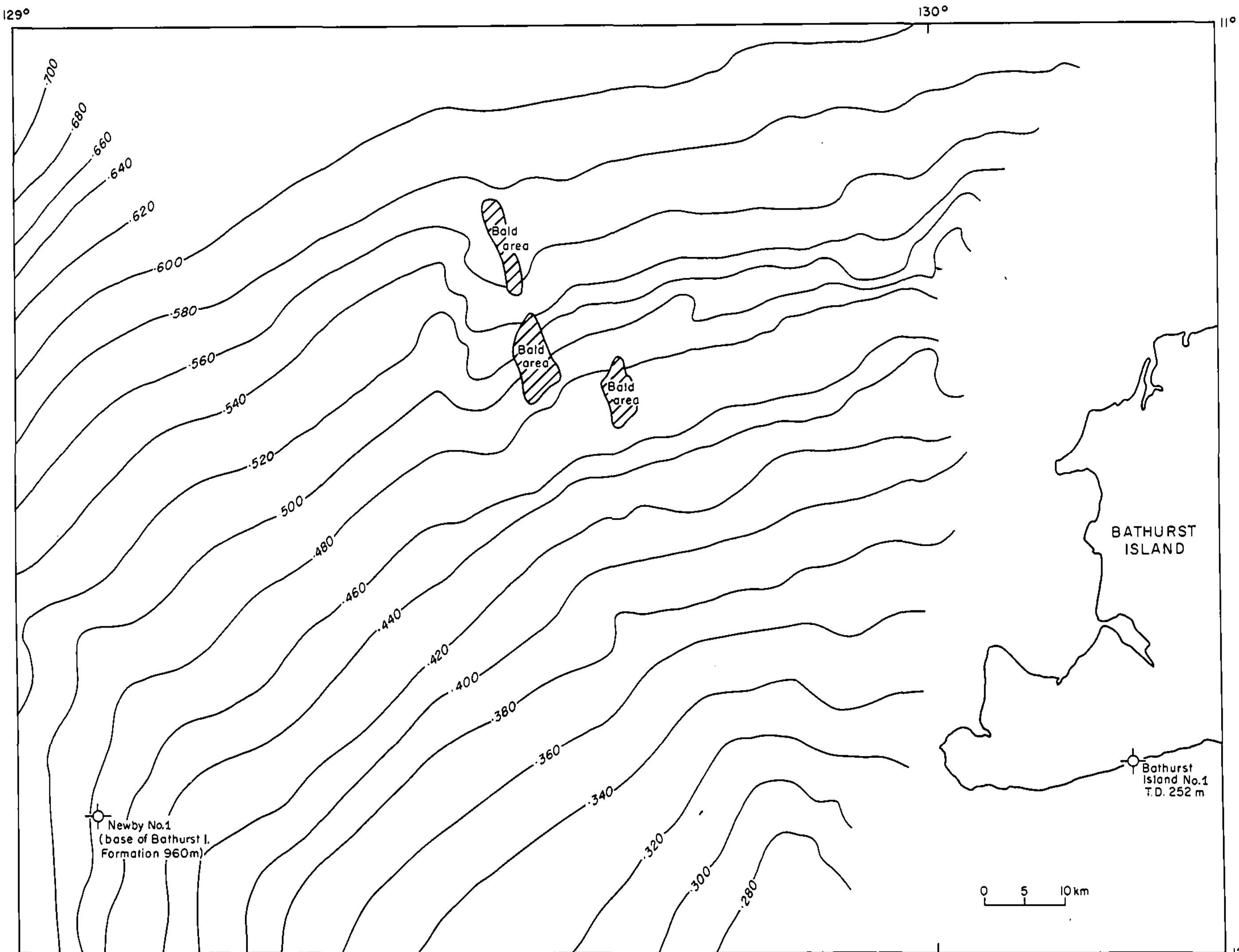

Fig. 4. Structural contour map of Horizon 2 (in milliseconds) at the base of the Bathurst Island Formation. NT/A/439

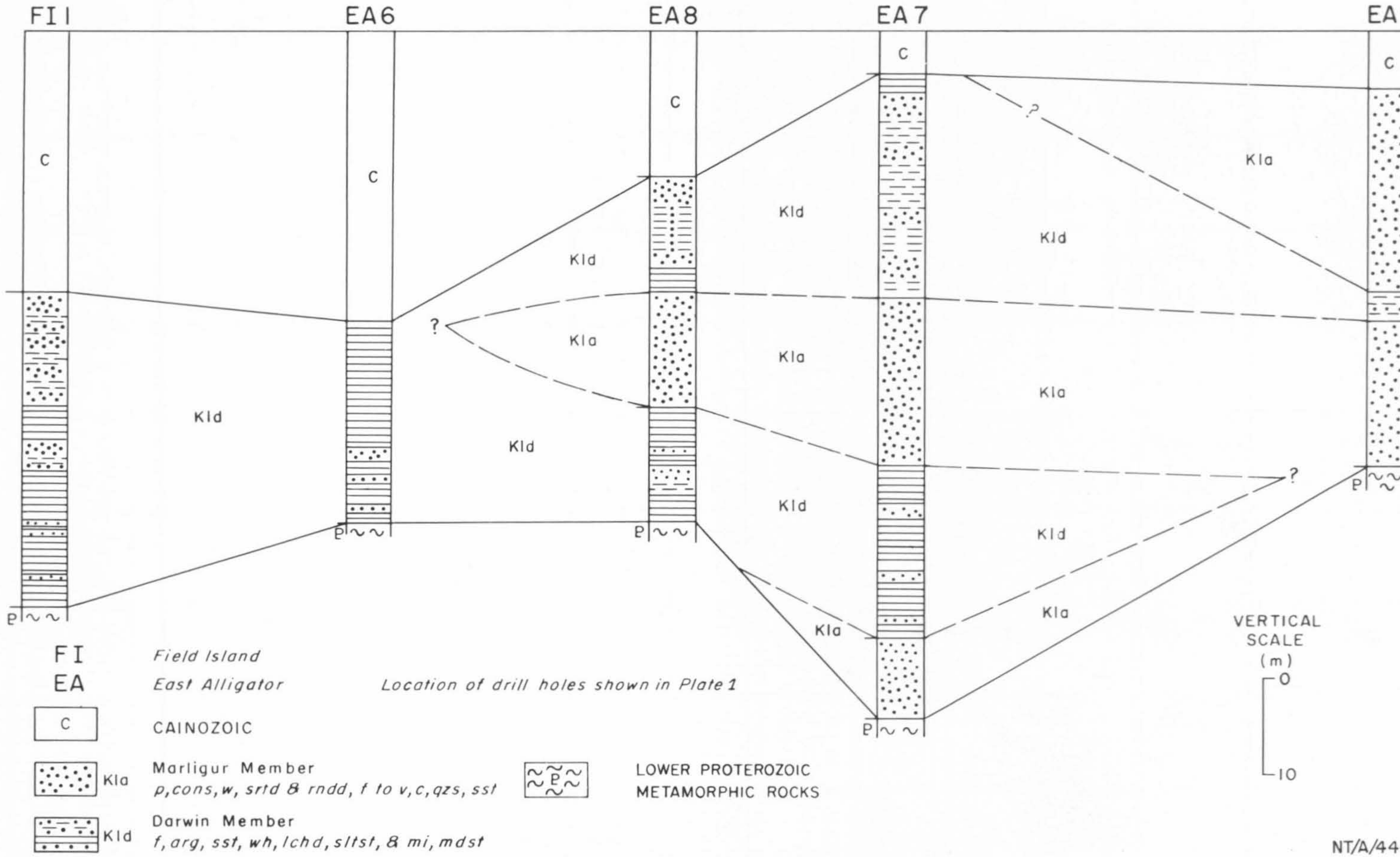

Fig. 5. Correlation from BMR East Alligator No. 9 to BMR Field Island No. 1 to demonstrate the interfingering relation between the Marligur and Darwin Members of the Bathurst Island Formation.

Plate 2, fig. 1. Outlier of Kombolgie Formation, Tor Rock, Cobourg Peninsula. The unconformity between this unit and the underlying migmatites of the Nimbuwah Complex is marked by the break in slope at the base of the scarp. (GA/7895)

the Mullaman Beds (p. 45) has demonstrated that the Mullaman Beds consist of two distinct lithological units and that because of misuse the name Mullaman Beds has become meaningless in the northern part of the Northern Territory.

Both the Darwin and Marligur Members are overlain by a sequence of massive dark grey pyritic mudstone known as the Wangarlu Mudstone Member. Offshore this unit is Albian to Cenomanian, but on the Bathurst Terrace it is wholly Cenomanian (Burger, Appendix 1). The Wangarlu Mudstone Member is restricted in outcrop to the cliffs along the southern coastline of Cobourg Peninsula, but it is known from exploration well and drill-hole information to extend in the subsurface southwards into the southern Cobourg Peninsula Sheet area (Hughes, 1973) as well as westwards across the Bathurst Terrace (Fig. 2).

The overlying Moonkinu Member (Pl. 2, fig. 2) crops out in all three northern Sheet areas and has been intersected in all wells drilled in the area except BMR Cobourg Peninsula Nos 1, 2, and 4 (Hughes, 1973). It is a deltaic sequence of interbedded fine sublabile sandstone, siltstone, and mudstone. Macrofossils collected from the Moonkinu Member exposed in the cliffs on the southern coasts of Bathurst and Melville Islands (Hughes, 1976) were identified by Henderson (Table 4); Henderson considered that they are middle Cenomanian, and part of a cosmopolitan fauna that existed throughout the world at that time. All the genera are shared with Europe and two species are common European forms. Burger (Appendix 1) and Norvik & Burger (1976) also consider that the Moonkinu Member is Cenomanian.

The Darwin Member, Wangarlu Mudstone Member, and Moonkinu Member all extend westward across the Bathurst Terrace, over the Van Diemen Rise, and into the Bonaparte Gulf Basin. All are present in Newby No. 1, Flat Top No. 1, and in the type section of the Bathurst Island Formation in Petrel No. 1 (Fig. 13).

Tertiary

On Bathurst and Melville Islands Tertiary quartzose sandstone of probable Eocene age (White, Appendix 2) unconformably overlies the chemically weathered surface of the Moonkinu Member. This unit, the Van Diemen Sandstone, gradually thickens northward across the islands and at its type section on Cape Van Diemen is more than 60 m thick (Pl. 3). Shallow seismic reflection profiling to the north and west of the islands by Jongsma (1974) has

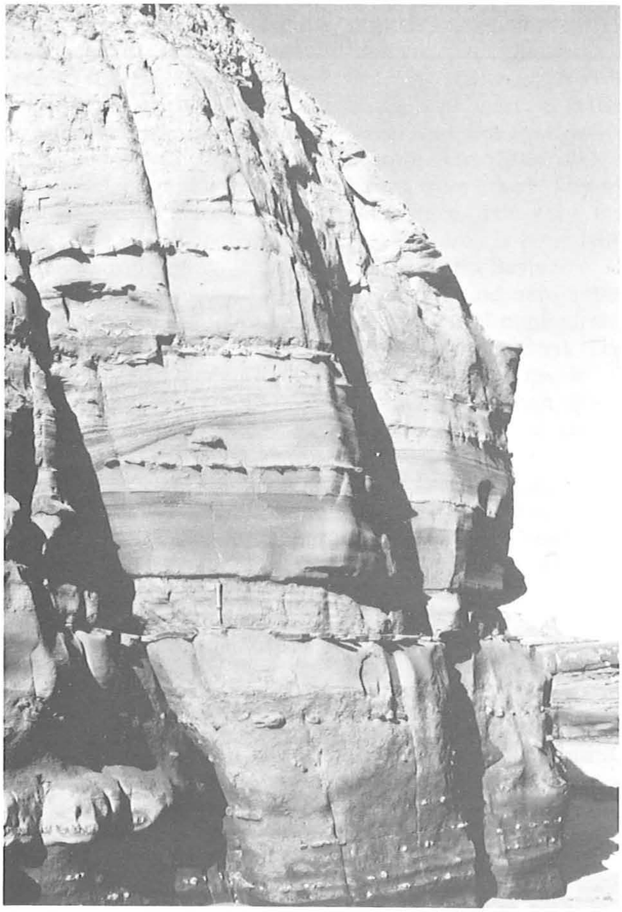

Plate 2, fig. 2. Part of the type section of the Moonkinu Member, illustrating the regular nature of the bedding, low-angle cross-bedding, and irregular ferruginous and calcareous concretions aligned parallel to bedding. (GA/7890)

revealed a series of unconformities in the top few hundred metres of section, including a basal Tertiary horizon (S4) which correlates with the unconformity observed onshore at the base of the Van Diemen Sandstone. The basal Tertiary horizon can be traced in several of Jongsma's profiles, including the traverses 1.5 km west of Cape Fourcroy, Bathurst Island, and the traverses north of Melville Island. The distribution and regional northwesterly dip of the S4 surface is shown in Figure 6. S4 is not present in the southeastern part of the area, and Tertiary rocks do not crop out in the Cobourg Peninsula Sheet area.

A trizonal laterite profile up to 40 m thick is present in most of the exposed Cretaceous and Tertiary rocks. Drilling and observation have shown that the weathering profile is extensive. Unweathered Cretaceous rocks are present only along zones of uplift, such as Wangarlu Bay, Cobourg Peninsula, and the southern coasts of the islands, where coastal erosion of the tilted Cretaceous strata is continually exposing fresh sections. The weathering profile consists of a ferruginous crust grading down through a mottled zone to a leached pallid zone. Pisolitic sediments (Czp) deposited during the reworking of the original laterite profile occur on the northern peninsulas of Cobourg Peninsula and Croker Island.

Quaternary

Consolidated calcarenite, coquina, and sandy conglomerate rich in organic debris (Qp) unconformably overlie and abut against laterites

TABLE 4. DISTRIBUTION OF AMMONITES AND OTHER MACROFOSSILS IN THE MOONKINU MEMBER ON BATHURST AND MELVILLE ISLANDS

Genera and species (identified by R. Henderson)	*Localities (Map reference No., see Plate 1)*															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Sciponoceras glaessneri			x	x	x	x	x	x	x							
Sciponoceras sp. nov.			x			x						x				
Hypoturrilites gravesianus			x													
Turrilites (Turrilites) costatus			x													
Chimbuites mirindowensis			x													x
Acanthoceras mirialampiense			x	x	x											
Acanthoceras tapara					x											
Acanthoceras sp. indet.											x	x	x		x	x
Euophaloceras lonsdalei				x							x	x				
? *Collingnoniceras* sp.				x												
Sciponoceras sp.													x			
? *Chimbuites sp.*					x											
Inoceramus concentricus				x	x	x	x				x	x				
Trigonia sp.				x												
? *Teredo* bored wood				x												x
Unidenified myoid bivalve				x												x
Unidentified scaphopod				x												
Unidentified gastropods	x	x	x				x				x			x		
Spatangoid echinoid indet.												x				
Unidentified bivalve													x			
Teeth										x						
Worm borings										x						

Plate 3. Type section of the Van Diemen Sandstone at Cape Van Diemen, Melville Island. (GA/7888)

in all three Sheet areas. They are best developed on Cobourg Peninsula and the adjacent offshore islands where they form thin lenticular bodies adjacent to the present coastline. They usually occupy breaks within the low laterite cliffs and at the present time lie several metres above high-tide level, reflecting either eustatic changes in sea level or minor tectonic uplift during the Quaternary. These beach deposits are considered to be Pleistocene on the basis of their stratigraphic position.

Quaternary sediments are widespread, but thin and generally unconsolidated; many are modified by soil formation (Qs). Red sandy soils have developed on the Van Diemen Sandstone, whereas grey to yellow sandy soils are more common over Cretaceous bedrock.

Superficial alluvium (Qa) is widespread. Thick extensive accumulations of dark grey argillaceous sediments occur as flood-plain deposits over the Murgenella Plains of southern Cobourg Peninsula (Pl. 4). Elsewhere, fine sand and minor gravel have accumulated along the larger watercourses. Towards the coastal margins the saline organic muds and silts of the tidal flats grade into alluvium.

Large amounts of quartz-rich sand and organic debris (Qc) form beach and littoral deposits along the western and northern coasts of Bathurst Island and along the northern coast of Melville Island. By comparison, beach sand deposits in the Cobourg Peninsula Sheet area are small except on the western side of Croker Island where beach deposits extend inland from Palm Bay for as much as 5 km. A similar situation occurs along the west coast of southern Cobourg Peninsula where former beach deposits and strandlines occur several kilometres inland.

Aeolian quartz-rich sands occupy a 20-km coastal strip on southern Bathurst Island. They form sets of dunes orientated northwest and rising locally to more than 20 m. The dunes have formed barriers to the short streams draining to the south, and brackish lagoonal and lake deposits commonly occur on the landward side. The dunes are well vegetated and the sand is strongly iron-pigmented. Sand dunes south of De Courcy Head and on Cape Croker have been blown up to 1 km inland over low saddles in the coastal cliffs.

STRUCTURE

Except for the Proterozoic rocks of southern Cobourg Peninsula the structural history of the area has been relatively simple. The only tectonic force evident is tensional faulting. No compressional forces have acted during the Phanerozoic. The Bathurst Terrace is part of the very stable north Australian craton. To the north and west it is flanked by the Money Shoal and Bonaparte Gulf Basins respectively. During the Mesozoic and Cainozoic these basins were affected by more or less continuous subsidence, but very little tectonism. To the east the area is bounded by the stable Proterozoic Arafura Basin.

Seismic and aeromagnetic data indicate that the structural configuration of the area is relatively uncomplicated. They show that the basement surface dips to the northwest from a depth of less than 300 m at Cape Gambier, Melville Island, to about 2000 m in the northwest corner of the Bathurst Island Sheet area. The Hyland seismic survey (Amberg, 1967) revealed a marked increase in depth to basement west of Newby No. 1 where the Van Diemen Rise forms the boundary between the Bathurst Terrace and the adjoining Bonaparte Gulf Basin.

The only structure disclosed in the basement rocks by the seismic surveys is a series of northwest-trending faults that dip to the northeast. According to Laws & Kraus (1974) this northwesterly structural grain, which has also been recognized in the southeastern Bonaparte Gulf Basin, is the result of Early Palaeozoic faulting possibly related to aborted rift development.

Two major fault zones have been recognized displacing the cover sediments in the Cobourg Peninsula Sheet area. On Grant Island a prominent fault has displaced the strata which now dip 38° southwest. The linear coastline between De Courcy Head and Laterite Point resembles a regressed fault scarp and, in association with the close spacing of the bathymetric contours along this coast, suggests a continuation of the Grant Island fault zone to the south. Drilling at Black Rock uranium prospect has revealed several northwest-trending faults which align with the Grant Island fault system. Post-Cretaceous vertical displacements of almost 100 m probably occurred along the fault zone. Another fault system has displaced the laterite profiles along the southern coast of Mountnorris Bay. In places the laterite profile has been completely eroded on the upthrown side of the fault. This indicates post-laterite Cainozoic movements of up to 30 m, the average thickness of preserved laterite in the area.

On Bathurst and Melville Islands the only structures observed were broad undulations of

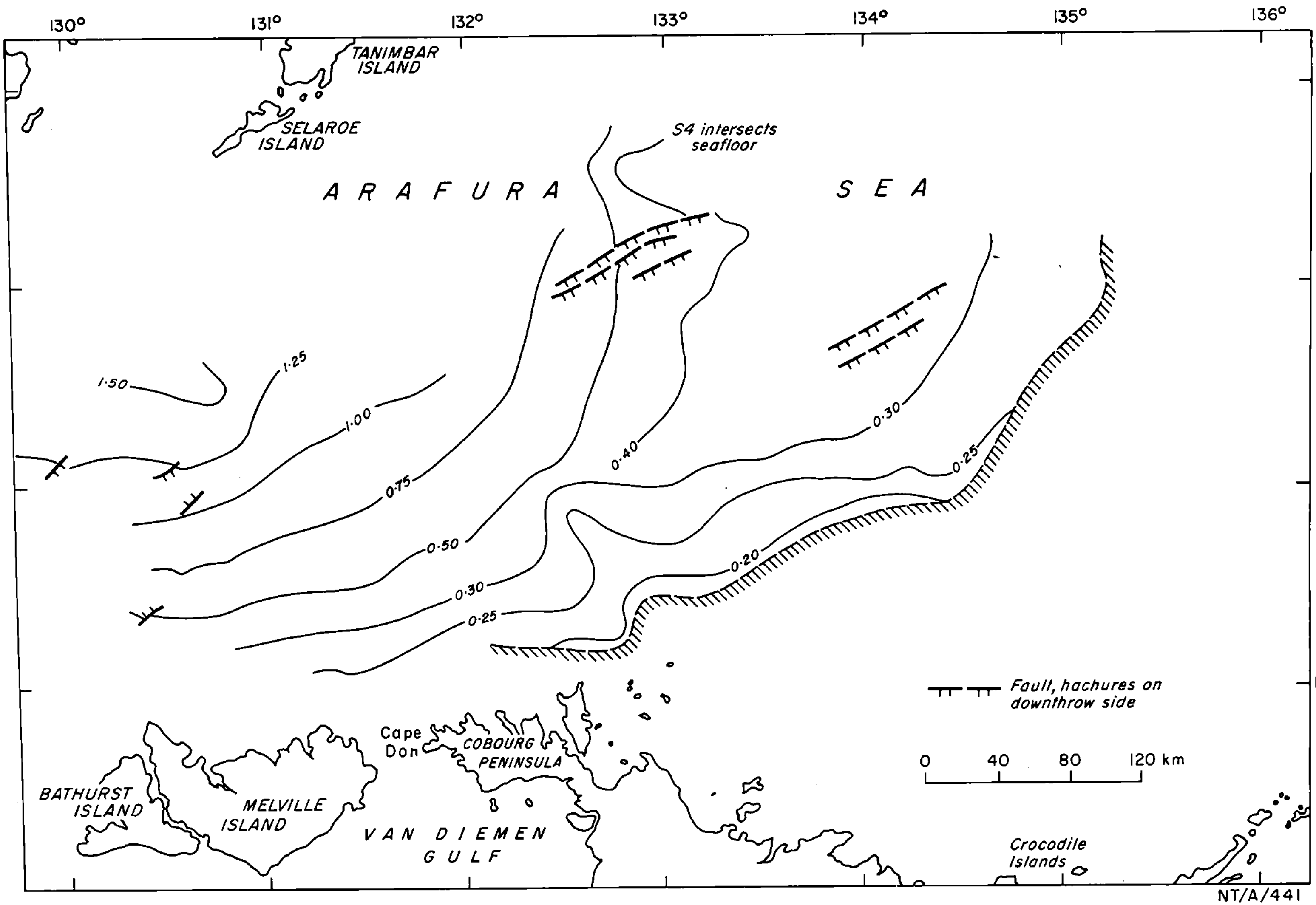

Fig. 6. Isochrons on S4, the probable base of the Van Diemen Sandstone; intervals 0.05, 0.10, and 0.25 second (after Jongsma, 1974).

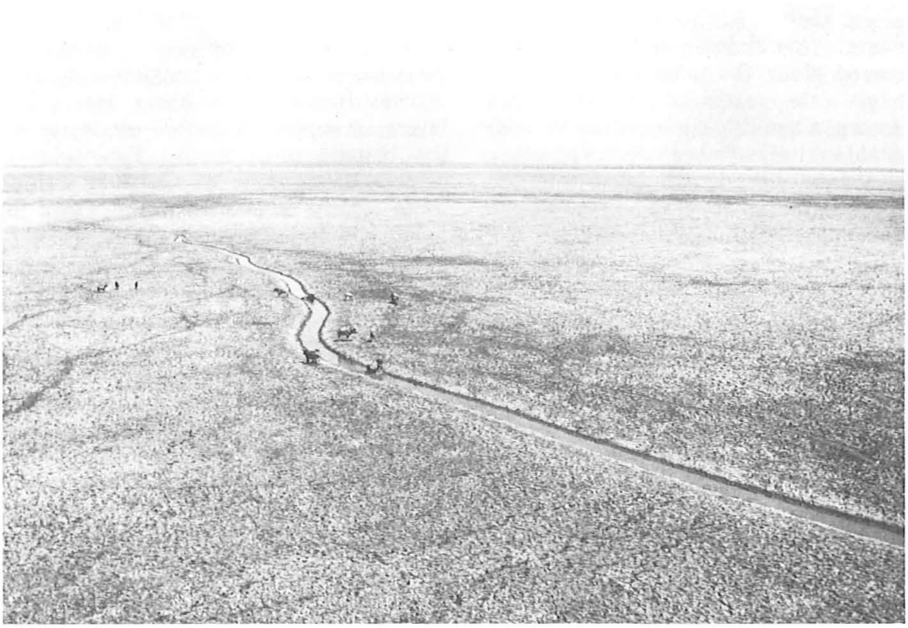

Plate 4. Flood plain of Murgenella Creek, Cobourg Peninsula, illustrating the extensive accumulation of alluvium (Qa). (GA/7886)

bedding and small-scale compaction faults in the Moonkinu Member. Dips of up to 7° northwest were measured in the rocks exposed along the southern coasts of both islands. They are related to regional northwest tilting that occurred within the cover sediments during the Early Tertiary.

The Lower Proterozoic rocks in the southern Cobourg Peninsula Sheet area are highly deformed and strongly folded. All metamorphosed rocks in the area have been isoclinally folded with the degree of structural complexity increasing with metamorphic grade. Various interpenetration fabrics have developed in the inner zones of the complexes where partial or complete anatexis has occurred.

