COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

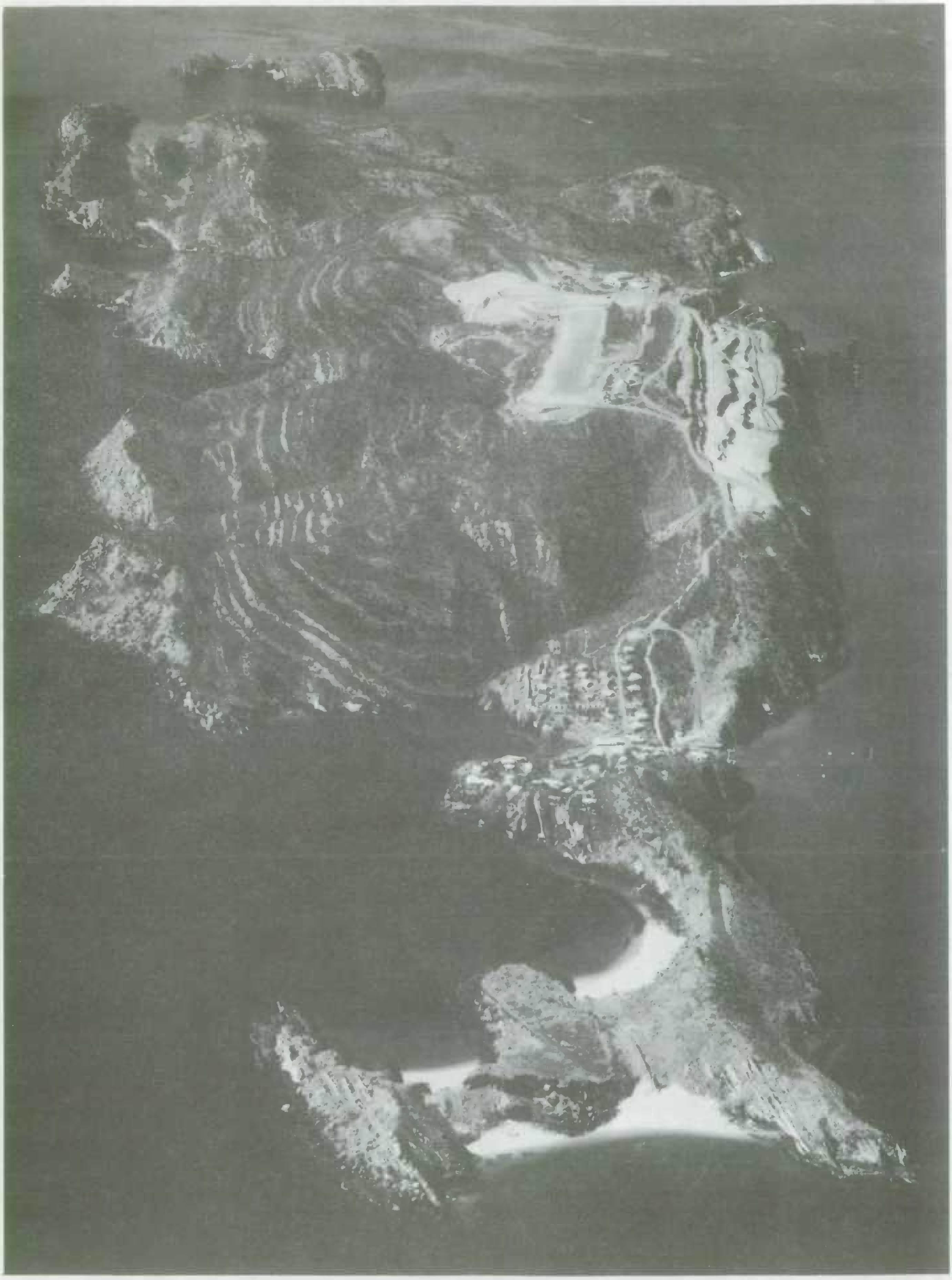
Record 1971/1

THE GEOLOGY OF THE YAMPI 1:250,000 SHEET AREA SE/51-3 WESTERN AUSTRALIA

by

J. Sofoulis[1], D.C. Gellatly, G.M. Derrick,
R.A. Farbridge[1], and C.M. Morgan[2]

[1] Formerly Geological Survey of Western Australia.
[2] Formerly Bureau of Mineral Resources.



Frontispiece; Cockatoo Island, Yampi Sound, looking east. (Reproduced by permission of Aerial Photographs and Surveys, Perth)

THE GEOLOGY OF THE YAMPI 1:250,000 SHEET AREA SE/51-3

WESTERN AUSTRALIA

CONTENTS

Page

SUMMARY

The Yampi Sheet area lies on the coast of the West Kimberley region in the north of Western Australia.

The area is rugged and deeply dissected. It has a drowned ria-type coastline, with many offshore islands. The physiography is closely controlled by the resistance of the underlying bedrock. Ridges of sandstone and quartzite on the Yampi Peninsula have been peneplained producing a well defined erosion surface.

The rocks present range in age from Precambrian to Cainozoic. The oldest Precambrian rocks are the Halls Creek Group, a series of eugeosynclinal sediments of probable Archaean age. These have been strongly folded, and metamorphosed in the greenschist and locally amphibolite facies, and intruded in Lower Proterozoic time by sills of dolerite (Woodward Dolerite), and by tonalite (Nellie Tonalite), referred to the early Lamboo Complex.

They are followed by acid tuffs of the Whitewater Volcanics (which elsewhere lie unconformably on the older rocks) and related high-level porphyries (Mount Disaster Porphyry and Mondooma Granite) all of which are assigned to the middle Lamboo Complex.

Later plutonic granites (Lennard Granite, Secure Bay Adamellite, Kongorow Granite, Tarraji Microgranite, Cone Hill Granite), belong to the late Lamboo Complex.

These rocks are overlain unconformably by sandstone and basalt and minor siltstone and conglomerate of the Kimberley Group, which contains the King Leopold Sandstone, Carson Volcanics, Warton Sandstone, Elgee Siltstone, and Pentecost Sandstone. The Pentecost Sandstone includes the iron ores and associated hematitic sediments of the Yampi Sound area.

The Kimberley Group is intruded by sills of Hart Dolerite and, in the northwest part of Yampi Peninsula, by the Wotjulum Porphyry.

The Precambrian rocks have been faulted, and strongly folded on west-northwest and northeast axes. Beds are overturned locally. Two periods of regional metamorphism have affected the area.

Palaeozoic rocks, which include reef limestones and boulder beds, crop out locally and probably underlie the Mesozoic and Cainozoic rocks in the southern parts of the area.

Cainozoic deposits are mainly superficial and related to drainage and dissection since the Tertiary period. Drowning of the coastal areas has taken place in Recent time.

Iron ore currently being mined at Cockatoo and Koolan Islands forms the only economic mineral deposits known in the area. Copper has been produced intermittently from the Halls Creek Group in the Little Tarraji River area and from the Wotjulum Porphyry at Coppermine Creek. Minor copper occurrences have been reported from other localities in the Halls Creek Group and also from the Warton Sandstone.

Mica and a little beryl have been produced from a pegmatite near Limestone Springs.

Inlets in the northeast of the area have been investigated for possible tidal power sites. Water supplies from surface pools and shallow bores are sufficient for present pastoral purposes.

INTRODUCTION

Location

The Yampi 1:250,000 Sheet area (Fig. 1) lies in the western part of the Kimberley Land Division of Western Australia between latitudes 16° 00'S and 17° 00'S, and longitudes 123° 00'E and 124° 30'E. It includes the Yampi Peninsula, the northeastern part of Dampier Peninsula, and hundreds of offshore islands.

The port of Derby, the main centre of communications for the West Kimberley region, is situated south of Stokes Bay near the head of King Sound, some 30 km south of the southern boundary of the Sheet area.

Habitation, Industry, Access, and Communications.

The two principal centres of permanent habitation and industry are the iron ore centres of Cockatoo Island and Koolan Island, operated by Dampier Mining Coy Ltd, a subsidiary of Broken Hill Pty Ltd. These two islands supply regular shipments of iron ore to the company's works at Newcastle and Port Kembla

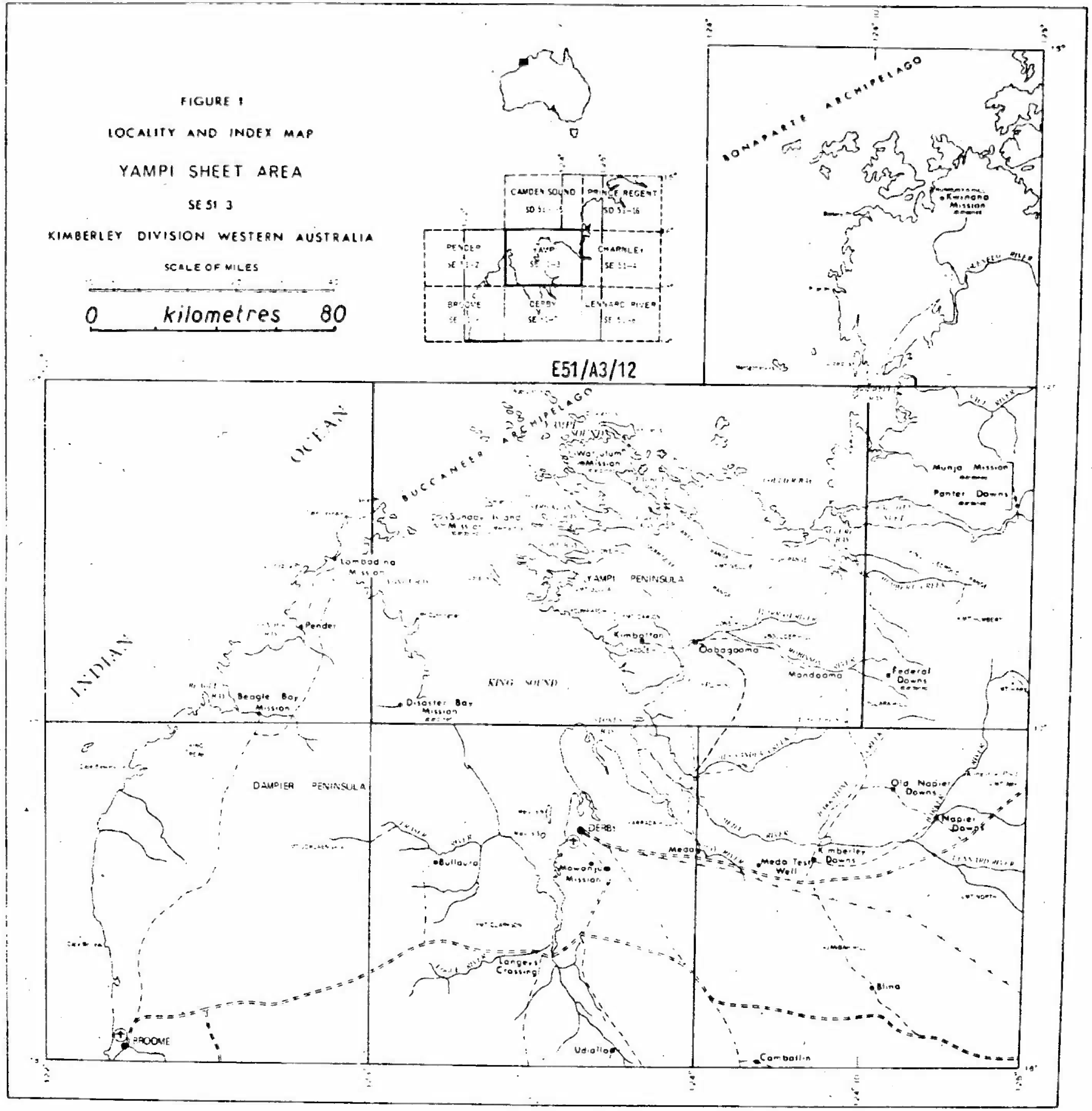


FIGURE 1
LOCALITY AND INDEX MAP
YAMPI SHEET AREA
SE 51 3
KIMBERLEY DIVISION WESTERN AUSTRALIA
SCALE OF MILES
0 kilometres 80
CAMDEN SOUND
PRINCE REGENT
PENDER
YAMPI
CHARNLEY
BROOME
DERBY
LENNARD RIVER
E51/A3/12
BONAPARTE ARCHIPELAGO
Kunmunya Mission
BUCCANEER ARCHIPELAGO
INDIAN OCEAN
Munja Mission
Panter Downs
Lombadina Mission
YAMPI PENINSULA
Pender
Kimbolton
Oobagooma
Mandoama
Federal Downs
KING SOUND
Beagle Bay Mission
Disaster Bay Mission
DAMPIER PENINSULA
Old Napier Downs
Napier Downs
DERBY
Meda
Meda Test Well
Kimberley Downs
Bulluara
Mowanjum Mission
Langeys Crossing
Blina
BROOME
Udialla
Camballin

FIGURE 1.

13

and to overseas markets. Approximately 180 persons are engaged in the industry at Cockatoo, and 150 at Koolan.

There are airstrips suitable for light aircraft at both islands and a regular passenger, mail, and freight service to and from Derby (135 km distant) is maintained by the Company's 'Pioneer' aircraft. Other communications with the mainland are provided by radio telephone. Both islands are ports of call for ships of the State Shipping Service. Most of the mainland and island coasts are accessible by shallow draught vessels.

Small-scale mining last took place in the Mondooma area in 1947 (Stuarts Mica Mine). A number of abandoned copper workings in the Little Tarraji River area, and at Coppermine Creek, were worked prior to 1920. During the last decade, these areas have received periodic visits from prospectors and exploration companies. The areas of mineral potential are now included in Temporary Reserve 2680H held by Pickands Mather Company International, who are currently engaged in geological mapping and geochemical sampling.

The only permanent mainland settlements are at Oobagooma homestead, at the tidal limit of the Robinson River, and the newly established Kimbolton homestead at the southern flank of the Kimbolton Range, 22 km by rough bush track west-northwest from Oobagooma. Both homesteads are in communication with the Flying Doctor Radio base at Derby. Oobagooma has an airstrip suitable for light aircraft. It is linked with Derby by a graded inland road, and a coastal road, which meet north of Meda homestead and connect with the Derby-Kimberley Downs road 48 km east of Derby (see Fig. 1).

The southeastern part of the area is accessible by a graded track which extends northwards from Kimberley Downs homestead through Limestone Spring to Mondooma Yard on the Robinson River and from there to Oobagooma.

Access to Dampier Peninsula is by a graded road from Broome which connects with Beagle Bay Mission, Pender Bay Homestead, Lombadina Mission, and Cape Leveque (see Fig. 1).

An airstrip, situated between Walcott Inlet and Secure Bay, constructed in 1962 for communication purposes during tidal power scheme investigations, is currently in disrepair.

Indigenous aborigines no longer inhabit the region. Isolated missions which catered for aboriginal communities at Disaster Bay, Sunday Island, Wotjulum (10 km southeast from Coppermine Creek head) and Munja (head of Walcott Inlet, Charnley Sheet area) have now been abandoned, and all inhabitants transferred to Mission Stations (or school hostels) at or closer to Derby. Some are employed in the cattle industry.

Climate

The climate of the area is monsoonal with well defined wet and dry seasons. Average rainfall within the area ranges from 680 to 850 but it is very variable from year to year. Normally most of the rain falls between December and March. Very heavy falls occur occasionally within a short period with consequent disruption to communications.

Temperature data for Derby (Speck et al., 1964), which are probably an accurate guide to the coastal regions of the Sheet area, indicate average minima from 14°C (July) to 27°C (December) and maxima from 29°C (July) to 37°C (November and December). The area is subject to cyclonic weather conditions during the period January to March.

Vegetation

The typical vegetation of low-lying parts of the area is grassy open eucalyptus woodland. Sandstone ridges support only stunted wattle and soft spinifex. Low hills especially in the coastal areas have a heavy cover of tall cane grass. Black soil areas are treeless with a cover of tussocky grass. Baobabs, river gums, paper barks, and pandanus palms fringe the watercourses. Sand plains in the south of the area support stands of tall wattle scrub (pindan).

Bare mud flats of sheltered bays and inlets have mangrove thickets on the seaward fringe and are locally being encroached on the landward margin by samphire meadows.

A comprehensive description of the vegetation of the region is given by Speck & Lazarides (1964).

PREVIOUS INVESTIGATIONS

Cape Leveque was sighted by Tasman in 1644 and later named by De Freycinet during a French naval expedition to Australia in 1801-03 (Sharpe, 1963). The coastal parts of Dampier Peninsula in the Yampi Sheet area were visited by William Dampier in the ship <u>Cygnet</u> (commanded by Captain Read), in 1688 (Sharpe, 1963). Commander Phillip Parker King explored the coastline in 1820-21 and named Sunday Island and numerous other prominent coastal features (King, 1827). Geological specimens collected by King were described by W.H. Fitton (1825), who recorded that the coastal areas were composed almost entirely of sandstone.

John Lort Stokes, an officer and later commander of H.M.S. Beagle (then commanded by Captain John Clements Wickam) explored and surveyed the coast more fully in 1838-41. He established from native sources the names Koolan (fighting island) Cockatoo (father island) and Yampi (water).

Government surveyor Ord accompanied Hann in an expedition into the region in 1898 (Hann, 1901), and it is probable that surveyors from this party visited Oobagooma (native name: grassland or pastoral proposition) and areas to the east. Government surveyors Leeming, Ryan, and Crossland continued the naming and mapping of prominent physiographic features of the Sheet area.

Fitzgerald (1907) and Basedow (1918) described briefly some of the island and other coastal mainland rocks after their visits to Sunday Island Mission and other localities of this Sheet area.

The iron deposits of Yampi Sound were known as early as 1890, when pearling luggers collected ore from the islands for use as heavy ballast. Some of the first leases were taken up in this area in 1907 (Koolan Island) but large scale shipment of iron ore did not eventuate until Cockatoo Island (in 1951) and Koolan Island (in 1964) were brought into full scale production.

Numerous published and unpublished reports on these iron deposits, and other geological features of the Yampi Sound area, are listed in the bibliography. The more significant reports are those by Campbell (1909), Canavan & Edwards (1938), Finucane (1939), Canavan (1953), and Reid (1958, 1965). Chloritoid was reported from Yampi Sound by Simpson (1915), who also analysed hematite quartzite from Yampi Sound and water samples from Cone Bay area (Simpson, 1916).

Small copper deposits discovered early in the century at Coppermine Creek, Little Tarraji River, and Mondooma areas were described briefly by Maitland (1919), Simpson (1952), Harms (1959), Low (1963), and Sofoulis (1967).

Those of the Little Tarraji River and adjacent areas were investigated by Western Mining Corporation Ltd and described in unpublished company reports by Woodall (1957), Reid (1958, 1959), Triglavcanin (1958), and Harper (1959).

The geology of the Dampier Peninsula was described by Brunnschweiler (1951, 1957) and McWhae et al. (1958). Speck et al. (1964) provided a summary description of the physiography and geology of the whole of the Yampi Sheet area and adjoining regions.

The most notable contribution to the regional study was by Harms (1959), who produced the first geological map of the region, based on air photographs and some ground traverses. His map, and subdivisions of the major Precambrian rock units, provided the framework for subsequent investigations, and together with the Bureau of Mineral Resources preliminary interpretation of the Yampi Sheet area (Perry & Richard, 1965), assisted in planning the 1966 mapping.

PRESENT SURVEY

This report is a product of a joint survey programme commenced in 1962, by the Bureau of Mineral Resources and the Geological Survey of Western Australia, to map the Precambrian rocks of the Kimberley Division in the northern part of Western Australia.

Most of the Yampi 1:250,000 Sheet area was mapped during the 1966 field season from a base camp established at Kongorow Pool on the Barker River, in the Lennard River Sheet area. Personnel engaged in this survey were D.C. Gellatly, G.M. Derrick, C.M. Morgan (BMR), and J. Sofoulis and R. Farbridge (GSWA). The survey of the Yampi Sheet area was completed during the 1967 field season by Gellatly, Sofoulis, and Derrick. All members of the field party contributed to the compilation of the geological map and to this report. It has been compiled and edited by Gellatly. Authorship of individual chapters is indicated in the list of contents.

This report, together with those on the Lennard River, Charnley, and Lansdowne 1:250,000 Sheet areas will form the basis for a bulletin entitled 'Precambrian Geology of the Kimberley Region: The West Kimberley' to be published by the Bureau of Mineral Resources. Other bulletins of this series are: The East Kimberley (Down and Gemuts, 1969; Gemuts, in press), and the Kimberley Basin (Plumb, in prep.).

Vertical air-photographs at a scale of 1:50,000 taken in 1949 by the RAAF were used during the survey. Photo mosaics, scale 1:63,360 and 1:250,000 and topographic maps on scale of 1:50,000 (unpublished) and 1:250,000 also are available.

Survey Method: The accessible southern parts of the area were investigated on foot using 4-wheel-drive vehicles for transport. A helicopter, operating from bases at Koolan Island and Oobagooma airstrips, was used for mapping the inaccessible ranges and the offshore islands. During helicopter operations, three geologists were positioned each day for cross-country traverses, while a fourth used the helicopter for spot observations. At the end of the day all geologists were collected from pre-selected pick-up points and returned to base.

Rubber floats were fitted for the island traverses, and landing skids for the inland work. Approximately 85 helicopter flying hours were logged in the Sheet area during the 1966 field season and 15 hours during the 1967 season. A few light aircraft flights were used for reconnaissance.

Information from field work was plotted initially on transparent photo-overlays and was then transferred to 1:50,000 compilation sheets. The resultant maps were subsequently reduced to 1:250,000 and redrawn to produce the geological map accompanying this report.

PHYSIOGRAPHY

The Yampi Sheet area includes part of the physiographic North Kimberley and Fitzroyland divisions as defined by Jutson (1934). The constituent physiographic provinces and subprovinces of these divisions are given in Table 1. Figure 2 shows the distribution of the various physiographic units within the Sheet area.