Numerous photo-interpreted lineaments in the Nimbuwah Complex are probably small faults and joints. In places north-trending and west-trending joints in the Kombolgie Formation form a well defined grid pattern which according to Walpole et al. (1968) is the result of a homogenous horizontal stress field. Basement structures are reflected through the thin Mesozoic and Cainozoic sediments near the Wellington Range. A similar pattern persists over the remainder of the peninsula landmass but these lineaments are surface expressions of a well developed joint system within the laterite profile.

CHEMICAL WEATHERING

The rocks outcropping in the three Sheet areas have all undergone some degree of chemical weathering. The extent of alteration appears to depend largely on the parent lithology of the rocks involved. The sublabile sandstone and argillaceous rocks of the Bathurst Island Formation have been deeply weathered. The well developed trizonal profile formed as a result of the chemical breakdown of feldspars to clay minerals, and ferromagnesian minerals to iron oxides. This was followed by a redistribution of the silica, iron, and alumina under the influence of downward and lateral groundwater movements to form an upper ferruginous zone, a mottled zone, and a lower pallid zone. A deep weathering profile has also formed in the quartzose sandstone of the Van Diemen Sandstone on which it has produced a thick ferruginous zone, a thin mottled zone, and a poorly defined pallid zone of leached white sandstone with a low clay content. Unlike the profiles developed in the Bathurst Island Formation, the texture of the parent sandstone is preserved in the weathering profiles of the Van Diemen Sandstone owing to the persistence and abundance of quartz grains.

Laterite profiles have not developed in the siliceous hard sandstone of the Kombolgie

Formation because of the low iron content of the rocks and their clean quartz-rich composition. However, iron staining and impregnation have occurred along the numerous joints and faults to give the scarps of the Wellington Range plateau a pinkish appearance. In addition, detrital laterites have been observed adhering to the surface of the Kombolgie Formation. Where exposed the igneous and metamorphic rocks of southern Cobourg Peninsula are only slightly weathered.

In the Northern Territory Hays (1967) recognized four Land Surfaces which formed during periods of lateritization and erosion in the late Mesozoic and Cainozoic. He believed that the main period of lateritization on the mainland occurred during the Late Cretaceous and Early Tertiary in association with the development of the Tennant Creek Land Surface. Although the correlation of land surfaces over large areas is hazardous, Hays related the development of the standard laterite profiles on Bathurst and Melville Islands to a northern extension of the Tennant Creek Surface. This is the case for the laterite profiles developed in the Bathurst Island Formation. However, later in the Tertiary much of this land surface was buried by the Van Diemen Sandstone and it is a much younger surface that is now exposed, and being eroded, over much of both islands.

Profiles in the weathered rocks of the Bathurst Island Formation on Cobourg Peninsula indicate that the sediments have undergone a fairly complex history of weathering since their deposition in the Cenomanian. Initially, probably in the Late Cretaceous, lateritization accompanied by erosion and denudation removed the soluble components from the sediments, and iron, silica, and alumina were concentrated to form in-situ laterite profiles. The end product was a relatively flat terrain underlain by in-situ laterite. Later, the peninsula was tilted towards the northwest. This generated sufficient relief to provide optimum drainage and, with the dense vegetation reducing physical erosion in favour of uniform slope wash and percolation through the profile, ideal conditions prevailed for the further chemical and mechanical reworking of the laterite. This second cycle of weathering led to the deposition of the detrital bauxite that now overlies the truncated laterite profiles on the northern extremities of Cobourg Peninsula and Croker Island. The only residual in-situ bauxite and laterite on Cobourg Peninsula occupy topographically high areas such as Mount Roe and Mount Bedwell.

Field observations such as truncated laterite profiles, sharp irregular erosion contacts between zones in the present profile, and the presence of ironstone conglomerate as well as detrital fragments of lower layers in upper layers all support a detrital origin for much of the bauxite on Cobourg Peninsula. In this respect the bauxite of Cobourg Peninsula is more closely related to that of Gove than the in-situ residual deposits at Weipa.

All the bauxite deposits examined on Cobourg Peninsula have an iron-enriched hard capping up to 0.5 m thick. This surface feature is the result of climatic changes since the deposition of the bauxite and reflects a change to a drier, more seasonal climate. Thus the Cobourg Peninsula bauxite, like all the other known bauxite deposits of northern Australia, is a fossil bauxite. It probably formed during the Tertiary as it is underlain by Upper Cretaceous rocks and, in places, overlain by Pleistocene coquina, calcarenite, and conglomerate.

GEOLOGICAL HISTORY

According to Smart et al. (1974) the gneiss, schist, quartzite, migmatite, and other basement rocks were derived, at least in part, from Lower Proterozoic sediments of the Pine Creek Geosyncline. Preliminary isotopic dating of gneiss and schist from the Nimbuwah and Nanambu Complexes suggests an age of 1800 m.y. for the deformation, metamorphism, and migmatization of these sediments. The distribution of the Lower Proterozoic Koolpin Formation in the southern Cobourg Peninsula Sheet area and Sheet areas to the south suggests that during this period of crustal instability the Lower Proterozoic sediments were updomed at numerous centres, intensely folded, and anatectically melted to produce the basement complexes. Before cooling of the complexes was complete, dolerite derived from an alkali basalt magma was intruded to form the Oenpelli Dolerite.

After the Pine Creek Orogeny a long interval of terrestrial weathering and erosion produced a level craton across which rivers deposited quartzose sand and quartz-rich gravel. At first, dolerite and quartzite ridges hindered the drainage, but by the end of the Proterozoic they had been buried below a sheet-like body of sandstone and conglomerate (Kombolgie Formation).

The marine sedimentary history of the area began in the Early Permian with the ingress of a shallow sea. Deltaic conditions prevailed west of the Van Diemen Rise and argillaceous sand, silt, and calcareous ooze were deposited (Kulshill Formation). Continued transgression of the sea into this area resulted in the development of open marine conditions and in the Late Permian marine sand, silt, and mud were deposited with beds of biogenic limestone (Hyland Bay Formation). The transgression reached its peak in the Early Triassic when marine mud (Mount Goodwin Formation) was laid down. The Triassic sequence as a whole reflects a major regression of the sea with the Mount Goodwin Formation grading upwards, through Middle Triassic thick fluvial sand, into Upper Triassic redbeds. Thus, by the Late Triassic a continental environment again prevailed throughout the entire area.

After a period of erosion the sea returned to the area in the Late Jurassic and lapped across the Van Diemen Rise; paralic to fluvial conditions developed over much of the Bathurst Terrace. By Neocomian time a shallow epicontinental sea covered Bathurst Island and Melville Island Sheet areas as well as much of what is now the northwestern Northern Territory. However, the Neocomian sea did not extend as far east as the Cobourg Peninsula Sheet area.

After a brief regression at the end of the Neocomian the sea returned in the Aptian and flooded the Bathurst Terrace and the mainland, depositing the fine sand and radiolarian mud of the Darwin Member. For the first time, the sea encroached into the Cobourg Peninsula Sheet area and, with the deposition of the nearshore sand of the Marligur Member, ended an extremely long period of erosion. In the Albian, gradual uplift of the areas to the south caused a regression of the sea from the northwestern Northern Territory, and sedimentation during the Late Cretaceous was restricted to the area of the Bathurst Terrace and adjoining offshore basins. In the early to middle Cenomanian open marine conditions existed and pyritic mud and silt (Wangarlu Mudstone Member) accumulated. However, the sea began to retreat from the region before the end of the Cenomanian and the ensuing deltaic environment resulted in the deposition of sublabile sand, silt, and mud (Moonkinu Member). Measurements taken of direction and inclination of cross-bedding within the Moonkinu Member indicate that the provenance of the unit was to the northwest. By the Early Tertiary terrestrial conditions were dominant throughout the area and chemical weathering of the emerged sediments had produced an extensive cover of laterite.

Earth movements in the Early Tertiary resulted in the slight northwest tilting of the rocks overlying the Bathurst Terrace. Much of the area remained above sea level throughout the Tertiary and the area now occupied by the Van Diemen and Beagle Gulfs underwent subaerial erosion. Rivers flowed across this landsurface from eroding hilly areas underlain by Proterozoic rocks in the south to a coastline near the present-day northern coastlines of Bathurst and Melville Island. It was during this period of fluviatile activity that quartzose sand and muddy silt accumulated to form the Van Diemen Sandstone.

The northwest tilting of Cobourg Peninsula caused renewed erosion of the laterite developed in the Upper Cretaceous rocks. The parent laterite profiles were partly truncated and the rocks subjected to further leaching under conditions favourable for bauxitization. Reworked colluvial pisolitic layers rich in alumina were laid down on the lower slopes to form the bauxite deposits of Cobourg Peninsula. A late-stage climatic change resulted in progressive induration of the bauxite with iron oxides.

The Quaternary marine history of the area is recorded by a number of submarine terraces and notches revealed by echosoundings and continuous seismic profiles run across the Arafura Shelf by Jongsma (1974). The terraces reflect several sea-level changes within the area during the Pleistocene and, by combining these morphological features with age determinations on sediments from the terraces, Jongsma (1974) was able to recognize the following sequence of events:

1. A eustatic sea-level still stand at about −200 m before 170 000 years B.P. (possibly related to the Riss Glacial Stage).
2. A transgression before 30 000 years B.P.
3. A subsequent lowering of sea level after 30 000 year B.P., which fluctuated, forming terraces between −180 and −120 m (Wurm Glacial Stage).
4. A transgression from about −120 m at 15 000 years B.P. This marked the beginning of the Holocene transgression and caused the submergence of much of the area to isolate the islands, produce Cobourg Peninsula, and drown the ancient river valleys, resulting in Dundas and Apsley Straits.

Periods of higher than present-day sea levels also occurred in the area during the Quaternary. Evidence for these is provided by the sets of former strandlines in ancient sand bodies located up to 3 km inland in all three Sheet areas. Furthermore, in the Cobourg Peninsula Sheet areas stranded beach deposits of calcarenite, coquina, and sandy conglomerate crop out adjacent to the present coastline and overlie truncated laterite profiles. These reflect either high sea levels or minor uplift during the Quaternary.

The final stages in the history of the area include the stripping of laterite, formation of soils, and the widespread deposition of sand.

MINERAL OCCURRENCES

Mineral Sands

Ilmenite, zircon, and rutile are present in beach sands along the coasts of Bathurst and Melville Islands. The size of the deposits is poorly known, but areas of relatively high concentration include Andaranangoo Creek, Lethbridge Bay, Wangiti Beach, Cape Van Diemen, Murrow Point, and Cape Fourcroy. The results of analyses suggest that further investigation is justified and that economically viable deposits may exist.

Several investigations have been made to assess the concentration of heavy minerals in the beach sands of Bathurst and Melville Islands (Mackay, 1956; Murphy, 1970). Seventy-three sand samples were collected from Bathurst and Melville Islands by BMR in 1972 and 1973. A hand auger was used to collect a column of sand which was then mixed and quartered to obtain a representative sample. These samples were sent to AMDEL, South Australia, for heavy-mineral separation and semiquantitative mineralogy; the results are given in Table 5 and Appendix 3.

The principal components of the heavy fraction are opaques, zircon, and rutile, with minor amounts of tourmaline, kyanite, andalusite, staurolite, goethite, monazite, and chlorite. The opaque fraction consists of ilmenite (in varying stages of alteration to leucoxene) and rutile, with minor amounts of hematite, goethite, and maghemite. Traces of chlorite occurred in two samples (Appendix 3). All heavy fractions examined were quite similar mineralogically, with zircon, rutile, and ilmenite the dominant constituents; they also had near-identical suites of accessory minerals. The immediate provenance of the heavy minerals is the Van Diemen Sandstone which contains thin laminae of heavy minerals of the same composition as the mineral sands (Table 5). The heavy-mineral assemblage is now undergoing its second cycle of erosion and deposition, having been originally derived from the Lower Proterozoic igneous and metamorphic complexes to the south.

In 1973 detailed sampling was carried out in five areas.

Andaranangoo Creek, Melville Island (samples 73050124 to 73050136). The surface concentration of heavy minerals increases eastwards from Burra Burra Head to Radford Point (samples 73050124-127, 133-135). Mineral sands are accumulating at the base of the foredunes at the present time, and sediments transported to the mouth of Andaranangoo Creek are being deposited by the prevailing currents to form a prograding sand bar adjacent to the mouth of the creek. Samples 73050128-131 were collected from this sand bar. The results (Table 5) indicate that high concentrations of heavy minerals exist, and logs taken of the profiles show that the deposits are surface concentrations up to 10 cm thick with thin bands of heavy minerals down to 1.2 m. Samples 73050132 and 136 were taken from low vegetated former strandlines behind the beach.

The increase in percentage of heavy minerals eastwards along the beaches and the concentration of mineral sands in a prograding sand bar suggest that longshore drift is a major factor controlling the present-day accumulation of heavy minerals in this area.

Cache Point, Melville Island (samples 73050137-140). The beaches between Radford Point and Cache Point have surface accumulations of heavy minerals up to 5 cm thick with thin laminae down to 20 cm. The beaches are narrow and generally bordered by low weathered cliffs of Van Diemen Sandstone. Heavy minerals are being eroded from the cliffs and redeposited on the adjoining beaches. Storm activity is continually eroding the beaches along the northern coast of Melville Island and these surface concentrations of heavy minerals are largely transient.

Cape Van Diemen, Melville Island. Samples 73050141, 142, 147, and 148 were taken from the beach sand deposits, and 73050145 was collected from a foredune. Only small surface concentrations were present. 73050143, 144, and 146 are from holes augered into aeolian deposits occupying shallow depressions. Cape Van Diemen is exposed to the northwest trade winds and here aeolian activity is the dominant factor influencing the reworking and concentration of heavy minerals. The samples collected from Seagull Island (73050120-123) indicate that very little mineral sand is accumulating offshore.

Caution to Murrow Point, Bathurst Island. (samples 73050111-117). Only transient surface concentrations and thin laminae down to 30 cm are present in the beach and foredune deposits. The mineral sands are underlain by uneconomic yellow coarse sands and shell debris.

Lethbridge Bay, Melville Island. Samples 73050150 and 152 represent the beach sands of this area, and 73050151 and 153 the dune sands. The results suggest very low concentrations of heavy minerals. However, more detailed sampling, especially of the older inland sand deposits, is required before the area can be assessed. Beaches east of Lethbridge Bay are composed entirely of coarse sand and shell debris and augering revealed no heavy minerals.

Sampling on Bathurst and Melville Islands has shown surface accumulation of heavy minerals. However, the size of the deposits is poorly known, and as the sampling technique was restricted to a maximum depth of 1.2 m the results are inconclusive. The total thickness of the sand deposits is unknown and the possibility of concentration at greater depths unexplored.

The aim of any future survey should be (1) to evaluate the total volume of sand available in each area and determine the average grade; (2) determine the factors controlling present-day concentration of heavy minerals in an attempt to develop a model for the evaluation of ancient beach systems present at some localities; (3) locate areas of potentially high concentration with detailed sampling for placer deposits; e.g. at the base of old cliff-lines or along the lines of highest stand of a former transgression, as well as investigating sand bars near the mouths of major streams and areas where natural traps such as headlands obscure the free passage of longshore currents; (4) recognize the physiological units present and attempt to develop a history of deposition; and (5) collect material for radiocarbon dating.

The largest bodies of sand, i.e. greatest potential volume of payable ground, occur at Lethbridge Bay, Wangiti Beach, and Andaranangoo Creek. Holes to depths of 10 to 15 m on a systematic grid and drilled to below the water table would be necessary to evaluate the potential of these areas. A suggested distribution of holes at Andaranangoo Creek is given in Figure 7. Photo-interpretation of the area led to the recognition of a series of strandlines and ancient sand bodies, as well as several different physiographic units in the coastal deposits. On the basis of differences in topographic expression and orientation of strandlines three periods of transgression were recognized in the inland sand bodies.

Lines 1 and 2: General reconnaissance across the different units to determine their thickness and average grade. In addition, line 1 is positioned to investigate the possibility of high concentration of heavy minerals in the prograding sand bar adjacent to Andaranangoo Creek.

Lines 3 and 4: Located along the lines of highest strand of two former transgressions to test the possibility of heavy-mineral accumulation at this level during the higher sea levels.

Lines 5 to 10: Normal to lines 3 and 4 at 300 m spacings and with sample sites about 150 m apart to evaluate total volume and average grade of sand available in the inland sand bodies.

Lines 11 and 12: Along the base of modern foredunes to test for high concentrations of heavy minerals.

Line 13: Parallel to the base of an old sea cliff to evaluate the possibility of placer deposits accumulated during a former transgression.

Although continuous seismic profiling by Jongsma (1974) has shown a series of submarine terraces and notches relating to periods of lower sea levels in the Quaternary, there is very little chance of high concentrations of heavy minerals offshore from Bathurst and Melville Islands. Any concentration is likely to have been restricted to ancestral strandlines and, as such, would be subject to reworking and partial destruction by a transgressive sea. The bulk of the littoral sand would migrate landwards with the rising sea and any heavy minerals that may have been concentrated in the low-level shoreline would become redeposited on the new beaches.

A surface sample collected from Trepang Bay, Cobourg Peninsula, proved on analysis to contain 77.0 percent by weight heavy minerals, almost entirely undifferentiated opaques with only a trace of zircon. Larsen (1965) noted that the beach sand and ferruginous Cretaceous sandstone on Cobourg Peninsula were so rich in iron oxides that in places they could become a potential source of iron ore (e.g. Black Point and Danger Point).

Bauxite

The first reference to bauxite on Cobourg Peninsula was by Brown (1908) who reported the presence of pisolitic laterite. Brown's description directed the attention of Owen (1954)

TABLE 5. MINERALOGICAL COMPOSITION OF THE HEAVY-MINERAL FRACTIONS AS DETERMINED BY AMDEL

Zi = Zircon; Ru = Rutile; To = Tourmaline; Ky = Kyanite; St = Staurolite; An = Andalusite; Go = Goethite; Mo = Monazite; Cl = Chlorite.

Location	*Sample No.*	*Interval sampled*	*Weight % heavy fraction*	*Undifferentiated Opaques (see Appendix 3)*	*% Zi*	*% Ru*	*% To*	*% Ky*	*% Others*
Cape Van Diemen	72050035	0–5 cm	22.24	50–60	30–35	<1	1	Tr	—
Cape Van Diemen	47	Surface	15.76	60–70	Tr	<1	4–8	10–15	St 5–10
Cape Van Diemen	51	0–75 cm	0.26	70–80	3–5	<1	5–10	1–2	St 1–2
Cape Van Diemen	54	0–75 cm	1.00	70–80	15–20	1–2	2–4	—	—
Cape Van Diemen	64	Surface	5.41	50–60	20–30	4–6	1–2	—	St 1–2
Cape Van Diemen	73	0–80 cm	0.18	50–60	—	—	20–25	5–10	An 4–6
Cape Van Diemen	73050141	0–90 cm	1.9	40–50	30–40	5	5–10	—	—
Cape Van Diemen	142	0–1.2 m	0.9	40–50	30–40	10–15	2–5	1–2	Go 2
Cape Van Diemen	143	0–15 cm	3.1	55–65	15	10	2–5	<1	Go 3; St 1–2
Cape Van Diemen	144	15 cm–1.2 m	2.5	45–50	35	10–15	2–5	<1	St 1–2, Mo 1–2
Cape Van Diemen	145	0–1.2 m	0.8	55	20	10	5–10	<1	Go 1
Cape Van Diemen	146	0–1.2 m	2.1	50	25	15	5–10	<1	Mo 2–3
Cape Van Diemen	147	0–1.2 m	0.3	65	5	5	10–15	<1	Go 10
Cape Van Diemen	148	0–1.2 m	0.2	30	<5	<5	30–40	1–2	Go 15–20
Van Diemen Sandstone	73050118		1.3	70–75	15	5	2–3	<1	Mo 1–2; Go 1
Van Diemen Sandstone	119		1.8	70	20–25	3–5	2–3	<1	—
Van Diemen Sandstone	121		0.8	70	15	10–15	1–2	1	Mo 1–2
Radford Point	72050066	0–1.2 m	0.35	80–85	8–10	2–3	—	—	—
Radford Point	73050137	0–80 cm	1.1	30–35	5–10	10	30–40	2–4	Go 5
Radford Point	138	0–50 cm	6.2	35–40	15–20	20	10–15	4–8	St 2–4
Radford Point	139	0–5 cm	69.8	30–35	25–30	25–30	2–4	1–2	—
Radford Point	140	0–1.2 m	0.4	35–40	40	15–20	2–3	1–2	—
Andranangoo Creek	73050124	0–1.2 m	0.5	50–60	35	5–10	—	2–3	—
Andranangoo Creek	125	0–1.2 m	0.1	40	35	5–10	2–3	3–5	Go 10
Andranangoo Creek	126	0–1.2 m	0.2	55	15	15	10	—	Go 2–4
Andranangoo Creek	127	0–6 cm	3.6	35	40	10	5–10	<1	Go 1
Andranangoo Creek	128	0–1.2 cm	6.9	30–40	20	25–30	5–1	1–2	St 1–2
Andranangoo Creek	129	0–17 cm	6.1	40	25	30	2–5	<1	—
Andranangoo Creek	130	17 cm–1.2 m	1.1	50–55	25	5–10	8–12	<1	—
Andranangoo Creek	131	0–1.2 m	1.1	40–50	30–40	5–10	3–5	1–2	—
Andranangoo Creek	132	0–50 cm	0.9	50	20–25	20	3–5	<1	—
Andranangoo Creek	133	0–1.2 m	0.6	30–35	35	20–25	3–5	1–2	—
Andranangoo Creek	134	0–30 cm	31.6	5–10	55	30–35	1–3	<1	—
Andranangoo Creek	135	30 cm–1.2 m	11.2	20	40	30	3–5	1–2	St 1–2
Andranangoo Creek	136	0–1.2 m	2.8	30	40	25–30	2–5	<1	—

TABLE 5. MINERALOGICAL COMPOSITION OF THE HEAVY-MINERAL FRACTIONS AS DETERMINED BY AMDEL (*Cont.*)

Location	*Sample No.*	*Interval sampled*	*Weight % heavy fraction*	*Undifferentiated Opaques (see Appendix 3)*	*% Zi*	*% Ru*	*% To*	*% Ky*	*% Others*
Murrow Point	72050041	0–90 cm	0.32	20–30	30–40	2–5	—	—	—
Murrow Point	44	Surface	11.66	30–40	30–40	10–20	—	—	—
Murrow Point	73050113	0–40 cm	1.5	40	30	10	1–2	—	Go 5–10
Murrow Point	114	0–50 cm	0.6	40	30–35	10	5	<1	Go 10
Murrow Point	115	0–1.2 m	0.2	35–40	30	10–15	1–3	1	Go 15
Murrow Point	116	0–60 cm	1.3	45	30	15	1–3	1	Go 5
Murrow Point	117	0–1.2 m	0.3	50	25	10	2–5	1–2	Go 5
Caution Point	72050067	0–1.2 m	0.56	70–80	20–30	—	—	—	—
Caution Point	73050111	0–8 cm	1.5	10	60	25	1–2	<1	Go 1
Caution Point	112	0–30 cm	21.4	5–10	65–70	25	—	—	Go 2
Seagull Island	73050120	0–1.2 m	0.2	30	—	—	40	—	St 30
Seagull Island	122	0–1.2 m	0.1	15–20	2–4	—	50–60	10–15	St 1–2
Seagull Island	123	0–1.2 m	—	—	—	—	—	—	—
Lethbridge Bay	73050149	0–20 cm	1.2	25	35–40	20–25	3–6	3–6	Go 3
Lethbridge Bay	150	0–85 cm	0.4	25	30	15–20	5–15	—	Go 15
Lethbridge Bay	151	0–1.2 m	1.5	20	50–55	20	1–2	1	Go 2
Lethbridge Bay	152	0–75 cm	0.2	45	15	10	5–15	1–2	Go 10
Lethbridge Bay	153	0–90 cm	0.9	40–50	25	15–20	5–10	2–5	—
Cape Fourcroy	72050048	Surface	96.46	20–30	60–70	5–7	—	—	—
Cape Fourcroy	49	Surface	17.79	30–40	50–60	2–4	—	—	—
Buchanan Island	72050034	0–80 cm	0.84	35–45	40–50	1–2	1–2	—	—
Buchanan Island	42	0–80 cm	1.57	90–95	1–5	—	1–2	—	—
Buchanan Island	52	0–85 cm	0.39	80–90	10–15	1–2	—	—	—
Ant Cliff	72050037	0–30 cm	0.44	70–80	20–25	2–4	—	—	—
Boradi Bay	39	0–75 cm	2.13	10–20	30–40	30–40	1	—	—
Cape Helvetius	45	0–1.2 m	1.12	100	—	—	—	—	—
Wangiti Beach	46	0–90 cm	1.78	40–50	35–45	2–6	—	—	—
Bowen Bay	55	0–80 cm	3.08	70–80	15–20	2–4	1–2	—	—
Conder Point	56	0–75 cm	0.27	80–90	8–10	1–2	—	—	—
Tinganoo Bay	63	0–80 cm	0.14	20–30	40–50	5–10	1–2	—	St 1–2
Point Jahleel	65	0–60 cm	—	—	—	—	—	—	—
Cape Gambier	70	0–90 cm	4.30	80–90	5–10	1–2	—	—	—
Point Jual	71	0–60 cm	0.19	60–70	30–40	1–2	—	—	—