TABLE 1

Physiographic Subdivisions - Yampi 1:250,000 Sheet area

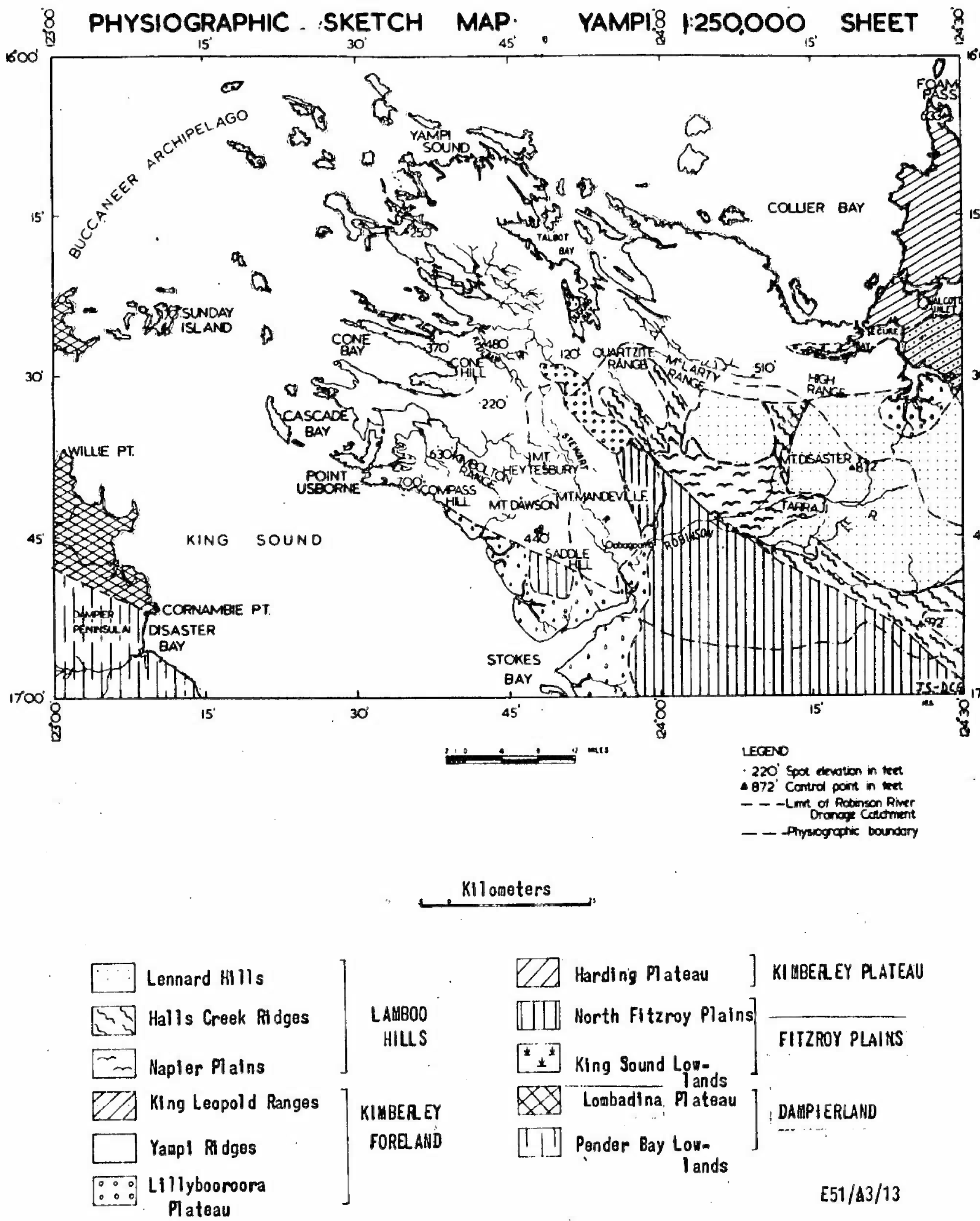
Division	Province	Sub-Province
North Kimberley[1]	Kimberley Plateau[2]	Harding Plateau[6]
	Kimberley Foreland[2]	King Leopold Range[6,7] Yampi Ridges[2] Lillybooroora Plateau
Fitzroyland	Lamboo Hills[5]	Lennard Hills[7] Halls Creek Ridges[7] Napier Plains[7]
	Fitzroy Plains[2]	North Fitzroy Plains[7] King Sound Lowlands
	Dampierland	Lombadina Plateau[4] Pender Bay Lowlands[4]

[1]Jutson (1934)
[2]Wright (1964)
[3]Traves (1955)
[4]Brunnschweiler (1957)
[5]Dow & Gemuts (1969)
[6]Gellatly et al. (1969)
[7]Gellatly et al. (1968)

Kimberley Plateau Province

The Harding Plateau is a rugged and deeply dissected sandstone plateau containing numerous cuestas formed by erosion-resistant beds of sandstone, overlying softer sandstone, siltstone, or dolerite. It is found only near the eastern margin of the Sheet area between Foam Passage and Secure Bay. Elevation of the Plateau decreases southwards from 190 m near Raft Point to about 90 m near Secure Bay. Drainage is mainly consequent with subsequent tributaries following strike valleys in easily eroded siltstone, dolerite or soft sandstone.

FIGURE 2.



E51/A3/13

Fig. 3a Peneplained plateau surface of the Yampi Peninsula south of Dugong Bay. Lillybooroora Plateau in centre. Flat-topped, steeply dipping sandstone beds of Yampi Ridges in foreground and distance. (Neg GA 1144) D.C.G.

Fig. 3b Flat-topped parallel sinuous ridges of Kimberley Group sandstone formations forming part of Yampi Ridges physiographic subprovince: 15 km east of Cone Hill. The strike valleys are formed over siltstone and basic rocks (Photo. GSWA) J.S.

Kimberley Foreland Province

The King Leopold Range occurs only on the eastern margin of the Sheet area. There it forms a broad gently convex deeply dissected ridge with prominent cliffs on its southern margin. Butte topography is well developed. Maximum elevation is around 360 m. Minor drainage is mainly consequent and partly joint controlled. With increasing dips the King Leopold Range presses westwards into the Yampi Ridges.

The Yampi Ridges occupy most of the Yampi Peninsula. They consist of a series of parallel flat-topped ridges and of hogbacks and cuestas formed by beds of steeply dipping resistant sandstone with intervening beds of easily eroded siltstone, basalt, and dolerite. Elevations range from 30 to 240 m above sea-level, and relief from 60 m to 150 m.

The flat ridge tops have uniform elevation and form a striking peneplain that stretches from Collier Bay to Yampi Sound and King Sound. This peneplain comprises remnants of an earlier erosion surface (the Low Kimberley Surface) which slopes gently downwards from the High Range area to the west, south-west and south. The minimum elevation of this peneplain is about 150 m, e.g. as at Koolan and Cockatoo Islands.

The Lillybooroora Plateau forms part of the Yampi Peninsula but differs from the surrounding area physiographically in that parallel ridges give way to a uniform smooth plateau surface flanked by areas of rounded hills with a dendritic drainage pattern.

Major streams throughout the Yampi Peninsula are controlled by northwest-trending strike valleys developed in siltstone and volcanic rock in the Kimberley Group sequence. Minor streams generally breach the resistant strike ridges.

Lamboo Hills Province

The Lennard Hills comprise land-forms developed on the older Precambrian igneous rocks (Lamboo Complex). Landforms of this sub-province are predominantly dissected plateaux (e.g. Mt Disaster, rocky tors, and broad whalebacks, separated by narrow sandy pediments. The lower lying and southwestern parts of the Lennard Hills are characterized by broad convex pediments which generally have scattered granite tors and monadnocks along minor drainage divides.

Maximum elevations are about 240 to 270 m and conform with the general level of the Low Kimberley Surface in this area. Relief over most of the Lennard Hills is generally less than 90 m and commonly ranges between 30 m and 60 m. Minor streams are mostly dendritic.

The Halls Creek Ridges, which are inextensive in the Yampi Sheet area, are developed on schist and phyllite. Landforms are low ridges and irregular round-topped hills with closely spaced dendritic minor drainage. Together these features produce a hummocky topography.

The Napier Plains consist of areas of tussocky black soil separated from river courses by sandy levees, of areas of residual sandy soils, and of scattered inselbergs with surrounding pediments. Minor streams are anastomosing and commonly have well developed meanders (Fig. 4).

Fitzroy Plains Province

The North Fitzroy Plains are extensive sandplains in the southern part of the Sheet area southeast of Oobagooma. They consist of deep red and yellow sands overlying ferricrete and forming a gently undulating pindan-covered plain developed largely upon Palaeozoic and possibly Mesozoic rocks. Drainage is poorly defined and dendritic.

The King Sound Lowlands comprise extensive coastal mudflats southeast of Point Usborne. Mangrove communities flourish on the seaward fringe of the mudflats and line tidal creeks, some of which have prominent meanders.

Dampierland Province

The Lombadina Plateau occupies the northern part of the Dampier Peninsula west of King Sound. The Plateau, which is covered by a veneer of sandy soil, has an average elevation of only 30 m. It is bounded to the south by a low escarpment of sandstone cliffs which form much of the coastline and extend northwest from Cornambie Point. Pleistocene sand dunes are found locally on the plateau surface.

The Pender Bay Lowlands, a low lying sand plain depression to the south of the Lombadina Plateau, were probably the course of a large Tertiary river system flowing westwards to Pender Bay (Brunnschweiler 1957).

Fig. 4a Meandering minor tributary stream, Napier Plains physiographic sub-province, 1 km southwest of Lome Hill. (Neg GA 1882) D.C.G.

Fig. 4b Broad meanders of tidal reaches of Robinson River, Rounded inselberg ridges of King Leopold Sandstone in middle distance. Tidal mudflats of Robinson estuary and Stokes Bay in distance. (Neg GA 1887) D.C.G.

Drainage

Major drainages in the area fall into two broad systems: those around the periphery of the peninsula draining directly seaward, and those that comprise the Robinson River system and drain into King Sound. The McLarty Range, a strike ridge of sandstone, forms the divide between these two drainage systems in the north; in the west the divide is irregular and independent of lithology.

Principal river courses of the peripheral drainage system are dominantly subsequent following strike valleys. Minor tributaries are principally consequent or subsequent; an exception is the area of dendritic drainage surrounding the southern part of Secure Bay. The rivers are mainly stony-bottomed and have immature longitudinal profiles.

The Robinson River and its principal tributaries are mainly dendritic, but the headwaters of its western tributaries are commonly subsequent. Minor tributaries vary with topography: in the east they tend to follow joints and are reticulate, whereas in the west the tributaries are mostly subsequent. The rivers of this system are mature and sandy-bottomed in their lower courses. Tributaries and the upper parts of the main rivers are sandy-bottomed where granite underlies the catchment but are stony elsewhere. The Robinson River becomes mature in the lower part of its course and in the estuarine reaches exhibits broad meanders (Fig. 4). These are believed to be fluvial meanders that predate the drowning rather than a result of estuarine conditions. Meanders in tidal creeks in mangrove swamps on the other hand have developed on the coastal muds and are a more recent development.

Coastal Features

A drowned coastline with ria features is strongly developed north of Point Usborne, where dissected Kimberley Group rocks strike at right angles to the coast. The relative rise in sea level has produced flooded strike valleys previously developed in easily eroded materials. This has left upstanding sandstone promontories, and numerous offshore islands, many of them with linear distribution and forming strike extensions of mainland structures.

The depth of submergence in the Buccaneer Archipelago has been estimated by Reid (1958) at approximately 60 m. The drowning of these deeply dissected terrains has produced a rocky, locally cliffed, coastline. Promontories and bays commonly have irregular shapes, controlled by prominent strike ridges of sandstone and modified only in part by later marine erosion.

Limestone reefs locally fringe parts of the north mainland coast and are extensive about the islands. Beaches are scarce and confined mainly to restricted bays of the outer coast and islands. Mudflats (partly mangrove-covered) occupy sheltered bays, inlets, and estuaries. Other small bays cut off from the sea by sandbars have formed intratidal lagoons.

Some wave-cut platforms of the Yampi Sound areas have been described by Edwards (1958). They are attributed to wave action at the change of hardness between softer atmospherically weathered rocks and the harder, comparatively unweathered rocks that lie below the mean high water mark.

The coastline flanking Collier Bay is controlled by the regional structural trend of the Kimberley Group rocks. Drowned river gorges, where rivers broke out from broad lowland valleys, are now narrow tidal channels. Thus the narrow Yule Entrance and The Funnel, originally river gorges are now tidal, and give access to broad mangrove fringed reaches of Walcott Inlet and Secure Bay respectively.

INTRODUCTION TO STRATIGRAPHY

Precambrian, Palaeozoic, and Mesozoic rocks are exposed in the Yampi 1:250,000 Sheet area. Nomenclature of the older Precambrian units follows that used in the Lennard River Sheet area (Gellatly et al., 1968). Definitions of additional units are given in Appendix I. Nomenclature of the younger Precambrian is based on that of Harms (1959) as modified by Dow et al. (1964).

The older Precambrian rocks - The Halls Creek Group and the Lamboo Complex - are assigned to the Archaean (?) and Lower Proterozoic respectively. The younger Precambrian rocks, of the Kimberley Basin succession, are assigned to the Carpentarian system. Subdivision of the Precambrian into Archaean (?), Lower Proterozoic, and Carpentarian is based on isotopic age determinations (Bofinger, 1967; Bennett & Gellatly, 1970).

The oldest Precambrian rocks, metamorphosed flysch sediments of the Halls Creek Group, are tentatively assigned to the Archaean, but at present this is based on only one age determination.

ERA	PERIOD	ROCK UNIT AND SYMBOL	THICKNESS IN METRES	LITHOLOGY	TOPOGRAPHY	DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	REMARKS
CAINOZOIC	QUATERNARY	Qa		Alluvium; river sand and gravel.	River flats and terraces.	Along all main rivers.	Superficial deposits; overlie other rock units unconformably	Mainly coarse sand or silty sand.
		Qc		Coastal mud, silt and sand.	Coastal mud flats; tidal marsh, intertidal lagoons; tidal channels.	Extensive around shores of King Sound; locally along coastline of Yampi Peninsula.		Bare mud-flats, locally with salt encrustations; intertidal parts support mangrove thickets. Coarse sands in tidal channels.
		Qs		Beach sand; white sands with shell debris.	Beaches, sand bars, beach dunes.	Isolated beaches between headlands.		
		Ql		Fragmental Limestone, and active coral reefs.	Low benches near shoreline. Submerged reefs.	Fringing islands of Buccaneer Archipelago.		Limestone outcrops too small to show on 1:250,000 map.
	UNDIFFERENTIATED CAINOZOIC	Czs		Residual soil, sand, eluvium, colluvium.	Undulating scrub covered sand plains.	Widespread in low lying areas; also in valleys flanking rivers and separating rock exposures.		Low longitudinal sand dunes locally.
		Czb		Black soil: black to dark grey heavy textured cracking clay soils.	Plains with some shallow depressions. Gilgai patterns with hummocky surfaces. Local relief 0.3 to 0.6 m.	Flanking lower reaches of Robinson River and main tributaries.		Generally grass covered; boggy in wet season.
		Czl		Ferricrete: ferruginous pisolitic sandy soil; ferricrete conglomerate	Surface veneers associated with eluvial soils, sand plains, and pediments.	Mainly in southwest and southeast.		Mainly associated with Phanerozoic sediments.
		Tp	Up to 6 m	Laterite; pisolitic, aluminous; Detrital, limonitic iron ore ("canga")	Flat-lying residual cappings on plateau surface.	Cockatoo and Koolan Islands (canga); northwest of Mount Nellie (laterite).		Possibly remnants of a formerly extensive laterite surface. Canga deposits mostly mined out.
		PENEPLANATION,		WEATHERING,	DISSECTION	AND SOIL	ACCUMULATION	
	TERTIARY	Borda Sandstone	4 m	Ferruginous, uncemented angular sandstone rubble; Pisolitic limonite.	Low outcrops.	Apex Island and Cunningham Point.	Post-dates Pender Bay Conglomerate.	Outcrops too small to show 1:250,000 scale. Contains material reworked from Pender Bay Conglomerate.
					D I S C O N F O R M I T Y			
		Pender Bay Conglomerate Tc		Conglomerate; dark grey boulder to pebble sized clasts.	Low outcrops.	South of Cunningham Point.	Overlies Jowlaenga Formation.	Fluviatile deposit probably contemporaneous with Emeriau Sandstone to the West. Overlies Jowlaenga Formation.
					U N C O N F O R M I T Y			

TABLE 2: STRATIGRAPHY - YAMPI 1:250,000 SHEET AREA SE/51-3 - MESOZOIC AND PALAEOZOIC

ERA	PERIOD	STAGE OR GROUP	ROCK UNIT AND SYMBOL	THICKNESS IN METRES	LITHOLOGY	TOPOGRAPHY	DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	REMARKS
MESOZOIC	CRETACEOUS	APTIAN	Melligo Sandstone Klm		Quartz-Sandstone; medium to coarse-grained silicified locally.	Low rises, mesas or buttes; low cliffs.	Coastal sections on east coast of Dampier Peninsula.	Mostly overlies Jowlaenga Formation. Overlies Precambrian on Apex Island.	
		VALANGINIAN	Jowlaenga Formation Klj	75 m to 120 m	Sandstone; fine to medium, often ferruginous, well bedded.	Low mesas and buttes; low coastal headlands.	Scattered outcrops along east coast of Dampier Peninsula.	May be equivalent to Jarlemai Siltstone (Brunnschweiler, 1954).	
					U N C O N F O R M I T Y				
PALAEOZOIC	PERMIAN		Grant Formation Pg	Unknown in Yampi area. 132 m in type area.	Sandstone; conglomerate, tillite, siltstone and shale. Glacial and aqueo-glacial.	Low outcrops, partly soil covered.	Small exposures in southeast.	Overlies Fairfield Formation in southeast.	Excellent aquifer.
	PERMIAN(?)		Lillybooroora Conglomerate Plc	Up to 60 m	Boulder and cobble conglomerate; megaclasts are quartzite, well lithified.	Rounded boulder-strewn hills; flat topped masses and valley side benches flanking Proterozoic sandstone ridges.	In valley floors; as extensive hills and isolated masses to north and northwest of Oobagooma.	Overlies Precambrian unconformably.	Well-defined dendritic drainage pattern developed.
					U N C O N F O R M I T Y				
	DEVONIAN	FAMENNIAN	Fairfield Formation Df	195m+	Silty crystalline limestone and calcarenite; calcareous shale and siltstone.	Low outcrops on plains to southeast of limestone range		Conformably overlies reef complex.	Partly of Carboniferous age subsurface and on the adjacent Lennard River Sheet.
		FRASNIAN - FAMENNIAN	Windjana Limestone Dw	Reef Complex 240 m total	Algal-stromatoporoid reef limestone, partly dolomitized		In extreme southeast.	Interfingers with back-reef and fore-reef.	Reef-facies; discontinuous.
			Pillara Limestone Dp		Limestone, partly dolomitized.	Massive outcrops in narrow, hilly, limestone range.	Of Sheet area only.	Interfingers with reef and fore-reef.	Back-reef facies, well-bedded and flat lying.
			Napier Formation Dn		Calcarenite and calcirudite, and megabreccia, minor dolomite.			Interfingers with reef and back-reef.	Fore-reef and inter-reef facies. Distinguished from back-reef by steep depositional dips.
					M A J O R U N C O N F O R M I T Y				

ERA	PERIOD	GROUP	ROCK UNIT AND SYMBOL	THICKNESS IN METRES	LITHOLOGY	TOPOGRAPHY	DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	REMARKS
			Wotjulum Porphyry Bqw	Up to 900m	<u>Quartz feldspar porphyry</u>; grey; contains abundant euhedral or anhedral quartz phenocrysts, minor pink feldspar.	Dissected low rocky hills and pavements	Restricted northwest part of Yampi Peninsula.	Intrudes Warton Sandstone, Elgee Siltstone and Pentecost Sandstone	Wotjulum Porphyry and Hart Dolerite appear to be mutually exclusive. Minor copper mineralisation in quartz veins at Coppermine Creek
		POST KIMBERLEY GROUP	Hart Dolerite Bdh	Up to 1200 m	<u>Dolerite</u>; dark-grey, medium grained; some grey granophyre.	Rounded boulder-strewn hills or low undulating hills in valleys.	Widespread sills in Kimberley Group of Yampi Peninsula, except in northwest.	Intrudes Halls Creek Group Whitewater Volcanics, Lennard Granite, and all formations of Kimberley Group.	
						INTRUSIVE CONTACTS			
			Pentecost Sandstone Bkp	1350 to 360 m (total)	<u>Sandstone</u>; white, well-sorted quartz sandstone and minor feldspathic sandstone; grey <u>siltstone</u> minor glauconitic sandstone.	Resistant mesas in northeast; flat-topped strike ridges in west.	Widespread in northern and central parts of sheet area.	Overlies Elgee Siltstone conformably. Oldest rocks overlying it are Palaeozoic.	Top of formation not preserved: all sections incomplete.
			Yampi Member Bkpy	Up to 730 m	<u>Arkose and feldspathic sandstone</u>: <u>Aematitic quartz sandstone</u>: <u>siltstone</u>. Minor iron ore, glauconitic sandstone.	Rounded hills and gently dipping cuestas in east. Rocky steep sided plateaus in west.	North coast of Yampi Peninsula and adjacent islands.	Lies conformably on lower beds of Pentecost Sandstone in east: overlies Elgee Silstone in northwest.	Contains hematite ores at Koolan and Cockatoo Island.
CARPENTARIAN			Elgee Silstone Bke	35 m to 480 m	<u>Siltstone</u>, with fine-grained sandstone interbeds; conglomerate.	In scarp slopes and valleys; no strong outcrop expression.	A narrow band in the northern and central parts of Sheet area.	<u>Mostly</u> conformable on Warton Sandstone and overlain conformably by Pentecost Sandstone. Locally overlaps unconformably on to Carson Volcanics.	Intruded by Wotjulum Porphyry.
						LOCAL DISCONFORMITY			
		KIMBERLEY GROUP	Warton Sandstone Bkw	340 m to 520 m	<u>Sandstone</u>; white to cream, coarse to medium-grained, partly feldspathic; siltstone; andalusite granofelds.	Prominent scarps, ridges and restricted plateaux.	Widespread in northern and central parts of Sheet area.	Conformable on Carson Volcanics.	Strongly cross-bedded; megaripples present locally. Partly removed by erosion. Thicknesses refer to complete sections.
			Carson Volcanics Bkc	360 m to 1140 m	<u>Tholeiitic basalt and spilite</u>; Dark grey, green, commonly amygdaloidal; tuffaceous siltstone, agglomerate, feldspathic sandstone.	Rounded hills in valleys; poor outcrop. Locally.	Widespread in northern and central parts of Sheet area.	Conformable on King Leopold Sandstone.	Thickens northeastwards.
			King Leopold Sandstone Bkl	1050 m to 1200 m	<u>Sandstone</u>; coarse-grained white to pale buff.	Broad, flat-topped ridges, ranges and dissected plateaux.	Widespread in northern central and western parts of Sheet area.	Overlies Speewah Group with probable partial unconformity. Probably locally unconformable on older Precambrian.	Cross-bedding common. Some beds poorly sorted.
						PARTIAL UNCONFORMITY			
			Speewah Group Bp	Up to 360 m	<u>Sandstone</u>; pale purple-grey to buff quartz sandstone, locally micaceous, and chloritoid-bearing; minor pebble conglomerate	Narrow steeply-dipping ridges.	Thin discontinuous belt from Secure Bay to Mangrove Creek. Also around Cone Hill.	Overlies older Precambrian unconformably.	Constituent formations of type area not recognizable. Difficult to distinguish from King Leopold Sandstone.

ERA	PERIOD	GROUP	ROCK UNIT AND SYMBOL	THICKNESS IN METRES	LITHOLOGY	TOPOGRAPHY	DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	REMARKS
PROTEROZOIC	LOWER PROTEROZOIC	LAMBOO COMPLEX	Cone Hill Granite Pbkc		Granite; coarse grained, mainly porphyritic biotite granite. Minor xenoliths.	Low rocky promontory, dissected along joint lines.	To west and southwest of Cone Hill.	Overlain unconformably by King Leopold Sandstone.	Contains roof pendants of tourmaline-rich Halls Creek Group. Includes varieties similar to both Lennard and Kongorow Granites.
			Kongorow Granite Pbkk		Granite and adamellite; foliated, porphyritic, biotite-rich. Locally contains mafic xenoliths.	Not topographically distinct from enclosing Lennard Granite.	Rare small outcrops east and southeast of Boulder Hill.	Intrudes Lennard Granite.	Mainly dykes and veins. Few outcrops large enough to show at 1:250,000 scale.
			Tarraji Micro-granite Pbkt		Microgranite; pale grey porphyritic, with pheno-crysts of potash feldspar, plagioclase and biotite.	Small, prominent peaked hills.	Six miles northeast of Mount Disaster; also small scattered outcrops near Tarraji River.	Intruded Lennard Granite.	More resistant to weathering than surrounding Secure Bay and Lennard Granite. May be related to Lennard Granite.
			Secure Bay Adamellite Pkbs		Adamellite; coarse-grained, even-grained, pale grey. Locally sparsely porphyritic.	Prominent rocky hills and low tors.	To north and northwest of Mount Disaster.	Intrudes Mount Disaster Porphyry and Lennard Granite.	Contains xenoliths of Lennard Granite, but elsewhere, has possibly been contact-altered by Lennard Granite.
			Lennard Granite Pbkl		Granite; coarse-grained grey, leucocratic porphyritic, biotite granite. Muscovite rich marginally. Tourmaline pegmatite, aplite and quartz veins.	Rounded whalebacks and rocky tors; low rock pavements. Tors commonly surrounded by thinly veneered pediments.	Extensive in southeast part of Sheet and as far westwards as Mangrove Creek.	Intrudes Halls Creek Group, Whitewater Volcanics, Mondooma Granite. Overlain unconformably by Kimberley Group.	Low biotite content and coarse porphyritic nature distinctive. Contains metasedimentary xenoliths locally near contacts with Mondooma Granite.
						INTRUSIVE	CONTACTS		
			Mondooma Granite Pbko		Granite, microgranite, and microgranodiorite; porphyritic with 2-3 mm phenocrysts of quartz and feldspar.	High, rounded but rugged boulder-strewn hills.	Eastern border of sheet area between Secure Bay and Alexander Creek.	Intrusives into White-water Volcanics and Halls Creek Group in Charnely Sheet area. Intrudes and contains xenoliths of Mount Disaster Porphyry. Intruded by Lennard Granite.	Probably equivalent to Bickley's Porphyry on Lennard River Sheet area.
			Mount Disaster Porphyry Pbkd		Microgranite; and minor microgranodiorite; porphyritic with felds-par phenocrysts up to 3cm.	Prominent steep-sided boulder-strewn hills.	At Mount Disaster.	Probably intrudes White-water Volcanics. Intruded by Lennard Granite, Secure Bay Granite, and Mount Disaster Porphyry.	Occurs mainly in association with Whitewater Volcanics.
						INTRUSIVE	CONTACTS		
			Whitewater Volcanics Bw		Undifferentiated; mainly crystal-poor rhyodacitic ash-flow tuff; minor rhyolitic lava.			Unconformable relationship with Halls Creek Group inferred from Lansdowne Sheet area. Overlain by King Leopold Sandstone. Intruded by Mount Disaster Porphyry, Mondooma Granite, and Lennard Granite.	Most crystal-poor tuffs in Yampi area probably occur low in Whitewater sequence.
			Bwa		Tuff; crystal-rich (and minor crystal poor) rhyodacitic, densely welded ashflow tuff.	Prominent rounded boulder-strewn hills.	East of Mount Disaster, minor outcrops southeast of Cone Hill and east of Mondooma Yard.		Lithologically similar to Mondooma Granite.
			Bws		Greywacke; fine-grained bedded tuffaceous grey-wacke, and bedded tuff.				Shows well developed graded bedding. K-feldspars have marginal quartz inclusions.

UNCONFORMITY

ERA	PERIOD	GROUP	ROCK UNIT AND SYMBOL	THICKNESS IN METRES	LITHOLOGY	TOPOGRAPHY	DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	REMARKS
PROTEROZOIC	LOWER PROTEROZOIC	LAMBOO COMPLEX	Nellie Tonalite Pbn		Tonalite and granodiorite; mesocratic with hornblende and biotite.	Low rounded hills and discontinuous ridges.	Flanking northeastern margin of Quartzite Range.	Contacts with Halls Creek Group are concordant and locally migmatitic.	Resembles more mafic varieties of McSherry's Granodiorite (Lennard River Sheet area). Strongly sheared locally.
						INTRUSIVE	CONTACTS		
			Woodward Dolerite Pbd	Sills up to 150 m thick	Metadolerite and metagabbro; dark green, fine to coarse-grained amphibolite: locally porphyritic.	Discontinuous boulder-strewn ridges or isolated hills up to 30 m relief. Locally as low rock pavements.	Between Boulder Hill and southeast corner of Sheet area: also in arcuate belt from Mount Nellie to Grants Find..	Intrudes Halls Creek Group. Intruded by Lennard Granite.	Sills are mostly discontinuous and lenticular. Well foliated. Locally difficult to distinguish from Hart Dolerite near Mount Nellie.
						INTRUSIVE	CONTACTS		
ARCHAEAN		HALLS CREEK GROUP	Halls Creek Group Ah	Unknown	Muscovite, sericite and chlorite schist; phyllitic shale siltstone and greywacke; minor chloritized, andalusite and garnet schist, and minor gneiss in southeast.	Low, hummocky hills and ridges.	Headwater areas of Townshend River, Mangrove Creek, and Little Tarraji River; also in southeast.	Intruded by Woodward Dolerite and granites of Lamboo Complex. Unconformably overlain by King Leopold Sandstone. Probably lateral equivalents of Olympio Formation.	Strongly folded, and cleaved. Metamorphic grade highest in southeast.

The Lamboo Complex (Lower Proterozoic) has been provisionally divided into three parts. The early Lamboo Complex comprises folded stratiform amphibolites within the Halls Creek Group, known as the Woodward Dolerite, and also the Nellie Tonalite.

The middle Lamboo Complex comprises the Whitewater Volcanics and high-level intrusive quartz-feldspar porphyries (Mount Disaster Porphyry, and Mondooma Granite).

Younger plutonic intrusives, mainly Lennard Granite, and its associated derivatives, the Secure Bay Adamellite and Tarraji Microgranite, and also the Kongorow and Cone Bay Granite of the Yampi Sheet area, are assigned to the late Lamboo Complex.

The relative positions of certain units may require modification when isotopic age determinations become available.

The Halls Creek Group and Lamboo Complex constitute a basement for the Kimberley Basin Succession. The Speewah Group (Gellatly et al., 1965) at the base, is exposed only around the margins of the Basin. It can be recognized only locally in the Yampi Sheet area.

The Kimberley Group, which conformably overlies the Speewah Group in other parts of the Kimberley Basin, is extensively exposed in the map area. This Group, which is up to 10,000 feet (3000 metres) thick, contains the King Leopold Sandstone, Carson Volcanics, Warton Sandstone, Elgee Siltstone, and Pentecost Sandstone. The King Leopold Sandstone at the base of the Group may contain beds that are lateral equivalents of the Speewah Group.

The formations of the Kimberley Group are generally conformable, but in this area minor unconformities exist between Pentecost Sandstone and Warton Sandstone and between Elgee Siltstone and the underlying Warton Sandstone and Carson Volcanics.

Sills of Hart Dolerite and of quartz feldspar porphyry (Wotjulum Porphyry) intrude the Kimberley Group. The Wotjulum Porphyry is confined to the northwest, where the Hart Dolerite is absent.

Palaeozoic and Mesozoic formations underlie the southern part of the Sheet area but are poorly exposed. The nomenclature used for these formations follows that of Guppy et al. (1958), Brunnschweiler (1951, 1954, 1957) and Playford & Lowry (1966).

Superficial deposits, of Cainozoic age, comprise laterite, residual soils, alluvium and tidal flat muds.

Table 2 summarizes the stratigraphy of the Yampi Sheet area.

ARCHAEAN

HALLS CREEK GROUP

Introduction

The Halls Creek Group is the oldest unit exposed in the Sheet area. It consists of eugeosynclinal sediments that have been metamorphosed mostly to greenschist facies. The Group occurs in broad belts, and as roof pendants between and within granite plutons.

The derivation of the name has been documented by Gellatly et al. (1968). Only the topmost formation (Olympio Formation) of a fourfold division of the Halls Creek Group in the type area is recognized in the Yampi Sheet area.

Stratigraphic Relationships

The base of the Halls Creek Group is not exposed. The Group is overlain unconformably by the King Leopold Sandstone and Palaeozoic conglomerate, and is intruded by the Woodward Dolerite and granites and porphyries of the Lamboo Complex, and by the Hart Dolerite.

Field Occurrence

Extent and location of outcrop. The Halls Creek Group forms a discontinuous belt extending from the southeast of the Sheet area northwest to the headwaters of the Townshend River, Sandy Creek, and the Little Tarraji River. Small isolated outcrops occur 6 km east of Cone Hill and about 5 km north of Mount Mandeville. Total extent of Halls Creek Group outcrops is about 200 sq km but a further 680 to 750 sq km of soil-covered areas are probably underlain by Halls Creek Group.

Topographic expression and photo-pattern. In the Tarraji River-Robinson River area, the Halls Creek Group forms low discontinuous strike ridges which usually project up to 10 m and rarely to 30 m above the soil and pindan scrub. The Group is better exposed around Mount Nellie and the Townshend and Little Tarraji River headwaters, where it shows the characteristic hummocky topography with closely spaced drainage. In the southeast it forms isolated rounded hills and ridges.

Lithology. The most abundant rock type is grey and pale red-brown phyllite and slightly recrystallised siltstone. These rocks are well foliated, and laminated to thin-bedded, but bedding is commonly obliterated by a well developed cleavage. Flaggy to blocky fine to medium-grained feldspathic sandstone, subgreywacke, and greywacke are subordinate.

The arenaceous rocks are little affected by metamorphism. The pelites contain garnet, chloritoid, and andalusite in restricted areas of higher grade metamorphism (see chapter on metamorphism). Garnetiferous phyllite occurs in the southeastern part of the Sheet area between Limestone Spring and Mondooma Yard and andalusite-bearing phyllite to the southeast of Parderoo Pool, at the eastern edge of the Sheet area. The garnet is dull red-brown, and forms porphyroblasts from 0.5 to 1.5 cm diameter. It is associated with coarse flakes (0.5 cm) of muscovite, arranged in conjugate directions forming two cleavages. The andalusite forms porphyroblasts up to 1 cm across and 3 cm long which diminish in size westwards and eventually disappear from the phyllites two or three kilometres from the eastern Sheet boundary. Chloritoid phyllite occurs 8 km east and southeast of Boulder Hill (Figures 4, 5). Phyllite with discordant biotites found in the Townshend River area possibly represents chloritoid phyllite in which the chloritoid is pseudomorphed by biotite.

The psammitic rocks are less abundant than the pelitic rocks, but generally they outline the bedding in the sequence. They are dull buff to grey, and show little or no cleavage development. In the Mondooma area they locally show current-bedding and have a granoblastic texture.

Rare variants of these common rock types include porphyroblastic magnetite-muscovite schist near Sandy Creek, chlorite-sericite schist with pyrite pseudomorphs and well-cleaved 'roofing slate' from east of Boulder Hill, and quartz-feldspar-biotite-tourmaline gneiss forming the wall rock in parts of the Mondooma Mica mine.

Quartz veins ranging from 1-30 cm wide are ubiquitous. The quartz is generally pale blue-grey to white, massive, and forms pinch-and-swell lenticles or ptygmatic and folded veins in the phyllites. Masses of pale green chlorite are widespread in the veins, and tourmaline is a constant accessory. Minor copper mineralization associated with these veins is present in the Mondooma, Little Tarraji, and Townshend River areas (see Economic Geology).

Contact Relationships

The Halls Creek Group is intruded by the Woodward Dolerite, Mondooma Granite, Lennard Granite, Nellie Tonalite, and Mount Amy Granite, and is overlain unconformably by the King Leopold Sandstone.

Contacts with Woodward Dolerite. The Woodward Dolerite occurs as folded sills within the Group, but very few contacts have been observed. Usually the pelites or psammites are slightly hornfelsed, producing, for example, the granoblastic texture in psammite in the southeast of the Sheet.

Contacts with Mondooma Granite. The Halls Creek Group is in direct contact with the Mondooma Granite 3 km north and north-northwest of Clara Hill. The granite contains a few small sedimentary xenoliths and the Halls Creek Group appears slightly recrystallized. Otherwise both rock types are unaltered.

Contacts with Nellie Tonalite. Localized development of lit-par-lit migmatite at the contact, e.g. 8 km west-northwest of Mt Nellie, suggests that the Nellie Tonalite intrudes the metasediments. Elsewhere the contact is sheared.

Contacts with Lennard Granite. Metamorphism is generally confined to recrystallization of the muscovite in the phyllite to larger decussate aggregates, and to obliteration of cleavage for a few feet from the contact. A possible exception is the development of andalusite in the far southeast of the Sheet area, just north of Clara Hill. Some of the andalusite is due to regional metamorphism, but a granoblastic hornfels with andalusite may possibly be a product of thermal metamorphism. Most of this occurrence lies in the Charnley Sheet area, and has been described by Gellatly et al. (1971).

Fig. 5a Banded chloritoid psammites, 6 km east-southeast of Boulder Hill. Prominent foliation is bedding. Scale is 25 cm long. (Neg GA 9647)
G.M.D.

Fig. 5b Section of chloritoid psammites parallel to bedding. Chloritoid development is irregular, but mostly is sub-parallel to bedding. Locality as above. (Neg GA 9643) G.M.D.

In general, this lack of contact metamorphism contrasts with the amount of recrystallization undergone by xenoliths of probable Halls Creek Group in the Lennard Granite, e.g. in xenolith swarms near contacts between the Lennard and Mondooma Granites. Some inclusions are only slightly modified, but most are in all stages of reconstitution to massive and banded biotitic and amphibolitic gneiss.

Contacts with Mount Amy Granite. Pegmatite and aplite related to the Mount Amy Granite intrude the Halls Creek Group near Clara Hill. The metasediments are partly granitized, and contain large quartz augen and feldspar porphyroblasts.

Petrography

Psammitic rocks. Quartz-chlorite-muscovite psammites occur in the Halls Creek Group throughout the Sheet area. Two specimens from near the Quartzite Range show a granular mosaic of fine-grained quartz cut by small oriented flakes of pale green chlorite. The chlorite contains minor inter-layered slivers of muscovite, and defines a foliation, probably the earliest cleavage. This cleavage is intersected by thin stringers of muscovite, which probably represent a second cleavage. The mica in this cleavage contains numerous fine-grained ferruginous inclusions. Accessories are mainly rutile, zircon, and minor sphene and tourmaline.

Higher grade psammites occur in the southeast. They contain a granoblastic mosaic of quartz and feldspar (mainly plagioclase) cut by abundant sub-parallel flakes of biotite, which is pleochroic from brown to pale straw. It is intergrown with muscovite, which appears to be oriented at a small angle to the biotite. It is also slightly skeletal and poikilo-blastic. A single anhedral grain of poikiloblastic garnet was noted. Accessory minerals are chlorite, calcite, and abundant zircon.

The chloritoid-bearing rocks southeast of Boulder Hill are also predominantly psammitic. In one sample chloritoid forms pale green coarse-grained poikiloblastic flakes up to 2 mm long, and is highly sieved with quartz inclusions. In another sample the poikiloblastic chloritoid contains quartz inclusions showing a regular hour-glass pattern. The matrix of these rocks is mainly granoblastic quartz and minor amounts of oriented sericite/muscovite flakes. Chloritoid orientation is independent from that of muscovite. Accessories are abundant yellow-green tourmaline showing secondary overgrowths, and rare zircon and ferruginous opaques.

Pelitic rocks. The metamorphic grade of these rocks ranges from greenschist to almandine-amphibolite facies. Only greenschist facies rocks were examined in thin section, although garnetiferous schists are found locally in the southeast. The most abundant and widespread pelites are quartz-sericite phyllites. Granoblastic quartz forms lenticular aggregates up to 2 mm wide, and is closely associated with sericite/muscovite flakes throughout the rock. The micas are highly oriented, and define both first and second cleavages. The second cleavage is marked by a greater amount of fine-grained opaque material associated with the sericite. In one specimen large subhedral ?ilmenomagnetite grains partly altered to sphene are abundant. Quartz forms mosaics in the strain shadows bordering these porphyroblasts.

Some pelites are highly chloritic, and contain pale green oriented chlorite stringers defining an early cleavage, and large discrete plates of muscovite transecting the schistosity. Accessory minerals are tourmaline (olive green to pale yellow absorption), sphene, and in one specimen, abundant rutile.

Discussion

The rocks of the Halls Creek Group show a general lithological uniformity over the Sheet area and are tentatively equated with the Olympic Formation. The siltstones and greywackes which predominate in this area commonly show primary sedimentation features suggestive of deep water, probably eugeosynclinal, deposition.

LOWER PROTEROZOIC

LAMBOO COMPLEX

WOODWARD DOLERITE

Introduction

Metamorphosed basic sills and dykes restricted to the Halls Creek Group are referred to the Woodward Dolerite, and named after the Woodward Range, in the Mount Ramsay Sheet area (Gemuts, in press).

Field Occurrence

The Woodward Dolerite is confined to the southeastern part of the Yampi Sheet area near Limestone Spring, and to small areas at the headwaters of the Little Tarraji River, Townshend River, and Sandy Creek. Exposures cover about 25 sq. km, but is poorly exposed and probably include a much greater area.

It forms prominent elongate dark grey to black hills, up to 90m high, surrounded by soil plains or low-lying poorly exposed phyllites. Many of the hills support a thick growth of cane grass, which in places gives rise to a smooth-toned light-coloured photo pattern.

The unit occurs as sills 6 m to several hundred metres thick which intrude, and have been folded with, the Halls Creek Group. The folding and distribution of individual sills are not as well defined as in the Lennard River Sheet area because of the discontinuous nature of the dolerite outcrops and the relatively poor exposures of the Halls Creek Group. The sills are indistinctly layered; dips range from 35° to 70°.

Macroscopic Appearance and Lithological Variation

The Woodward Dolerite is uniformly dark green to grey, medium to coarse-grained, and even-grained to porphyritic. In most cases the ophitic to subophitic texture of the dolerite has been obscured by re-crystallization to amphibolite. The amphibolite is massive, but locally shows banding or layering defined by variations in mafic content or by phenocryst size. Some sills show relict fine-grained chilled margins and coarse-grained porphyritic central zones.

The coarsely porphyritic phase of the Dolerite is very distinctive. It forms layers up to 20 m. thick which are bounded by non-porphyritic amphibolite, or by phyllite. The phenocrysts of plagioclase are usually 1 to 3 cm diameter, and appear to consist of two or more smaller crystals aggregated together. The giant 'glomerocrysts' up to 20 cm diameter which are found in the Charnley Sheet area are rare in the Yampi Sheet area. Typical texture of the porphyritic phase is shown in Figure 6A

Boundaries of the porphyritic amphibolite with even-grained varieties are gradational. In one locality the porphyritic phase grades laterally as well as vertically into even-grained material.

Along shear zones the Dolerite is changed to chlorite schist in which large feldspar augens are prominent.

Contact Relationships

Contacts with the enclosing Halls Creek Group are poorly exposed, although at one sharp contact a narrow zone of hornfels has been developed in the metasediments. Thin lenses of pegmatite are common in the Dolerite, and these contain coarse flakes of muscovite, biotite, and minor garnet. The pegmatites extend discontinuously in the Limestone Springs area for up to 1 km, and usually range from 0.3 to 3 m. thick. Minor copper and major mica mineralization are associated with these pegmatites (see Economic Geology).

Petrography

Two even-grained and one porphyritic dolerite from the south-east corner of the Sheet and eight fine to coarse-grained dolerites from the Little Tarraji area were examined in thin section.

In general the original subophitic texture is moderately well preserved, although many samples are completely recrystallized. Deuteric alteration is widespread, and small veinlets of epidote and calcite are common. The predominant minerals are amphiboles and plagioclase. In all specimens amphibole forms from 50 to 70 percent of the rock. It shows variable pleochroism, and two distinct pleochroic schemes are as

Fig. 6a Typical texture of porphyritic Woodward Dolerite showing prominent plagioclase phenocrysts. 6 km west of Clara Hill. (Neg M 431/21) G.M.D.

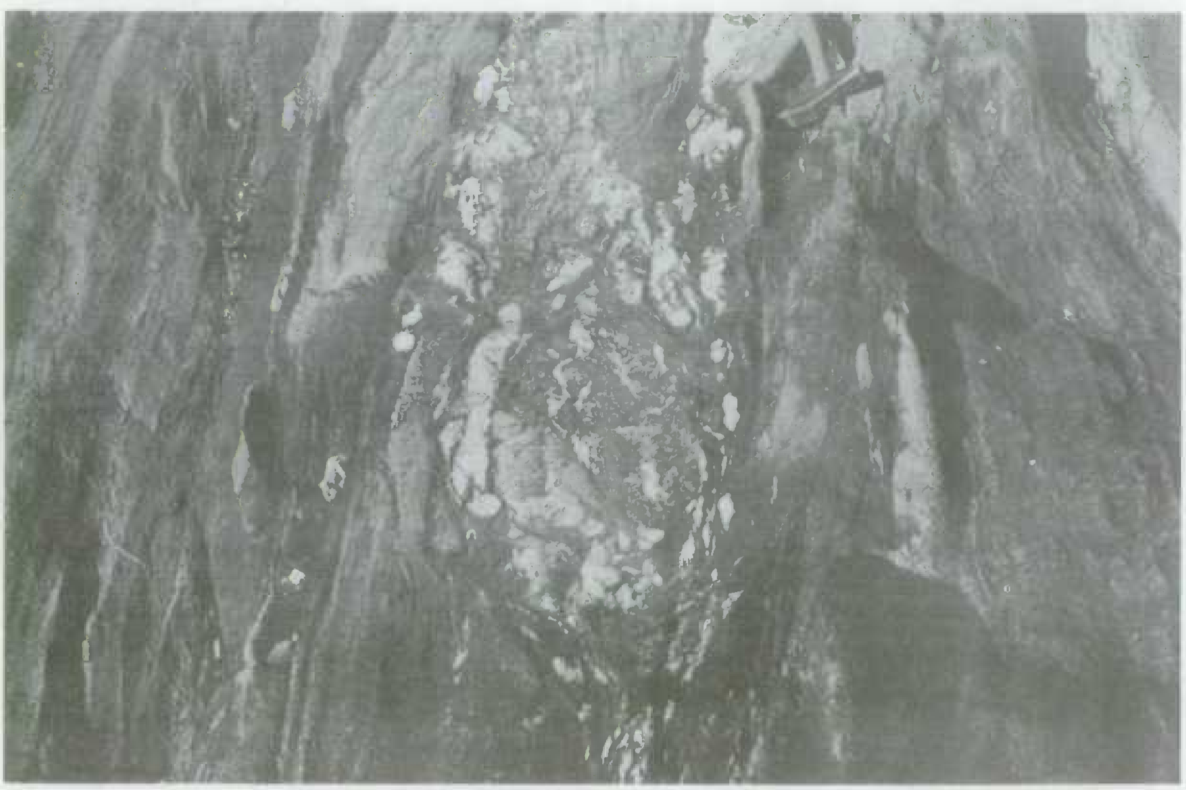


Fig. 6b Boudin of tonalite with surrounding lenticles of quartz, in quartz-biotite schist of Halls Creek Group near margin of Nellie Tonalite 8 km north-west of Mount Nellie. (Neg M 1000/7) D.C.G.

follows: X = pale fawn, Y = green, Z = pale blue-green, and X = pale fawn, Y = brown-green, and Z = brown. These differences probably reflect slightly higher temperatures of recrystallization in the amphibolite containing the brown amphibole. The pale green amphibole is probably actinolite, which is granular or less commonly lath-like, well-twinned, and poikilitically encloses some plagioclase and small quartz grains. Quartz also forms small granular mosaics in some samples.

Plagioclase in the even-grained varieties of amphibolite is interstitial to the amphibole. It forms from 25 to 30 percent of the rock, and is usually granular. Diffuse albite and pericline twin lamellae are common, but allow no determination of composition. The plagioclase in the porphyritic phase forms glomerocrysts in which two or three individual grains up to 5 mm are intergrown or aggregated. Most composite fields are flecked with oriented needles of amphibole and contain patches of recrystallized granular (0.3 to 0.6 mm) plagioclase. The coarse grains show albite and pericline twinning, and a composition of An_{55}, sodic labradorite, was determined. Alteration to chlorite, sericite and epidote is widespread but variable in degree.