TABLE 5. MINERALOGICAL COMPOSITION OF THE HEAVY-MINERAL FRACTIONS AS DETERMINED BY AMDEL (*Cont.*)

Location	*Sample No.*	*Interval sampled*	*Weight % heavy fraction*	*Undifferentiated Opaques (see Appendix 3)*	*% Zi*	*% Ru*	*% To*	*% Ky*	*% Others*
South coast Bathurst Island	72050036	0–45 cm	0.13	40–50	40–45	4–6	<1	—	—
South coast Bathurst Island	50	0–75 cm	0.55	97–100	1–2	1	—	—	—
South coast Bathurst Island	69	0–60 cm	1.06	98–99	1–2	—	—	—	—
South coast Bathurst Island	72	Surface	0.37	85–95	5–10	—	—	—	—
West coast Bathurst Island	72050043	0–1.1 m	1.24	80–90	5–10	<1	<1	—	—
South coast Melville Island	72050038	0–1.1 m	0.63	70–80	15–20	—	1–2	—	—
South coast Melville Island	57	0–1.2 m	1.34	80–90	5–10	2	1	—	—
South coast Melville Island	74	0–1.2 m	0.23	70–80	10–20	—	2–5	—	—
South coast Melville Island	75	0–80 cm	0.92	30–40	50–60	3–5	1–2	—	—
North coast Melville Island	72050040	0–80 cm	0.14	20–25	15–20	1–2	—	—	Cl 50–60
	68	0–75 cm	0.68	40–50	45–55	2–4	<2	—	—

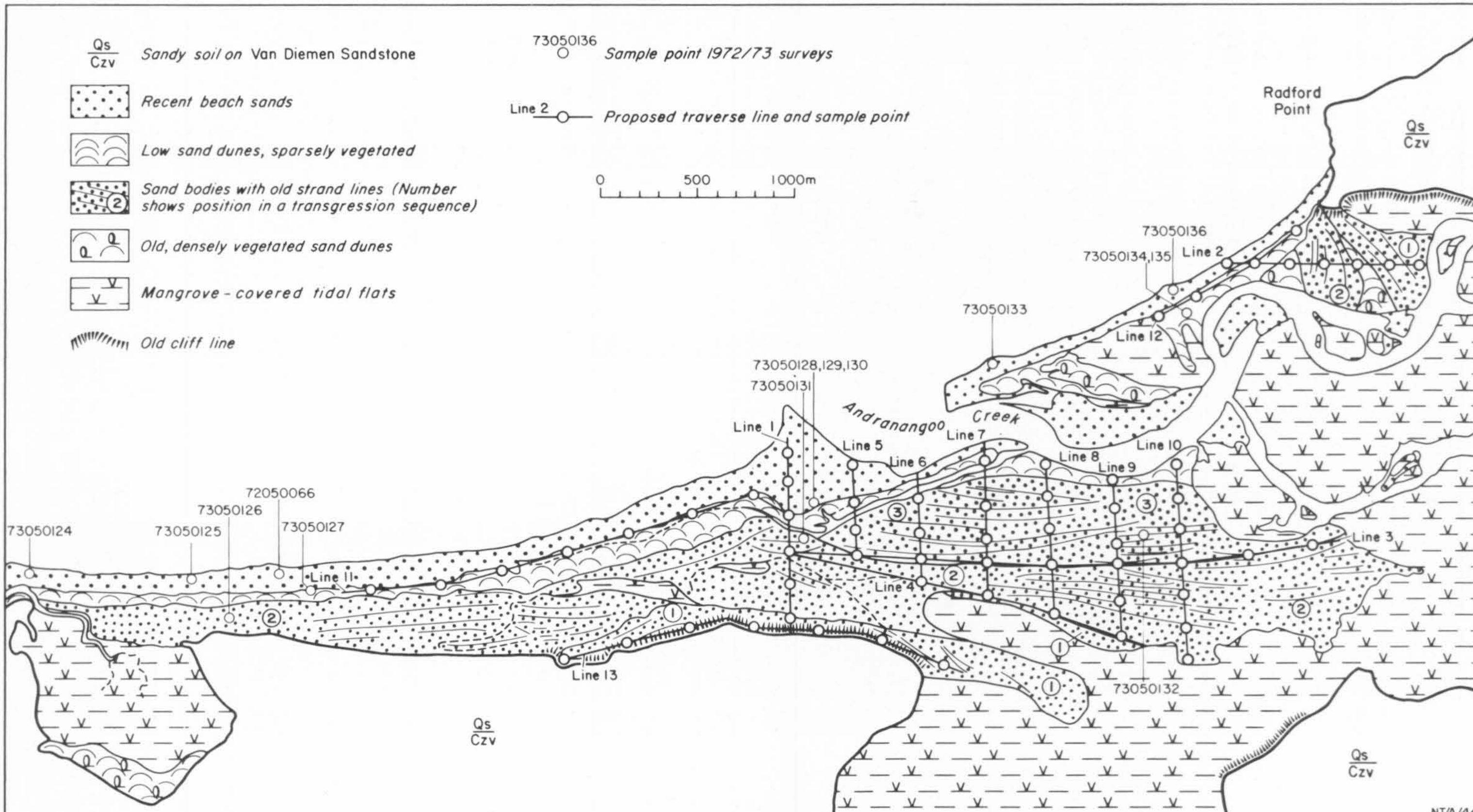

Fig. 7. Photo-interpretation of the Andaranangoo Creek deposit showing suggested traverse lines and sample points for detailed evaluation of the heavy-mineral content.

TABLE 6. MAJOR-OXIDE ANALYSES OF BAUXITES

Sample locality	Al_2O_3	Fe_2O_3	SiO_2	*Reactive* SiO_2	TiO_2	*Company or organization*
Peacock Island	44.1	8.2	7.0	4.3	2.5	BMR (average of 2 analyses)
Cape Croker	47.6	—	9.2	—	—	Reynolds Metals (2 analyses)
Cape Croker	47.0	11.3	16.4	15.2	2.5	BMR (1 analysis)
Danger Point	33.2	18.7	31.1	29.5	1.7	United Uranium (4 analyses)
Smith Point	36.0	9.4	14.0	13.2	2.1	BMR (1 analysis)
Smith Point	36.6	16.7	29.6	25.8	1.7	United Uranium (8 analyses)
Smith Point	37.3	11.8	30.2	—	1.6	Swiss Aluminium (7 analyses)
Turtle Point	30.2	25.2	28.7	—	1.7	BMR (2 analyses)
Turtle Point	40.2	18.7	21.3	18.5	1.8	United Uranium (3 analyses)
Midjari Point	46.3	10.8	15.0	7.2	3.2	Swiss Aluminium (12 analyses)
Midjari Point	44.9	12.7	17.1	15.2	2.5	United Uranium (4 analyses)
Midjari Point	48.7	8.4	17.2	15.7	3.4	BMR (3 analyses)
Vashon Head	39.5	11.5	21.0	—	2.2	Swiss Aluminium (2 analyses)
Vashon Head	46.3	10.3	14.1	—	2.6	United Uranium (13 analyses)
Trepang Bay	40.1	18.8	17.9	7.6	1.6	Swiss Aluminium (10 analyses)
Araru Point	46.5	15.0	12.0	9.2	2.6	United Uranium (4 analyses)
Araru Point	42.3	17.4	18.1	12.2	3.3	Swiss Aluminium (12 analyses)
Araru Point	29.5	19.4	33.5	32.5	1.9	BMR (1 analysis)
Lingi Point	42.1	10.6	23.3	—	2.5	Swiss Aluminium (7 analyses)
Stewart Point	34.5	16.5	31.5	30.0	1.6	BMR (1 analysis)
Darmarl Point (Croker Island)	37.5	18.0	24.0	23.0	2.0	BMR (1 analysis)
Milikapiti Hill (Melville Island)	33.5	9.5	41.5	36.6	1.8	BMR (1 analysis)
Piper Head (Melville Island)	22.3	24.1	38.0	24.7	1.2	BMR (1 analysis)

Note: Loss of volatiles on ignition and minor amounts of CaO, MgO, Na_2O, and K_2O account for the discrepancies in total percentages of analyses shown in this table.

of BMR to the north coast of Cobourg Peninsula and led to the discovery of bauxite. As a result of Owen's reconnaissance Rio Tinto Exploration Pty Ltd (Matheson, 1957) tested the pisolitic deposits of northern Croker Island, and Reynolds Metal Co. (Kidd, 1961) drilled the more favourable areas on Croker Island. They proved the existence of commercial grades but concluded that the deposits were too small to be of economic value. In 1965 United Uranium N.L. (Larsen, 1965) discovered areas of bauxite on Vashon Head, Smith Point, and Danger Point. Swiss Aluminium (1969) found uneconomical occurrences of lateritic bauxite in widely scattered outcrops at Lingi Point, Araru Point, and Midjari Point.

Recent BMR mapping (Hughes & Senior, 1973) has shown that the pisolitic crust, in which the bauxite occurs, is more extensive than formerly thought (Czp, Plate 1). The pisolitic layer averages 2 m in thickness and forms a gently north-sloping landsurface which becomes coincident with sea level on the northern extremities of some headlands. The presence of bauxite on wave-cut platforms, detrital fragments washed up on offshore islands, and the evidence cited previously for much lower sea levels in the Tertiary all suggest an additional, but unknown, offshore distribution.

The bauxite formed as a consequence of the reworking of the in situ laterite profiles developed in the sediments of the Bathurst Island Formation. Slight tilting of the northwest part of Cobourg Peninsula Sheet area initiated further leaching of the weathered rocks, and the parent laterite profiles were partly truncated by erosion. The reworked material was then redeposited to form pisolitic layers rich in alumina.

Field observations to support a detrital origin for the bauxite on Cobourg Peninsula are outlined on Page 31. The texture of the bauxite under the microscope is consistent with a detrital origin. The pisolites vary in size from 0.1 to 1.3 mm and most have a number of concentric shells of varying colour. The cores are generally more ferruginous than the outer shells, commonly have fragments of older pisolites or laterite as a nucleus, and many contain

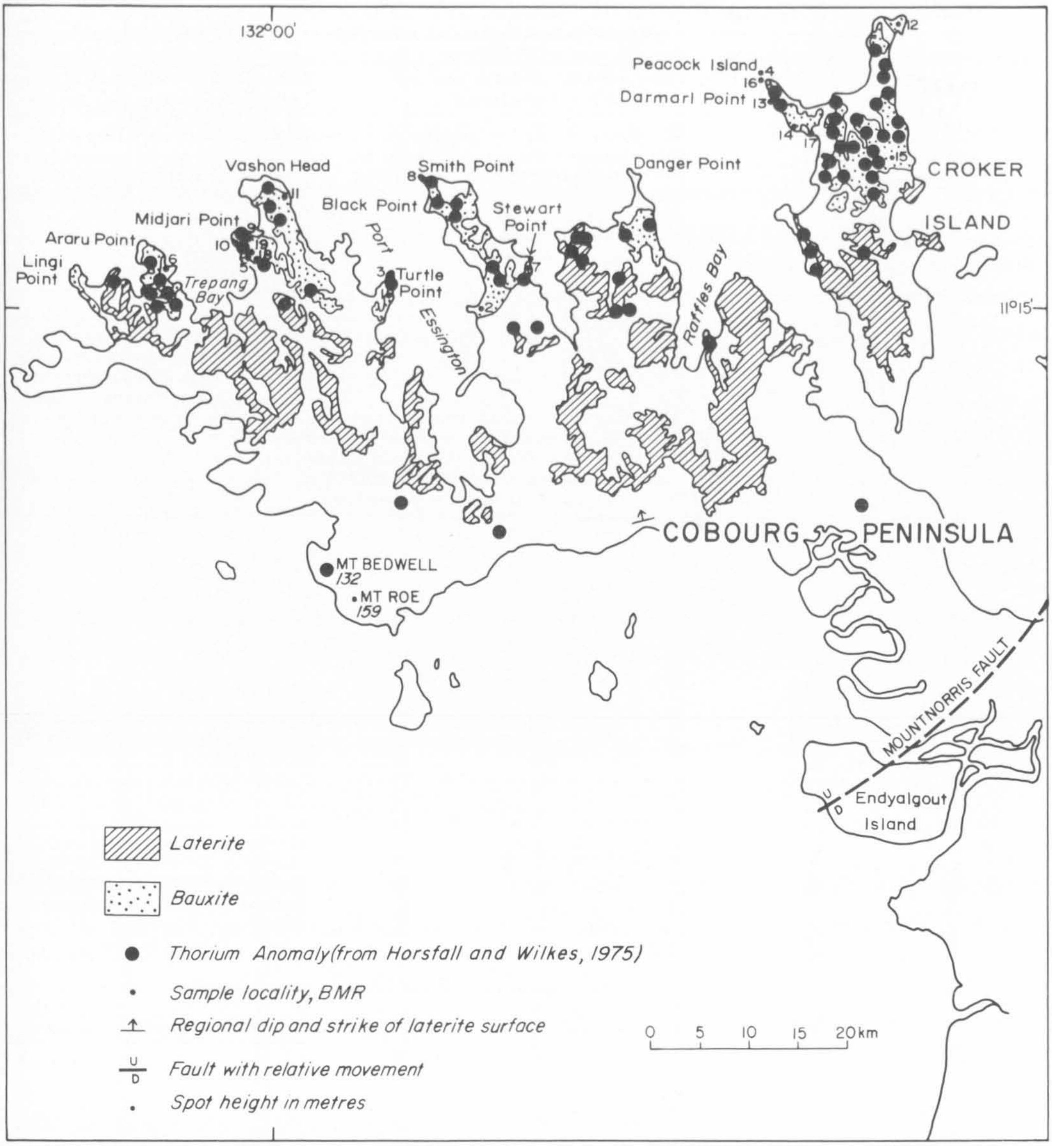

Fig. 8. Bauxite and laterite distribution in relation to thorium anomalies.

an abundance of fine angular quartz grains and other detrital fragments. The cores and inner shells are commonly fractured and the shells exhibit complex histories of growth. The pisolites are set in a matrix of very fine quartz and indeterminate phyllosilicates with a framework of reworked quartz, feldspar, calcite, tourmaline, opaques, broken pisolites, and rock fragments.

There is a close correlation between the distribution of bauxite and thorium anomalies detected during an airborne radiometric survey by Horsfall & Wilkes (1975) (Fig. 8). Thirteen samples of bauxite from Cobourg Peninsula were analysed for thorium and uranium by X-ray fluorescence. The thorium concentrations range from 6 to 54 ppm and average 35 ppm; the uranium concentrations range from less than 3 ppm to 12 ppm and average 5 ppm. The results suggest that radiometry may prove to be a useful tool in prospecting for bauxite. There is also the possibility

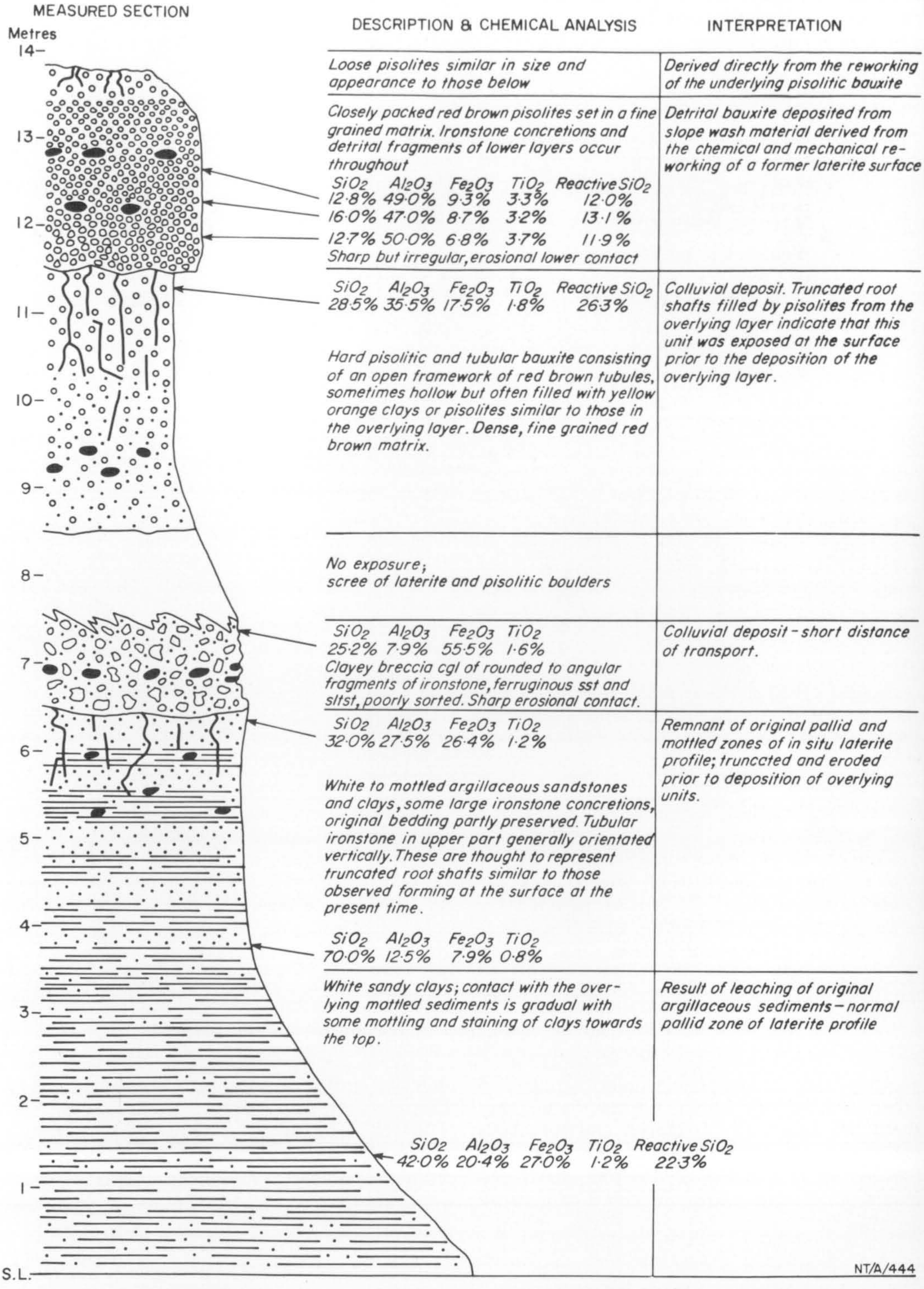

Fig. 9. Exposed profile of weathered rocks and bauxite at Midjari Point, Cobourg Peninsula.

of by-product recovery of thorium. X-ray diffraction studies of five samples of bauxite from Cobourg Peninsula indicated that gibbsite is the only alumina mineral present and that kaolinite and hematite make up the balance. The results of chemical analyses by both private companies and BMR are given in Table 6. The bulk of the silica present is reactive and this is one of the factors seriously limiting the economical potential of the deposits. Other factors include the lack of access both by land and sea, shipping problems associated with the shallow water and reefs surrounding the peninsula, the wide distribution of the deposits, and restrictions on mining activity in the area much of which is a flora and fauna reserve.

Notes on the main deposits are given below.

Croker Island. Most of the island is covered by laterite, but bauxite occurs only in the north. It is pisolitic and overlies a hard reddish brown tubular laterite with a sharp contact. The tubular laterite in turn overlies a truncated mottled zone also with a sharp, but irregular contact. The bauxite layer has an average thickness of 1.5 m. Company estimates of reserves vary from 5 000 000 tonnes of greater than 40 percent available alumina (Matheson, 1957) to 660 000 tonnes of greater than 30 percent available alumina (Kidd, 1961).

Midjari Point. The highest-grade bauxite and the greatest thickness of bauxite on Cobourg Peninsula occur at Midjari Point. Figure 9 summarizes the observations and interpretations made at this locality. Inland the pisolitic bauxite forms low rubbly outcrops across the high ground.

Vashon Head. Discontinuous outcrops of pisolitic bauxite on Vashon Head peninsula cover about 48 km^2. Cliff sections along the coast reveal thicknesses of up to 2 m of pisolite bauxite. However, this thins quite rapidly to the south and is replaced by a truncated laterite profile. Larsen (1965) considered the possibility of a bauxite deposit of up to 50 million tonnes in this area.

Araru and Lingi Points. The maximum thickness of pisolitic bauxite in this area is 0.5 m. It generally rests directly on mottled-pallid sediments of the former laterite profile. The deposit is small and outcrops are widely scattered.

Smith Point. Pisolitic and tubular bauxite was encountered during a traverse along the narrow headland separating Port Essington and Port Bremer. The bauxite is exposed in the cliffs around the coast, and inland as small discontinuous rises. The deposits occupied about 20 km^2 and the pisolitic layer varies in thickness from 0.5 m near Smith Point up to 2 m in the cliffs around Berkeley Bay and Point Stewart.

Turtle Point. Low cliffs adjacent to Turtle Point expose a profile showing an upper layer of dark red pisolitic bauxite about 2 m thick, overlying tubular and mottled ferruginous sandstone.

Danger Point. Larsen (1965) noted the presence of pisolitic bauxite over a small area 1.5 km south of Danger Point. At Danger Point itself, 2 m of coquina containing fragments of pisolitic bauxite overlies ferruginous and mottled fine sandstone of a truncated laterite profile. A similar sequence is also present at the extremities of Vashon Head and Smith Point.

Bauxite is present in two areas on northern Melville Island. Pisolitic and nodular bauxite crops out as erosion remnants on the peninsula separating Shark Bay and Snake Bay over an area of about 15 km^2. The maximum thickness of the pisolitic layer is 6 m and according to Patterson (1958) the available alumina in the deposit ranges up to 35 percent. Small deposits of aluminous laterite occur between Shark Bay and Garden Point. Three surface samples had available alumina contents of 14, 24, and 16 percent respectively.

Hydrocarbon potential

Commercial hydrocarbons have not been found in the area, but traces of oil and gas have been noted both onshore and offshore in Permian, Jurassic, and Cretaceous rocks. Bitumen has been noted adhering to rocks along the coastlines of the islands and Cobourg Peninsula. Analyses of samples collected indicate that the bitumen has the composition of crude oil, and the fact that samples collected over a period of several years show identical composition discounts the possibility of oil spillage. Bathurst Island No. 2 was abandoned prematurely when a small flow of methane and water caused deterioration of the hole. Small flows of methane associated with water were also recorded near total depth in Tinganoo Bay No. 1. Offshore, methane was recorded in Permian sandstone intersected in Flat Top No. 1 and, to the west of the area mapped, uneconomic high-pressure gas was encountered in the Hyland Bay Formation in Petrel No. 1.

The hydrocarbon potential of the Palaeozoic and Mesozoic rocks in the area depends on updip migration of hydrocarbons from the Bonaparte Gulf and Money Shoal Basins. Porous clastics forming good reservoirs have been located in the Permian, Triassic, and Jurassic sequences along the eastern edge of the Bonaparte Gulf Basin (Newby No. 1 and Flat Top No. 1). These, in conjunction with thick organic-rich shales in the Cretaceous and Lower Permian (source beds), and the possibility of stratigraphic traps make the western edge of the Bathurst Island Sheet area prospective for oil and gas. Here the Permian, Triassic, and Jurassic sandstones pinch out against the Van Diemen Rise and are capped by Cretaceous mudstone (Wangarlu Mudstone Member). Newby No. 1 and Flat Top No. 1 were both drilled to test this possibility but neither penetrated economic hydrocarbons.

No structural traps have been located by seismic surveying, and owing to the quiet tectonic history of the area the chances of finding sizable structures are small.

The Money Shoal Basin, north of the area mapped, is not well known and only two oil exploration wells, Money Shoal No. 1 and Lynedoch No. 1, have been drilled in it. According to Balke et al. (1973) the total sedimentary section exceeds 4500 m near the depocentre of the Money Shoal Basin. Balke et al. (op. cit.) also reported an almost complete lack of mappable seismic reflections over a large part of the Money Shoal Basin below a seismic event in the Lower Cretaceous rocks. Additional geophysical exploration and drilling are required to provide more data before an accurate evaluation can be made of the hydrocarbon potential of the basin.

Groundwater

Perennial spring-fed streams originating from aquifers within the Van Diemen Sandstone are common on both islands. The water is of good quality and the water supplies of Garden Point and Pickertaramoor are provided by spring-fed streams (Lambert River and Takamprimilli Creek respectively). Domestic water for Bathurst Island Mission was originally obtained from 16 wells sunk into a permeable layer of laterite developed in the Cretaceous rocks. However, this was unreliable and water is now drawn from sub-artesian bores which intersect aquifers in the Van Diemen Sandstone.

Snake Bay Native Welfare Settlement obtains its water supply from a system of sand spears which tap aquifers in Quaternary clayey sands at a depth of about 8 m. The yield is insufficient and investigations to locate an alternative supply are necessary. Several unsuccessful bores have been drilled by Water Resources Branch.

No fresh water was intersected in Bathurst Island Nos. 1 and 2 and all water resources investigations on the island have indicated that the Cretaceous sequence has little potential as an aquifer (Dunn, 1962; Barclay, 1964; Laws, 1967; Lau, 1972). Tinganoo Bay No. 1 flowed very brackish water at a rate of 0.2 m^3/h from a basal Upper Jurassic conglomeratic sandstone.