Less commonly plagioclase forms laths up to 5 mm long, and in one specimen they are associated with quartz-alkali feldspar granophyric intergrowths.

The accessory minerals are mainly ilmenite with abundant associated sphene, some clinozoisite/epidote and rare calcite. Very fine-grained amphibole shreds occur in the plagioclase grain boundaries.

Discussion

Difficulty was experienced in certain areas in the field distinguishing Woodward Dolerite from Hart Dolerite. The latter is readily identified where it intrudes the Kimberley Group. Around Mount Nellie both dolerites are metamorphosed and almost indistinguishable. The Woodward Dolerite locally contains a darker green amphibole than the Hart Dolerite. However with metamorphic convergence due to strong shearing the two types become identical.

NELLIE TONALITE

Introduction

The name Nellie Tonalite (new name) is applied to a belt of mesocratic, foliated hornblende-biotite tonalite, diorite, and granodiorite lying to the west and northwest of Mount Nellie. The tonalite is locally migmatitic. It is in places difficult to distinguish the Nellie Tonalite from the Woodward Dolerite and the Hart Dolerite since all are locally sheared and metamorphosed in the greenschist facies. The Nellie Tonalite can generally be distinguished in hand specimen from both dolerites by its higher biotite content; also it usually has a darker green amphibole than is found in the Hart Dolerite nearby.

The reference area is 1652E, 29194N, in the Mangrove Creek Valley, about 8 km northwest of Mount Nellie.

Field Occurrence

The Nellie Tonalite is confined to a narrow, northwest-trending discontinuous belt, about 19 km long with an average width of 1.6 km, that flanks the northeastern margin of the Quartzite Range. It forms rounded hills and ridges with an even-grey photo-pattern. The form of the tonalite mass is unknown since only one margin is exposed. A strong foliation is inclined to the southwest and south at angles of 40° to 60°, and is probably parallel to the plane of the contract. Along parts of its margins the Tonalite is intensely sheared.

In hand specimen the rocks are medium to coarse-grained, dark grey and grey-green, gneissose or schistose, and contain conspicuous biotite and hornblende in a quartz-feldspar matrix. Locally leucocratic hornflende-free varieties are interbanded with a mesocratic hornblende-bearing rock, producing migmatites in which the two components alternate in bands 10-30 cm thick. The strongly sheared equivalents are grey-green chlorite schist and phyllite.

Contact Relationships. Contacts with the Halls Creek Group phyllites are obliterated by intense shearing, and evidence of intrusive relationships cannot be established. The tonalite is overlain unconformably by the King Leopold Sandstone to the southwest. No contacts have been observed with the Hart Dolerite, but the latter post-dates the King Leopold Sandstone, and thus also the Nellie Tonalite. The

Tonalite is intruded locally by small lenticular quartz pods up to 20cm thick and 60-120 cm long.

Petrography

The Nellie Tonalite includes granodiorite, tonalite and diorite all of which are characteristically rich in mafic minerals. Undeformed specimens generally contain appreciable amounts of micropegmatite. Most specimens are hornblende bearing.

A typical specimen consists essentially of quartz (ca 5%); unzoned subhedral crystals of calcic oligoclase (ca 25%) showing albite, carlsbad, and rarely baveno twinning, and containing abundant small inclusions of hornblende; micropegmatite (15%); large (2 mm to 4 mm) subhedral poikilitic hornblende (35%) showing strong pleochroism (X = very pale brown, Y = grass green, Z = blue-green); small decussate flakes of yellow-brown to grey-brown biotite (10%); and scattered anhedral grains of carbonate (5%); and minor accessory black opaque iron oxide, small granules of epidote associated with biotite, elongate apatite crystals mostly as inclusions in hornblende, and small scattered grains of sphene and goethite.

The mesocratic material in the migmatites consists of small anhedral interstitial grains of quartz (15%) equant euhedral and subhedral zoned plagioclase (50%) of composition about An_{30}, small parallel flakes of brown biotite concentrated into films and lenticles (25%), and scattered grains of carbonate. Accessories (less than 5%) are hornblende, micropegmatite, black opaque oxide, bright green chlorite, epidote and apatite.

The leucocratic bands of the migmatites contain less biotite (5 to 10%), and more quartz (20 to 25%) and potash feldspar (?10%), some of it as micropegmatite. The rock is slightly sheared, and the biotite is partly altered to an assemblage of pale green chlorite and sphene.

A highly sheared equivalent of the normal (hornblende-rich) tonalite illustrates the ultimate stage in the mineralogical changes associated with strong shearing. The rock consists entirely of bands of very pale green, slightly pleochroic, length-fast chlorite showing parallel extinction, alternating with bands and lenticles of quartz. Both chlorite and quartz are studded with 0.3 mm euhedral crystals of sphene which makes up about 8 percent of the rock.

Discussion

Lithologically the Nellie Tonalite resembles the more mafic varieties of McSherrys Granodiorite. The presence of migmatites suggests possible correlation with the Tickalara Metamorphics, but the migmatites are localized and confined to the marginal areas of the mass. The main part of the outcrop is homogeneous, except where modified by later deformation, and this suggests an igneous origin. This concept is supported by the primary nature of much of the plagioclase twinning, and the euhedral form and zoning of some of the plagioclase.

In some specimens an abundance of small euhedral inclusions of amphibole (derived from secondary clinozoisite?) within some plagioclase crystals and the absence of zoning in these plagioclases, suggest an early period of moderately high grade metamorphism. A later period of strong, predominantly dynamic, metamorphism has resulted in development of chlorite schist from the Tonalite.

MIDDLE LAMBOO COMPLEX

WHITEWATER VOLCANICS

Introduction

The Whitewater Volcanics are an almost continuous sequence of acid volcanics throughout the East and West Kimberleys. The name is derived from acid volcanic rocks in the East Kimberley called the Whitewater Formation by Smith (1963), after Whitewater Well in the Dixon Range Sheet area, and subsequently renamed Whitewater Volcanics by Dow et al., (1964).

Petrographic nomenclature used here is that of Branch (1966) and Ross & Smith (1961), who define the terms ash-flow tuff, welded tuff, etc. To distinguish further between some of the rocks the non-genetic terms crystal-rich tuff and crystal-poor tuff have been introduced. The former

45

is used when crystals and crystal fragments make up more than 50 percent of the rock.

Field Occurrence

The Whitewater Volcanics occur principally near the eastern margin of the Sheet area, and are found in three distinct localities: on the southern shore of Secure Bay forming the eastern part of the Mount Disaster massif; to the south around the Pardaboora River; and about 2 km east of Cone Hill. The total area of outcrop is 95 sq. km, of which about 80 sq. km occur in the Secure Bay area.

The Whitewater Volcanics form rugged rocky hill country and are more resistant to weathering than the granites of the area. The main outcrop forms an upstanding massif rising to some 180 to 240 m. above the surrounding country.

The structure of the Whitewater Volcanics near Secure Bay is uncertain because of the paucity of well preserved bedding. Interpretation of the structure is based on rare measured dips on flow banding in the crystal-rich ash-flow tuffs and on the attitude of the bedded tuffs (ash-fall tuffs?). The Volcanics (along with the associated Mount Disaster Porphyry) probably form a large roof pendant within a complex of later granites. Limited evidence available suggests the presence of a northeast-trending anticlinal axis in the Volcanics about 11 km east of Mount Disaster and a complementary syncline, with a more easterly trend, lying about 3 km to the north of this. Dips range from 35° to vertical and the folds may be described as 'close' (terminology of Fleuty, 1964). The total thickness present is probably about 2,400 to 3,000 m.

The main rock types are pale grey crystal-rich tuff and dark grey crystal-poor tuff, both consisting of phenocrysts of feldspar and less abundant quartz in a cryptocrystalline matrix. These tuffs are generally massive but locally show streaky flow-banding. Intercalated with these tuffs are remnants of a thin member of fine-grained bedded tuff which consists of dark grey fine-grained acid volcanic material with small (1 mm) scattered grains of quartz and feldspar. Graded bedding is well preserved locally (Figure 7A).

Contact Relationships

Contacts have been observed only with Mount Disaster Porphyry (q.v.). In general, bedding in the volcanics is parallel to granite contacts, but on Shovel Creek the Lennard Granite cuts across the strike of the Volcanics and aplite and pegmatite veins derived from the granite cut the Volcanics 5 km southeast of Mount Disaster.

Petrography

The Whitewater Volcanics in this area can be subdivided lithologically into two suites; coarse-grained ash-flow tuffs with a maximum grain size of about 4 to 5 mm, and less abundant fine-grained bedded tuffs with a maximum grain size of 1 to 2 mm. The ash-flow tuffs contain from 35 percent to 70 percent of phenocrysts, and may be divided into crystal-rich (more than 50 percent phenocrysts) and crystal-poor (less than 50 percent) varieties; the bedded tuffs contain only about 1 percent to 10 percent of phenocrysts.

The fine-grained bedded tuffs consist of scattered splinters and crystals of quartz, potash feldspar, and sericitized plagioclase in a very fine-grained matrix (average grain diameter = 0.05 to 0.01) consisting mainly of the same minerals plus minor amounts of pale brown phlogopite, pink zircon, epidote, and amphibole. Bedding is outlined by thin films of quartz granules. Rare veinlets of fluorite cut one of the rocks. Potash feldspar is a microperthite which in one specimen shows narrow overgrowths containing abundant small quartz inclusions. These overgrowths with quartz inclusions are similar to those found in the Mondooma Granite.

The crystal-rich and crystal-poor tuffs contain abundant euhedral to subhedral crystals, and markedly anhedral crystal fragments and splinters - of quartz, potash feldspar, and highly sericitized acid plagioclase, ranging from about 1 mm to 5mm. These are set in a cryptocrystalline matrix (? devitrified glass) of quartz-feldspar-biotite with associated epidote, clinozoisite, and rare small granules of zircon and iron oxide. The matrix is structureless and lacks glass shards. Narrow cloudy overgrowths containing small quartz granules occur on potash feldspar phenocrysts in some of the tuffs.

The composition of the tuffs varies within narrow limits; the main indicator of compositional variations in the tuffs is the percentage

Fig. 7a Tuffaceous sediments of Whitewater Volcanics showing well-developed graded bedding. Shovel Creek, 2 km north of King Creek track. (Neg G 6918) D.C.G.

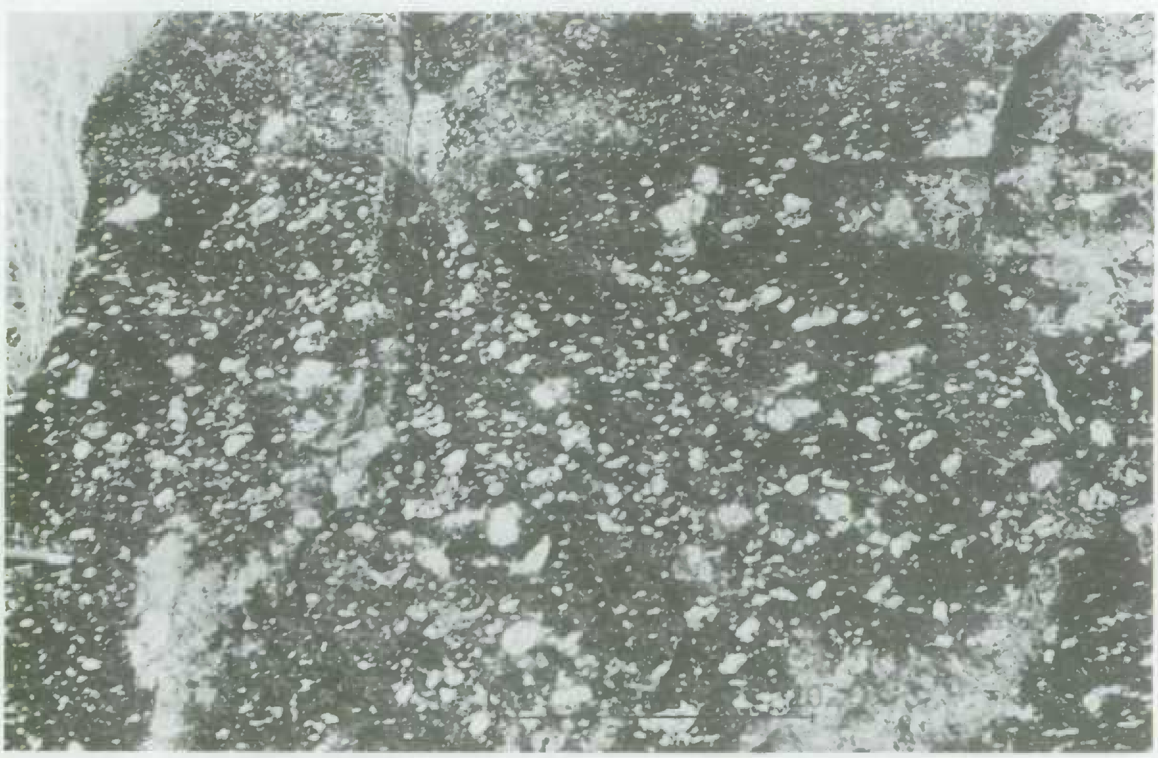


Fig. 7b Typical texture of Mount Disaster Porphyry. Photograph shows contact with crystal-rich ash-flow tuff of Whitewater Volcanics. Note the flow alignment of phenocrysts common to both rock types. 9 km east-southeast of Mount Disaster (Neg G 9690). D.C.G.

of quartz phenocrysts, which ranges from about 3 to 15 percent of the total rock. Plagioclase generally predominates over potash feldspar but relative proportions are difficult to estimate because of the highly altered nature of the plagioclase. Tentative estimates of relative abundances of phenocrysts indicate that the rocks range from rhyodacite to basic dacite.

Discussion

In the Lennard River Sheet area the subdivisions of the Whitewater Volcanics appear to be at least partly stratigraphic in their occurrence; in the Yampi Sheet area the same sequence cannot be recognized and it is probable that only part of the Whitewater succession is preserved there. The base is not exposed and the succession probably corresponds to the upper part of the Lennard River succession. A tentative correlation is given below:

YAMPI	LENNARD RIVER
5. Minor tuffaceous sediments (possibly overlain by autoclastic quartz feldspar porphyry).	5.
4. Crystal-rich rhyodacite ash-flow tuff intruded by Mount Disaster Porphyry.	4. Crystal-rich rhyodacite ash-flow tuff intruded by Mount Disaster Porphyry.
(Intruded by Lennard Granite, Secure Bay Granite, etc.).	3. Crystal-poor rhyodacite ash-flow tuff.
	2. Dacite and rhyodacite biotite-rich ash-flow tuff.
	1. Bedded rhyodacite tuff; minor tuffaceous siltstone, sandstone and conglomerate.

The Whitewater Volcanics are closely related spatially to the Mount Disaster Porphyry. Although the two rock types have been observed in sharp contact, their age relationships are uncertain. They are interbanded locally and, although the Mount Disaster Porphyry is known to intrude Whitewater Volcanics in the Lennard River Sheet area, there is no marginal chilling or flow foliation of phenocrysts that might demonstrate similar age relationships here.

The presence of peripheral quartz inclusions in potash feldspar in a bedded tuff is significant since most other rocks in the West Kimberley (Bickleys Porphyry and Mondooma Granite) that show this phenomenon are apparently intrusive. Evidence of this specimen suggests that the quartz inclusions can result from crystal growth during welding or possibly during subsequent thermal metamorphism, and cannot be taken as evidence of an intrusive origin.

MOUNT DISASTER PORPHYRY

Introduction

The name Mount Disaster Porphyry (new name) has been applied to very distinctive, probably intrusive, biotite-bearing porphyritic microgranite found on the Yampi, Charnley, Lennard River, and Lansdowne 1:250,000 Sheet areas. The Mount Disaster Porphyry contains prominent large phenocrysts of quartz, potash feldspar, and plagioclase. Feldspar phenocrysts are generally 2 to 3 cm long. The relatively large phenocryst size and the fine-grained matrix give the rock a distinctive appearance.

It has affinities with Bickleys Porphyry*, but differs from it in the larger size of phenocrysts present. Its distribution is closely related to that of the Whitewater Volcanics, to which it may also be related.

The reference area is around Mount Disaster (2045E, 29040N) in the eastern part of the Yampi Sheet area.

Field Occurrence

Three outcrops of Mount Disaster Porphyry are known in the Sheet area. The total area of outcrop is about 36 sq km. The principal outcrop forms Mount Disaster peak, at the western end of the Mount Disaster massif and extends eastwards for 9 km along the northern margin of the massif

---

*In the original mapping of the Lansdowne 1:250,000 Sheet area (Gellatly et al., 1965), the Mount Disaster Porphyry was included with Bickleys Porphyry as a coarser-grained variant.

to Secure Bay. A further outcrop is found a short distance to the south of the eastern part of the main one. A small isolated occurrence is found to the west near the Tarraji River.

The Porphyry forms prominent steep-sided hills, more erosion-resistant than the adjacent Lennard and Secure Bay Granites, but similar in weathering characteristics and photo-pattern to the contiguous Whitewater Volcanics.

The form and mode of occurrence of the Mount Disaster Porphyry are uncertain. Foliation dips have been observed locally and these are parallel or subparallel to the bedding in the Whitewater Volcanics. Also, these dips are parallel to the trend of the outcrops, and it is likely that in the Yampi Sheet area the Mount Disaster Porphyry forms stratiform bodies.

In hand specimen the Porphyry is a grey rock, consisting of euhedral phenocrysts of white to pink potash feldspar (2 cm to 4 cm), pale grey or blue-grey quartz (0.5 cm to 1 cm), and opaque white or very pale green plagioclase, in a dark grey fine to medium-grained biotite-bearing siliceous groundmass. The groundmass generally shows streaky flow-banding which curves round the phenocrysts, but in places is massive and structureless.

In the Yampi area no cross-cutting veins of the Porphyry have been noted, and no late stage veins have been found cutting the Porphyry.

Contact Relationships

The Mount Disaster Porphyry adjoins outcrops of Lennard, Secure Bay, and Mondooma Granites, Tarraji Microgranite, and Whitewater Volcanics. Contacts have been observed only with the Whitewater Volcanics.

About 8 km east-northeast of Mount Disaster bands and lenses of the Porphyry up to 1 m across are enclosed in tuffs of the Whitewater Volcanics. As seen in two dimensions in outcrop these lenses are discontinuous and could be xenoliths; on the other hand they locally show flow-alignment of phenocrysts parallel to the contacts, suggesting that they may be intrusive. Where continuous bands of the two rock types are found both show flow-alignment of phenocrysts parallel to the contact; neither type shows contact alteration. The contacts are mostly sharp, but locally they appear to be gradational. On the southern margin of the massif 11 km east of Mount Disaster the Porphyry forms alternating layers about 180 m thick with the Whitewater Volcanics. Contacts are sharp and well defined, but slightly sheared. Both the Porphyry and the Whitewater Volcanics show poorly developed flow-alignment of phenocrysts.

Petrography

In thin section the Mount Disaster Porphyry consists of phenocrysts of potash feldspar, plagioclase and quartz, totalling about 50 to 60 percent of the rock in a fine grained matrix (average grain diameter 0.05 mm).

Plagioclase, the most abundant type of phenocryst, occurs as anhedral to subhedral grains up to 1 cm and is partly or wholly altered to a fine grained aggregate of sericite and zoisite. Potash feldspar forms euhedral to subhedral slightly rounded phenocrysts up to 3 cm across, consisting of microcline microperthite showing incipient cross-hatching and containing 1 to 2 mm nuclei of oligoclase and 0.2 mm inclusions of quartz. Inclusions tend to form narrow zones parallel to the crystal margins. Quartz phenocrysts, up to 5 mm across, show resorption embayments.

The matrix consists of quartz and microcline, plus abundant small grains of sericite and clinozoisite, and small lenticular clots of biotite, epidote, sphene, and a pale green chlorite.

Discussion

Evidence of the contacts observed between the Mount Disaster Porphyry and the Whitewater Volcanics are inconclusive regarding the relative ages of the two, and whether the Porphyry is extrusive or intrusive.

A summary of evidence in favour of an extrusive origin (or against an intrusive one) is as follows:

1. No definitely intrusive veinlets of the Porphyry have been found.

2. Fine grain size of groundmass.

3. Absence of late stage veins within the Porphyry (e.g. aplites and pegmatites).

4. Localized gradational contacts with Whitewater Volcanics.

Evidence in favour of an intrusive origin (or against an extrusive one) is as follows:

1. Localized flow-foliation noted parallel to contact with Whitewater Volcanics.

2. Large phenocryst size.

3. Glass shards, and fragmental crystals absent.

MONDOOMA GRANITE (new name)

Introduction

Mondooma Granite refers to porphyritic microgranite and minor coarse and even-grained granite, found in the southeast part of the Yampi Sheet area and extending southeastwards into the Charnley and Lennard River Sheet areas.

It is similar to Bickleys Porphyry of the Lansdowne and Lennard River Sheet areas, but tends to be more granitic in texture. The Mondooma Granite was named because of this textural difference and because of distance of separation from outcrops of Bickleys Porphyry. In hand specimen the Mondooma Granite closely resembles the coarse-grained crystal-rich ash-flow tuffs of the Whitewater Volcanics but can generally be distinguished from these in thin section.

The name is taken from Mondooma Creek and yard where extensive areas of this granite are exposed.

Field Occurrence

The Mondooma Granite crops out over 100 sq. km. in the Yampi Sheet area, and is confined to the east and southeast parts of it. More extensive outcrops are found in the Charnley Sheet area. It is particularly well exposed around Clara Hill and north of the Pardaboora River, where it forms bold and moderately rugged boulder-strewn hills with relief of up to 120 metres. The photo pattern is generally dark coloured due to a lack of soil and vegetation on most of the hills.

The Granite is usually massive, but shows a number of variable but shallow-dipping foliations which suggest that it is possibly a sheet intrusion.

It is typically light grey and porphyritic, though massive, even-grained varieties do occur. The phenocrysts are chiefly quartz, which rarely exceeds 7 mm diameter, feldspar, biotite, hornblende and, rarely, hypersthene. The groundmass is generally microgranitic, and is not as fine-grained as some varieties of the Whitewater Volcanics. The bipyramidal form of the quartz phenocrysts is distinctive, but is less apparent in the even-grained varieties of granite.

The Mondooma Granite locally contains areas of non-porphyritic or only sparsely porphyritic biotite-bearing microgranite. These variants (see below) which lithologically resemble the Richenda Micro-granodiorite (Lennard River Sheet area) and the Tarraji Microgranite, are completely enclosed by the Mondooma Granite and have gradational contacts with it.

Coarsely porphyritic lenticular patches up to 6 m across and 30 m along are common in the Mondooma Granite, and these resemble the Mount Disaster Porphyry. Phenocrysts of alkali feldspar up to 1.5 cm. long, and of quartz and plagioclase are common in these zones. Such coarsely porphyritic zones are more abundant in the Charnley Sheet area (Gellatly et al.,1969).

An association of non-porphyritic microgranodiorite and micro-tonalite forms three small rounded hills about $2\frac{1}{2}$ km north-northeast of Parderoo Pool, in the southeast of the Sheet area. It has been shown separately on the accompanying map, and is of very limited extent.

The granodiorite shows a shallow-dipping foliation defined by probable flow banding and alignment of small basic xenoliths. The banding also is partly compositional, and suggests the mass is a small incipiently layered lenticular intrusion.

In hand specimen the granodiorite is grey, mesocratic and even and medium-grained. It contains numerous bands, veins and inhomogeneous patches. Intergrowths of quartz and radial aggregates of tourmaline are common along joint cracks.

Because of lack of outcrop, contact relationships are unknown, but it is assumed on petrographical evidence to be a variant of the Mondooma Granite.

Contact Relationships

Contacts with Halls Creek Group. The Mondooma Granite intrudes the Halls Creek Group, but contact effects are limited to slight recrystallization of the metasediments and a narrow chilled margin, containing a few xenoliths, in the granite.

Contact with Mount Disaster Porphyry. About 19 km east of Mount Disaster on the King Creek track the Mondooma Granite contains rare xenoliths of Mount Disaster Porphyry up to 60 cm, and scattered xenoliths of similar material have been noted about 3 km farther south.

Contacts with Whitewater Volcanics. Contacts with the Volcanics are indistinct and appear gradational, the principal changes being a coarsening of the groundmass in the Mondooma Granite, the presence of pyroxene or pyroxene pseudomorphs in it, and a greater resistance to weathering displayed by the Mondooma Granite.

The Mondooma Granite is intruded by rare aplite dykes and quartz veins. Contacts with the Lennard Granite are described in the section on that unit.

Petrography

Three types of Mondooma Granite are recognized. These are (a) porphyritic, (b) medium to coarse even-grained granite, and (c) non-porphyritic and sparsely porphyritic microgranite.

Porphyritic granite is common in the vicinity of Clara Hill, and east-northeast of Mount Disaster. It differs texturally from type (b) and locally contains pyroxene, which is absent in (b). The texture is porphyritic, with abundant phenocrysts of quartz, plagioclase, potash feldspar, biotite, hornblende and orthopyroxene. The groundmass is a fine-grained holocrystalline mosaic of quartz and potash feldspar.

Quartz occurs as large subhedral corroded phenocrysts. The plagioclase is generally andesine, and appears more strongly zoned than in the type (b) granite; some grains contain marginal zones of quartz blebs, and are enclosed poikilitically by orthopyroxene. Potash feldspar is perthitic and generally untwinned, and contains the characteristic marginal zone of quartz blebs, the inner boundary of which is irregular. The feldspar appears to have a low to moderate 2V. Biotite forms decussate patches with hornblende.

All phenocrysts are embayed and corroded.

Accessories are magnetite-ilmenite, sphene, zircon, apatite, calcite, zoisite and myrmekite. Magnetite-ilmenite is partly altered to sphene.

Orthopyroxene (3 to 5 percent) was observed in one specimen; an iron-rich variety with weak pleochroism from X=Y= very pale fawn, Z = pale green. It forms subhedral phenocrysts which are marginally altered to a fine-grained indeterminable amphibole and coarse-grained blue-green hornblende. An analysis of a pyroxene concentrate from the Charnley area indicates that the mineral is eulite of composition about Fs_{75-80} (Gellatly et al., 1969).

Type (b) is typical of the exposures southeast of Mount Disaster. It contains quartz (30 percent) which occurs as large discrete composite patches, and plagioclase (20 percent) which is andesine, An_{40}, and only slightly zoned. Most of the subhedral crystals are unaltered, but smaller grains in the matrix are saussuritized. Potash feldspar (40 percent) is perthitic microcline which forms large subhedral crystals containing zones of quartz blebs near the crystal margin. Myrmekite is associated with the potash feldspar. Biotite (19 percent) occurs as poikilitic platy phenocrysts showing a red-brown to straw pleochroism, and which contain inclusions of zircon, apatite, and sphene. Hornblende (2 percent) is possibly sodic, with X = olive fawn, Y = deep olive green and Z = deep blue-green.

In thin section rocks of type (c) are medium-grained and sparsely porphyritic and have a xenomorphic-granular texture. They are notably poorer in potash feldspar than other rocks of the Mondooma Granite (Table 3). Texturally they are intermediate between normal Mondooma Granite and other medium grained and intrusives in the area (e.g. Tarraji Micrögranite), having a coarser-grained groundmass, and being densely

TABLE 3 - ESTIMATES OF MODAL COMPOSITION - MONDOOMA GRANITE, YAMPI 1:250,000 SHEET AREA

Specimen No.	66.16 2012	66.16 2031	66.16 2032	66.16 2033	66.16 2034	66.16 2035	66.16 2053	66.16 2132	66.16 2133	66.16 2134	66.16 2135	66.16 2136	66.16 2020*	66.16 2021*	66.16 2022*
Phenocrysts Quartz	15	10	10	15	25	25	30	14	18	15	6	12	30	30.4	27.7
K feldspar	28	13	20	15	27	35	20	30	15	20	15	33	-	2.2	9.2
Plagioclase	20	30	30	40	35	20	35	25	30	35	48	20	45	40	43
Biotite	2	8	4	6	3	4	5	1	1	1	1	3	20	21.8	13.3
Hornblende	-	4	1	4	Tr	1	-	Tr	3	1	2	2	4	3.8	5.1
Pyroxene	-	-	-	Tr	-	-	-	Tr	3	3	3	Tr	Tr	-	-
Groundmass Quartz	20	15	10	7	2	5	4	8	10	10	9	15	-	-	-
K feldspar	10	10	18	10	3	7	5	18	17	13	12	10	-	-	-
Plagioclase	3	8	7	2	5	3	1	3	2	1	3	5	-	-	-
Others	2	2	-	1	-	-	-	1	1	1	1	-	1	1.8	1.7
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

* Non porphyritic and sparsely porphyritic microgranodiorite and microtonalite: phenocrysts and groundmass not differentiated. 2021 and 2022 are measured modal analyses.

studded with small equidimensional quartz grains. The ferromagnesian minerals, biotite, hornblende, and rare relict pyroxene are similar to those in the Mondooma Granite but biotite is relatively more abundant and the mafic mineral content is slightly greater.

Discussion

Textural differences and their significance. The differences in texture between the even-grained granitic phase and porphyritic microgranitic phase of the Mondooma Granite are summarized below:

	Microgranite	Granite
1.	porphyritic	even-grained
2.	plagioclase strongly zoned	plagioclase weakly zoned
3.	alkali feldspar usually untwinned microperthite	alkali feldspar microcline microperthite
4.	High temperature symmetry form of quartz	high temperature symmetry form poorly developed or absent
5.	Highly corroded and/or disrupted phenocrysts	minor corrosion and no disruption of grains
6.	Usually hornblende (and in one specimen hypersthene) present.	Usually biotite is only mafic constituent.

These features suggest that the granite has crystallized and been intruded at a slightly greater depth in the crust than the microgranite, and has consequently cooled more slowly. The slow cooling rate in the granite explains the lack of zoned plagioclase and high temperature quartz forms, and the presence of a relatively low temperature form of alkali feldspar.

The microgranite shows evidence of rapid cooling, e.g. retention of the high temperature symmetry form of quartz and alkalie feldspar (internally, however, the quartz has inverted to the beta form); strong zoning of plagioclase; and the lack of exsolution lamellae and zoning in the rare orthopyroxene. The corrosion and fragmentation of some of the phenocrysts suggest also rapid variations in magma-phenocryst equilibrium and rapid disruptive intrusion.

Significance of zones of quartz blebs in potash feldspar. The zone of quartz blebs or inclusions in potash feldspar is unique to the Mondooma

Granite and associated volcanics. The inner boundary of the zone is sharp, while the outer boundary is a diffuse one marked by a reduction in the numbers of quartz blebs (Fig. 8). The quartz blebs are not in optical continuity, and in this respect the texture is unlike normal granophyric texture.

The quartz blebs in the potash feldspar resemble small equant grains of quartz in the groundmass of the microgranite, although the groundmass quartz is generally coarser-grained. This suggests that growing potash feldspar crystals incorporated quartz blebs and prevented their further development. Quartz grains remaining in the groundmass continued to develop to a greater size than those in the potash feldspar.

The inner boundary of the quartz bleb zone commonly conforms to the shape of a corroded, embayed crystal (Fig. 8). This boundary probably marks a restoration of crystallization following after a period of disequilibrium between phenocrysts and cooling magma, in which the phenocrysts were partially resorbed by the margins.

Significance of zones of quartz blebs in plagioclase. Quartz blebs occur less commonly in the outer margins of plagioclase grains. In some cases these blebs appear to have been incorporated from the matrix by the growing plagioclase crystal. More commonly they appear to have been incorporated in situ from adjacent potash feldspar grains. The zone of quartz blebs in plagioclase usually marks the boundary between the primary core and secondary rim albite or, in some cases, myrmekite. These latter two features generally develop at the expense of potash feldspar at interfaces. Thus the inner boundary of the quartz bleb zone in plagioclase probably marks the original extent of the contiguous potash feldspar grains.

These textures suggest that the development of rim albite (or sodic overgrowths) and myrmekite post-dated the inclusion of quartz blebs in both plagioclase and potash feldspar, and were probably part of the final stages of crystallization.

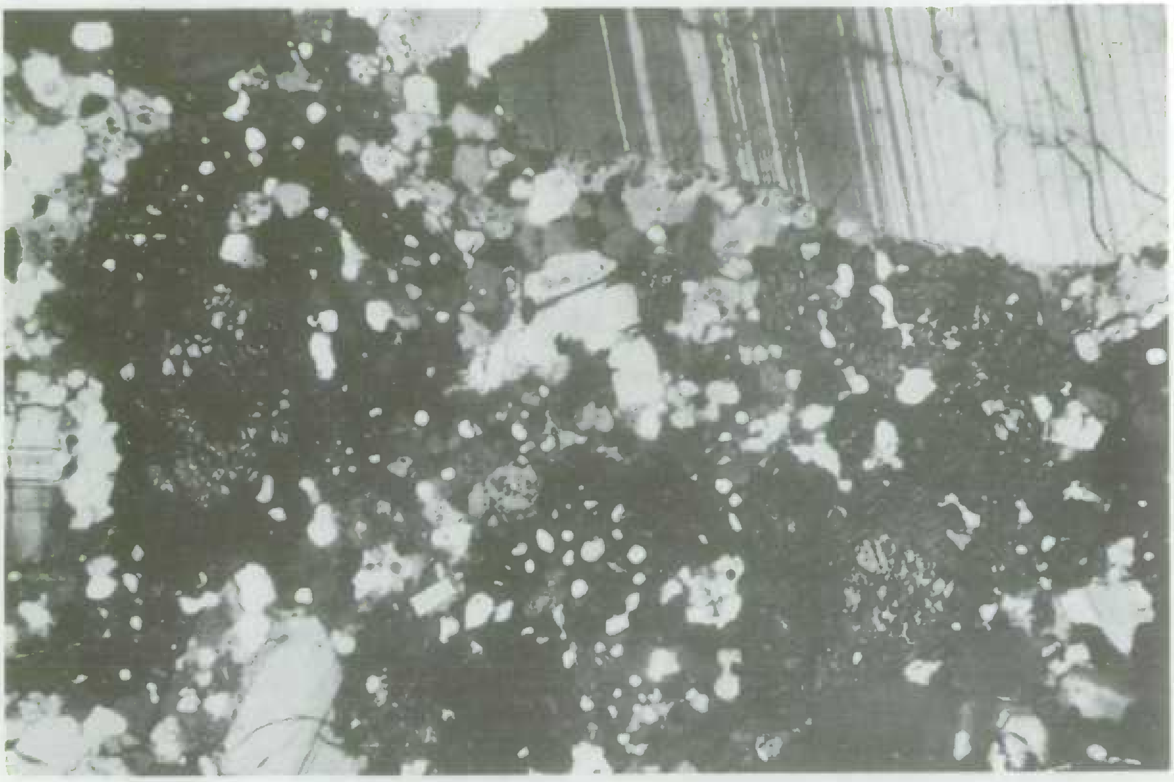


Fig. 8a Typical texture of Mondooma Granite, showing phenocrysts of plagioclase (lower left) and poikilitic amphibole surrounding pyroxene (upper left and lower right). The groundmass is studded with small equidimensional quartz grains. (Neg 838/17) G.M.D.

Fig. 8b Phenocryst of plagioclase with overgrowth of potash feldspar in Mondooma Granite. Both feldspars contain zones rich in granular quartz inclusions. Myrmekite is developed at feldspar interface. (BMR neg.) C.Z.

LATE LAMBOO COMPLEX

LENNARD GRANITE

Introduction

The Lennard Granite of the Yampi Sheet area is an extension of that mapped in the Charnley and Lennard River Sheet areas. It is essentially a leucocratic coarse-grained biotite granite characterized by irregular feldspar phenocrysts and an allotriomorphic-granular texture.

The reference area lies in the Lennard River Sheet area (Gellatly et al., 1968).

Field Occurrence

The Lennard Granite is exposed in a broad elongate belt which extends from the High and McLarty Ranges in the north to the Robinson and Pardaboora Rivers in the southeast of the Sheet area. It is bounded by Kimberley Group sediments and Hart Dolerite along the northern margins, by acid volcanics and microgranites in the east, and by Halls Creek Group metasediments along its southwest margin. The Halls Creek Group also separates the northwestern extremity of the mass, between the Little Tarraji River and Mount Nellie, from the remainder of the pluton. Total area of outcrop of Lennard Granite is about 750 sq. km.

Immediately north of the Pardaboora River the granite forms large whalebacks elongated southeast, with small eluvium-filled valleys between them. To the west soil cover increases and near Boulder Hill large isolated knobs and domes completely surrounded by soil and sand-covered plains, are common. To the north and northwest, broken hills separated by small sandy pediments are typical. Shear zones which cut the granite are generally silicified, and form prominent ridges. General relief is about 90 m. The photo pattern is mainly light-coloured, due to large exfoliation surfaces and abundant sandy soil associated with the granite. Minor drainage is generally controlled by the regional northwest foliation.

The Lennard Granite is probably a domed batholith flanked on the east, west, and southwest by older rocks. The major structural feature of the mass is a regional foliation, which trends southeast or

61

south-southeast, and generally dips steeply to the southwest. This foliation is ubiquitous in a belt extending from the Mondooma yard area northwest to Mount Nellie, but is less striking in the area north and northwest of Mount Disaster. A mineral lineation is generally present, plunging at from 40° to 80° to the south and southeast. The foliation is defined mainly by xenolith and phenocryst orientation, and along the southeast margin in particular it is parallel or sub-parallel to both bedding and cleavage in Halls Creek Group phyllite.

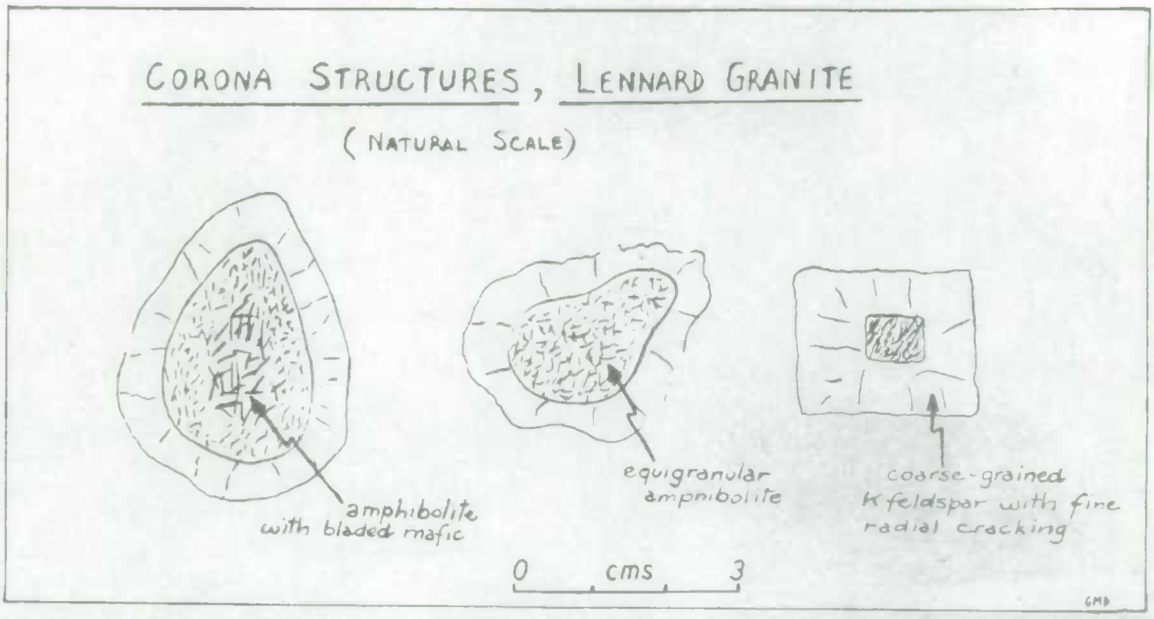
The major joints, lineaments, and shear zones trend northwest or north. North-trending shear zones are common in the Mount Disaster-High Range area. Many of these shear zones contain quartz veins and aplite dykes. A warped aplite dyke northeast of Boulder Hill suggests small-scale folding in the granite.

The granite is generally light grey, coarse-grained, and moderately porphyritic. The phenocrysts, mainly potash feldspar, are usually closely packed, but in places are more equant and separate. Quartz occurs locally as phenocrysts and is commonly a pale opalescent blue. Biotite is the predominant mafic mineral. The potash feldspar phenocrysts range from 1 cm to 3 cm, although rare crystals are 5 cm or more in length. The phenocrysts are mostly subhedral; many of the larger ones are rounded. Both in shape and general structure the phenocrysts of the Lennard Granite resemble closely those in the Mount Disaster Porphyry.

Coronas of potash feldspar are commonly developed around small basic xenoliths (Fig. 19). Generally the outer rim of feldspar conforms to the outline of the xenolith, and some of the rounded feldspar phenocrysts in the marginal zones of the intrusive appear to have developed from this structure.

Some phenocrysts show two-stage growth. Both core and overgrowth consist of potash feldspar and the boundary between them is outlined by a narrow zone containing biotite inclusions.

Xenoliths are moderately abundant, particularly adjacent to contacts with the Halls Creek Group and Mondooma Granite. They are mainly banded amphibolite, fine-grained diorite, and porphyritic microgranodiorite, which range in size from 5 cm to 1.5 metres. Some of the



E51/A3/14

Fig. 9b Feldspathic corona structures surrounding mafic inclusions in Lennard Granite, 1 km southeast of Duck Hole. G.M.D.

Fig. 9a Typical texture of Lennard Granite showing corona structure of K-feldspar surrounding mafic inclusions, 1 km southeast of Duck Hole. Scale is 25 cm long. (Neg 9644) G.M.D.

large xenoliths show an acid margin, and also 'dents du cheval'-type phenocrysts. Many of the xenoliths are partly resorbed (Fig. 10).

Along the eastern margin at its contact with Mondooma Granite the Lennard Granite becomes noticeably granodioritic, and contains zones of agmatite, in which innumerable metasedimentary xenoliths are contained in a granodioritic matrix. These reach their greatest abundance in the King Creek region of the Charnley Sheet area (Gellatly et al., 1969). Near Mount Nellie the Lennard Granite is mainly adamellitic and even-grained, and contains numerous metasedimentary xenoliths in all stages of assimilation. However, the eastern and southern margins of this discrete mass are comparatively free of xenoliths, and contain abundant muscovite. The boundaries between the marginal muscovite-bearing adamellite and central granite are gradational.

Mafic and salic banding is found locally in the granite near some contacts with the Halls Creek Group. The banding is defined by alternations of biotite-rich and biotite-poor medium-grained granite or by alternations of fine-grained and coarse-grained porphyritic granite, and is usually parallel to either cleavage or bedding in the adjacent Halls Creek Group. The biotite-rich bands show a diffuse 'upper' contact and a sharp 'lower' contact with the more salic bands (Fig. 10), and this possibly reflects banding or grading in original sedimentary material. Alternatively the more regular banding shown in Figure 10 may be igneous layering, similar to that from the Charnley Sheet area (Gellatly et al., 1969).

Contact Relationships

The Lennard Granite intrudes the Halls Creek Group, Whitewater Volcanics, and Mondooma Granite, and is intruded by the Kongorow Granite, Secure Bay Adamellite, and the Tarraji Microgranite.

Contacts with the Halls Creek Group have been observed 5 km west, and 6 km east, of Boulder Hill, and 3 km northeast of Mondooma Yard. In most places the granite at the contact is undeformed, even-grained locally, and is biotite-rich, or locally muscovite-rich as along the margins of the Mount Nellie/Little Tarraji River pluton.

Near Duck Hole, the Lennard Granite has hornfelsed schists of the Halls Creek Group causing regrowth of micas to produce a massive miscovite-rich hornfels. Bedding has been destroyed within 10 m of the contact and cleavage within 20 m of it. The granite is massive and coarse-grained right up to the contact and contains xenoliths of biotite-rich metasediment up to 60 cm across and thin schlieren of basic material, and shows indistinct banding of phenocryst-rich and phenocryst-free material. The xenoliths are rimmed by borders of leucocratic granite, and some of the larger feldspars have small xenolithic mafic cores. Some 4 km east-northeast of Duck Hole the Lennard Granite, close to a raft of metasediment some 100 m long, contains small scattered biotite-rich xenoliths in which euhedral feldspar porphyroblasts up to 4 cm have developed.

East of Boulder Hill shearing has occurred along the contact, and all gradations are found between sheared granite and sericite schist. A rock transitional between these extremes contains augen of quartz and feldspar, which may be either relict phenocrysts or newly-developed porphyroblasts. Aplite, pegmatite, and quartz veins are present locally in the contact zones, and intrude the metasediments up to 6m from the contact.

Contacts with Mondooma Granite. A sharp contact has been observed 9 km north of Parderoo Pool. There, a marginal mesocratic and agmatitic facies of the Lennard Granite apparently intrudes the Mondooma Granite, but with very little contact effect.

In the area 20 km east-southeast of Mount Disaster, the Lennard Granite close to its contact with Mondooma Granite contains scattered xenoliths of fine to medium-grained biotite-rich banded metasediment. The Lennard Granite there is usually biotite-rich and porphyritic with rare 1 cm quartz, feldspar, and biotite phenocrysts in a microporphyritic groundmass containing 2 mm euhedral feldspar phenocrysts. The feldspars are opaque and creamy white. This variant of the Lennard Granite resembles the Lerida Granite of the Lansdowne Sheet area, and grades westwards into normal coarsely porphyritic leucocratic Lennard Granite.

Further examples of these xenolith-rich zones in the Lennard Granite close to its contact with Mondooma granite have been described from the Charnley 1:250,000 Sheet area (Gellatly et al., 1969).