Because of a lack of permanent surface water in the Cobourg Peninsula Sheet area the settlements depend on supplies from water-bores. Most water-bores are shallow and tap unconfined Quaternary aquifers, the supplies from which diminish during the dry season. Croker Island Mission derives its domestic and stock water from a series of bores in Quaternary sand and laterite. Until recently Murgenella Forestry Settlement relied on one bore pumping water from aquifers within the laterite. In 1972 a serious shortage of water threatened to force the abandonment of the settlement. However, during the BMR stratigraphic drilling on southern Cobourg Peninsula (Hughes, 1973) an abundant supply of good-quality artesian water was discovered in aquifers within the Marligur Member of the Bathurst Island Formation. Flows of up to 70 m^3/h were obtained from an uncased 9-cm diameter hole. Water Resources Branch, Darwin, has since drilled, and completed as water-bores, two holes into the Marligur Member. Bore No. 8206 will relieve the water supply problem at Murgenella, and Bore No. 8207 is planned to provide water to a portable abattoir which is to be set up on the edge of the Murgenella Plains. This will allow the expansion of the local buffalo meat industry.

The Water Resources Branch of the Department of the Northern Territory, Darwin, has records of 97 water-bores drilled in the three Sheet areas. Table 7 summarizes the data.

Uranium

The discovery of high-grade uranium ore at Nabarlek in 1970 prompted exploration by Union Carbide (Australian and New Zealand Exploration Company) in the Proterozoic rocks in the southeast Cobourg Peninsula Sheet area (about 30 km north of Nabarlek). Ground checking of airborne radiometric anomalies by Union Carbide geologists has shown that many are due to surface concentration of uranium in detrital laterites or black soil. Only two anomalies, 2 km apart in the Black Rock Prospect, were considered to warrant further investigation and were drilled. Low-grade uranium mineralization was found at both anomalies but not in sufficient quantity to be economic. According to Senior & Smart (1976), the mineralization is localized on the eastern side of a northwest-trending mylonitized brecciated zone in gneiss and schist of the Nimbuwah Complex. As with all known uranium deposits in the Alligator Rivers region (i.e. Ranger I, Koongarra, Nabarlek, and Jabiluka) the host rocks are strongly chloritized and hematized. Another similarity is that the mineralization occurs immediately below the Carpentarian unconformity surface.

Manganese

Cretaceous rocks in the Cobourg Peninsula Sheet area are similar to those on Groote Eylandt in which manganese oxide ore bodies have been found. An occurrence of manganese was noted in 1969 by Union Carbide geologists in an area which is now part of the Murgenella Wildlife Sanctuary. Since 1969 the Cretaceous rocks, particularly those toward the base of the sequence, have been unsuccessfully prospected for manganese.

Phosphate

Phosphatic nodules occur as irregular layers in the Moonkinu Member along the south coast of Bathurst Island. The nodules are elliptical and up to 1 m long. Analyses by Parker (1966) indicated P_2O_5 contents of 10 to 20 percent. Phosphatic nodules and pellets between 188 and 200 m in Bathurst Island No. 1 contain 2 to 3 percent P_2O_5, and samples from Bathurst Island No. 2 between 43 and 305 m contain up to 12 percent P_2O_5. However, neither the grade nor the concentration of P_2O_5 in the nodules is of commercial value.

Construction Materials

Limestone. Coquina and calcareous sandstone form linear bodies adjacent to the present-day coastlines in the Cobourg Peninsula Sheet area, but they are probably too small to be considered as an economic source of lime for Darwin. Up to 5 m of consolidated coquina beach sand disconformably overlies a truncated laterite profile along South West Bay, South Goulburn Island, and about 4 m of raised beach sandstone and coquina limestone crops out on McCluer Island. Other outcrops in the Cobourg Peninsula Sheet area occur on North Goulburn Island, Grant Island, Oxley Island, Lawson Island, Valencia Island, the northeast coast of Croker Island and on the mainland at Vashon Head, Smith Point, and Danger Point. The average thickness of the bodies is 2 to 3 m. They vary greatly in lateral extent.

Laterite. Bricks hewn from the ferruginous capping of the laterite were used in the construction of early settlements (Fort Dundas, Melville Island; Raffles Bay, Cobourg Peninsula; Victoria, Port Essington, Cobourg Peninsula). The blocks were cemented together with mortar using lime made from shell and coralline debris. Victoria was abandoned in 1849, but the walls of many buildings are still standing and in good condition (Pl. 5).

Clay. Rix (1964) investigated the pottery clay resources of northern Melville Island, taking samples from Goolumbini Creek and Piper Head. The samples collected from Goolumbini Creek proved, on analysis, to be useless for any kind of ceramics because of a high sand content and low plasticity. Initial testing of small samples of kaolinitic clay from Piper Head suggested that it was satisfactory for moulding and could be burnt at 900°C to 1100°C. The product was white, free from cracks or deformation, and took a transparent commercial glaze well. A larger sample (23 kg) representative of the three main clay lenses at Piper Head was tested by the Division of Building Research, CSIRO. The results showed that the clay has low plasticity and is mechanically weak. The maximum temperature in the firing range tested (800°-1050°C) was not sufficient to give it the mechanical strength necessary for ceramics or pottery. As a whole the clay deposits at Piper Head are not suitable for pottery making, but small selective samples within the layers are of higher quality and could possibly support a small-scale local industry.

DESCRIPTION OF PALAEOZOIC, MESOZOIC, AND CAINOZOIC ROCK UNITS

Kulshill Formation

Status and derivation of name: Australian Aquitaine (1966) first used the name informally for the Lower Permian sequence intersected in Kulshill No. 1. Caye (1968) introduced the name Kulshill Formation into the literature to describe part of the Permian section penetrated by Kulshill Nos. 1 and 2.

Type section: Kulshill No. 1 drilled by Australian Aquitaine in 1966. Dickins et al. (1969) defined the Kulshill Formation as the interval between 596 and 1813 m in Kulshill No. 1.

TABLE 7. SUMMARY OF WATER-BORES
COBOURG PENINSULA

*Reg. No.**	*Name*	*Location*	*Depth (m)*	*Water level (m)*	*Aquifer*	*m³/h*	*Remarks*
5086	Black Point Bore	Port Essington	6	6.0	Czl laterite	0.5	Abandoned
5513	Mission Hill Bore No. 1	Croker I	31	30.4	Qs sand	0.9	Operating
5540	Ryans Lookout No. 5	Croker I	25	24.4	Qs clayey sand	2.7	Potential domestic supply
5539	Cup o Tea Point No. 4	Croker I	27	—	—	—	Abandoned
5538	Timor Springs No. 3	Croker I	24	10.6	Qs sand clay	13.5	Operating
7263	No. 6 Domestic Supply	Croker I	36	32.8	Qs coarse sand	4.8	Operating
7264	No. 7 Domestic Supply	Croker I	32	19.8	Qs medium sand	0.6	Collapsed
7265	No. 7a Domestic Supply	Croker I	34	19.8	Qs medium sand	3.0	Operating
7266	Back Jungle No. 8	Croker I	41	24.3 32.0 35.0	Qs medium sand	4.0	Operating
7267	Palm Bay No. 9	Croker I	22	10.6	Qs silty sand	0.8	Operating (stock only)
7268	Main Airstrip No. 10	Croker I	16	9.1	Qs sandy silt	0.9	Operating (stock only)
7269	Four Mile South No. 11	Croker I	18	15.5	Qs medium sand	1.2	Abandoned
7270	The Point No. 12	Croker I	24	22.8	Qs sandy silt	3.6	Potential domestic supply
7271	Nine Mile South No. 13	Croker I	18	15.8	Qs medium sand	5.5	Potential domestic supply
7272	Jap Cr No. 14	Croker I	25	7.6	Qs sandy silt	—	Abandoned
7633	W.L. No. 1	Murgenella	20	10.4 13.7	Qs	7.5	Potential domestic supply
7634	W.L. No. 2	Murgenella	21	13.7	Qs	8.0	Potential domestic supply
7836	72/1	Croker I	38	32.0	Czl Fe sandstone	13.5	Operating
7839	72/1	Croker I	31	15.2 16.7	Qs gravelly clay	14.5	Operating
7850	W.L. No. 4	Murgenella	38	2.7	Qs	5.5	Operating
7852	W.L. No. 3	Murgenella	65	14.6	Qs	—	Abandoned
7853	W.L. No. 5	Murgenella	38	—	—	—	Abandoned
5695	Sand Spear No. 1	Murgenella	3	—	—	—	Abandoned
5696	Sand Spear No. 2	Murgenella	3	—	—	—	Abandoned
5697	Sand Spear No. 3	Murgenella	3	—	—	—	Abandoned
8206	Murgenella 73/1	Murgenella	259	5.7	Kla, Marligur Member	45.5	Potential domestic supply
8207	Murgenella 73/2	Murgenella Plains Abbatoir site	93	flowing	Kla, Marligur Member	10.9	Potential domestic supply and industrial supply

* Bore registration number of the Department of the Northern Territory, Darwin.

MELVILLE ISLAND

*Reg. No.**	*Name*	*Location*	*Depth (m)*	*Water level (m)*	*Aquifer*	*m^3/h*	*Remarks*
5064-5073		Snake Bay	15	—	—	—	All abandoned, exact location uncertain
5074	Spring Hole No. 2	Snake Bay	21	—	—	—	Abandoned, exact location uncertain
5075-5083		Snake Bay	15	—	—	—	All abandoned, exact location uncertain
5553	Snake Bay No. 1	Snake Bay	43	—	—	—	Abandoned
5555	Snake Bay No. 2	Snake Bay	66	—	—	—	Abandoned
5556	Snake Bay No. 3	Snake Bay	37	—	—	—	Abandoned
5563	Snake Bay No. 4	Snake Bay	29	—	—	—	Abandoned
5592	Snake Bay No. 5	Snake Bay	32	—	—	—	Abandoned
5593	Banjo Swamp 1/66	Snake Bay	7	6.8	Qs sand	1.3	Abandoned
5594-5597		Snake Bay	15	—	—	—	All abandoned
5598	Banjo Swamp 6/66	Snake Bay	12	11.5	Qs sand	—	Abandoned
5619	No. 1 Job 324	Garden Pt	15	7.3	Qs clayey sand	—	Abandoned
6072	Sand Spear E2	Snake Bay	9	2.1	Qs fine sand	8	Potential domestic supply
6193	Sand Spear E1	Snake Bay	4	—	—	—	Abandoned
6194	Sand Spear E3	Snake Bay	8	7.9	Qs fine sand	8	Potential domestic supply
6195	Sand Spear E4	Snake Bay	10	2.1	Qs fine sand	6	Potential domestic supply
6208-6210		Snake Bay	15	—	—	—	Abandoned, sand spears
6211	Sand Spear E12	Snake Bay	4	3.9	Qs gravel and sand	7	Potential domestic supply
6212	Sand Spear E14	Snake Bay	10	8.8	Qs gravel and sand	3	Potential domestic supply
7111	Bango Swamp No. 8	Snake Bay	10	1.5	Qs clayey sand		Operating (10/72) sand spear
7112	Bango Swamp No. 7	Snake Bay	14	1.5	Qs clayey sand		Operating (10/72) sand spear
7113	Bango Swamp No. 6	Snake Bay	8	1.5	Qs clayey sand		Operating (10/72) sand spear
7114	Bango Swamp No. 5	Snake Bay	8	1.5	Qs clayey sand	8.5	Operating (10/72) sand spear
7115	Bango Swamp No. 4	Snake Bay	6	1.5	Qs clayey sand		Operating (10/72) sand spear
7116	Bango Swamp No. 3	Snake Bay	7	1.5	Qs clayey sand		Operating (10/72) sand spear
7117	Bango Swamp No. 2	Snake Bay	8	1.5	Qs clayey sand		Operating (10/72) sand spear
7118	Bango Swamp No. 1	Snake Bay	8	1.5	Qs clayey sand		Operating (10/72) sand spear
7121	Observation hole No. 5	Snake Bay	9	1.5	Qs clayey sand		Observation
7607	Paru No. 1	Paru Village	36	—	—	—	Abandoned
7608	Paru No. 2	Paru Village	20	—	—	—	Abandoned
7609	Paru No. 3	Paru Village	23	—	—	—	Abandoned
7610	Paru No. 4	Paru Village	15	—	—	—	Abandoned
7611	Paru No. 5	Paru Village	46	—	—	—	Abandoned

* Bore registration number of the Department of the Northern Territory, Darwin.

TABLE 7. SUMMARY OF WATER-BORES (*Cont.*)
BATHURST ISLAND

*Reg. No.**	*Name*	*Location*	*Depth (m)*	*Water level (m)*	*Aquifer*	*m³/h*	*Remarks*
5875	Bathurst Is No. 1	5 km W of mission	32	—	—	—	Abandoned
5885	Bathurst Is No. 2	10 km W of mission	49	47.2	Qs clayey sand	28	Potential domestic supply
5886	Bathurst Is No. 3	20 km W of mission	35	—	—	—	Abandoned
5887	Bathurst Is No. 4	24 km W of mission	55	—	—	—	Abandoned
5902	Bathurst Is No. 5	37 km W of mission	30	—	—	—	Abandoned
5903	Bathurst Is No. 6	32 km W of mission	8	—	—	—	Abandoned
5904	Bathurst Is No. 7	10 km W of mission	55	27.4	Qs sandy clay	45	Potential stock of irrigation supply
5936	Observation Bore No. 8	10 km W of mission	30	27.4	Qs sand	20	Observation
5920	Bathurst Is 69/2	10 km W of mission	50	43.0	Czv lateritic sandstone	5	Potential domestic supply
6921	Bathurst Is 69/3	10 km W of mission	32	21.3	Qs fine sand	5	Potential domestic supply
6922	Bathurst Is 69/1	10 km W of mission	50	45.0	Czv fine sandstone	5	Potential domestic supply
7416	Bathurst Is 70/2	13 km W of mission	70	20.4	Qs silty clay	—	Abandoned
7466	Bathurst Is 70/3	13 km W of mission	53	45.7	Czv lateritic sandstone	23	Operating (10/72)
7467	Bathurst Is 70/1	13 km W of mission	48	47.2	Czv lateritic sandstone	23	Operating (10/72)
7612	Bathurst Is 70/5	10 km W of mission	46	45.7	Czv lateritic sandstone	20	Operating (10/72)

* Bore registration number of the Department of the Northern Territory, Darwin.

Plate 5. Ruins of the married officers' quarters at Victoria (1838-49). Bricks were hewn from nearby outcrops of ferruginous laterite. (GA/7900)

Lithology: The type section of the Kulshill Formation can be divided into three members which, in ascending stratigraphic order, are

1813-1453 m	silicified sandstone
1452- 948 m	microconglomerate shale; tillite
948- 596 m	greywacke

Offshore, only the upper greywacke member is known. Typically it is composed of very fine to fine and rarely coarse, argillaceous sandstone with intercalations of dark grey micaceous silty and carbonaceous shale, and minor limestone. The lithology of the Kulshill Formation in Flat Top No. 1 (Australian Aquitaine, 1969) is essentially the same (Fig. 10).

Distribution: Restricted to the western edge of the Bathurst Island Sheet area within the area mapped, but widespread to the south and west.

Thickness: In Flat Top No. 1, 589 m. The Kulshill Formation thins rapidly eastwards and pinches out against the Van Diemen Rise.

Contacts and relations: Along the eastern edge of the Bonaparte Gulf Basin the Kulshill Formation rests directly on quartzite believed to be Lower Proterozoic. It is conformably overlain by the Hyland Bay Formation.

Fossils and age: Correlations with other wells in the Bonaparte Gulf Basin suggest an Early Permian age for the entire sequence.

Hyland Bay Formation

Status of name: ARCO reserved the name Hyland Bay Formation with the Register of Stratigraphic Names, Canberra in 1969. The formation was described in the literature by Laws & Brown (1974) but has not been defined.

Derivation of name: Hyland Bay, Cape Scott 1:250 000 topographic Sheet; longitude 129°42'E, latitude 13°59'S.

Type section: The interval between 3464 and 3979 m in Arco Petrel No. 1 petroleum exploration well (Arco, 1969) has been designated the type section for the Hyland Bay Formation (Fig. 11).

Lithology: The Hyland Bay Formation intersected in Flat Top No. 1 is composed of fine to coarse, friable quartzose sandstone with silty, micaceous lignitic, and pyritic shale, and three massive beds of biomicrite (Fig. 11). This agrees closely with the lithology of the type section which is predominantly arenaceous with shale and limestone interbeds.

Distribution: The limestone beds are characteristic of the Hyland Bay Formation and have been recognized throughout the southern Bonaparte Gulf Basin. They generate good continuous seismic horizons, two of which (hori-

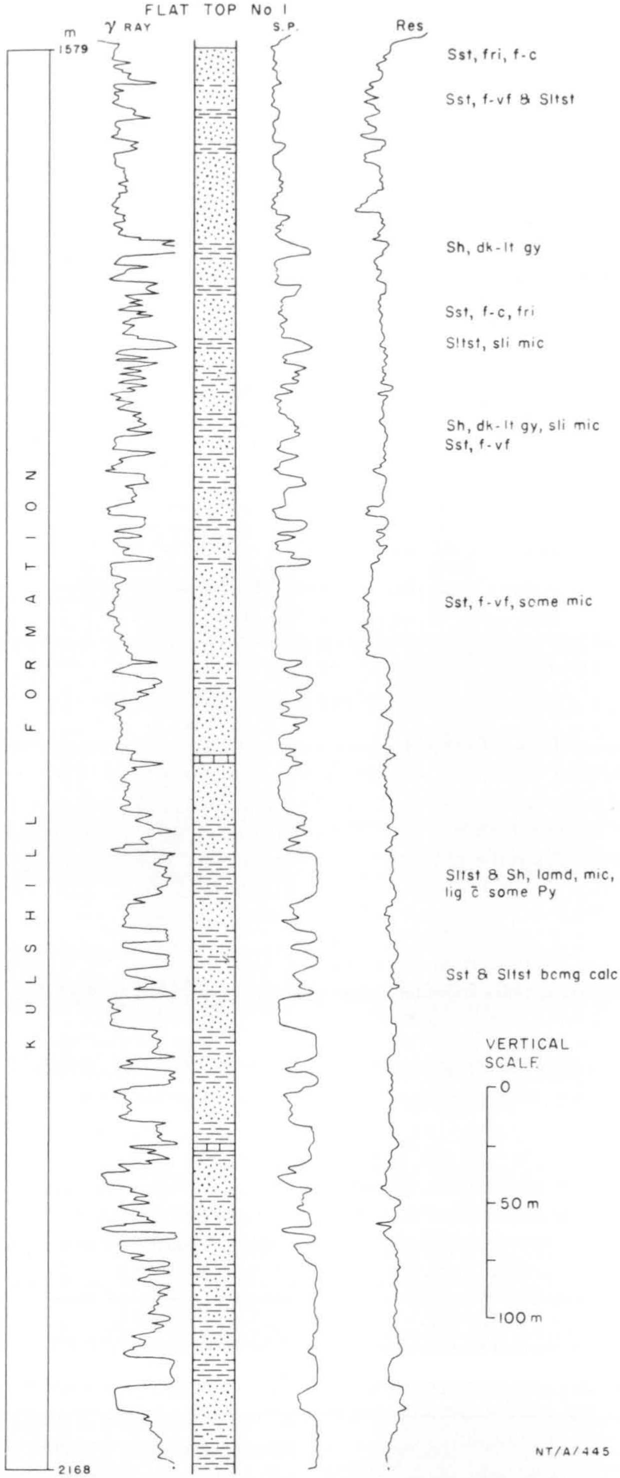

Fig. 10. Stratigraphic sequence in the Kulshill Formation in Flat Top No. 1 (Australian Aquitaine, 1969).

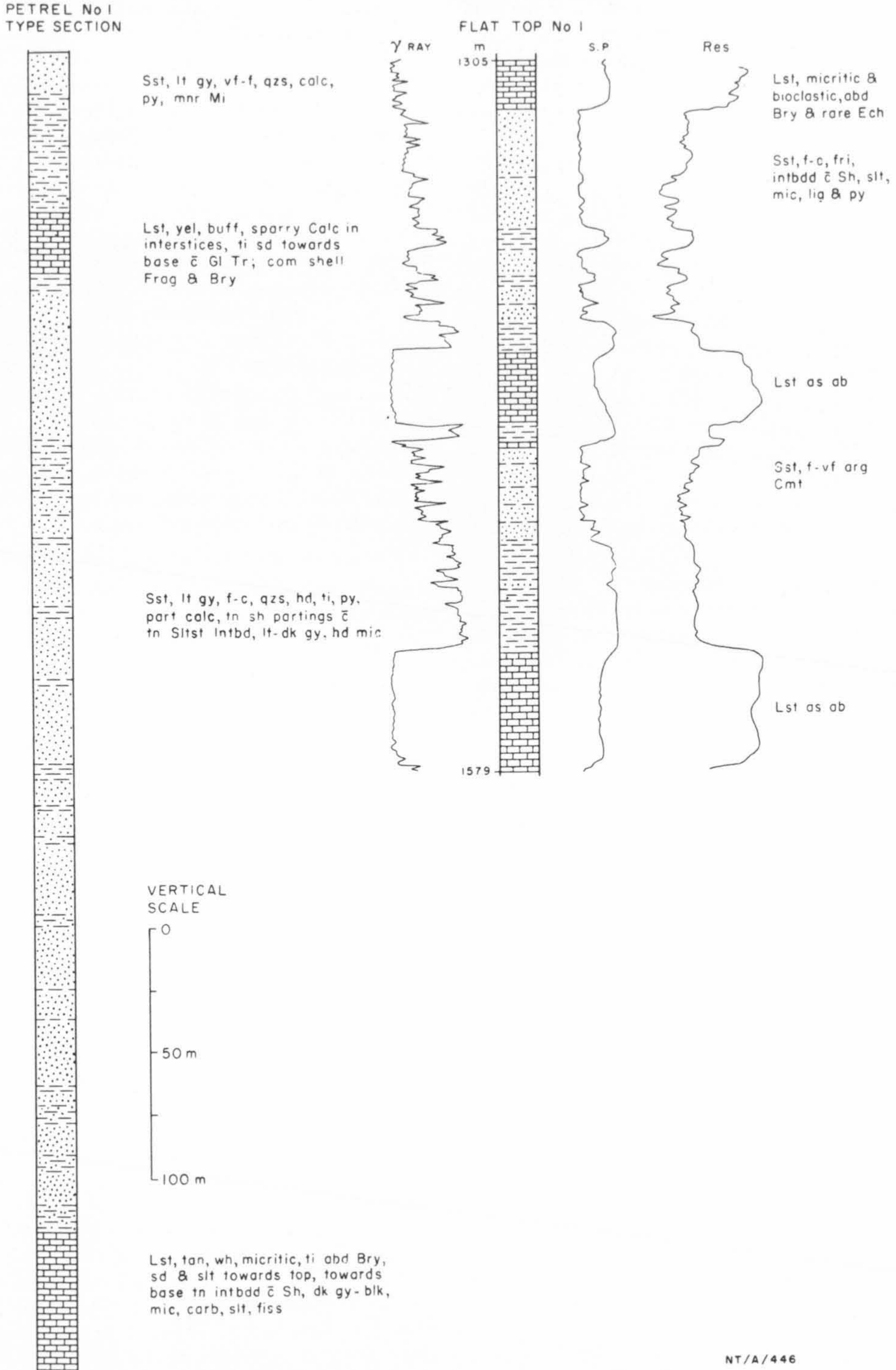

Fig 11. Well sections through the Hyland Bay Formation in Petrel No. 1 (Arco, 1969) and Flat Top No. 1 (Australian Aquitaine, 1969).

zons 4 and 5) have been used to map the formation in the Timor Sea area (Fig. 3). In the area covered by this report the Hyland Bay Formation does not crop out, and is restricted to the western edge of the Bathurst Island Sheet area.

Thickness: In its type section the Hyland Bay Formation is 515 m thick, but it thins eastward towards the Basin margin and in Flat Top No. 1 is only 274 m. It is absent in Newby No. 1 owing to pinch out against the Van Diemen Rise.

Contacts and relations: The base of the formation has been nominated as the bottom of the basal limestone bed in both Petrel No. 1 and Flat Top No. 1 (Fig. 11). The passage upwards into the overlying Mount Goodwin Formation appears to be transitional and conformable. In both wells the boundary is marked by the appearance of the massive dark grey shale characteristic of the Mount Goodwin Formation.

Fossils and age: Abundant bryozoans and echinoids in the limestone beds. The sandstone beds overlying the upper limestone in Petrel No. 1 contains abundant foraminifers and shell fragments. The fauna indicates that the formation is Upper Permian.

Mount Goodwin Formation

Status of name: Reserved in 1970 by Arco, described briefly by Laws & Brown (1974) but not defined.

Derivation of name: Mount Goodwin, Port Keats 1:250 000 topographic Sheet; longitude 129°38′, latitude 14°15′S.

Type section: The interval between 2892 and 3464 m in Arco Petrel No. 1 (Arco, 1969) (Fig. 12).

Lithology: The Mount Goodwin Formation is a predominantly shaly unit. The shale is light to dark grey, fissile, and generally silty and micaceous. Several thin beds of very fine siliceous sandstone and kaolinitic siltstone occur throughout the sequence.