Fig. 10a Lennard Granite showing partially resorbed xenolith and nebulitic mafic swirls. Boulder Hill (Neg G9628) GMD

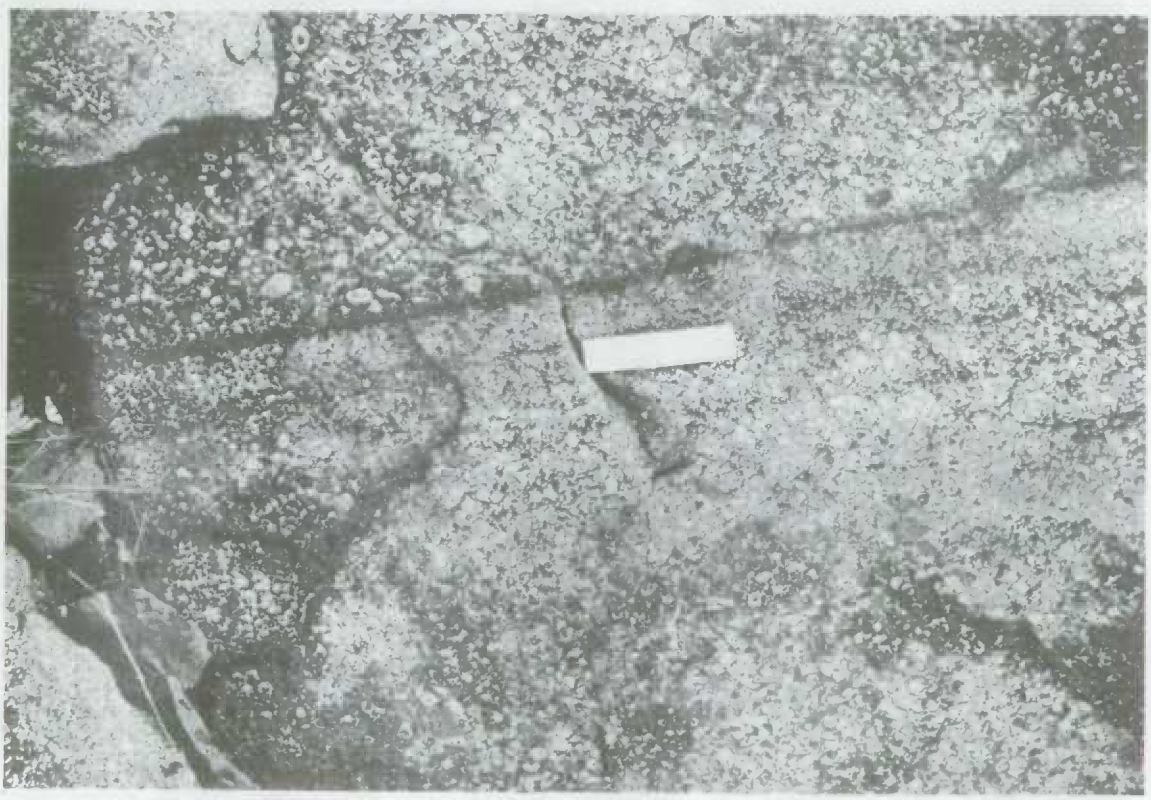


Fig. 10b Lennard Granite showing compositional and grain-size banding. Boulder Hill (Neg G9628) GMD

Contacts with Kongorow Granite. The Lennard Granite at Boulder Hill is intruded by veins and small dykes of a dark grey porphyritic granite which resembles some varieties of the Kongorow Granite found in the Lennard River Sheet area. These are abundant locally, but most are too small to be shown at 1:250,000 scale. The grey granite is medium to coarse-grained, and contains only sporadic phenocrysts from 1 to 3 cm. long. The relationships are shown in Figure 11. Similar intrusive relationships of Kongorow Granite into Lennard Granite have been noted 6 km. east-northeast of Duck Hole. There the Kongorow Granite shows streaky flow banding parallel to the contact with the enclosing Lennard Granite and phenocrysts in the Kongorow Granite have preferred orientation parallel to the contact (Fig.11b).

Contacts with Whitewater Volcanics. Veins of Lennard Granite cut the volcanics east of Mount Disaster, and in one locality the Lennard Granite contains rare 0.3 to 1.5 m. xenoliths of crystal-rich ashflow tuff of the Whitewater Volcanics.

Petrography

Three specimens have been examined from exposures southeast of the Tarraji River. Two are part of the marginal granodioritic phase of the Lennard Granite (66.16.2028, 66.16.2025), while the third (66.16.2027) is typical of most of the mass near Boulder Hill. Four samples of the Lennard Granite from near Mount Nellie, and three from near the Little Tarraji River headwaters have been examined by Peers (GSWA Petrological Report No. 111), whose comments are incorporated in the following descriptions.

The granites are all coarse-grained, but are even-grained to porphyritic. Average grain diameter is about 5 mm. They show xenomorphic granular texture, and varying degrees of foliation.

Quartz forms large composite fields up to 1 cm. diameter, though most large grains are bordered by a fine-grained granular quartz mosaic. Boundaries between the quartz grains are embayed and sutured. Epidote and liquid-gas inclusions along old fracture planes are common, and extinction is generally strained. Plagioclase ranges from oligoclase to andesine (An_{38}). Most grains are zoned to more sodic rims, which are emphasized where plagioclase is in contact with potash feldspar. Alteration to sericite and epidote is widespread, but variable in degree. Potash feldspar is fresh microperthitic microcline which occurs as phenocrysts and as anhedral interstitial grains. The cross-hatching typical of microcline is not well developed, particularly in the phenocrysts, which in two specimens are graphically intergrown with quartz. Myrmekite is sparsely developed at potash feldspar/plagioclase interfaces. Biotite forms flakes up to 2 mm. diameter, and generally occurs in aggregates of from 2 to 5 flakes. Pleochroism is variable, and in some specimens ranges from a light fawn/red brown scheme to a fawn/olive green or brown combination. Finer-grained aggregates of a pale green-brown biotite and pale yellow epidote are usually marginal to the larger grains. Muscovite, which is present only in the marginal phase of the pluton near Mount Nellie, forms large ragged plates and flaky aggregates up to 5 mm. diameter, sieved with quartz and feldspar. Minor accessories include apatite and zircon, which are common and occur mainly as inclusions with pleochroic haloes in biotite. Iron oxide is less abundant (ilmenite? or titanomagnetite?) and has an ubiquitous corona of sphene. Blue-green tourmaline is a rare constituent.

The granodiorites are similar petrographically to the granites, and differ only in having lower potash feldspar and higher biotite contents. The biotite shows a straw to fawn-brown pleochroism, and is partly replaced along cleavage planes by thin slivers of epidote and quartz.

Discussion

The Lennard Granite shows only minor variation over a wide area. The most significant variation is probably the development of a marginal muscovite adamellite phase in the Mount Nellie pluton adjoining metasediments of the Halls Creek Group. The presence of muscovite appears to be due to contamination of the margins with pelitic material, and is comparable to the development of biotite at other contacts with the Halls Creek Group. The development of muscovite or biotite is probably controlled by the composition of xenoliths undergoing assimilation, i.e. incorporation of iron-poor pelites or argillites would probably favour the development of muscovite rather than biotite, and vice versa.

Marginal granodioritic phases (e.g. northwest of Mondooma Yard) of the Lennard Granite however may result from assimilation of basic to intermediate xenoliths.

Fig. 11a Kongorow Granite intruding Lennard Granite, Boulder Hill area. Note aplite selvage along top contact (Neg 9674) G.M.D.

Fig. 11b Kongorow Granite intruding Lennard Granite (upper right). Kongorow granite shows flow orientation of phenocrysts parallel to the contact: 5 km east-northeast of Duck Hole (Neg M 1000/1) D.C.G.

Fig. 12a Myrmekite in Kongorow Granite. Note twinning in plagioclase component. (X80 crossed nicols) (Neg M 692/26) G.M.D.

Fig. 12b Typical texture of Cone Hill Granite, 2 km southwest of Cone Hill. (Neg 753/15). G.M.D.

SECURE BAY ADAMELLITE

The name Secure Bay Adamellite (new name) has been given to coarse-grained, generally non-porphyritic biotite adamellite with associated granite and granodiorite found in the Yampi 1:250,000 Sheet area. It occurs in close association with the Lennard Granite but is less markedly porphyritic, or non-porphyritic, whereas the Lennard Granite is strongly porphyritic with phenocrysts commonly making up about 30 percent or more of the rock. Sharp contacts have been found between the Secure Bay Adamellite and the Lennard Granite but the age relations found are conflicting. There is a possibility that the two types may grade into one another locally. The type locality is near the extreme southwestern corner of Secure Bay (2102E, 29023N) in the Yampi Sheet area.

Field Occurrence

Outcrops of the Secure Bay Adamellite are confined to the region around Secure Bay. The total extent of the outcrops is approximately 65 sq. km. The main mass of the Adamellite is an elongate west-trending pluton 16 km. long and 3 to 5 km. wide stretching from Secure Bay in the east to the Little Tarraji River in the west. A small subsidiary stock occurs 3 km. to the north of the eastern end of the main mass.

The Secure Bay Adamellite forms prominent rocky hills with intervening low-lying tors and sandy pediments. The tors show horizontal jointing and weather into large rectangular blocks. It is mostly more resistant to erosion, and thus more prominent topographically, than the adjacent Lennard Granite, which, in this area, forms low whalebacks, and is similar in its topographic expression to the Tarraji Microgranite. Boundaries between these two rock types can be delimited with certainty only on the ground.

A vertical west-trending contact has been noted on the northern margin of the main mass and it is interrupted by north-south shear zones, which have resulted in schisting of the granite along them, and which have caused sinistral displacement of the contacts of up to 1 mile.

In hand specimen the Secure Bay Adamellite is a massive pale grey, coarse-grained, non-porphyritic or sparsely porphyritic biotite granite. It locally contains rare equidimensional or short tabular potash feldspar phenocrysts up to 1 cm across, mostly averaging only ten or twenty phenocrysts per square metre of exposed rock surface. In a few localities, especially 3 km north of Mount Disaster, phenocrysts gradually become more abundant and in places make up from 10 to 20 percent of the rock.

The adamellite is cut by rare thin quartz veins, containing crystals of clear, glassy quartz up to 5 cm long, and by rare veins of aplite and tourmaline-bearing pegmatite. Traces of fluorite have been noted on joint surfaces, 6 km east of Mount Disaster.

Contact Relationships

The Secure Bay Adamellite adjoins outcrops of Lennard Granite, Tarraji Microgranite and Mount Disaster Porphyry. Contacts have been observed only with Lennard Granite.

Contacts with Lennard Granite. On the shore of Secure Bay, about 8 km east-northeast of Mount Disaster, a sharp contact has been observed between Secure Bay Adamellite and Lennard Granite. There is no contact alteration of either type. The Secure Bay Adamellite shows streaky flow-banding parallel to the contact, and contains xenoliths of Lennard Granite. This indicates that the Secure Bay Adamellite is the later. However, about 6 km north-northwest of Mount Disaster it appears that the Lennard Granite intrudes the adamellite. Here the phenocrysts in the Lennard Granite show parallel flow-orientation parallel to the contact, and the Secure Bay Adamellite is highly altered and rich in muscovite close to the contact.

Contacts with Mount Disaster Porphyry. About 3 km east of Mount Disaster, thin veins of pink leucocratic even-grained granite cut the Mount Disaster Porphyry within 100 m of its contact with the Secure Bay Adamellite. The vein material differs from the nearby adamellite in hand specimen only in its lower biotite content and is considered to have been derived from the main mass of adamellite.

Petrography

In thin section the Secure Bay Granite is coarse-grained with a hypidiomorphic-granular texture. It consists essentially of quartz, potash feldspar, plagioclase, and biotite, along with minor accessory muscovite, zircon, and apatite, and secondary clinozoisite and sericite. Modal analyses (Table 4) indicate that it is a quartz-rich adamellite.

TABLE 4

Modal Analyses of Secure Bay Adamellite

	(1)	(2)
Quartz	38.7	30.8
Plagioclase	25.2	26.5
Potash feldspar	26.7	31.4
Biotite	9.4	10.6
Muscovite	Tr.	0.7
Clinozoisite	Tr.	Tr.
?Monazite	Tr.	Tr.
Apatite	Tr.	Tr.
	100.0	100.0

1. Biotite adamellite; 6 km. north of Mount Disaster (Y10-11-22; R66-16-2043).
2. Biotite adamellite; $6\frac{1}{2}$ km. northeast of Mount Disaster (Y9A-08-3; R66-16-2044).

Quartz, which is unusually abundant, occurs as large (up to 4 mm.) deformed composite grains and smaller interstitial ones. Potash feldspar forms large equant subhedral grains of slightly turbid microcline-microperthite containing euhedral inclusions of plagioclase, and is in part micrographically intergrown with quartz. Plagioclase grains are tabular and euhedral to subhedral; they are slightly kaolinized, show finely developed albite twinning, are only slightly zoned, and have a composition of An_{20-25}. Biotite occurs in small aggregates associated with muscovite, and consists of interlaminated red-brown, grey-brown, and pale green varieties. It contains small inclusions of apatite, and of pale yellowish ?monazite surrounded by dark haloes.

Discussion

The close spatial and temporal relationships between the Secure Bay Adamellite and the Lennard Granite, and the gradation within the Secure

Bay Adamellite from non-porphyritic types to phenocryst-rich types resembling the Lennard Granite suggest that the two are petrogenetically related. Since the first phase to crystallize in the Lennard Granite was potash feldspar, the residual liquid would presumably have been relatively enriched in (normative) quartz and plagioclase. Such a liquid, if separated either wholly or partly from the early-formed potash feldspar phenocrysts, could have crystallized to form the non-porphyritic and porphyritic phases respectively of the Secure Bay Adamellite.

TARRAJI MICROGRANITE

The Tarraji Microgranite (new name) is a porphyritic biotite microgranite, found as small scattered outcrops in the headwater area of the Tarraji River and on the southwestern shores of Secure Bay. It is characterized by its medium-grained texture, and by the presence of potash feldspar, biotite, and quartz as phenocrysts. The reference area is 10 km. northeast of Mount Disaster on the western shore of the southern part of Secure Bay.

Field Occurrence

Mappable outcrops of the Tarraji Microgranite are confined to a north-south belt extending for 10 km. and lying about 6 km. to the east of Mount Disaster. The outcrops have irregular shape and total 10 sq. km. in area. Individual outcrops range from 2 km. to about 10m. across.

The microgranite forms prominent sharp-peaked rocky hills which stand out from the surrounding slightly lower ground formed by the Lennard Granite and Secure Bay Adamellite.

The form of the microgranite bodies is uncertain, but they are thought to occur as stocks and plugs cutting other acid intrusives.

In hand specimen it is a pale grey porphyritic biotite microgranite containing sparse euhedral phenocrysts of potash feldspar (from 0.5 cm. to 1.0 cm), biotite (2 to 3 mm) and quartz (3 to 4 mm) in a fine grained biotite-bearing groundmass. Muscovite is prominent in one locality. The microgranite locally shows flow alignment of elongate feldspar phenocrysts and of small 2 cm. to 5 cm. lenticles of basic material. Rare 1 cm. quartz-feldspar-tourmaline veinlets cut the microgranite.

Near a contact with Mount Disaster Porphyry 5 km east-southeast of Mount Disaster, the Tarraji Microgranite contains scattered ovoid feldspar phenocrysts probably derived from the porphyry. The Microgranite here is very variable in texture and locally shows textural similarities to the Whitewater Volcanics and also to the Lennard Granite. These variations in texture are attributed to assimilation of pre-existing ashflow tuff and granite.

Contact Relationships

The Tarraji Microgranite adjoins outcrops of Lennard Granite, Secure Bay Granite, Mount Disaster Porphyry, and Mondooma Granite. Contacts have been observed only with Lennard Granite, 5 km east-southeast of Mount Disaster. The Lennard Granite has a poorly defined flow foliation which is cut by the contact with Tarraji Microgranite and phenocrysts in the Microgranite have preferred orientation parallel to the contact, indicating that the Tarraji Microgranite is the later of the two.

Petrography

In thin section the Tarraji Microgranite is a medium-grained rock with a hypidiomorphic-granular texture and average grain diameter of 0.3 mm. Phenocrysts are rare and none were encountered in the thin sections examined. The rock consists essentially of quartz, potash feldspar, plagioclase, and biotite; and minor accessory muscovite, metamict allanite, iron ore, sphene, ?monazite, garnet, apatite and tourmaline; and secondary clinozoisite and sericite.

Quartz forms about 25 to 30 percent of the rock and potash feldspar is more abundant than plagioclase. The rocks are microgranite and microadamellite.

Quartz occurs mostly as small intergranular grains but a few grains up to 1.5 mm are also present. Potash feldspar includes both microcline and microcline-microperthite; grains are equidimensional, anhedral to subhedral, and up to 1 mm across, and contain euhedral inclusions of plagioclase. Plagioclase (An_{25}) forms euhedral tabular crystals up to 1 mm long. They show albite twinning, are slightly zoned, and are partly altered to sericite and clinozoisite. Green-brown biotite occurs as separate flakes and in lenticular aggregates associated with clinozoisite, and contains inclusions of ?monazite surrounded by dark haloes.

All outcrops of Tarraji Microgranite occur close to Lennard Granite (which is the most widespread granite in the area) and may thus be petrogenetically related to it. The occurrence of the principal masses of Microgranite close to a north-south lineament suggests possible tectonic activity late in the crystallization history of the Lennard Granite and release of a new fraction of magma.

KONGOROW GRANITE

Introduction

The Kongorow Granite is named after Kongorow Pool, in the Lennard River Sheet area. The unit has been defined by Gellatly et al. (1968).

Field Occurrence

The Kongorow Granite crops out 5 km. north of Limestone Springs, where it forms small low domes and tors, associated with amphibolite (Woodward Dolerite) and pegmatite. The Kongorow Granite is widespread also as small dykes and veins intrusive into Lennard Granite. These dykes are not represented at 1:250,000 scale.

Macroscopic Appearance

Two distinct types of granite are included in the Kongorow Granite. Type a exposed near Limestone Springs is coarse-grained and porphyroblastic. It is a dark grey-blue rock containing porphyroblasts of potash feldspar up to 2 cm. or more, quartz, plagioclase, and abundant biotite. It is highly foliated, and in places is a quartz-feldspar-biotite gneiss. Folded veins and bands of aplite and pegmatite are common, and contain tourmaline (1 cm. long), muscovite (books up to 3 cm. diameter), and garnet (up to 8 mm. across).

Type b, occurring as veins and dykes, is a medium to coarse-grained light-grey, well-foliated, porphyritic biotite-muscovite granite. Phenocrysts of potash feldspar are smaller (1 to 1.5 cm.) and more sporadic than in type a. Muscovite grains have random orientation, and are closely associated with grains of potash feldspar. Small aplite veins are common at contacts with Lennard Granite.

Contact Relationships

Contacts with Halls Creek Group. The type a granite is closely associated with the Halls Creek Group. It is concordant with the phyllites, and shows similar foliation, though the actual contact is not exposed.

Contacts with Lennard Granite. The type b granite intrudes the Lennard Granite, and forms veins and dykes, from 5 cm to 1.5m thick, which are markedly transgressive and show narrow chilled margins. Aplite selvedges are common, but are usually developed only at one contact (Fig. 11).

Petrography

Only the type b Kongorow Granite has been examined. In thin section it shows a hypidiomorphic granular texture. Quartz (35%) forms clear and unstrained granular mosaics and larger single grains. Potash feldspar (34%) occurs as phenocrysts up to 1.2 cm, large grains from 2 to 4 mm, and finer-grained interstitial material. It is a microperthitic microcline, in which cross-hatched twinning is not well developed. Plagioclase (12.5%) forms partly saussuritized subhedral to anhedral grains 1.5 to 3 mm long. Most grains are normally zoned, but some reverse zoning is present. Two crystals were zoned from An_{25} to An_{20}, and from An_{20} to An_5. Clear sodic rims are present on grains which are enclosed by potash feldspar.

Myrmekite (5.6%) is very well developed (Fig. 12). Some patches are quite coarse-grained, and the plagioclase fraction of the intergrowth shows albite twinning very clearly. It is usually developed between groundmass quartz and potash feldspar and along potash feldspar intergrain boundaries. It forms petaloid protuberances into potash feldspar. In many cases the plagioclase of the myrmekite is in optical continuity with the plagioclase phase in adjacent microperthite crystals. Biotite (8%) forms discontinuous lamellae through the rock, and muscovite (4%) forms decussate patches, although both are intergrown in places. Zircon and apatite are abundant, and are generally associated with the mafics. Some biotite flakes are chloritized.

Discussion and Correlations

The two types of granite considered as Kongorow Granite on Yampi are of two different ages. Type b definitely post-dates the Lennard Granite, while type a has possibly been developed during metamorphism of the Halls Creek Group, and is probably older than the Lennard Granite; it is tentatively regarded as pre-Whitewater Volcanics in age.

Similar relationships exist in the Lennard River Sheet area, where at least five allied rock types are incorporated in the Kongorow Granite. Some of these variants are probably pre-Lennard Granite, and pre-Whitewater Volcanics, but at least one is younger.

Because of the lithological similarity between the two types it has not been possible to separate the younger phase of the Kongorow Granite on both Yampi and Lennard River Sheets from the older phase. The two phases have been grouped together and their differing age relationships recognized.

CONE HILL GRANITE

The Cone Hill Granite (new name) is named after Cone Hill, which is immediately west of the centre of the Yampi Sheet area. It has been named separately because of its location remote from other granite outcrops. It is a porphyritic granite, and contains variants that resemble both Lennard and Kongorow Granites.

Field Occurrence

The Cone Hill Granite forms a rocky peninsula which extends for about 8 km. westwards from Cone Hill into Cone Bay. A number of small islands offshore from the peninsula also consist of granite. The extent of outcrops is about 40 sq. km.

The granite forms broken, rocky and irregular topography, which is cut by a number of prominent northeast-trending gullies formed along joint lines. The coastline is rocky, with some low cliffs unrelated to lithology. Outcrop is relatively subdued at the eastern end of the peninsula but more rugged towards the western end, where large whalebacks are common.

The Granite occupies the core of an anticline overturned to the north. The anticline, which is rimmed by King Leopold Sandstone, is probably closed, since most of the islands west of Cone Bay are also of King Leopold Sandstone. The eastern margin of the granite is fault-bounded.

Macroscopic Appearance

In hand specimen the Cone Hill Granite is light grey, coarse-grained and generally porphyritic (Fig. 13). The phenocrysts are predominantly white to pale grey tabular euhedral crystals of alkali feldspar, and less abundant, plagioclase and quartz. The size and proportion of phenocrysts vary considerably over short distances. The alkali feldspar phenocrysts are mostly 2 to 5 cm long, and form from 10 to 20 percent of the rock. Some are up to 10 cm long. Many of these larger grains are scattered through the granite, but in places are concentrated into zones (Fig. 13), where they constitute almost half the rock, and show rough flow alignment.

Euhedral biotite (accompanied by muscovite) is the mafic mineral in the granite. Small amphibolitic xenoliths are common. These, together with alkali feldspar phenocrysts, outline a steeply dipping east-west foliation.

Small veins and dykes of tourmaline-bearing aplite and pegmatite are widely distributed through the mass: a grey medium-grained aplite is generally associated with phenocryst accumulations. Large inclusions of quartz-mica-tourmaline schist are present along the northeastern margin of the peninsula; these may be Halls Creek Group metasediments.

Contact Relationships

Within the Cone Hill Granite there are both sharp and gradational contacts between different types of porphyritic granite. The two types of porphyritic granite resemble the Lennard and Kongorow Granites from the Lennard River Sheet area, but no definite relationships could be established. The porphyritic granite with abundant matrix (Kongorow-type) has possibly developed metasomatically from the Lennard-type in certain areas (Fig. 13).

The granite is overlain unconformably by micaceous chloritoid-bearing arenites of the Speewah or Kimberley Groups. A north-south shear or fault zone in the granite, and a fold zone in the overlying sandstone, separate the Cone Hill Granite from Hart Dolerite and Whitewater Volcanics along the eastern margin of the mass.

Petrography

Two specimens typical of most of the granite mass have been examined. They are porphyritic adamellite. The average mode is: quartz 35%; alkali feldspar 30%; plagioclase 30%; muscovite + biotite 5%. The texture is allotriomorphic-granular.

Quartz forms fields up to 1 cm diameter, composed of numerous smaller grains. Extinction is generally strained, and grain boundaries are strongly sutured. Plagioclase is highly saussuritized, but twinning is still recognizable. The grains are slightly zoned; the average composition is An_{20}. Alkali feldspar occurs as phenocrysts of slightly perthitic, poorly twinned microcline, and mosaics of granular (0.6mm) microcline. The grains in the mosaic are anhedral; the phenocrysts are subhedral to euhedral. Both types are clear and unaltered. Biotite and muscovite occur as large (1 to 2 mm) intergrown flakes. The muscovite appears to post-date the biotite, which is pleochroic in green and brown. The micas define a gneissosity. Accessories include vermiform myrmekite, rare epidote/clinozoisite, zircon, and sporadic large (1 to 3 mm) grains of tourmaline.