Distribution: This unit is widespread and has been intersected in most wells drilled in the Bonaparte Gulf Basin. It onlaps onto the western edge of the Bathurst Island Sheet area where it wedges out against the Van Diemen Rise.

Thickness: 572 m in the type section but thins eastwards to 193 m in Flat Top No. 1.

Contacts and relations: The Mount Goodwin Formation grades upward into Middle Triassic sandstone. Recent palynological work by Australian Aquitaine (Pontalier, pers. comm.) has resulted in the identification of Middle Triassic spores in Petrel No. 1 between 2826 and 2892 m. An increase in the grainsize to a dominance of sandstone at 2892 m in Petrel No. 1 marks the conformable boundary between the Lower Triassic Mount Goodwin Formation and the overlying undifferentiated Middle to Upper Triassic sequence. A similar change in lithology at 1112 m is taken as the boundary between the two formations in Flat Top No. 1. Throughout the Basin the Mount Goodwin Formation conformably overlies the Hyland Bay Formation.

Fossils and age: Fossil content is low. The Lower Triassic age of the formation is determined on the basis of its stratigraphic position between known Upper Permian and known Middle Triassic rock units, and by correlation with other wells outside the area mapped.

Undifferentiated Middle to Upper Triassic

Description: The Triassic sequence was deposited during a major marine regression. The marine shale of the Mount Goodwin Formation passes upwards into fine to coarse fluvial sandstone of Middle Triassic age which in turn is conformably overlain by Upper Triassic redbeds. In Flat Top No. 1 two members can be distinguished within the Middle to Upper Triassic interval. The lower member (1030-1112 m) is composed of fine to coarse sandstone interbedded with minor shale, and the upper member (978-1030 m) is predominantly shaly with only minor beds of very fine sandstone. The shale is micaceous, ferruginous, and varies from red-brown to green. The upper member forms a redbed sequence. Originally, the interval occupied by the redbeds was assumed to be Jurassic and the exact age eluded precise determination until the lower Upper Triassic spore *Camerosporites* sp. was identified in the redbed sequence intersected in Bougainville No. 1 (Laws & Campbell, 1972).

In Petrel No. 1 the redbeds occupy the interval between 2229 and 2471 m, and the lower member of the undifferentiated Middle to Upper Triassic section is present between 2471 m and the base of the unit at 2892 m. The Middle to Upper Triassic sequence shows a similar distribution to that of the underlying Mount Goodwin Formation and is everywhere disconformably overlain by the Jurassic to Neocomian Petrel Formation.

No names have been proposed for the formation or its members.

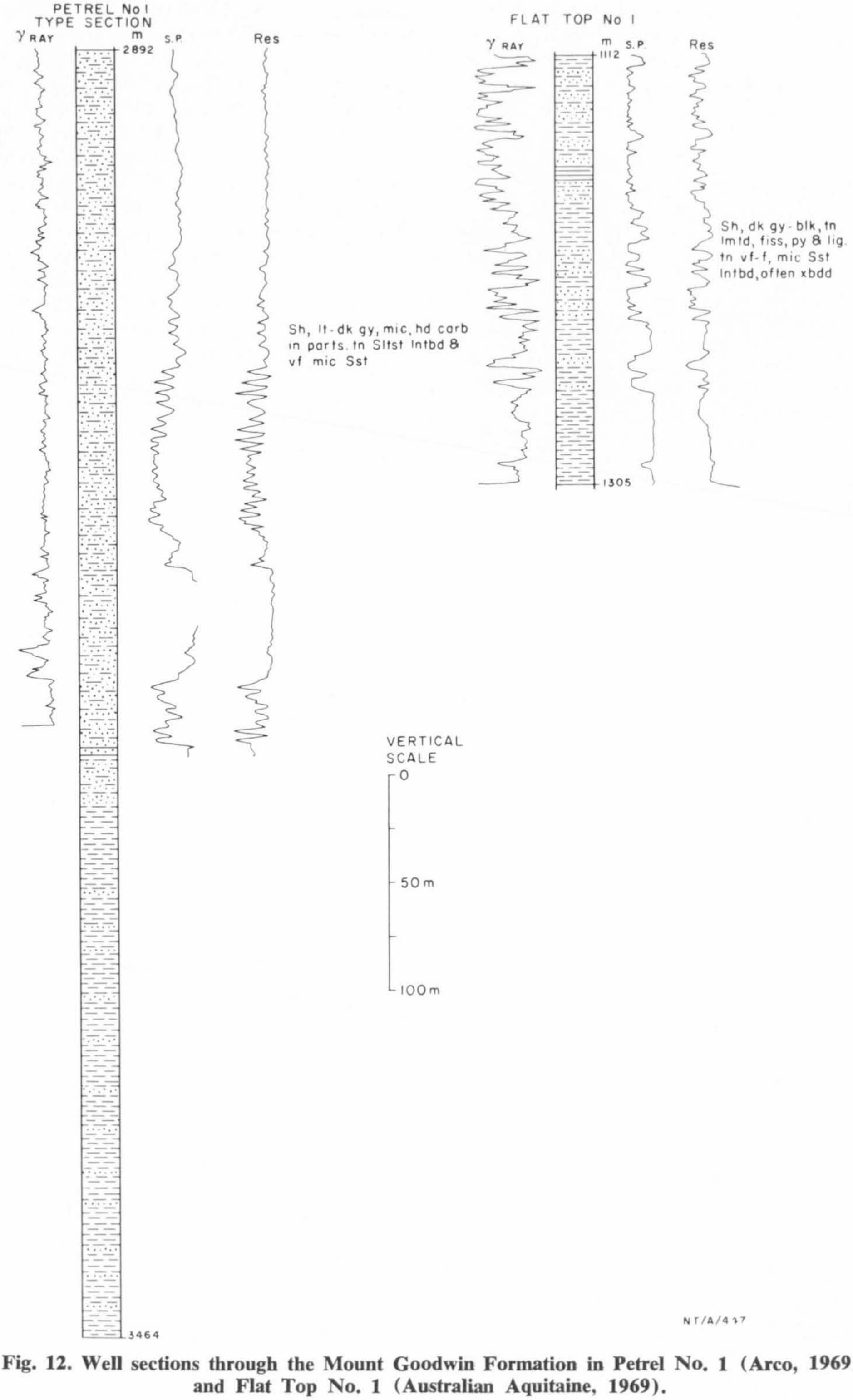

Fig. 12. Well sections through the Mount Goodwin Formation in Petrel No. 1 (Arco, 1969) and Flat Top No. 1 (Australian Aquitaine, 1969).

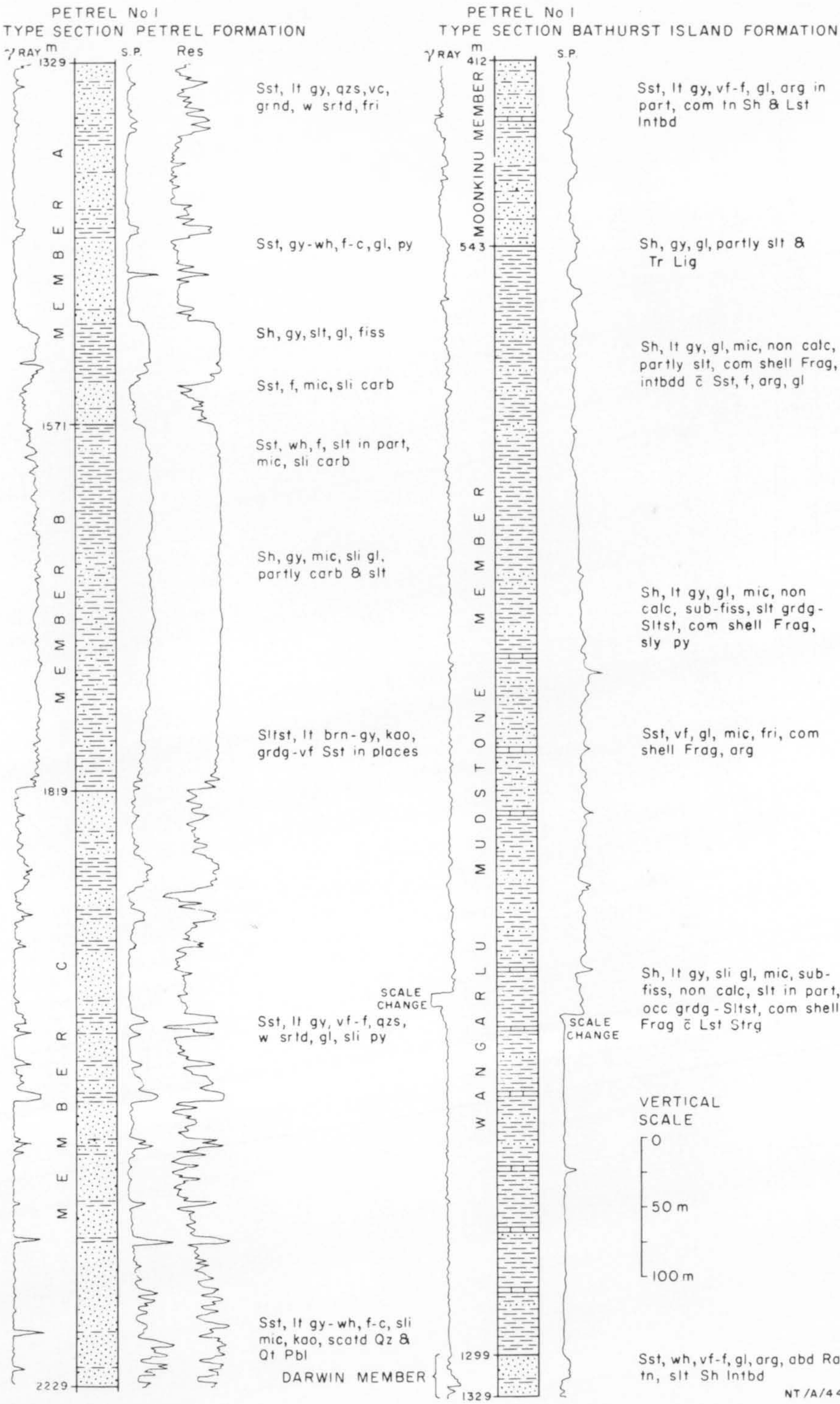

Fig. 13. Type sections of the Petrel and Bathurst Island Formations (after Arco, 1969).

Tinganoo Bay Beds

Derivation of name: Tinganoo Bay, latitude 11°23′S, longitude 131°28′E, Melville Island topographic 1:250 000 Sheet. The Tinganoo Bay Beds were first described by Hughes & Senior (1974).

Distribution: The Tinganoo Bay Beds are known only from Flinders-Pexa Tinganoo Bay No. 1 (Pemberton, 1971), where they occur between 569 and 583 m (T.D.).

Lithology: Coarse quartzose sandstone and conglomerate containing angular to rounded pebbles of quartz and quartzite, grading down into a fine micaceous sandstone within a few shale laminae.

Thickness: The total thickness is unknown. Assuming little change in regional dip, and by extrapolation from the Dundas Strait seismic survey (Prastka & Polyniak, 1965) it is probable that at Tinganoo Bay there is 100 m of sediment between the base of the Bathurst Island Formation and Proterozoic basement.

Contacts and relations: In Flinders-Pexa Tinganoo Bay No. 1 the Tinganoo Bay Beds are disconformably overlain by the Bathurst Island Formation. The Petrel Formation occupies a similar stratigraphic position but the two units are lithologically distinct (Fig. 2).

Fossils and age: A moderately well preserved spore-pollen assemblage from 576.4 m in Tinganoo Bay No. 1 indicates that the Tinganoo Bay Beds are late Upper Jurassic (Burger, Appendix 1).

Petrel Formation

Status and Derivation of name: Arco reserved the name Petrel Formation with the Register of Stratigraphic Names, Canberra in 1970. Laws & Brown (1974) briefly described the formation but it has not been defined. The name is derived from Petrel No. 1, a petroleum exploration well drilled by Arco in 1969 at latitude 12°49′S, longitude 128°28′E.

Type section: The type section of the Petrel Formation is the interval between 2229 m and 1329 m in Petrel No. 1 (Arco, 1969) (Fig. 13).

Lithology: Three members were recognized by Arco (1971) in the type section of the Petrel Formation (Fig. 13).

Member A. 1329-1571 m; predominantly arenaceous, comprising a series of very fine to very coarse, in part conglomeratic, quartzose sandstone; in places glauconitic, pyritic, and kaolinitic.

Member B. 1571-1819 m; in contrast with Member A this unit comprises a series of grey to brown glauconitic and micaceous shale, invariably silty and commonly grading into calcareous siltstone. In the top 30 m are a few thin very fine to fine micaceous sandstone beds.

Member C. 1819-2229 m; the basal member is similar to Member A in that it is predominantly arenaceous. It is composed of fine to coarse quartzose friable sandstone with scattered pebbles of quartz and quartzite. There are a few silty and shaly intervals.

Towards the eastern margin of the Bonaparte Gulf Basin the shale and siltstone of member B are absent, and in both Flat Top No. 1 and Newby No. 1 the dominant lithology of the Petrel Formation is white friable fine to medium quartzose sandstone with a few interbeds of greyish brown shale. The absence of the marine shale member B and the increased proportion of paralic to fluvial sandstone reflect the basin-edge position of these two wells.

Distribution: From the eastern edge of the Bonaparte Gulf Basin the Petrel Formation extends eastwards over the Van Diemen Rise and across part of the Bathurst Terrace. The Petrel Formation also extends southwards across the Bathurst Terrace (Fig. 2) and onto the mainland where it crops out below the Darwin Member of the Bathurst Island Formation (Fig. 14).

Thickness: The known maximum thickness of the Petrel Formation is 900 m in Petrel No. 1. The Petrel Formation thins rapidly eastwards and in Newby No. 1 on the eastern edge of the Bonaparte Gulf Basin, it is only 145 m thick. Across the Bathurst Terrace the formation forms a thin blanket of sandstone which probably does not exceed 100 m in thickness.

Contacts and relations: Both onshore and offshore the Petrel Formation is disconformably overlain by the Darwin Member of the Bathurst Island Formation. However, the nature of the lower contact and the age of the rocks beneath it is variable. Within the Bonaparte Gulf Basin the Petrel Formation usually disconformably overlies Middle to Upper Triassic rocks whereas on the Bathurst Terrace and across the mainland the Petrel Formation rests unconformably on steeply dipping Proterozoic basement rocks.

The coarse clastics of the Tinganoo Bay Beds are laterally equivalent to the Petrel Formation and reflect a change in facies across the

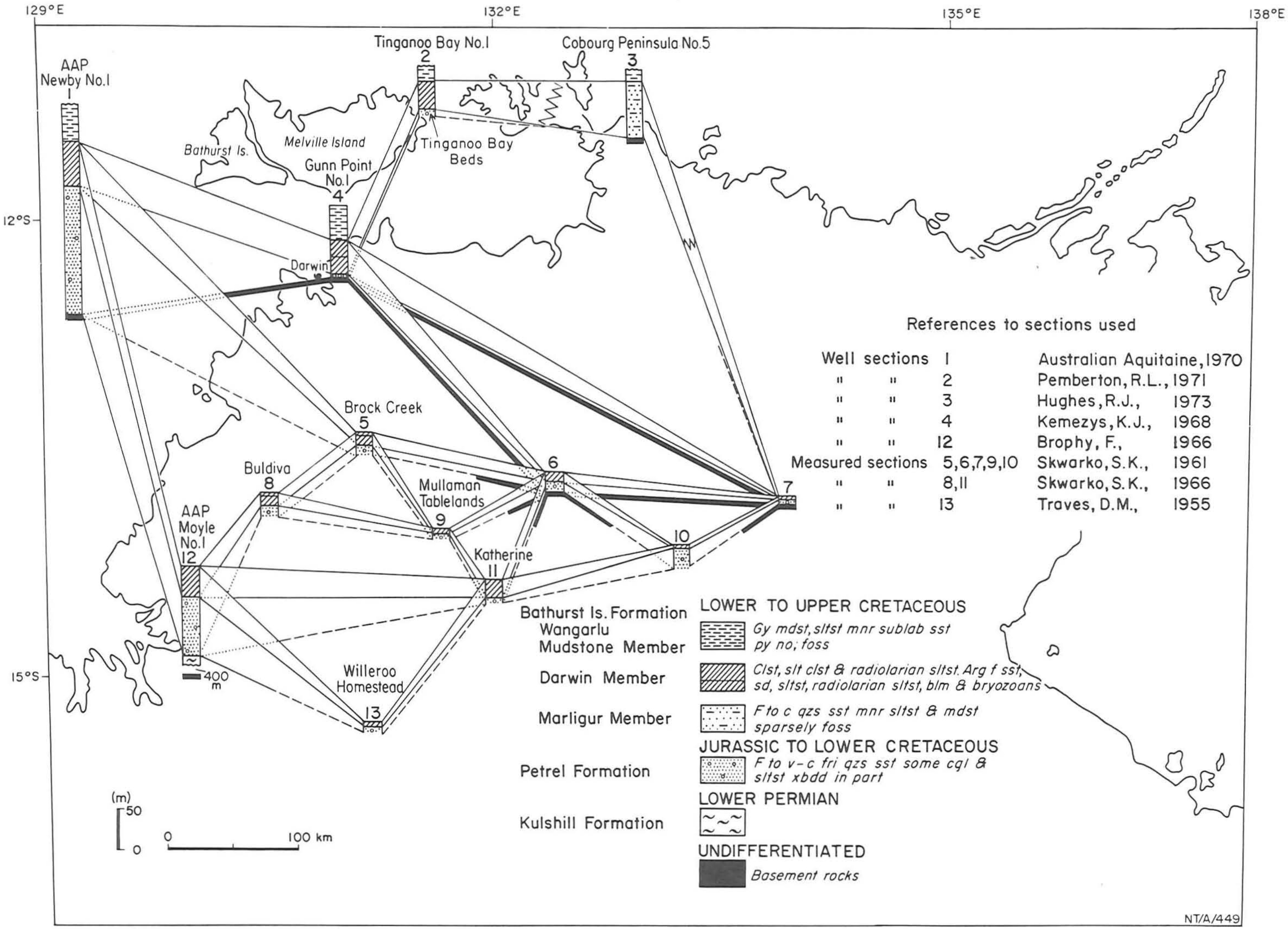

Fig. 14. Distribution of Jurassic and Cretaceous rock units across northwestern Northern Territory.

Bathurst Terrace from paralic conditions in the west to non-marine conditions to the east.

Fossils and age: Palynological examination of cores from the Petrel Formation have shown that offshore it ranges in age from Early Jurassic to Neocomian. Jurassic plant fossils and Neocomian marine fossils (Skwarko, 1966) are abundant in some of the exposures of the Petrel Formation on the mainland. In Moyle No. 1 (Brophy, 1966) the spore *Cicatricosisporites* sp. is present from 61 to 67 m, suggesting that the interval of weathered sandstone in Moyle No. 1 between 36 and 105 m is Upper Jurassic to Cretaceous rather than Lower Permian as previously thought.

Revision of the Mullaman Beds

It is proposed to divide the Mullaman Beds of the northern part of the Northern Territory into two units; a lower predominantly arenaceous unit which may be correlated with the Petrel Formation, and an overlying argillaceous unit to be known as the Darwin Member of the Bathurst Island Formation.

A summary of the evolution of nomenclature for the Mullaman Beds is given in Table 8.

Noakes (1949) gave the name Mullaman Group to the freshwater and marine sediments that crop out in the Katherine-Darwin region. Within the Mullaman Group he recognized two formations; a lower unnamed unit of plant-bearing sandstone and minor siltstone, and an upper argillaceous unit, the Darwin Formation. The division of the Mullaman Group into two formations was supported by Sullivan & Iten (1952) and Traves (1955). However, later workers downgraded the Mullaman Group to Mullaman Beds; a name which they then used to describe all the Mesozoic sediments in the northern part of the Northern Territory regardless of lithology, environment of deposition, or age. Consequently, the name Mullaman Beds has become meaningless.

Skwarko (1966) considered that the Mullaman Beds of both the Northern Territory and northwestern Queensland fall naturally into three belts of differing depositional characteristics; the Coastal Belt, the Inland Belt, and the Darwin Area. He recognized seven lithological units in the Coastal Belt, and three in the Inland Belt. With the possible exception of Unit 3, none of the Coastal Belt units extend into northwestern Northern Territory. On the other hand, the Mullaman Beds of the Katherine-Darwin region form part of Skwarko's Inland Belt and the three units he recognized in the Inland Belt may be correlated with the Petrel Formation and Darwin Member as shown in Table 8.

Figure 14 confirms the view that the Mullaman Beds can be divided into two lithologically distinct and mappable units in northwestern Northern Territory. The upper unit consists of silty claystone, sandy siltstone, radiolarian siltstone, and argillaceous fine sandstone. It is equivalent to the Darwin Formation as defined by Noakes (1949). The interval occupied by the Darwin Formation onshore can now be traced offshore through Newby No. 1 and Flat Top No. 1 to Petrel No. 1 where it occupies a hitherto unnamed interval (1299-1329 m) at the base of the Bathurst Island Formation (Figs. 2 and 13). Thus, it can be demonstrated that the upper unit of the Mullaman Beds is actually a member of the Bathurst Island Formation and it is proposed that this member be known as the Darwin Member.

The lower unit of the Mullaman Beds is a white fine to very coarse friable quartzose sandstone with minor conglomerate and shale beds. In outcrop the sandstone is massive and, apart from cross-bedding, has very few sedimentary structures. Jurassic plant remains are common and Neocomian marine molluscs have been collected at some localities. The lithology of this lower unit is identical to that of Member C of the Petrel Formation, and Figure 15 illustrates that the Petrel Formation can be traced from its type section offshore in Petrel No. 1 to Moyle No. 1 onshore. From there it may be mapped in outcrop across northwestern Northern Territory (Fig. 14).

Bathurst Island Formation

Derivation and status of name: From Bathurst Island, 60 km northwest of Darwin, Bathurst Island 1:250 000 topographic Sheet. Arco reserved the name Bathurst Island Formation in 1970 after drilling Newby No. 1. The name was used informally by both Arco and Australian Aquitaine in several unpublished well completion reports until Hughes & Senior (1974) formally defined it with the type section in Petrel No. 1.

Type section: The type section of the Bathurst Island Formation is the interval between 412 and 1329 m in Petrel No. 1 (Arco, 1969) (Fig. 13).

Lithology and distribution: Between 412 and 543 m the section in Petrel No. 1 is mainly very fine to fine argillaceous sandstone with thin beds of shale and limestone. Below 543 m the amount of shale increases and the section consists largely of marine glauconitic silty

TABLE 8. EVOLUTION OF NOMENCLATURE FOR THE MULLAMAN BEDS

Lithology	*Woods (1889)*	*Woolnough (1912) Hossfeld (1937)*	*Etheridge (1907) Whitehouse (1928)*	*Noakes (1949) Sullivan & Iten (1952) Traves (1955)*	*Skwarko (1966)*	*BMR Geologists 1962-1972*	*This Bulletin*
Silty claystone, siltstone, radiolarian siltstone, fine argillaceous sandstone, and minor conglomerate			*Point Charles Beds* used to describe the fossiliferous strata at Point Charles near Darwin. Also referred to as 'Point Charles Strata', 'Point Charles deposit', and 'Point Charles bed'	MULLAMAN GROUP *Darwin Formation* best developed in the coastal sections around Darwin and correlated by Noakes with radiolarian siltstone throughout the Katherine-Darwin region	MULLAMAN BEDS Darwin Area, Inland Belt Unit B & Unit C (the distinction between Units B and C corresponds to the division within the Darwin Member between the lower argillaceous fine sandstone etc. and the upper claystone, etc. as shown in Figure 14)	MULLAMAN BEDS The name Mullaman Group was changed to Mullaman Beds to comply with Section 27 of the Australian Code of Stratigraphic Nomenclature	*Darwin Member* of Bathurst Island Formation
Fine to coarse quartzose sandstone, minor conglomerate and shale beds	*Desert Sandstone* applied for a short time to any sedimentary cover in northern Northern Territory	*Plateau Sandstone, Plateau Sandstone Series* used to describe the sandstones capping the plateaux in northern Northern Territory		Unnamed formation of plant-bearing sandstone	Inland Belt Unit A		*Petrel Formation*

shale. The base of the formation is marked by a distinctive unit of glauconitic argillaceous very fine sandstone with minor shale rich in Radiolaria. In Petrel No. 1 this unit ocurs between 1299 and 1329 m.

These lithological subdivisions of the Bathurst Island Formation can be recognized throughout the Bonaparte Gulf Basin and across the Bathurst Terrace where they crop out on the islands, Cobourg Peninsula, and to the south on the mainland (Fig. 2). They have been mapped as members of the Bathurst Island Formation and, in ascending stratigraphic order, are known as the Darwin Member, Wangarlu Mudstone Member, and Moonkinu Member. Another member of the Bathurst Island Formation, the Marligur Member, is restricted to the Cobourg Peninsula Sheet area and is laterally equivalent to the Darwin Member.

Thickness: At the type section, 917 m. The formation thins gradually towards the eastern edge of the Bonaparte Gulf Basin, where a thickness of 700 m is indicated by seismic data. It becomes still thinner over the Van Diemen Rise and eastwards across the Bathurst Terrace. In Tinganoo Bay No. 1 on the northeast coast of Melville Island the Formation is 569 m thick. The maximum thickness of the Bathurst Island Formation in the Cobourg Peninsula Sheet area is 289 m in BMR Cobourg Peninsula No. 3 (Hughes, 1973). The Bathurst Island Formation thins rapidly to the south and on the mainland the thickest section known is 83 m in Gunn Point No. 1 (Kemezys, 1968).