The inclusions of schist, thought to be metamorphosed pelites of the Halls Creek Group, consist essentially of quartz, which forms lenticular mosaics composed of small (0.2 to 0.4 mm) sutured and strained grains; and biotite and muscovite, the latter being more abundant. The biotite grains contain minor apatite and zircon. Tourmaline forms up to 3 percent of some of the schists, and occurs as large grains up to 5 mm long. The grains are zoned, the central part being a blue-green variety, probably schorl, and the exterior possibly the magnesian variety dravite, with e= colourless and o= yellow-brown. Large apatite and zircon grains occur scattered through the rock, which apparently contains no alkali feldspar. It is possible that much of the muscovite may have been derived from feldspar, but there is no evidence for this. The tourmaline

80

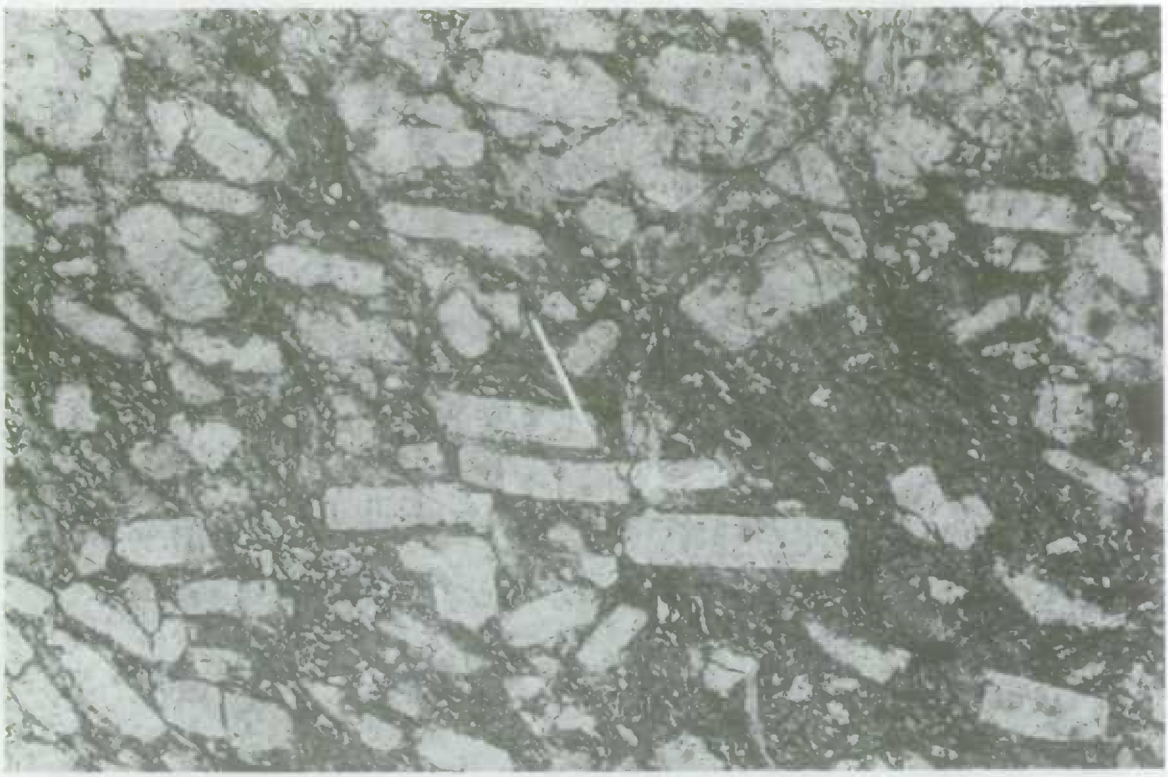


Fig. 13a Alkali feldspar phenocryst accumulation, Cone Hill Granite. Locality 2 km. southwest of Cone Hill (Neg M 753/14) G.M.D.

Fig. 13b Cone Hill Granite showing Kongorow-type granite (porphyritic and dark coloured) apparently replacing and/or digesting Lennard-type granite. Locality 2 km southwest of Cone Hill (Neg M 753/18) G.M.D.

is probably reconstituted detrital material which is generally abundant in Halls Creek Group rocks of lower grade.

Discussion

The Cone Hill Granite most closely resembles the Kongorow Granite of the Lennard River Sheet. Like that mass, it shows marked inhomogeneity and is locally intimately associated with the Halls Creek Group. Possible metasomatism is suggested by partial digestion of the coarse and even-grained granite (Fig. 13) to produce the porphyritic variety.

The abundant alkali feldspar phenocryst accumulations (Fig. 13) are suggestive of magmatic 'filter pressing'.

The alignment of phenocrysts (Fig. 13) probably reflects a flow foliation developed through flow in a partly consolidated magma.

ACID DYKES AND VEINS

Introduction

Included under this heading are minor intrusives of microgranite, aplite, pegmatite and quartz veins formed mainly as fault fissure and joint infillings in granite. These acid intrusives are found in the Lamboo Complex, Halls Creek Group, and Whitewater Volcanics.

Microgranite cutting Whitewater Volcanics

An isolated dyke (trend 75/200) cutting Whitewater Volcanics some 13 km east of Mount Disaster is a fine-grained pale grey-green rock in hand specimen, and contains conspicuous quartz grains up to 2 mm. It is a highly altered leucocratic porphyritic microgranite which in thin section consists of scattered, locally embayed quartz phenocrysts, in a fine-grained groundmass (0.1 mm) of discrete quartz and muscovite grains, and a felted mosaic of sericite probably replacing feldspar. Minor accessories are altered grains of a dark opaque mafic mineral (possibly tourmaline) and small euhedral pink zircons.

The embayed quartzes and the pink zircons, which are similar to those in the Whitewater Volcanics, suggest that this rock is related to the enclosing Volcanics.

Quartz veins

Quartz veins occur mainly throughout the Lennard Granite and Secure Bay Adamellite and the Halls Creek Group. In the granites, most veins occupy fault or shear zones, and trend approximately north-northwest or east-northwest. Most form prominent ridges rising up to 30 m above the surrounding granite or soil plain, and range in thickness up to 6 m or more. The granite immediately adjacent to some of the veins is sheared and phyllonitic.

The quartz veins in phyllite of the Halls Creek Group are generally parallel or sub-parallel to the bedding or cleavage planes. Most of these veins are thin (less than 8 cm) and lenticular; boudins are common. Many veins are crenulated and strongly deformed on a small scale. Larger quartz veins (up to 1 m thick or more) are less common in the Halls Creek Group, but are mineralized locally.

The veins consist mainly of massive milky white to pale rust-brown quartz. Aggregates of green-brown chlorite up to 10 cm across are widespread in the veins which are generally free from other minerals. Rare occurrences of finely banded white agate, and small (2 cm to 5 cm) euhedral quartz crystals have been noted in vughs. Small 'horses' of granite and phyllite are present locally.

Malachite is present in certain of the veins in the Sandy Creek/ Little Tarraji River and Mondooma areas (see Economic Geology). Traces of galena and pyrite occur in a complex of siliceous fault breccia and quartz veins 3 km north-northeast of Boulder Hill.

Aplite and Pegmatite

Aplite and pegmatite dykes and veins are common in the Lennard and Secure Bay granites. A few occur also in the Halls Creek group and Woodward Dolerite. The dykes are mainly of north-northeast and west trend, and range in thickness from 15 cm to 1 m with rare occurrences up to 9 m or more thick. They commonly fill irregular joint systems or zones of shearing in granites, and in some cases are faulted, or gently folded. Xenoliths or 'horses' of grey porphyritic granite up to 1 m across are contained in some of the larger dykes. The aplites and pegmatites commonly occur in close association; some pegmatites form well

83

defined zones in the centre of the larger aplite dykes. The mineralogy of both aplites and pegmatites is mostly simple. They consist essentially of quartz, potash feldspar sodic plagioclase, and tourmaline.

Black tourmaline (dravite or schorl) is a ubiquitous constituent of the dykes and is common as poikilitic grains in aplite and as large crystal masses in pegmatite, commonly with individual crystals up to 8 cm. long. Simpson (1948) has recorded tourmaline from pegmatite dykes at Cone Bay, Sunday Straits, Sunday Island and Talbot Bay.

Axinite, a hydrous borosilicate of iron, calcium, and aluminium, is said to be abundant southeast of Yampi Sound at a point on the shore of Talbot Bay (Simpson, 1948). From the description given, the axinite is probably contained in pegmatite veinlets associated with altered and sheared Wotjulum Porphyry.

Muscovite is a common accessory of the pegmatites cutting Woodward Dolerite near Stuart's Mica Mine at Mondooma (see Economic Geology). The same pegmatite has also yielded a small quantity of beryl.

BASIC DYKES

Introduction

Basic dykes are extremely rare in the Yampi Sheet area, particularly in comparison to the abundant swarms found in the southeastern part of the Lennard River Sheet area.

Field Occurrence

The principal dykes in the area are found at Boulder Hill and about 16 km. east of Mount Disaster; also a gently dipping basic sill is present 11 km. north-northeast of Mount Disaster.

The dykes are apparently vertical and trend east-northeast and north-northwest. These trends parallel those of the major quartz veins in the area and also the main faults in the granites. The sill mentioned dips northwards at 32°. All of these minor basic intrusions cut Whitewater Volcanics or granites of the Lamboo Complex.

In hand specimen they are medium-grained non-porphyritic dark grey-green rocks which locally have small pits on the weathered surface due to weathering of olivine alteration products. All the dykes have suffered mild metamorphism which has caused partial alteration of the constituent minerals, but original ophitic textures are still preserved.

Petrography

A specimen from a 13 km long east-northeast trending dyke to the east of Mount Disaster consists of relict cores of pale pink-brown pigeonite surrounded by broad irregular coronas of fibrous pale green amphibolite, along with intensely saussuritized subhedral plagioclase, and minor leucoxene enclosing lamellae of magnetite, and interstitial quartz.

A specimen from the sill mentioned above contains fresh 2 to 3 mm ophitic pigeonite in matrix of saussuritized plagioclase, chloritized euhedral olivine pseudomorphs (ca 5%), and minor iron oxide and interstitial pale green chlorite.

Discussion

As in the Lennard River Sheet area, there are probably minor basic intrusions of differing ages. The fracture system containing the dykes pre-dates the Kimberley Group, and the dykes are thus possibly pre-Kimberley Group in age. The sill is less altered than the dykes and could possibly have been a minor feeder for, or offshoot from, the Hart Dolerite which intrudes King Leopold Sandstone about 2½ km to the north.

CARPENTARIAN

The Carpentarian rocks of the Yampi area comprise the Speewah and Kimberley Groups, which together with the Bastion Group (not present in the Yampi Sheet area), constitute the Kimberley Basin succession.

SPEEWAH GROUP

The Speewah Group, which in the Landowne Sheet area (Gellatly et al., 1965) consists of feldspathic sandstone arkose and siltstone totalling about 1200 m, thins northwestwards in the Charnely Sheet area (Gellatly et al., 1969). Outcrops of possible Speewah Group rocks in the Yampi Area are similar in lithology and thickness to those in the Charnely area and make up the basal part of a sandstone sequence which consists mainly of King Leopold Sandstone. As in the Charnley area the constituent formations of the type area around Lansdowne Homestead cannot be recognized.

Distribution

The Speewah Group forms a band of narrow discontinuous outcrops along the southern margin of the High and McLarty Ranges, and around Cone Hill.

Stratigraphic Relationships

The Speewah Group lies unconformably on the Halls Creek Group, and Whitewater Volcanics, and non-conformably on the Lennard and Cone Hill Granites. It is overlain, apparently conformably, by the King Leopold Sandstone. However, the King Leopold Sandstone in the Quartzite Range area is thought to overlap onto the older Precambrian and is probably at least partly unconformable on the Speewah Group.

Lithology

In the High Range-McLarty Range area the Speewah Group consists mainly of white pale purple-grey, buff, and pale red-brown coarse-grained poorly sorted silica cemented quartz sandstone. It is well bedded and is generally cross-bedded with fore-sets up to 60 cm thick. Thin quartz pebble conglomerates containing pebbles of vein quartz up to 5 cm are present near the base of the sequence. Detritus of dark purple-brown weathered siltstone has been noted about 5 km east-northeast of Mount Nellie.

Around Cone Hill sediments tentatively assigned to the Speewah Group are white to brown micaceous sandstone and quartzite interbedded with massive to grey quartzite. The beds immediately overlying the Cone Hill Granite are red-brown to purple quartz sandstone and quartzite which locally contains minor amounts of chloritoid. Most of the sandstone here is silicified and small ptygmatic quartz veins are abundant. Joints and fractures in the sandstone are heavily silicified.

Thickness

A composite thickness of 135 m has been measured a few miles north-east of Mount Nellie, and a thickness of 360 m has been estimated from air photographs for the area around Cone Hill. It appears to be thinnest near the eastern boundary of the Sheet area.

Petrography

Two samples from the Cone Hill area are both muscovite-bearing quartzites. The quartz grains form an interlocking mosaic 0.1 mm to 0.3 mm grain size. Grain boundaries are variously straight and sutured.

Muscovite forms large anhedral flakes or flake aggregates which are generally developed in the grain boundaries.

In one specimen chloritoid forms from 5 to 10 percent of the rock. It occurs as large subhedral grains 0.5 mm long, and apart from limonitic material along microfractures, is very fresh. The chloritoid is inclusion free which suggests that the original sandstone was poor in potash but rich in alumina. Tourmaline, which occurs as large grains, is an abundant accessory.

Discussion

The basal beds of the Speewah Group can be traced more or less continuously from the type locality, but the upper boundary of the Group is difficult to recognize in the absence of siltstone formations, as in the type area. The basal sediments in the Cone Hill area have been tentatively assigned to the Speewah Group on lithological grounds, but could represent King Leopold sandstone.

Around the Quartzite Range, sandstones immediately overlying the older Precambrian are white clean washed, and moderately well sorted, and resemble those of the King Leopold Sandstone although their stratigraphic position is more akin to that of the Speewah Group.

Elsewhere in the area, sandstones at or near the base of the Kimberley Basin succession, and which could possibly belong to the Speewah Group (but cannot be distinguished lithologically from the King Leopold Sandstone) are present on Sunday Island, the Helpman Islands, and on the mainland about 5 km north of the Helpman Islands.

The limited thickness of the Speewah Group in the Yampi area and its possible absence in part of the area warrant comment. These features could be the result of a diachronous base to the Kimberley Basin succession (i.e. a younger base in the northwest than in the southeast), of an erosional break (or breaks) within the Speewah Group, of an erosional break between the Speewah Group and Kimberley Group, or a combination of these.

Conclusive evidence is lacking. However, it appears, especially from evidence in the Charnley area northwest of Mount Humbert where some of the constituent formations of the Speewah Group can be recognized, that minor erosional breaks within the sequence, possibly resutling from proximity to an ancient shoreline, are probably largely responsible for the limited development of the Speewah Group in this area.

KIMBERLEY GROUP

KING LEOPOLD SANDSTONE

The King Leopold Sandstone, which is the basal unit of the Kimberley Group, is continuous throughout the Kimberley region and extends on to the Yampi Sheet from the adjoining Charnley Sheet. It was defined by Dow et al. (1964) from the Lissadel Sheet area in the east Kimberley.

Distribution

The King Leopold Sandstone forms the McLarty, Quartzite, Wyndham, and High Ranges, and the northern and southern flanks of the Kimbolton Range. It also forms many of the islands between Yampi Sound and King Sound.

Stratigraphic Relationships

The King Leopold Sandstone in most places in the Sheet area overlies the Speewah Group. The contact is almost everywhere intruded by Hart Dolerite, but is apparently conformable as it is elsewhere in the Kimberley region. Around the Quartzite Range the Speewah Group has not been recognized and the King Leopold Sandstone lies unconformably on Halls Creek Group and on Nellie Tonalite. The formation is conformably overlain by the Carson Volcanics, and is extensively intruded by the Hart Dolerite. Near the centre of the Sheet area, and in the Saddle Hill area, the formation is overlain unconformably by Palaeozoic conglomerate.

Lithology

Mainland ranges and northwestern islands. Apart from minor variations in grain-size the lithology of the formation is uniform over most of the mainland and the islands between Mermaid and Gibbings Islands. It consists of white or light grey, buff or pale brown quartz sandstone when fresh and is yellow-brown, grey, or pink when weathered. Grainsize varies from fine to coarse and is greatest in the west, e.g. on Byron Island and on Sunday Island (see below). The sandstone locally contains minute quantities of muscovite, but is less muscovitic than rocks of the Speewah Group, especially those in the Cone Hill area.

The sandstone is thick to thin-bedded, and blocky to massive. Bedding, which is inconspicuous, is most clearly seen on air-photographs or at a considerable distance from the outcrop, where variations in hardness and alignment of vegetation are most obvious. Cross-bedding is of the trough type. This is best displayed on well exposed gentle dip slopes which consist of innumerable intersecting crescentic fore-set units. Cross-bedding is rarely detectable in metamorphosed sandstone. In the McLarty Range the formation is essentially unmetamorphosed and shows abundant cross-bedding with fore-set units 20 to 40 cm thick. Locally some cross-beds are overturned.

In the Wyndham Range, joints in the sandstone are filled with ferruginous sandstone breccia which is more erosion resistant that the adjacent sandstone.

Sunday Island, Mermaid Island, and the Cascade Bay area. The sandstone forming these islands is a coarse-grained tourmaline-muscovite quartzite of higher metamorphic grade than most of the King Leopold Sandstone found elsewhere in the Sheet area. It weathers to large rounded boulders reminiscent of granite topography and photo pattern.

The quartzite is white or light grey when fresh, and weathers to a light purple or yellow colour. Angular interlocking quartz grains are up to 1 cm long, although medium-grained varieties also occur.

Up to 5 percent of the rock consists of muscovite in oriented flakes 0.5 to 3 mm long. Tourmaline is invariably present, as fine to coarse subhedral to euhedral grains; in places it forms up to half of the quartzite in lenses a few centimetres long.

The sandstone is thick to thin-bedded, and flaggy to massive. Ripple-marks and low-angle cross-beds are present but rare. The sandstone on beaches and smaller islands is very friable, owing probably to muscovite weathering.

Fitzgerald (1907) reported the occurrence of garnetiferous crystalline rocks underlying the sandstone on the northwest shore of Sunday Island, but this area was not visited during the present survey.

Thickness

The thickness of the formation can be determined with reasonable accuracy only in the McLarty Range/High Range area and in the vicinity of Cone Hill. In both these places, however, it is intruded by dolerite and the position of the contact with the underlying Speewah Group is uncertain. Elsewhere in the Yampi Sheet area the base of the formation is not exposed.

89

The King Leopold Sandstone apparently thickens slightly both eastwards and westwards from the McLarty Range. With the exception of a thickness of about 1550 m estimated for the section south of Cone Hill, thicknesses are of the same order as those (900 m to 1200 m) found elsewhere in the Kimberley region. Some estimated thicknesses are as follows.

Mount Nellie (paced section - see appendix L-1). Here about 1170 m of sandstone is exposed in a composite section. Of this about 1050 m measured in the one locality belongs to the King Leopold Sandstone; the basal part of the sequence in this vicinity has been assigned to the Speewah Group.

Allora Island to the east of Sunday Island. The Sunday Island group is part of a basin structure, details of which are not known. An estimated minimum of 1200 m is exposed here.

South of Cone Hill. An estimated 1800 m of sandstone is present in a section between Cone Hill and the Kimbolton Range. Of this about 360 m is the basal muscovite-rich sandstone assigned to the Speewah Group overlying the Whitewater Volcanics and the Cone Hill Granite. In this area the apparent thickness may have been increased by reverse faulting.

North of Cone Hill (partly paced). In this area 1050 m of sandstone is exposed. The basal 360 m is equated with the basal muscovite-rich sandstone to the south of Cone Hill.

Petography

Two specimens have been examined in thin section: one from Sunday Island, and one from the southeastern end of the Quartzite Range. In addition the heavy mineral assemblage of five specimens has been examined.

Sunday Island. The rock is a recrystallized sandstone. Quartz grains are angular to subangular, interlocking, and between 0.5 mm and 1 cm long. A few angular grains about 0.1 mm are included in aggregates of tourmaline grains.

Parallel-sided muscovite flakes generally about 0.5 mm long and 0.1 mm wide are well oriented, and define a cleavage.

Tourmaline is the iron-bearing variety shorlite (e=colourless, w=olive green). Grains are euhedral to subhedral, and form oriented aggregates up to 0.5 mm long which lie at an angle of 10° to 15° to the orientation of the muscovite flakes. Small grains of quartz, muscovite, and sphene are included in some of the aggregates. Most of the tourmaline is concentrated between the large quartz grains, and probably defines original bedding. One small grain of apatite also occurs in the section.

Southeastern Quartzite Range. A sample from this area contains quartz, chlorite, muscovite and few accessories. The sandstone is even-grained, with most grains slightly flattened. The chlorite defines a cleavage, and is more abundant than the muscovite. Tourmaline and some limonitic stringers are the only accessory minerals.

The heavy minerals have been separated and studied from specimens of King Leopold Sandstone from Byron Island, south of Walcott airstrip, north of Cone Hill, near Mount Nellie, and northwest of Mount Nellie. In all five samples, of which four come from levels well above the base of the Formation, tourmaline was notably lacking. Zircon was the predominant heavy mineral in the two specimens, rutile in two others and anatase in the fifth. By contrast some thin sections of probable Speewah Group rocks from near Cone Hill and of quartzites from near the base of the Kimberley Basin succession on Sunday Island and at the southern margin of the Quartzite Range contain tourmaline as the dominant heavy detrital mineral, a feature which they have in common with some sandstone from the Speewah Group, especially the O'Donnell Sandstone in other areas. It is possible that examination of the heavy mineral suites in relation to other parameters, e.g. sorting characteristics, could help to differentiate rocks of differing provenance and possibly of different formations in the Kimberley area. In particular it could help to distinguish rocks of the Speeway Group from those of the King Leopold Sandstone in certain areas.

CARSON VOLCANICS

Introduction

The Carson Volcanics, which extend into the Yampi Sheet area from the adjoining Charnley Sheet area, consist essentially of basalt and minor tuff, feldspathic sandstone, and siltstone.

The name, which is taken from the Carson River and Escarpment in the Drysdale and Ashton Sheet areas, supersedes the original name of Mornington Volcanics used earlier by Guppy et al. (1958) and Harms (1959), and was defined by Dow et al. (1964).

Distribution

The Carson Volcanics occur mainly in discontinuous fold belts extending from King Sound northwards to Yampi Sound and eastwards to Doubtful Bay.

The formation, which is valley forming, is best exposed immediately north of the McLarty Range. In the western part of the Yampi Peninsula areas underlain by the Volcanics are largely soil covered. Relief is seldom greater than 45 m.