Contacts and relations: In Petrel No. 1 the Bathurst Island Formation is overlain unconformably by Upper Palaeocene sediments and is underlain disconformably by quartzose coarse sandstone of the Petrel Formation. On Bathurst and Melville Islands it lies unconformably below the Van Diemen Sandstone; elsewhere it is succeeded by a thin cover of Quaternary sediments.

Age: The interval between 412 and 1329 m in Petrel 1 ranges from Aptian to Cenomanian, possibly Turonian. The ages of the individual members and their faunas are discussed below.

Darwin Member

Derivation of name: From the City of Darwin, Darwin 1:250 000 topographic Sheet. The name is synonymous with the Darwin Formation which formed part of the Mullaman Group of Noakes (1949).

Type section: No type section was given to the Darwin Formation, although Noakes (1949) did state that the formation was best developed in the coastal cliffs in and around Darwin. It is proposed that the cliffs at Fanny Bay, Darwin, be the type section for the Darwin Member.

Lithology: At its type section a basal conglomerate of quartz fragments unconformably overlies steeply dipping Proterozoic rocks. Above this is up to 8 m of fine sandstone, which in turn is overlain by up to 11 m of claystone and radiolarian shale (Skwarko, 1966). The lithology of the Darwin Member varies from place to place but it is always fine-grained except for a basal conglomerate, and it is typically rich in Radiolaria.

Distribution: This distinctive unit has been recognized in all wells penetrating the base of the Cretaceous in the Bonaparte Gulf/Timor Sea area (Pontalier, Australian Aquitaine, pers. comm.). The Darwin Member extends beneath Bathurst and Melville Islands and was intersected in Tinganoo Bay No. 1. It crops out across the northwestern Northern Territory and extends as far east as BMR East Alligator No. 9 (Needham, 1976) (Fig. 15).

Thickness: From 30 m in Petrel No. 1 the Darwin Member extends eastwards forming a thin layer of argillaceous rocks across the Bathurst Terrace. In Tinganoo Bay No. 1 the Darwin Member is 42 m thick, but on the mainland it rarely exceeds 20 m.

Contacts and relations: Within the Bonaparte Gulf Basin and over two-thirds of the Bathurst Terrace the Darwin Member is the basal unit of the Bathurst Island Formation and disconformably overlies the Petrel Formation. In the Cobourg Peninsula Sheet area it is replaced as the basal member of the Bathurst Island Formation by the Marligur Member. Both members are laterally equivalent and the change in lithology indicates a change in the depositional environment from an epicontinental sea in the west to paralic conditions in the east.

West of the Van Diemen Rise the Darwin Member is conformably overlain by Albian to Cenomanian mudstone of the Wangarlu Mudstone Member. However, on the Bathurst Terrace the Albian appears to be missing (Burger, Appendix 1), suggesting a short break in deposition between the Darwin Member and the overlying Wangarlu Mudstone Member.

Fossils and age: The first fossils identified at Darwin were Radiolaria. Although Hinde (1893) listed fifteen forms, most were new

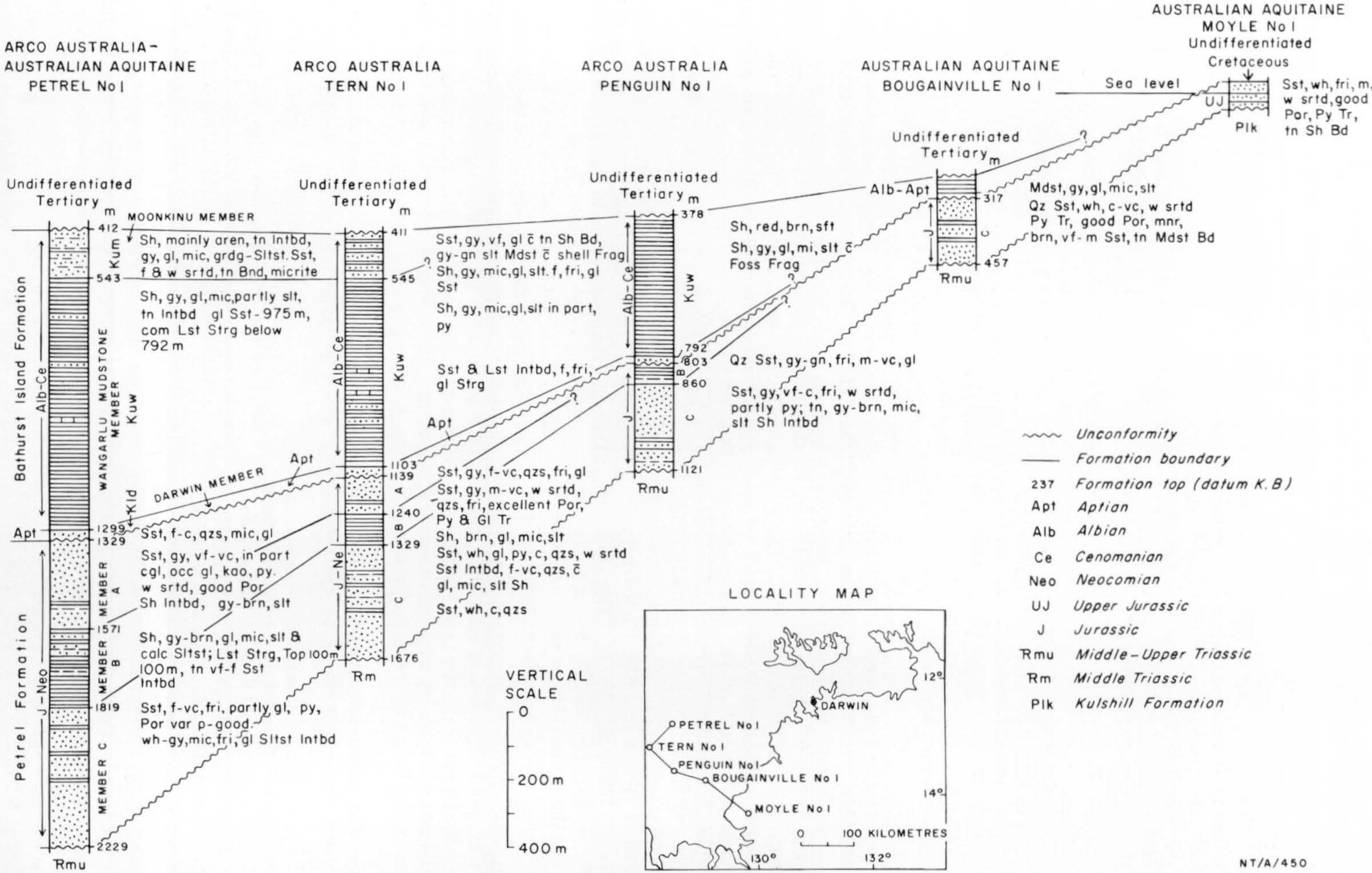

Fig. 15. Correlation of the Petrel Formation from its type section in Petrel No. 1 through three offshore exploration wells onto the mainland in Moyle No. 1.

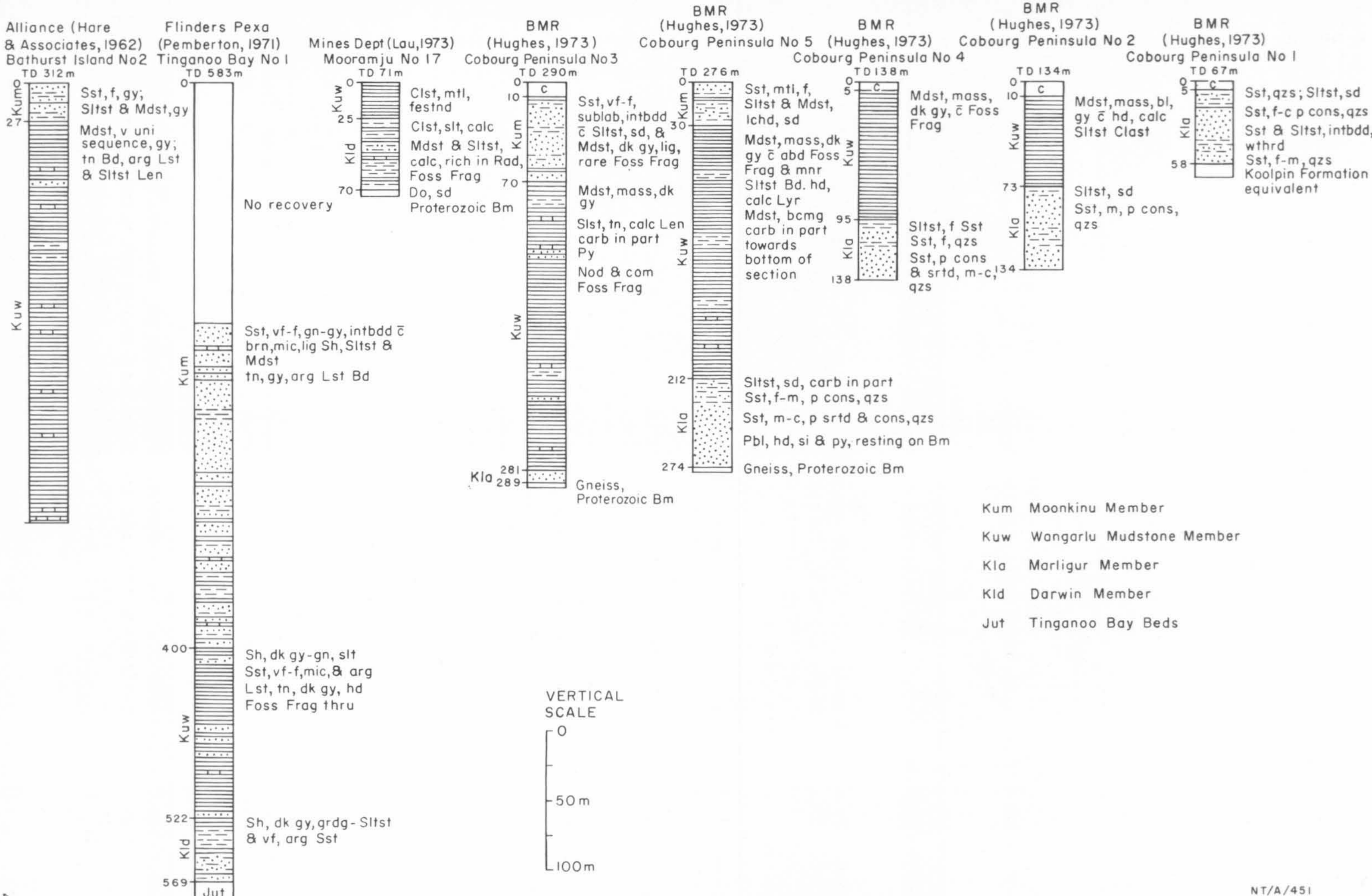

Fig. 16. Stratigraphic sections through the Bathurst Island Formation on the Bathurst Terrace (Location of drill holes shown in Plate 1).

species and unsuitable for dating. The Darwin Member is characterized both in outcrop and well sections by an abundance of Radiolaria.

Etheridge (1895, 1907) published descriptions of fossils found near Darwin and assigned a Lower Cretaceous age to them. The molluscan fauna of the Darwin Member has been described in detail by Skwarko (1966). Other fossils present in the Darwin Member include belemnites, brachiopods, echinoids, bryozoans, corals, and arenaceous foraminifers; none have been adequately described in the literature.

Palynological examination by Burger (Appendix 1) of cores from the Darwin Member indicate that it ranges in age from ?late Neocomian to Aptian. In the offshore exploration wells, including Petrel No. 1, Flat Top No. 1, and Newby No. 1, the interval occupied by the Darwin Member has been dated as Aptian on the basis of foraminifers.

Marligur Member

Derivation and status of name: From Marligur Creek, Cobourg Peninsula 1:250 000 topographic Sheet; longitude 133°12′E, latitude 11°50′S. Hughes & Senior (1974) defined and described the Marligur Member.

Type section: The type section is a low scrub-covered flat-topped hill 1 km east of Marligur Creek. A more complete section was subsequently drilled in Cobourg Peninsula No. 5 and this reference section is shown in Figure 16.

Lithology: Poorly sorted and consolidated, fine to coarse quartzose sandstone with angular to subangular clasts and thin pelitic interbeds. The pelitic interbeds are laminated, micaceous, and contain scattered fine to coarse sand grains. A gradual increase in grainsize, from sandy siltstone at the top to coarse sandstone near the base, is typical of the Marligur Member as intersected in all drill holes on Cobourg Peninsula (Fig. 16). The sandstone is porous and permeable; five of the seven holes drilled on Cobourg Peninsula have struck artesian water in the Marligur Member.

All outcrops visited were weathered. The argillaceous fraction is kaolinitic, and ferruginous mottling and silicification are common.

Distribution: Numerous but very poor exposures occur in the Wellington Range and extend to the northeast Alligator River and western Junction Bay Sheet areas. In subsurface the Marligur Member extends to the north as far as Mountnorris Bay, and to the southwest as far as the northwestern East Alligator 1:100 000 Sheet area (Fig. 15).

Thickness: Most outcrops reveal less than 2 m of the member. The greatest thickness intersected by drilling was 62 m in BMR Cobourg Peninsula No. 5. Drill-hole information available suggests that the Marligur Member maintains a fairly constant thickness over central Cobourg Peninsula Sheet area but that it thins rapidly to the north and south.

Contacts and relations: The Marligur Member rests unconformably on basement; a thin conglomerate of quartz and siliceous siltstone pebbles is present at the contact. In places the member overlies or abuts against steep escarpments of Kombolgie Formation. It is overlain in the subsurface by the Wangarlu Mudstone Member; a short hiatus may separate the two units. Where it crops out the Marligur Member is overlain by a thin Quaternary soil cover. The Marligur Member is laterally equivalent to the Darwin Member of the Bathurst Island Formation.

Fossils and age: A heteromorphic ammonite, ?*Bacculites* sp., numerous gastropods and crinoid ossicles, and worm borings are present in the Marligur Member. Spores from cuttings from BMR Cobourg Peninsula No. 4 are of ?late Neocomian to Aptian age (Burger, Appendix 1).

Wangarlu Mudstone Member

Derivation and status of name: From Wangarlu Bay, Cobourg Peninsula 1:250 000 topographic Sheet; longitude 132°20′E, latitude 11°12′S. Hughes & Senior (1974) defined and described the Wangarlu Mudstone Member.

Type section: The type locality is the cliffs on the northwest side of Wangarlu Bay, Cobourg Peninsula. A reference section through the Wangarlu Mudstone Member is provided by BMR Cobourg Peninsula No. 3, between 70 and 281.5 m (Fig. 16).

Lithology: Micaceous mudstone with some glauconitic siltstone and a few thin beds and laminae of fine sandstone and limestone. The mudstone contains disseminated pyrite which on oxidation leaves sulphurous encrustations. Scattered dark grey pyritic nodules, calcareous concretions, and carbonaceous material are common within the mudstone. In outcrop the mudstone is soft and shrinks on drying to crumbly blocks.

Distribution: The Wangarlu Mudstone Member Member is known throughout the area mapped and extends beyond the western edge of the Bathurst Island Sheet area into the Bonaparte Gulf Basin. It only crops out along the southern coast of Cobourg Peninsula, on southern Croker Island, and at Guialung Point. Elsewhere, it is overlain either by the Moonkinu Member or by thin Quaternary sediments.

Thickness: The maximum thickness observed at Wangarlu Bay is 14 m, but drilling has revealed up to 212 m of Wangarlu Mudstone Member in Cobourg Peninsula No. 3 (Fig. 16), 287 m in Bathurst Island No. 2 (Fig. 16), and 756 m offshore in Petrel No. 1 (Fig. 13).

Contacts and relations: The Wangarlu Mudstone Member is succeeded conformably by the Moonkinu Member over the entire area, except in the southern Cobourg Peninsula Sheet area where it is overlain by thin Quaternary sediments.

Fossils and age: Abundant fragments of bivalves, gastropods, and Upper Cretaceous ammonites including *Sciponoceras* and *Acanthoceras* occurred in several drill holes. In outcrop macrofossils are rare and most are *Mytilus* sp., although impressions of ammonites occur at Guialung Point. Palynological examination of both outcrop and drill-hole samples by Burger (Appendix 1) has shown that on the Bathurst Terrace the age of the Wangarlu Mudstone Member is Cenomanian. Studies on foraminifers from the Wangarlu Mudstone Member by Terpstra (*in* Kemezys, 1968) and Owen (*in* Pemberton, 1971) support this interpretation.

Moonkinu Member

Derivation and status of name: From Moonkinu Beach, 20 km southwest of Bathurst Island Mission, Bathurst Island 1:250 000 topographic Sheet; longitude 130°28′E, latitude 11°50′S. The Moonkinu Member was first described and defined by Hughes & Senior (1974).

Type section: The type section is the cliffs adjacent to Moonkinu Beach. Figure 17 shows a detailed stratigraphic section measured at the type locality.

Lithology: Fine to very fine sublabile sandstone interbedded with dark to light grey siltstone and mudstone. The sandstone is dark grey or grey to yellow, generally well sorted, and composed of angular to subangular quartz grains, opaque minerals, weathered feldspar and a little muscovite, glauconite, tourmaline, and zircon. Clasts and lenses of siltstone occur at irregular intervals in the sandstone beds. The mudstone is finely laminated, lignitic, soft, and friable where weathered. Fine sandstone lenses and partings are common in the mudstone intervals.

Calcareous and limonitic concretions are present in both the sandstone and mudstone beds and are aligned parallel to the bedding. Medium-scale low-angle cross-stratification is common within the sandstone beds. Other sedimentary structures observed include burrow structures, fine parallel lamination, and wavy lamination.

Distribution: The Moonkinu Member crops out in the cliff sections exposed along the southern coasts of both Melville and Bathurst Islands. Inland on both islands, outcrop is poor and generally restricted to small exposures adjacent to streams which have eroded through the Cainozoic cover. In the Notch Peak region, Melville Island and along the scarp marking the southern edge of the plateau the Moonkinu Member is exposed beneath a capping of weathered Van Diemen Sandstone.

In the Cobourg Peninsula Sheet area the Moonkinu Member is best exposed between De Courcy Head and Laterite Point. Two small areas of unweathered outcrop are present in Mountnorris Bay-Copeland Island and an unnamed headland south of Copeland Island. In the central portion of the Peninsula the Moonkinu Member occurs as discontinuous, highly weathered outcrops.

In the subsurface the Moonkinu Member is known throughout the area except in the Wellington Range.

Thickness: The greatest known thickness of the Moonkinu Member is 400 m in Tinganoo Bay No. 1. The unit thins westward to 131 m in Petrel No. 1, and eastward to 60 m in Cobourg Peninsula No. 3.

Contacts and relations: The Moonkinu Member forms the uppermost member of the Bathurst Formation and throughout the area it conformably overlies the Wangarlu Mudstone Member. It is unconformably overlain on the islands by the Van Diemen Sandstone, on Cobourg Peninsula by Quaternary sediments, and offshore by undifferentiated Tertiary sediments.

Fossils and age: Both macrofossils and microfossils indicate a Cenomanian age for the Moonkinu Member (p. 14 and Appendix 1).

Van Diemen Sandstone

Derivation and type section: From Cape Van Diemen, latitude 11°11′S, longitude 130°25′E, Bathurst Island 1:250 000 topographic Sheet. Hughes & Senior (1974) designated the cliffs

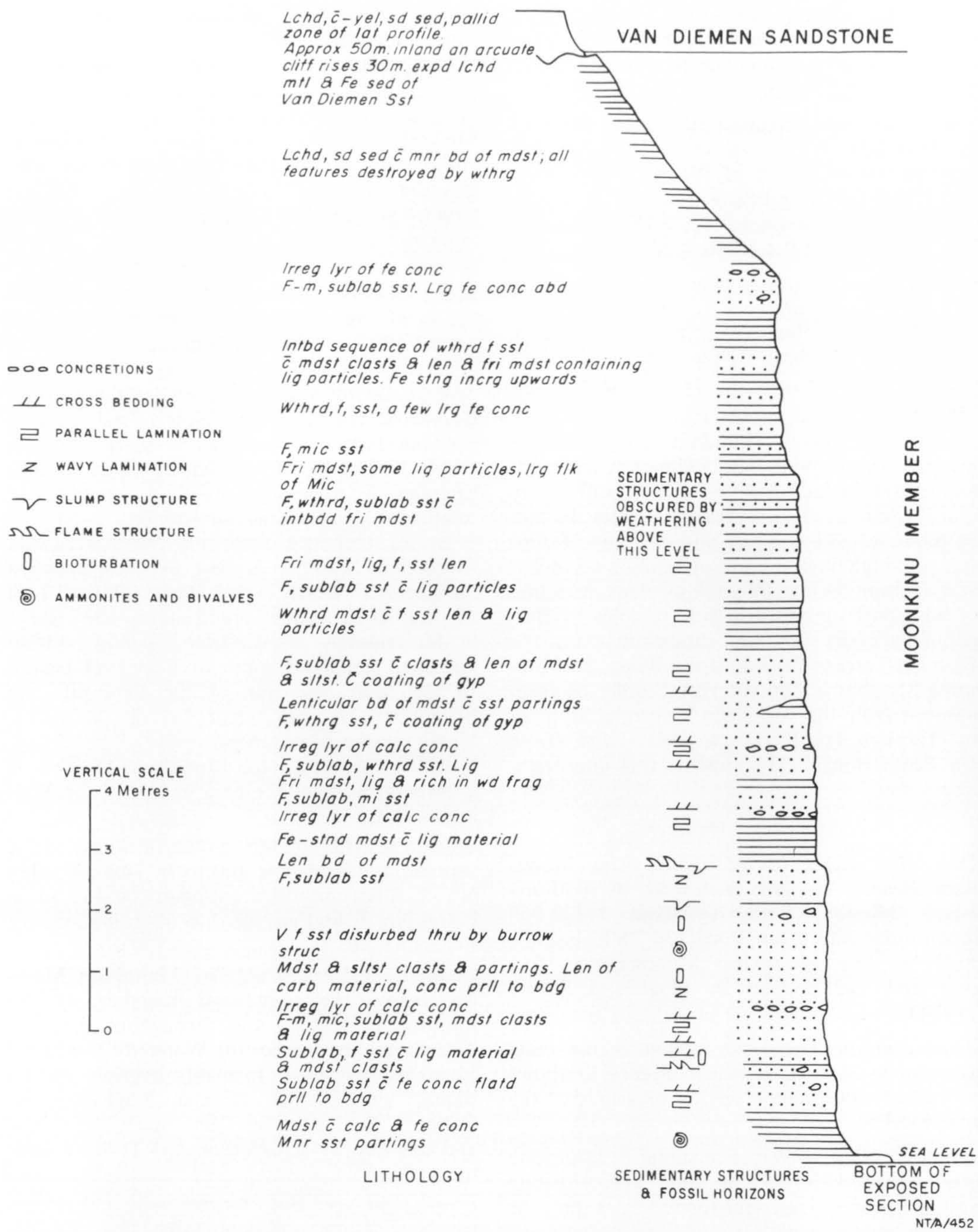

Fig. 17. Type section of the Moonkinu Member at Moonkinu beach, Bathurst Island.

on the northeastern coast of Cape Van Diemen as the type section of the Van Diemen Sandstone (Fig. 18).

Lithology: Friable white to yellow medium to coarse quartzose sandstone with intercalations of coarse sandstone, and minor lenses of siltstone and granular conglomerate. The sandstone is poorly sorted and composed predominantly of subangular to rounded quartz with a small percentage of opaque minerals and

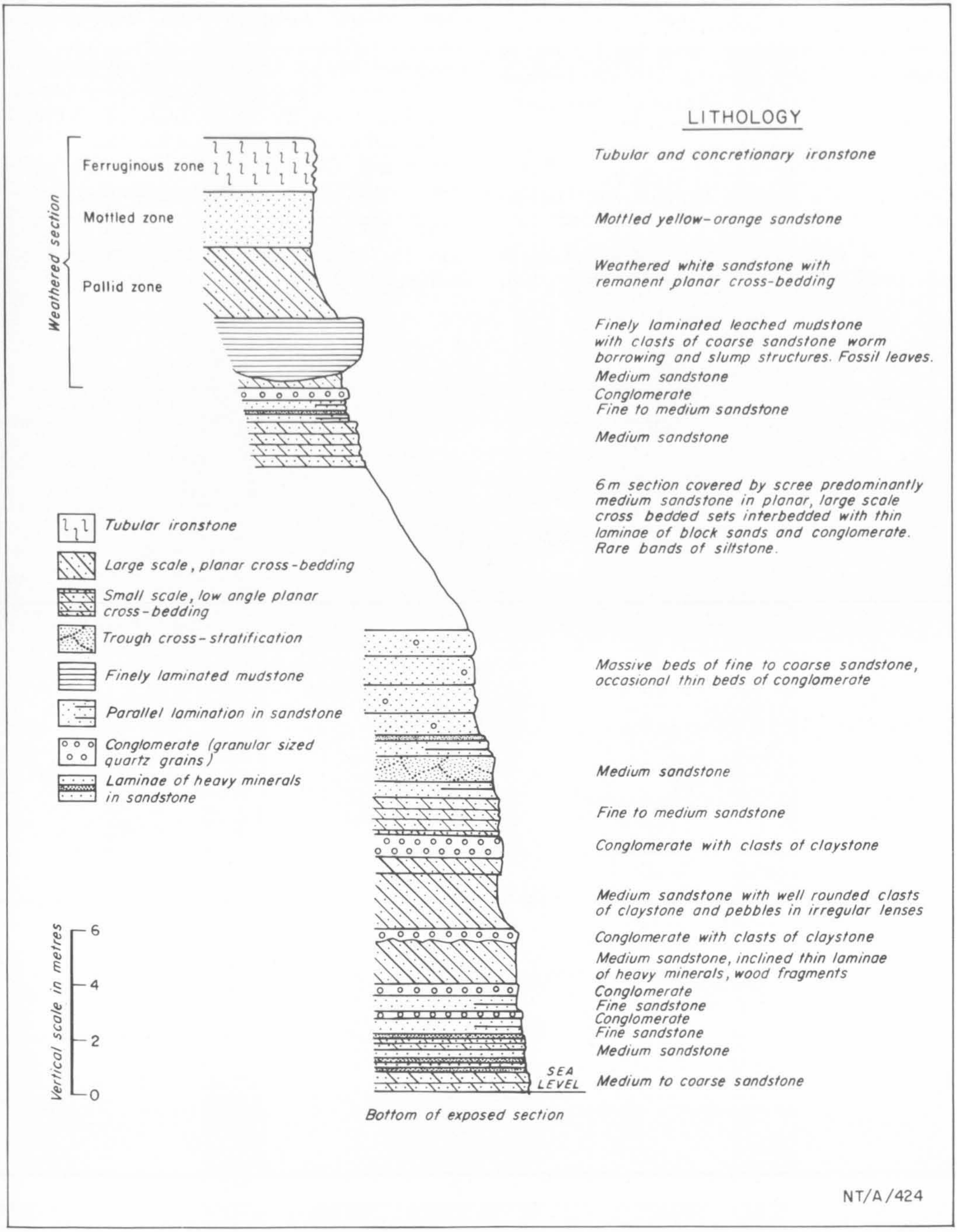

Fig. 18. Type section of the Van Diemen Sandstone at Cape Van Diemen, Melville Island.

rare tourmaline grains. Little matrix is present in the sandstone, and the grains are closely packed.

The sequence is generally cross-bedded by medium-scale high-angle sets. Small clasts of mudstone and clay are rare. The Van Diemen Sandstone is strongly weathered in outcrop and profusely iron-stained, especially inland.

Distribution: Discontinuous outcrops of Van Diemen Sandstone form low ridges and dissected plateaux on both Bathurst and Melville Islands.

Thickness: On southern Bathurst Island auger drill holes penetrated up to 60 m of Van Diemen Sandstone (Laws, 1967). The formation gradually thickens northwards.

Contacts and Relations: The Van Diemen Sandstone rests unconformably on the weathered surface of the Cenomanian Moonkinu Member. The contact is exposed at Moonkinu Beach on the south coast of Bathurst Island and at Piper and Luxmore Heads, Melville Island. Onshore the Van Diemen Sandstone is overlain by Quaternary sand and soil.

Fossils and age: Tertiary plant fossils collected from the Van Diemen Sandstone have been identified by White (Appendix 2).

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APPENDIX 1

PALYNOLOGICAL EXAMINATION OF OUTCROP SAMPLES AND SUBSURFACE SECTIONS IN THE BATHURST ISLAND, MELVILLE ISLAND, COBOURG PENINSULA, AND DARWIN SHEET AREAS

by D. Burger

OUTCROP SAMPLES BATHURST ISLAND, MELVILLE ISLAND, AND COBOURG PENINSULA

Outcrop samples collected during 1972 from Bathurst and Melville Islands and Cobourg Peninsula were palynologically examined. Most of the 26 samples contained sufficient spores, pollen, and microplankton for age determination. The results of the examination are listed in Table A. Dating of the microfloras is based on detailed palynological investigation of two wells, Bathurst Island Nos. 1 and 2, which penetrated Cenomanian strata on the south coast of Bathurst Island (Norvick & Burger, 1976).

Species on which dating of the samples is based are:

Classopollis sp. nov. (BMR 337)
Asteropollis asteroides Hedlund & Norris (BMR 1157)
Camarozonosporites sp. nov. (BMR 1128)
Gleicheniidites cf. *G. trijugatus* (Pierce) (BMR 1139)
Liliacidites sp. (BMR 1121)

TABLE A. RESULTS OF PALYNOLOGICAL AGE DETERMINATIONS OF OUTCROP SAMPLES FROM BATHURST AND MELVILLE ISLANDS AND COBOURG PENINSULA

Outcrop locality	*Latitude/ Longitude*	*Sample No.*	*Stratigraphic unit*	*Suggested age*
Bathurst Island	11°49′S 130°28′E	5900	Moonkinu Member	Cenomanian
	11°49′S 130°28′E	5931	Moonkinu Member	Cenomanian
	11°49′S 130°28′E	5932	Moonkinu Member	Cenomanian
Bathurst	11°46′S 130°20′E	5901	Moonkinu Member	Cenomanian
	11°46′S 130°20′E	5902	Moonkinu Member	Cenomanian
	11°47′S 130°18′E	5840	Moonkinu Member	Albian/ Cenomanian
	11°47′S 130°15′E	5841	Moonkinu Member	Cenomanian
	11°50′S 130°30′E	5903	Moonkinu Member	?Cenomanian
	11°50′S 130°31′E	5842	Moonkinu Member	Cenomanian
	11°50′S 130°30′E	5843	Moonkinu Member	Cenomanian
Bathurst Island	11°53′S 130°52′E	5904	Moonkinu Member	Cenomanian
	11°47′S 130°11′E	5845	Moonkinu Member	Cenomanian
Cobourg Peninsula	11°29′S 130°19′E	5850	Wangarlu Mudstone Member	Cenomanian

TINGANOO BAY No. 1, MELVILLE ISLAND

Core samples from Tinganoo Bay No. 1 could be dated by the presence of spores, pollen grains, microplankton, and foraminifers. The results are reviewed below.

TABLE B. AGE DETERMINATIONS ON CORES FROM TINGANOO BAY 1

Sample depth (m)	*Sample No.*	*Stratigraphic unit*	*Suggested age*
77.7	5566	Moonkinu Member	early Upper Cretaceous
483.1 487.7	5909	Wangarlu Mudstone Member	unknown
501.1	5584	Wangarlu Mudstone Member	Cenomanian
508.4	5585	Wangarlu Mudstone Member	Cenomanian
512.7	5586	Wangarlu Mudstone Member	Cenomanian
518.2	5587	Wangarlu Mudstone Member	Cenomanian
543.2	6091	Darwin Member	Aptian
547.1– 548.6	5905	Darwin Member	unknown
550.8	5589	Darwin Member	unknown
553.5	6090	Darwin Member	Aptian
558.4	6089	Darwin Member	Aptian
565.1	5906	Darwin Member	unknown
566.9	6088	Darwin Member	Aptian
569.1	5907	Tinganoo Bay Beds	unknown
570.0	6087	Tinganoo Bay Beds	?Aptian
570.3	5908	Tinganoo Bay Beds	?Aptian
573.3	6086	Tinganoo Bay Beds	?Aptian
574.6	6085	Tinganoo Bay Beds	?Neocomian
576.4	5911	Tinganoo Bay Beds	late Upper Jurassic

Upper Jurassic (583.4 to 576.4 m)

Sample No. 5911 yielded a moderately well preserved spore-pollen assemblage which contained many saccate pollens, among which *Aliaporites similis, A. grandis, Microcachryidites antarcticus,* and *Podosporites* sp. *M. antarcticus* first appear in late Upper Jurassic sediments of Australia, and is common in the Lower Cretaceous. However, the assemblage lacks other species known from the early Cretaceous and is therefore probably Jurassic rather than Cretaceous. The absence of marine microplankton in the assemblage points to non-marine depositional environments at the time.

Lower Cretaceous (574.6 to 543.2 m)

This part of the sequence is characterized by the presence of marine microplankton, the relative abundance of which increases upwards in the section. Sample No. 6085 contains *Cyathidites punctatus, Foraminisporis dailyi,* and *Perotrilites linearis,* indicating an early Cretaceous age for the assemblage. The microplankton recovered confirms this; the species *Canningia colliveri, Cyclonephelium distinctum,* and *Chytroeisphaeridia* sp. were found. The group of *Cyclonephelium* occurs commonly in the late Jurassic and early Cretaceous of the Papuan Basin, but diminishes to insignificance in the Aptian of both the Papuan and the Great Artesian Basin. The sample is therefore thought to be pre-Aptian.

The remaining samples from this part of the well section yielded a few poorly preserved fossils. Many of the recovered marine organisms represent new species of which the geological ranges are insufficiently known. The only factor of significance is the presence of *Dingodinium cerviculum,* a species which does not occur in sediments younger than Aptian in Australia and Papua. Much of this part of the sequence can be equated with Evans' (1966) *Dingodinium cerviculum* Dinoflagellate Zone of Aptian age. Other species found in this interval are *Chlamydophorella nyei, Canningia colliveri, Diconodinium* sp., *Spiniferites* spp., and cf. *Phoberocysta* sp.

The presence and relative abundance of these species in the assemblages indicates that deposition took place in shallow and open marine conditions.

Upper Cretaceous (528.2 to 77.7 m)

Foraminifers and dinoflagellates of Cenomanian (to perhaps uppermost Albian) age were recovered from samples in the interval 528.2-501.1 m.

THE DARWIN REGION

Core samples from the marine sedimentary sequence northeast of Darwin yielded reasonably well preserved microplankton assemblages. Age estimations of the samples (see Table C) are based on dinoflagellate species which have been described and reported from the Great Artesian Basin, Queensland, and Bathurst Island.

Spores and pollen grains were lacking or present in very low numbers only.

Core samples from strata penetrated by Gunn Point No. 1 and Lee Point Nos. 1 and 2 diamond-drill holes could also be dated on the basis of microplankton, spores, and pollen grains (Table D). Except for sample No. 5946, all samples represent sediments formed in marine environments.

TABLE C. AGE DETERMINATIONS OF CORES TAKEN IN MOORAMJU DIAMOND-DRILL HOLES NOS. 1, 5, 15, 17, 18

Mines Dept Mooramju DDH (Lau, 1973)	*Sample Depth (m)*	*Sample No.*	*Suggested age*	*Stratigraphic unit*
1	26.5	6095	?Cenomanian	Wangarlu Mudstone Member
5	25.2	6096	Cenomanian	Wangarlu Mudstone Member
	30.0	6097	?Cenomanian	
15	30.5	6099	?Aptian	Darwin Member
17	42.9	6100	Aptian	Darwin Member
	66.0	6101	Aptian	
18	44.0	6102	Aptian	Darwin Member
	54.0	6103	?Neocomian	

TABLE D. AGE DETERMINATIONS OF CORES TAKEN IN DIAMOND-DRILL HOLES GUNN POINT NO. 1 AND LEE POINT NOS. 1 AND 2

Mines Dept DDH	*Sample Depth (m)*	*Sample No.*	*Suggested age*	*Stratigraphic unit*
	30.8	5961	Cenomanian	
	38.4	5959	(?Albian)/ Cenomanian	Wangarlu Mudstone Member
Gunn Point No. 1	50.0	5947	?Cenomanian	
	55.1	5946	Aptian	
	83.2	6093	Aptian	Darwin Member
Lee Point No. 1	28.7	5813	?Aptian	Darwin Member
	38.1	5809	(early) Aptian	
Lee Point No. 2	17.1	5868	Aptian	Darwin Member

The present examination confirms Terpstra's (*in* Kemezys, 1968) report of the presence of Cenomanian foraminiferas at 30.8-34.8 m (101'-114'4") and 43.1-43.7 m (141'6"-143'6") in Gunn Point No. 1. Cenomanian strata rest immediately on Aptian strata between 50 and 55 m. This is more than a local phenomenon as the Albian is also absent in the Cretaceous rock sequences of Melville Island and Cobourg Peninsula.

BMR COBOURG PENINSULA STRATIGRAPHIC HOLES

Samples from cores and cuttings of BMR Cobourg Peninsula Nos. 1, 3, and 4 have been examined on spores, pollen and microplankton for a preliminary age determination of the drilled formations. The results are tabulated below (Table E).

TABLE E. AGE DETERMINATIONS OF CORES AND CUTTINGS FROM COBOURG PENINSULA NOS. 1, 3, AND 4

BMR stratigraphic hole	*Core*	*Sample depth (m)*	*Sample No.*	*Stratigraphic unit*	*Age*
C.P. No. 1	cuttings	36.5-39.5	6209	Marligur Member	?
	1	16.2-16.3	6201	Moonkinu Member	Cenomanian
	2	16.7	6223		?
		30.7	6221	Moonkinu Member	?
	3	31.9	6203		?
		61.6	6224	Moonkinu Member	?
	4	62.5	6204		Cenomanian
		93.3	6225	Wangarlu Mudstone Member	Cenomanian
	5	93.9	6205		?Cenomanian
		125.6	6222	Wangarlu Mudstone Member	Cenomanian
C.P. No. 3	6	125.9	6206		?
		126.5	6226		?Cenomanian
		157.3	6227	Wangarlu Mudstone Member	Cenomanian
	7	158.2	6228		?Cenomanian
		159.6	6229		Cenomanian
		160.0	6207		?
		212.1	6230	Wangarlu Mudstone Member	Cenomanian
		213.0	6231		Cenomanian
		214.2	6232		Cenomanian
		214.6	6208		?
	1	43.0	6233	Wangarlu Mudstone Member	Cenomanian
		43.7	6234		?Cenomanian
C.P. No. 4		44.2	6235		?
		44.5	6202		?Cenomanian
	cuttings	116-119	6210	Marligur Member	Neocomian/Aptian
	cuttings	122-125	6211		Neocomian/Aptian

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APPENDIX 2

TERTIARY PLANT FOSSILS FROM MELVILLE ISLAND, N.T.

by
Mary E. White

Plant fossils were collected by R. J. Hughes from the type section of the Van Diemen Sandstone at Cape Van Diemen, Melville Island; latitude 11°11′S, longitude 130°25′E. The BMR registered sample No. is 73050107. The rock is very fine-grained white, cream, or grey mudstone and the fossils occur as impressions, some with iron-staining. Preservation is good and some fine detail is visible on some of the impressions. A number of Dicotyledonous genera and one fern fragment are identified, and the age of the assemblage is Eocene to Recent.

All the genera identified are components of present-day Australian and Indomalayan floras. Most specimens have also been matched with specimens in an Eocene collection from Vegetable Creek in New South Wales described by Ettinghausen (1888).

The present collection from Melville Island has been studied by comparison with the Ettinghausen types in the Vegetable Creek collection at the Australian Museum, and by a study of living examples of the genera to which the specimens have been assigned. The *Grevillea* sp. identified has not been found before, as far as can be determined, and may be a new species. The choice of *Grevillea* and not one of the closely related genera is based on examination of specimens in the National Herbarium in Sydney, where I was generously assisted and advised by Mr D. MacGillivray.

List of Plants Identified

1. *Grevillea* sp. (probably sp. nov.)
   Family Proteaceae
2. *Elaeocarpus muelleri* Ett.
   Family Elaeocarpaceae
3. *Elaeocarpus* sp.
   Family Elaeocarpaceae
4. *Roupala sapindifolia* Ett.
   Family Proteaceae
5. *Ceratopetalum* cf. *C. macdonaldi* Ett
   Family Cunoniaceae
6. *Banksia* sp.
   Family Proteaceae
7. *Aralia* sp.
   Family Araliaceae
8. Seed
9. Flower or fruit
   Family Myrtaceae
10. *Pteris*
    Filicales

Description of Specimens

1. *Grevillea* sp.

Specimens F 23726, F 23727, F 23728, F 23729.

The range of size and form of the pinnate leaves which are referred to *Grevillea* sp. is seen in Plate 1, figs. 1-4. The pinnules are decurrent and pinnule margins may be slightly recurved. The midribs of the pinnules are strong and the secondary venation is fine. In specimen F 23728 (fig. 3) a single pinnule of a much larger pinnate leaf overlies the more complete front, indicating that leaves of larger size occurred.

Grevillea is a member of the family Proteaceae and contains about 200 extant species, including silky oaks and spider flowers.

2. *Elaeocarpus muelleri* Ett.

Specimen F 23730

Part of a large leaf is seen in Plate II, fig. 1. It has an undulating margin and a strong midrib. Some fine lateral veins can be seen. This leaf appears to be the same as the *Elaeocarpus muelleri* described by Ettinghausen at Vegetable Creek. A similar leaf from Cape Vogel, East Papua, was referred to the species by me (1970).

The leaf structure is consistent with leaves of species of *Elaeocarpus* examined in the herbarium.

Elaeocarpus is a genus of the family Elaeocarpaceae (to which the Blueberry Ash, common round Sydney, belongs) and there are more than 70 species in existence today.

3. *Elaeocarpus* sp.

Specimen F 23731.

A leaf with undulating margin is illustrated in Plate II, fig. 2. It is similar to several modern species of *Elaeocarpus*.

4. *Roupala sapindifolia* Ett.

Specimen F 23732.

The pair of leaves arrowed on section F 23732 are referred to *Roupala asapindifolia* Ett. (= *Rhopala sapindifolia* Ett., 1888). The genus is a member of the Proteaceae closely related to *Banksia*. The other pair of leaves in Plate III, fig. 1 are *Elaeocarpus* sp. and have delicately undulating margins.

Roupala is a genus distributed in tropical America, Australia, and New Caledonia.

5. *Ceratopetalum* cf. *C. macdonaldi* Ett.

Specimen F 23733.

A petiolate leaf with a finely crenulate margin is illustrated in Plate II, fig. 3. It resembles the specimen named *Ceratopetalum macdonaldi* by Ettinghausen.

Ceratopetalum is a member of the Cunoniaceae, a southern sub-tropical family.

6. *Banksia* sp.

Specimen F 23734.

Part of a leaf illustrated in Plate IV, fig. 1 is referred somewat doubtfully to *Banksia* sp. It is similar to leaves identified as *Banksia* by Ettinghausen.

Banksia is a member of the Proteaceae and more than 50 species are described in the Australian flora.

7. *Aralia* sp.

Specimen F 23735.

Part of a leaf which appears to be referable to *Aralia* is illustrated in Plate IV, fig. 2. The family Araliaceae (to which the Queensland Umbrella Tree belongs) is distributed in the Indomalayan region, tropical America, and Australia.

8. *Small flower or fruit*

Specimen F 23736.

A small flower cup or fruit similar to those which occur in Myrtaceae is seen in Plate IV, fig. 3. A five-parted calyx is attached to a receptacle which contains the ovary.

9. *Small pointed seed*

Specimen F 23737.

A small unidentified seed is illustrated in Plate IV, fig. 4.

10. *Fern fragment: Pteris humei* Ett.

Specimen F 23738.

A small fragment of the fern *Pteris humei* is identified and illustrated in Plate IV, fig. 5. It matches material in the Vegetable Creek collection.

11. All specimens not illustrated in the collection are numbered F 23739 and labelled individually when they contain determinate plant remains.

Conclusions

The plant assemblage from the Van Diemen Sandstone on Melville Island is Eocene or younger.

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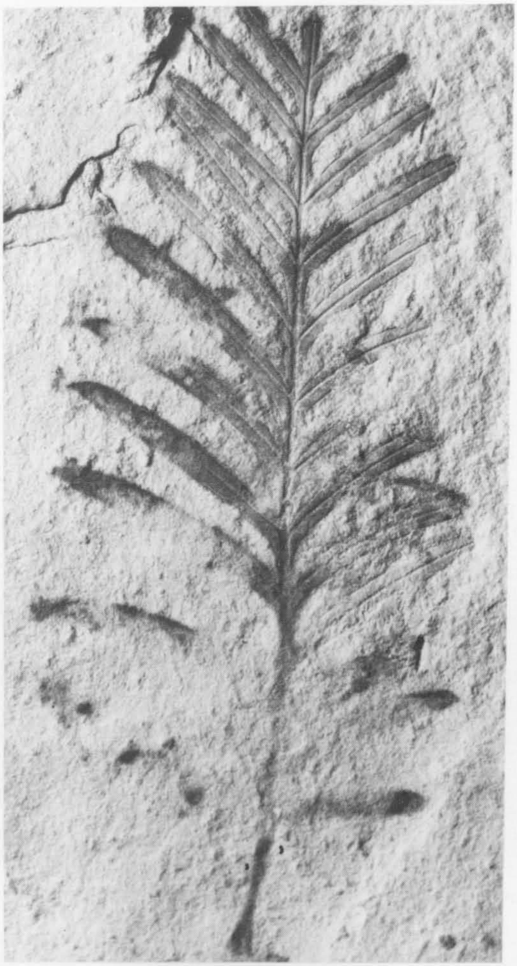
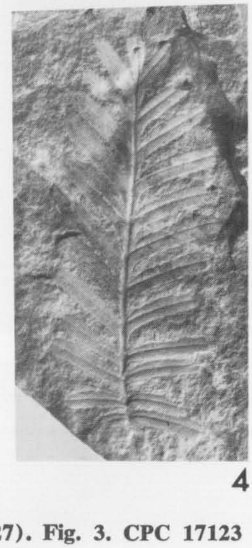
Plate I
Figs. 1-4 *Grevillea* sp. x2

1



2

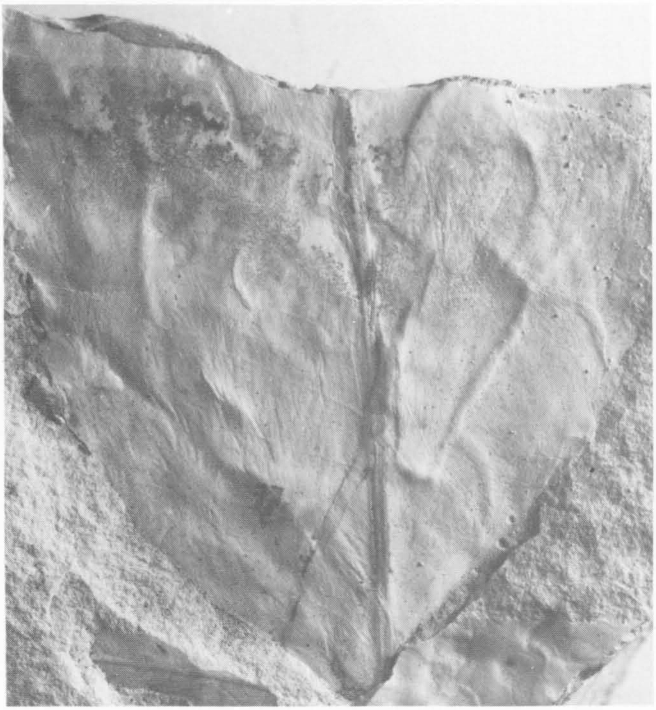
3



4

Fig. 1. CPC 17121 (F 23726). Fig. 2. CPC 17122 (F23727). Fig. 3. CPC 17123 (F 23728). Fig. 4. CPC 17124 (F 23729)

Plate II
(all figures magnified x2)



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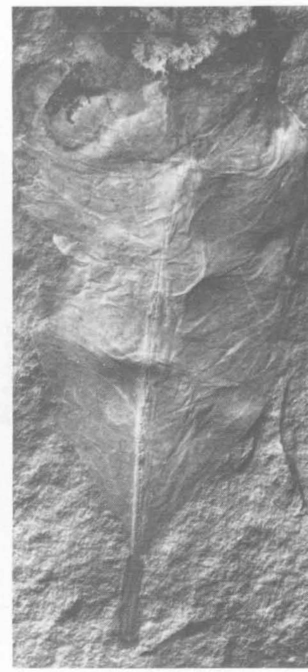
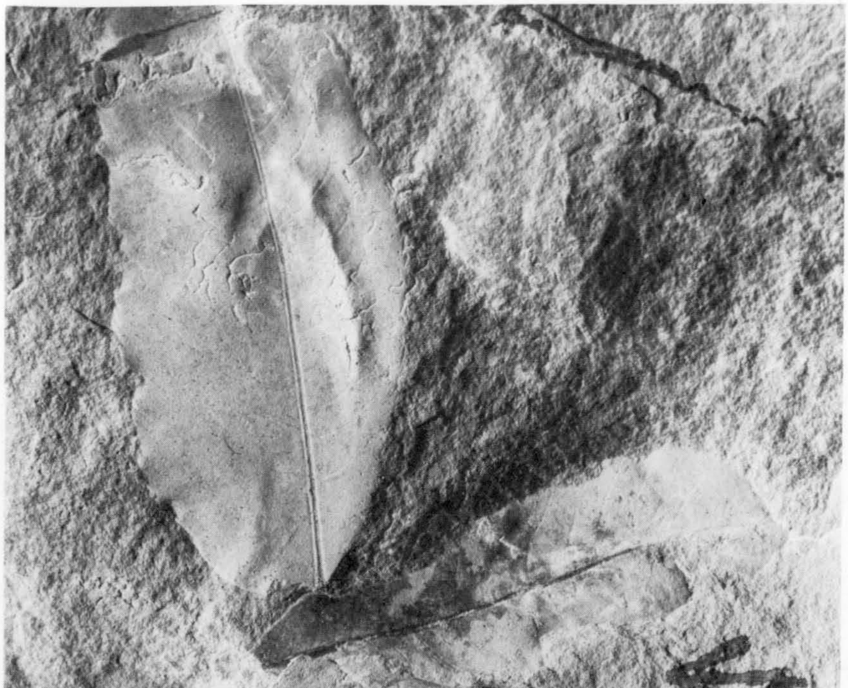


2

3

Fig. 1. *Elaeocarpus muelleri* **CPC 17125 (F 23730)**
Fig. 2. *Elaeocarpus* **sp.** **CPC 17126 (F 23731)**
Fig. 3. *Ceratopetalum* **sp.** **CPC 17128 (F 23733)**

Plate III

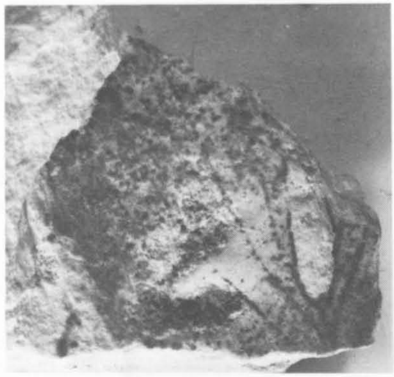


1

Fig. 1. *Roupala sapindifolia* **and** *Elaeocarpus* **sp. x2 CPC 17127 (F 23732)**

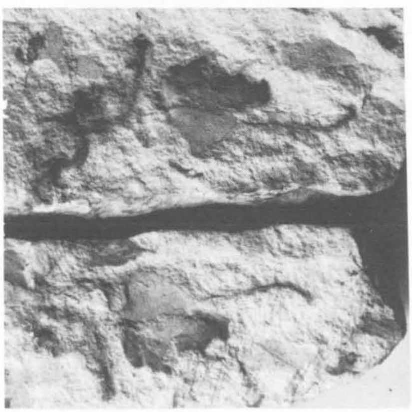
Plate IV
(all figures magnified x2)

1



2

4



3

5

Fig. 1.	*Banksia* **sp.**	**CPC 17129 (F 23734)**
Fig. 2.	*Aralia* **sp.**	**CPC 17130 (F 23735)**
Fig. 3.	**Flower Cup**	**CPC 17131 (F 23736)**
Fig. 4.	**Small Seed**	**CPC 17132 (F 23737)**
Fig. 5.	*Pteris humei*	**CPC 17133 (F 23738)**

APPENDIX 3

IDENTIFICATION OF OPAQUE MINERALS IN MINERAL SAND SAMPLES FROM MELVILLE AND BATHURST ISLANDS

by S. Whitehead*

Eight samples of heavy-mineral sands (Fig. 1) were submitted for the identification of opaque minerals with particular reference to ilmenite and chromite. The samples were mounted without further treatment, polished, and examined in incident light. The most abundant opaque minerals in these samples are completely altered ilmenite grains composed of porous, apparently amorphous iron-titanium oxide, rutile, and, in three samples, grains composed of fine-grained supergene iron oxides including hematite, goethite, and maghemite. Leucoxene occurs in subordinate to minor amounts and two samples contain some fresh and partly altered ilmenite. Traces of chromite were found in only two samples—those containing the fresh and partly altered ilmenite. Most of the ilmenite, altered ilmenite, leucoxene, and rutile grains are well sorted and rounded to subangular and between 0.1 and 0.3 mm.

Most of the supergene iron oxide grains are well rounded (larger) and some show textures suggesting that this iron oxide has cemented and/or replaced earlier sediments. The presence of maghemite accounts for most if not all of the magnetic grains in the respective samples.

The eight samples can be divided into three groups:

Samples 7205-0035, 0039, 0044, 0047, and 0064 contain completely altered ilmenite, leucoxene, and rutile. No fresh ilmenite and chromite were found, and only trace amounts of goethite and other ferric oxides.

Samples 7205-0048 and 0049 contain some fresh, partly altered, and completely altered ilmenite, leucoxene, and a trace of chromite. They also contain abundant large grains of supergene ferric oxides.

Sample 7205-0070 differs from all others in that it is composed almost entirely of well rounded grains composed of goethite, hematite, and some maghemite.

Textures in many of these grains suggest that they were derived from an earlier sediment which had been cemented and/or partly replaced by the supergene iron oxides. Non-opaque minerals are predominantly zircon with lesser amounts of tourmaline, kyanite, and staurolite.

Description of samples

Sample 72050035, PS 20031 (map ref.. No. HD3)

Well sorted grey sand containing up to 50% of colourless transparent grains. There are rare magnetic grains.

Polished section. A visual estimate of the minerals present is as follows:

	%
Altered ilmenite	30-35
Leucoxene	10-15
Rutile	5-10
Goethite	Trace
Non-opaque	40-50

Neither chromite nor fresh ilmenite were found in the section. The altered ilmenite grains are 0.1-0.2 mm in size, many are elongate, and they vary from subrounded to well rounded. A few are subangular. They are slightly porous and are composed of apparently amorphous iron-titanium oxide. Some of the grains show relict textures making former basal planes of the original ilmenite but no remnants of fresh ilmenite were found.

The leucoxene grains are similar to the altered ilmenite grains but a higher proportion are well rounded. They are pale grey to yellowish with internal reflections. Iron oxide, which is present in the altered ilmenite, has been largely leached from the leucoxene grains and the remaining titanium oxide has recrystallized.

Rutile grains are semi-translucent, dark reddish brown, and generally subangular. A few show twinning. The sample contains a few grains of porous fine-grained goethite. The non-opaque grains are mainly zircon with a few tourmaline and some quartz and rare kyanite.

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* AMDEL, Adelaide, South Australia.

Sample 72050039, PS 20032 (map ref. No. HD9)

The sample contains heavy-mineral grains mixed with an abundance of pale-coloured clay.

Polished Section. A visual estimate of the minerals present, disregarding the clay, is as follows:

	%
Altered ilmenite	10-15
Leucoxene	3-5
Rutile	25-30
Goethite	Trace
Non-opaque	50-60

The altered ilmenite and leucoxene grains are similar to those in the Sample 72050035 described above. Most are porous and subrounded to well rounded and between 0.1 and 0.3 mm in size. The rutile grains are generally more angular and fractured but some are well rounded.

The non-opaque grains are predominantly zircon but also include minor kyanite, staurolite, and tourmaline. Some grains are surrounded by an adhering layer of clay containing some very fine-grained quartz.

Sample 72050044, PS 20033 (map ref. No. HD7)

A well sorted, generally dark sand containing dark opaque grains, yellowish leucoxene, dark red rutile, and colourless zircon.

Polished Section. A visual estimate of the minerals present is as follows:

	%
Completely altered ilmenite	30-35
Leucoxene	5-10
Rutile	20-25
Non-opaque	30-35
Goethite	Trace

No fresh ilmenite or chromite was found. The grains are generally well sorted and between 0.1 and 0.3 mm in size. Many of the rutile, zircon, and altered ilmenite grains are elongate. The individual minerals are essentially very similar to those described in sample 72050035 and they vary from subangular to well rounded.

The non-opaque grains are predominantly zircon with traces of tourmaline, kyanite, and staurolite.

Sample 70250047, PS 20034 (map ref. No. HD4)

Dark heavy-mineral sand containing colourless transparent grains, dark opaque grains, and translucent reddish brown grains.

Polished Section. A visual estimate of the minerals present is as follows:

	%
Completely altered ilmenite	50-55
Leucoxene	5-10
Rutile	3-4
Goethite	Trace
Hematite (martite)	Trace
Non-opaque	30-40

The minerals grains are not as well sorted as in some of the other specimens and vary in size from 0.1 to 0.5 mm. The opaque grains are, however, essentially similar to those in other samples. The only trace of fresh ilmenite found is as a small inclusion in a non-opaque grain. Chromite was not found.

The non-opaque heavy minerals are predominantly tourmaline, kyanite, staurolite, and very few zircons.

Sample 72050048, PS 20035 (map ref. No. HD16)

Very dark heavy-mineral sand containing grains of different sizes. Many grains are attracted to a magnet.

Polished Section. A visual estimate of the minerals present is as follows:

	%
Fresh ilmenite	15-20
Partly altered ilmenite	2-3
Completely altered ilmenite	5-7
Leucoxene	Trace
Rutile	10-15
?Titaniferous magnetite	Trace
Chromite (partly altered)	Trace
Supergene ferric oxides including maghemite	30-40
Non-opaque	30-40
Sulphide (inclusions in ilmenite)	Minute trace

The ilmenite grains are well sorted (0.1-0.2 mm) and generally subrounded. A few have cavities from which an undetermined mineral inclusion has been leached.

The partly altered grains show all stages of replacement by porous amorphous iron-titanium oxide beginning at the surface and extending into the grain along some small fractures and basal parting planes. The completely altered ilmenite, leucoxene, and rutile grains are similar to those in other samples and are of similar grainsize to the ilmenite.

A significant proportion of this sample is composed of rounded and subrounded grains of porous, very fine-grained ferric oxides including hematite, maghemite, and minor goethite. These grains are larger than the other heavy-mineral grains and average 0.2-0.4 mm with a few up to 0.5 mm long. Some show fine colloform textures and many have small cavities from which a ?silicate mineral has been leached. Because of the presence of maghemite, mainy grains are probably magnetic and this accounts for the numerous magnetic grains in the sample.

The non-opaque grains are all zircon.

Sample 72050049, PS 20036 (map ref. No. HD17)

Dark heavy-mineral sand containing a small proportion of magnetic grains and abundant reddish brown grains.

Polished Section. A visual estimate of the minerals present is as follows:

	%
Ilmenite	5-10
Altered ilmenite	20-25
Leucoxene	5
Rutile	10-15
?Titaniferous magnetite	Trace
Chromite	Minute trace
Supergene ferric oxides (hematite, maghemite, and goethite)	20-30
Non-opaque	20-25

The ilmenite grains are subrounded to subangular and show all gradations from only very slightly altered to completely altered. Those grains showing minor alteration are listed as ilmenite and those showing extensive and complete alteration are listed as altered ilmenite.

Supergene iron oxide grains are similar to those in Sample 72050048 and those containing maghemite probably account for most of the magnetic grains in the sample. This sample contains a greater percentage of very porous reddish grains composed of ochreous and extremely fine-grained hematite and goethite. These oxides may have replaced some fine-grained rock.

A few heavy-mineral grains show an adhering layer of supergene iron oxide suggesting that some may have been derived from an earlier deposit which was at least partly cemented by supergene iron oxide. These grains were rounded before being coated or cemented by iron oxide.

The few chromite grains present are 0.05-0.1 mm across, subangular, and show a thin zone of alteration around the margin. Two zircon grains were found with inclusions of ilmenite containing exsolved lamellae of hematite. A few ilmenite and zircon grains contain inclusions of yellow sulphide.

The non-opaque grains are predominantly zircon with minor tourmaline and quartz.

Sample 72050064, PS 20037 (map ref. No. HD2)

Dark heavy-mineral sand without magnetic grains.

Polished Section. A visual estimate of the minerals present is as follows:

	%
Completely altered ilmenite	60-65
Leucoxene	5-10
Rutile	10-15
Goethite	1-2
Non-opaque	20-25

No fresh ilmenite or chromite was found.

The grains are well sorted and most are between 0.1 and 0.3 mm across. The altered ilmenite and leucoxene grains are well rounded to subrounded and most of the rutile grains subangular to subrounded but some show evidence of recent fracturing or rounded grains.

The supergene iron oxides are very porous fine-grained hematite and goethite. One rounded grain of altered ilmenite was surrounded by similar fine-grained goethite.

Non-opaque minerals are predominantly kyanite, tourmaline, and staurolite, with a trace of zircon and amphibole. Many tourmaline grains are very well rounded.

Sample 72050070, PS 20038 (map ref. No. HD30)

Dark brown, poorly sorted sand with a small percentage of magnetic grains.

Polished Section. The sample is composed predominantly of well rounded, porous grains 0.5 to over 2 mm in size composed of supergene ferric oxides mainly goethite and hematite but with a few contain maghemite. Many grains contain small inclusions or remnants of unleached silicate and/or quartz grains and the textures shown by some grains suggest that small, angular silicate and/or quartz grains have been cemented by the iron oxide. It is possible that some iron oxide has replaced clay.

One fragment of a large rounded grain shows evidence of layering in the sediment which has been cemented and partly replaced by goethite. Another contains remnants of mica flakes replaced partly by goethite and another shows a relict fine granular texture typical of siltstone or finegrained sandstone. A trace of fresh ilmenite occurs as very small (0.05 mm) grains included in a few of the large iron oxide grains.

Most heavy-mineral grains in this sample were derived from an older sediment which had been cemented and partly replaced by ferric oxides, predominantly goethite and hematite but with maghemite locally developed.

APPENDIX 4

LIST OF ABBREVIATIONS USED IN THE FIGURES

ab	Above	Lst	Limestone
Abd	Abundant	Lyr	Layer
aren	Arenaceous	m	Medium
arg	Argillaceous	mass	Massive
bcmg	Becoming	Mdst	Mudstone
Bd	Bed	Mic, mic	Mica (ceous)
bl	Blue	mnr	Minor
blk	Black	mtl	Mottled
Bnd	Band	Nod	Nodule
brn	Brown	occ	Occasional
Bry	Bryozoa	p	Poor (ly)
c̄	with	Pbl	Pebble
c	Coarse	Por	Porosity
Calc, calc	Calcite (areous)	Py, py	Pyrite
Cgl	Conglomerate	Qt	Quartz
Clst	Claystone	Qz, qzs	Quartz (ose)
Cmt	Cement	Rad	Radiolaria
com	Common (ly)	Res	Resistivity
cons	Consolidated	scatd	Scattered
dk	Dark	sd	Sandy
Do	Dolomite	sft	Soft
Ech	Echinoids	Sh	Shale
f	Fine (ly)	si	Siliceous
festnd	Ironstained	slt	Silty
fiss	Fissile	Sltst	Siltstone
Foss	Fossil	strg	Stringer
Frag	Fragment	srtd	Sorted
fri	Friable	Sst	Sandstone
Gl, gl	Glauconite (ic)	sublab	Sublabile
gn	Green	ti	Tight
grdg	Grading	tn	Thin
grnd	Grained	Tr	Trace
gy	Grey	uni	Uniform
hd	Hard	var	Various
lchd	Leached	vc	Very coarse
Intbd (d)	Interbed (ed)	vf	Very fine
lamd	Laminated	wh	White
Len	Lens	wthrd	Weathered
Lig, lig	Lignite (ic)	xbdd	Cross-beded
lt	Light (er)	Yel	Yellow

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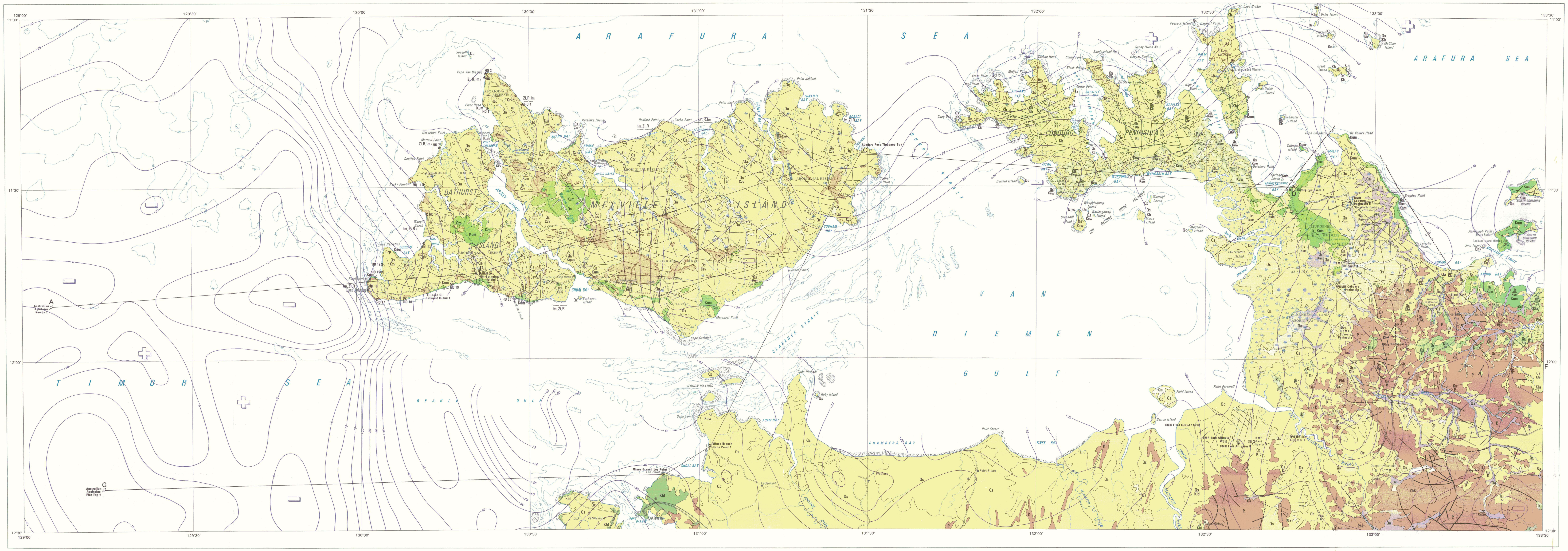
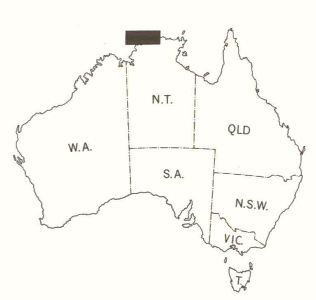
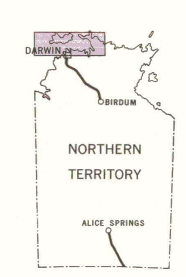
GEOLOGY OF BATHURST ISLAND, MELVILLE ISLAND AND COBOURG PENINSULA

NORTHERN TERRITORY 1977



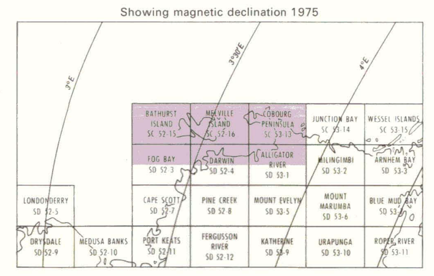
Compiled by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Resources. Issued under the authority of the Minister for National Resources
Topographic base compiled by the Bureau of Mineral Resources, Geology and Geophysics, from 1:250 000 Planimetric Series of the Division of National Mapping, Department of National Resources and the Royal Australian Survey Corps





INDEX TO ADJOINING SHEETS

Showing magnetic declination 1975



Scale 1:500 000

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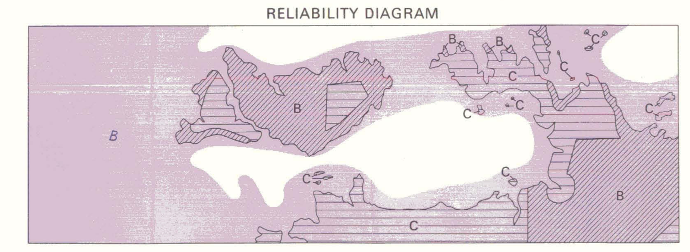
Transverse Mercator Projection

RELIABILITY DIAGRAM



Geology B Detailed reconnaissance and airphoto interpretation
C General reconnaissance; many traverses and airphoto interpretation

Gravity B Reconnaissance

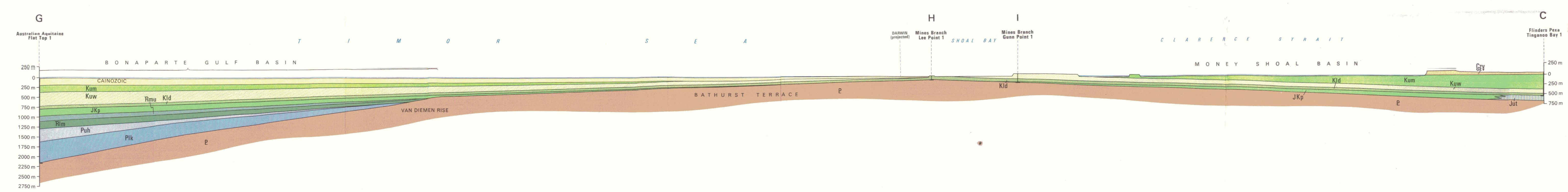
Geology Proterozoic 1953–58 by B. P. Walpole, P. W. Crohn, P. R. Dunn, M. A. Randal
1971–74 by R. S. Needham, P. G. I. Smart, A. L. Watchman
Mesozoic, Cainozoic 1972 by B. R. Senior, R. J. Hughes
1973 by R. J. Hughes
Compiled 1973–75 by R. J. Hughes, G. Matveev, I. T. Lamberts
Gravity data from Geophysical Branch BMR
Cartography by Geological Branch BMR
Drawn by Leigh-Mardon Pty. Limited, Melbourne
Printed by Mercury—Walch Pty Ltd., Hobart, Australia

Bibliographic reference: R. J. Hughes, 1977—The Geology and Mineral occurrences of Bathurst Island, Melville Island and Cobourg Peninsula, Northern Territory. Bur. Miner. Resour. Aust. Bull. 177

SECTIONS

Quaternary sediments omitted

Scale: $\frac{V}{H} = 4$



Reference

Thin superficial Quaternary sediments omitted

CAINOZOIC

QUATERNARY
- Qs — Red and mottled grey to yellow sandy soils
- Qc — Quartzose sand, shell and coral debris, saliferous organic mud and silt; coastal sediments
- Qa — Silt, fine sand, mud, minor gravel, alluvium

- Czp — Ferruginous to bauxitic pisolitic laterite
- Van Diemen Sandstone — Czv — Friable white to yellow, medium to coarse quartzose sandstone, lenticular beds of siltstone, and minor beds of granular conglomerate; strongly weathered in outcrop

MESOZOIC

LOWER TO UPPER CRETACEOUS

Bathurst Island Formation
- Kb — Mainly sublabile sandstone, siltstone, and mudstone, calcareous in part, argillaceous siltstone
- Moonkinu Member — Kum — Fine to very fine, sublabile sandstone interbedded with grey carbonaceous mudstone and siltstone. Calcareous and limonitic concretions
- Wangarlu Mudstone Member — Kuw — Mudstone, siltstone, and minor sublabile sandstone, scattered nodular pyrite
- Marligur Member — Kla — Fine to coarse quartzose sandstone, interbedded with micaceous siltstone and mudstone in upper part
- Darwin Member — Kld — Fine sandstone, radiolarian siltstone, and minor conglomerate

- K — Fossiliferous, poorly sorted quartzose sandstone; mudstone, siltstone, and conglomerate

(strongly weathered in outcrop with the development of a trizonal laterite profile)

JURASSIC TO NEOCOMIAN
- Petrel Formation — JKp — Friable, fine to coarse quartzose sandstone with interbedded brown to grey shale

UPPER JURASSIC
- Tinganoo Bay Beds — Jut — Coarse quartzose sandstone and conglomerate with angular to rounded pebbles of quartz and quartzite, minor fine micaceous sandstone

LOWER TO UPPER TRIASSIC
- Rmu — Fine to coarse quartzose sandstone and red-brown micaceous shale and sandstone
- Mount Goodwin Formation — Rlm — Hard, micaceous shale, thin interbeds of siltstone and very fine quartzose sandstone

PALAEOZOIC

LOWER TO UPPER PERMIAN
- Hyland Bay Formation — Puh — Fine to coarse friable sandstone, bioclastic limestone, and dark grey to black shale
- Kulshill Formation — Plk — Fine to coarse sandstone interbedded with shale and siltstone

(sections only)

CARPENTARIAN
- Kombolgie Formation — Phk — Medium to very coarse quartzose sandstone, siliceous. Basal conglomerate of quartzite and vein quartz clasts; minor basalt

- P — Undifferentiated Archaean and Lower Proterozoic, igneous, metamorphic and sedimentary rocks

Geological boundary
Fault (t, is indicates relative movement down, up)
Where location of boundaries, folds and faults is approximate, line is broken; where inferred, queried; where concealed, boundaries and folds are dotted, faults are shown by short dashes
Strike and dip of strata
Lineament
Joints
(airphoto interpretation)
Microfossil locality
Macrofossil locality
Plant fossil locality
Type section locality

Petroleum exploration well, abandoned
Drill holes: stratigraphic, scout, hand auger
Minor mineral occurrence
Unworked deposit
Prospect
Mine
Bx Bauxite
Cu Copper
Ilmenite
Rutile
Sn Tin
U Uranium
Zr Zircon

Bore
Abandoned bore
Artesian bore
Sub-artesian bore
Swamp
Mangroves
Bathymetric contours in metres, approximate
Mud
Coral reef, rock ledge
Former strand line

Road
Vehicle track
Railway
Landing ground
Settlement, homestead, mission
Lighthouse
Elevation in metres, approximate

Isogal (5 milligal interval)
"High" anomaly
"Low" anomaly
Density 2.2 g/cm³ Surveys in 1965 and 1967

Bouguer anomalies over marine areas are final contours, all land contours are considered preliminary

Copies of this map may be obtained from the Bureau of Mineral Resources, Geology and Geophysics, Canberra, A.C.T.

BATHURST ISLAND, MELVILLE ISLAND AND COBOURG PENINSULA
1:500 000