Fig. 14a Overturned crossbed in King Leopold Sandstone. McLarty Range 7 km north of Mount Nellie. (Neg G9682) DCG

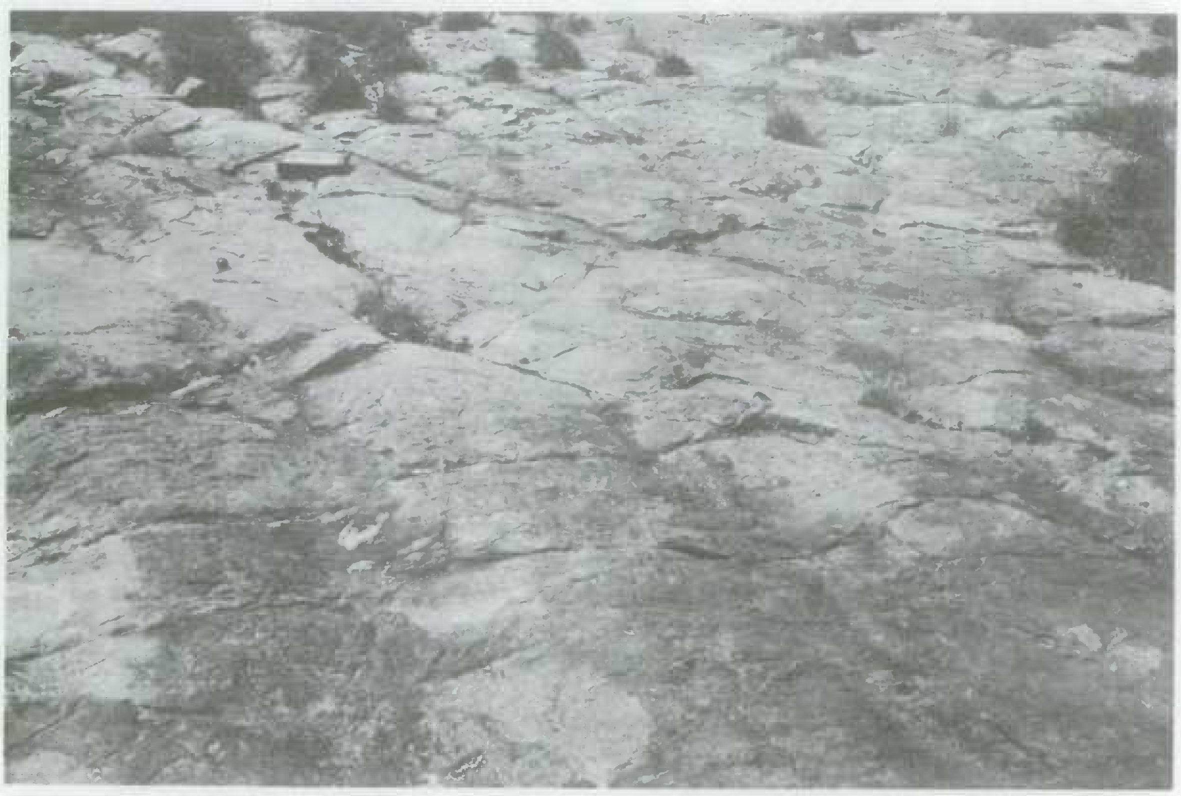


Fig. 14b Megaripples with wavelength up to 1 m in Warton Sandstone, 17 km north-east of Yule Inlet. (Neg M 1003/6) DCG

Thickness

The Carson Volcanics range from about 360 m in thickness in the Kimbolton Range, to about 1140 m in the area north of the McLarty Range (see section in appendix). The northward thickening is partly accounted for by a thicker accumulation of pyroclastics probably resulting from proximity to eruptive centres in the north.

Lithology

The Carson Volcanics in the Yampi Sheet area consist of altered, locally amygdaloidal, basaltic lavas, sediments, and pyroclastics. The basal part of the sequence consist of amygdaloidal altered basalt. This is generally overlain at between 135 m and 450 m from the base by feldspathic sandstone and phyllitic siltstone. These sediments, in turn, are overlain by basalt (in the south), and by basalt and pyroclastics in the north. Low grade metamorphism, increasing in intensity westwards, which has affected all Kimberley Group formations, is well displayed in the Carson Volcanics. Sections measured in the area are given in the appendix (sections C1 and C2), and petrological descriptions of the various rock types to this formation are summarized below (from G.S.W.A. Petrological Report No. 135, Miss R. Peers).

Basaltic Lavas. Metamorphosed basaltic lavas which comprise 50 to 75 percent of the succession are mainly fine to medium-grained, weakly to moderately foliated, grey-green and dark green amphibolitic and chloritic rocks which are products of regional metamorphism mainly in the greenschist facies. Locally, e.g. near the mouth of Lyddarba River, the assemblage andesine-hornblende is present, indicating that metamorphism has reached the almandine-amphibolite facies.

Mafic minerals of these altered rocks are variously chlorite, tremolite, actinolite, or hornblende, depending on the degree of metamorphism. Hornblende is pleochroic with X=pale green, Y=green, and Z=bluish green. Plagioclase ranges from albite to andesine. It is partly or in some cases completely recrystallized to assemblages consisting of one or more of the following: albite, quartz, sericite, epidote, and calcite. Small amounts of quartz, epidote, sphene, and apatite are found in the groundmass. Other accessories include opaque minerals altered to leucoxene and hematite.

Amygdaloidal lavas are dominant in the lower and upper parts of the formation. The amygdales are both spherical and oblate and range between 1 mm and 3 cm in diameter, and contain one or more of the minerals, chlorite, epidote, quartz, biotite, and feldspar. The amygdales generally show a decrease in size and abundance downwards within single flows, which range from 6 m to more than 100 m thick.

Some thin sections contain elongate curved amphibole crystals, which closely resemble the feathery pyroxenes typical of chilled basic lavas. Also, some of the feldspar laths appear to be hollow crystals, which similarly are regarded as typical of quenched submarine lavas.

Sediments. Sedimentary interbeds of the Carson Volcanics comprise between 15 and 20 percent of the total succession and are restricted mainly to the middle part of the sequence. The interbeds are laterally discontinuous, and appear to be missing in the Kimbolton Range region where the Carson Volcanics are relatively thin. They are best developed north of the McLarty Range, and are readily recognizable on air photographs as light coloured strips, which delineate local structure. Where possible these beds have been distinguished on the accompanying map.

They consist of white, grey, pale green, reddish-brown, and buff medium-grained quartz sandstone and feldspathic sandstone, which are generally well sorted, thin-bedded, cross-bedded, flaggy, and blocky. They range from 5 to 25 m thick and are interlayered with metamorphosed silty sediments. In thin section, the sandstones are composed of a mosaic of quartz grains, which are marginally recrystallized. Muscovite is generally developed along the margins of the feldspar (mainly microcline) grains.

Silty sediments associated with the sandstones range from 15 m to more than 60 m thick, and consist mainly of altered siltstone, tuffaceous siltstone, and mudstone. These sediments have been metamorphosed to grey, green, and brown chlorite, biotite, and muscovite schists, and quartz-sericite phyllites.

Most of the schists include minor amounts of quartz and feldspar, either as scattered grains in the groundmass or locally concentrated in irregular bands parallel to the foliation. The opaque minerals are completely altered to leucoxene, with minor hematite and irregular grains of sphene.

Stumpy crystals of diagenetic tourmaline, pleochroic from pink to bluish-green, occur in sericite phyllites (e.g. Y 7A-85-9 and 10), together with hematite or minute octahedra of (diagenetic?) magnetite. The same phyllites also include patches or flakes of a bright yellow-green sheet silicate which may be chlorite pseudomorphing glauconite. Most of the clastic rocks also include small amounts of carbonate.

Pyroclastics. Agglomerate beds and tuffaceous sediments occur in the upper part of the Carson Volcanics, particularly in the area between

Slug Bay and the McLarty Range to Walcott Inlet, where they constitute between a quarter and half of the sequence. Recognizable pyroclasts consist of altered basaltic bombs and chert and phyllite blocks up to 25 cm long and 10 cm across. These are variously rounded, subrounded, or angular, and are set in medium to fine-grained tuffaceous greywacke matrix, metamorphosed in places to chlorite, biotite, and sericite schist. Similar pyroclasts set in a basaltic matrix may represent flow breccias.

Many pyroclasts are altered to patches of biotite and chlorite (e.g. Y 7A-85-12), and are not readily distinguished from matrix material.

Pyroclastic layers occupy the top 225 m of the uppermost part of section C-1, while in section C-2 to the east the pyroclastic zone increases to 390 m.

The coarseness of the ejectamenta and the thickness of the pyroclastic sequence in the northern part of the area suggest proximity to an eruptive centre.

WARTON SANDSTONE

The name 'Warton Sandstone' was first used by Harms (1959), who separated the Elgee Shale and Pentecost Sandstone from the Warton Beds of Guppy et al. (1958). The name is derived from the Lansdowne Sheet area. Mine geologists on Koolan Island have subdivided the formation into three members, the Blinker Hill Sandstone Member[1], the Jap Bay Member[2], and the Arbitration Cove Sandstone Member[1].

Distribution

The Warton Sandstone extends on to the Yampi Sheet from the Charnley Sheet area. It forms narrow sinuous outcrops which crop out more or less continuously from Doubtful Bay in the northeast to the Cascade Bay-Kimbolton Range area in the southwest.

Stratigraphic Relationships

The Warton Sandstone lies conformably on the Carson Volcanics, and is overlain both conformably and unconformably by the Elgee Siltstone. The unconformity is present only in the area immediately north of the McLarty Range. The Warton Sandstone is intruded by the Hart Dolerite and Wotjulum Porphyry.

---

[1]Formerly "Quartzite", [2]Formerly "Formation".

The revised names are used here for the first time and the members formally defined. See Appendix 2.

Physiography

Where it dips steeply the Warton Sandstone forms a series of narrow strike ridges, hogbacks, and cuestas. In areas of more gentle folding, e.g. west of Talbot Bay, the Sandstone forms broader expanses of rugged, dissected plateaux.

Lithology and Thickness

These are summarized in seven measured sections contained in Appendix I, which have been plotted graphically in Figure 15.

Lithology. Quartz sandstone, feldspathic sandstone, and siltstone are the dominant rock types of the formation. Three broad divisions into two sandstone members separated by a thin siltstone member can be recognized in most areas. Locally up to three siltstone members can be recognized. Their correlation is uncertain but it is thought that the lowermost of these siltstones is the most continuous.

In general the lower sandstone unit is a massive white to buff quartz sandstone which is medium to coarse-grained, thick-bedded and invariably cross-bedded. Near Walcott Inlet it contains small bands of pebble conglomerate. The upper unit is also predominantly quartz sandstone, but is usually less massive and more thinly bedded than the basal unit. Most of the sandstone appears well-sorted.

Feldspathic sandstone is distributed through both basal and upper units, but in general is more common in the upper unit, e.g. in sections 5 and 7, where feldspathic sandstone constitutes 90% and 42% of the unit respectively.

The siltstone units of the Warton Sandstone are apparently confined to exposures in the Yampi Sheet area, although a thin siltstone unit was recorded from the Lennard River Sheet area. The siltstone is generally grey or green-grey when fresh, flaggy, laminated, and hematitic, and is associated with fine-grained feldspathic sandstone and micaceous shale. In the northwest siltstone of the Warton Sandstone has been metamorphosed to andalusite hornfels. The unit is ripple-marked and micro-cross-bedded, and in strongly deformed zones is metamorphosed to phyllite and chlorite schist. Chert interbeds and significant copper mineralization are present in the unit north of the McLarty Ranges.

The iron content of the Warton Sandstone (as determined empirically by colour) is low but variable. The formation contains significant hematite (up to about 5%) within and adjacent to siltstone horizons. Pale to deep purple sandstone with prominent specks of hematite is present in section W-7 immediately below the middle siltstone unit, which itself is usually hematitic.

96

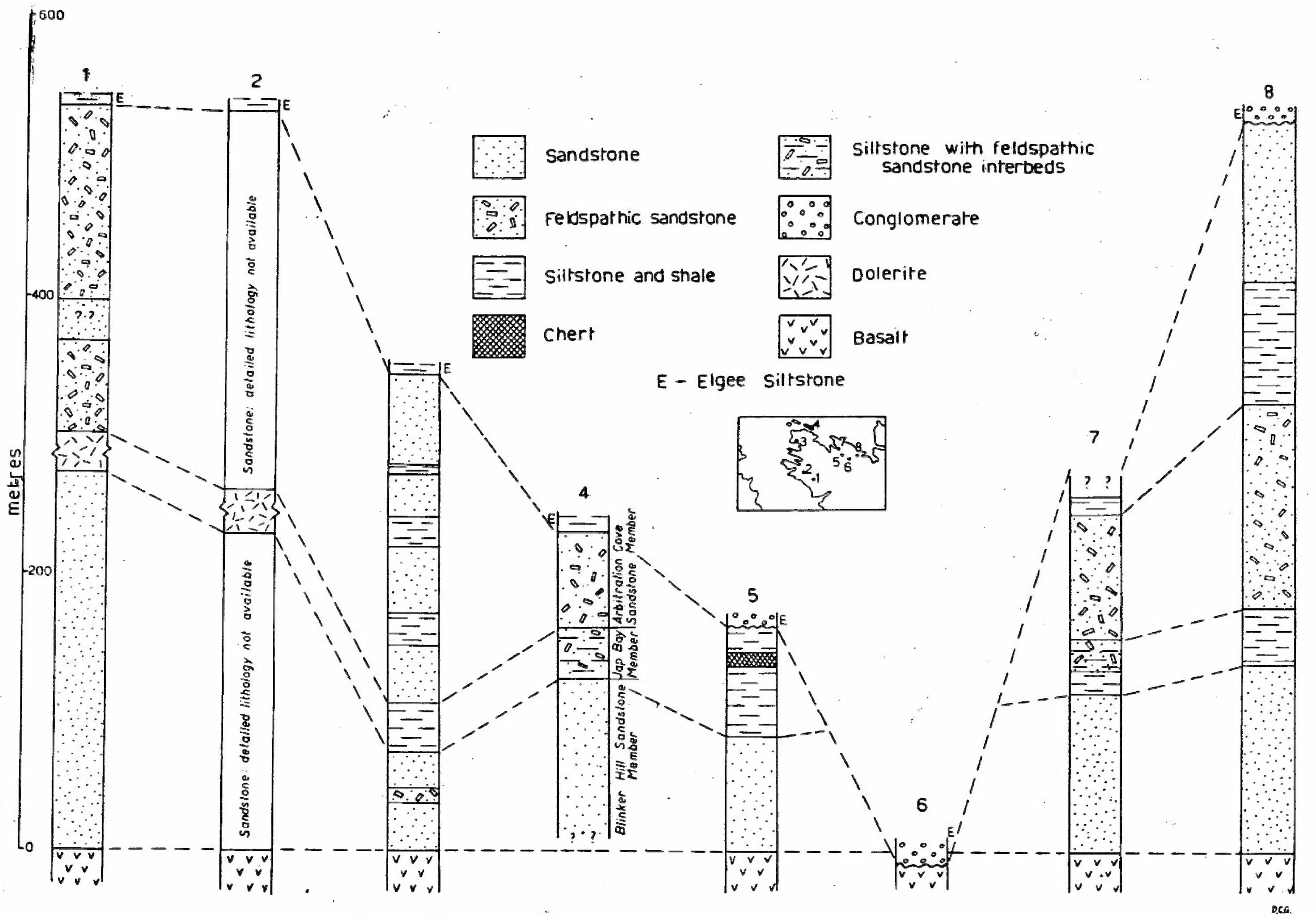


FIG. 15. WARTON SANDSTONE STRATIGRAPHY AND CORRELATIONS.

E 51/A3/15

FIGURE 15

Sandstone breccias are common in the Mount Dawson/Mount Heytesbury area, and appear to mark concealed fault lines.

Cross-bedding and ripple-marking are common. The cross-bedded units are from 15 cm to 1 m thick, and some of the larger units (in the basal part of the formation) show undivided fore-set laminae up to 15 cm thick. Palaeocurrent directions deduced from the cross beds range from the southwest (e.g. in parts of the Warton Sandstone near Shoal Bay and Walcott Inlet), to the north and northeast, the latter direction predominating over most of the Sheet area. Overturning of the cross beds is found locally. Ripple marks are present in quartz and feldspathic sandstone as well as the fine-grained siltstone unit. The ripples are asymmetric or interference-type, and wavelengths range from 2 cm to at least 10 cm. Interference ripples are particularly well exposed on a dip slope of Arbitration Cove Sandstone on Koolan Island. Asymmetric mega-ripples with a wavelength of 0.5 m are present close to the Charnley Sheet boundary about 16 km north of Walcott Inlet.

Thickness. The thickness of the Warton Sandstone is variable. It is thickest in the northeast and southwest of the Sheet (517 and 505 metres respectively), and thinnest immediately north of the McLarty Ranges, where erosion of the Sandstone has caused variable disconformable overlap of the Elgee Siltstone. In one place it has been removed completely by erosion.

In the northwestern part of the Sheet area the thickness ranges from about 240 m to 330 m. This is of the same order of thickness as those measured in the Lansdowne (240 m to 360 m) and Lennard River Sheet area to the east.

The thickness of the principal siltstone member (Jap Bay Member) ranges from 36 m near Shoal Bay and east of Talbot Bay to 66 m north of the McLarty Ranges. The average thickness of the Jap Bay Member on Koolan Island is 36 m.

Petrography

Clean-washed sandstone specimens are mainly silica-cemented and well-sorted. Two well-foliated, and phyllitic sandstones from the middle part of the formation have been examined in thin section. A further sample from the Warton Sandstone adjacent to the Hart Dolerite southeast of the Graveyard, contains cordierite.

Quartz forms lenticular grains up to 1 mm long which are marginally recrystallized to a fine-grained granular mosaic (a.g.d. 0.1 to 0.2 mm).

These quartz mosaics are enclosed in a chlorite-sericite quartz groundmass. The chlorite is pale green with fine lamellar twinning. It appears to be well oriented in the schistosity plane. Sericite flakes are associated with the chlorite, and in one sample cut across the schistosity. Cordierite, in anhedral grains up to 1.5 mm diameter, is colourless to pale yellow and contains abundant inclusions of biotite and quartz. It is biaxial positive, with a 2V of about 75°, and shows similar relief to quartz. Broad lamellar twinning and poorly developed segment twinning are also present. Accessory minerals include zoned green to yellow tourmaline, which is common only in certain bands, black to red-brown hematite, rare rutile and some apatite.

ELGEE SILTSTONE

The term Elgee Shale was used by Harms (1959) for a prominent scarp-forming siltstone member of the 'Warton Beds' of Guppy et al. (1958). The formation was renamed the Elgee Siltstone by Dow et al. (1964). The type area is the Elgee Cliffs (Lissadell Sheet). The name 'Hanging Wall Schist', used by mine geologists on Koolan Island, now refers to the Elgee Siltstone.

Distribution

The Elgee Siltstone forms narrow sinuous outcrops which extend as a more or less continuous belt from Doubtful Bay in the northeast to Irvine Island in the northwest, and southwards to the Kyulgam River. It also crops out farther south in an isolated syncline between Mount Olivia and Oobagooma Homestead.

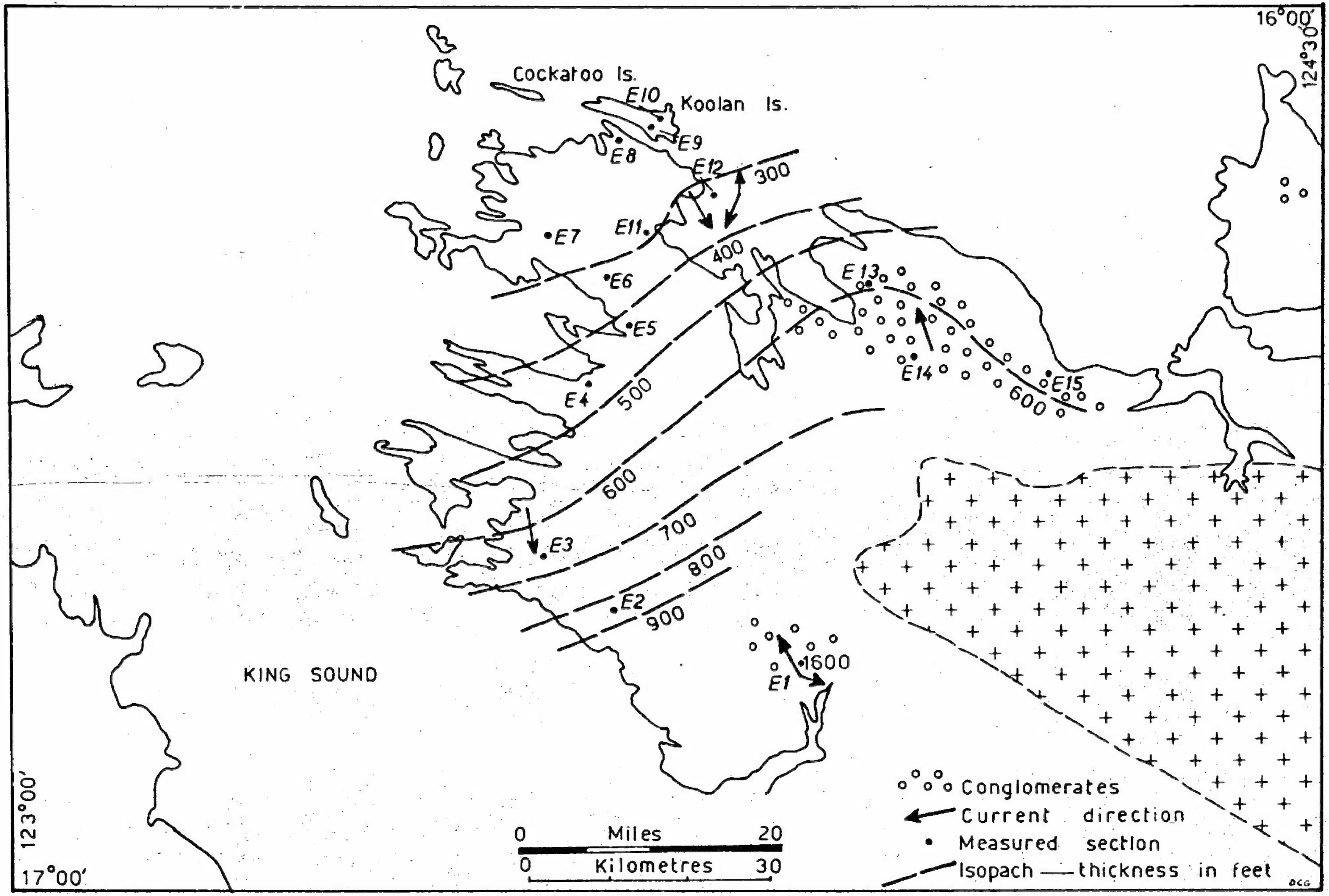
As a result of erosion it is absent between Secure Bay and Walcott Inlet; it is apparently present to the north of this, but is known only from thin, poorly exposed beds of pebble conglomerate, from red-brown siltstone detritus, from aerial observation of scattered outcrops.

Stratigraphic Relationships

The Elgee Siltstone overlies the Warton Sandstone and is overlain by the Pentecost Sandstone. The contact between the Elgee Siltstone and Warton Sandstone is mostly conformable, but in the area north of Mount Nellie, erosion of the Warton Sandstone has resulted in the Elgee Siltstone over-lapping disconformably on to successively lower horizons of the Sandstone. North of the McLarty Range, the Warton Sandstone is not represented in the sequence and the Elgee Siltstone disconformably overlaps on to the topmost beds of the Carson Volcanics. The boundary with the Pentecost Sandstone is everywhere apparently conformable, but the reduced thickness of the lower part of the Pentecost Sandstone on Koolan Island suggests the possibility of a diastem or paraconformity there.

Fig. 16a Cobble conglomerate at base of Elgee Siltstone, 12 km north of Mount Nellie. (Neg M 1003/5) DCG

Fig. 16b Load-ripple-casts in interbedded sandstone and siltstone overlying festoon cross-bedded sandstone of Elgee Siltstone, 2 km west of Mount Olivia. (Neg M1002/3) DCG



Isopachs — Elgee Siltstone

E51/A3/16

FIGURE 17

The lower boundary of the formation is characterized by an abrupt change from white quartz sandstone of the Warton Sandstone to siltstone, phyllite, or conglomerate of the Elgee Siltstone. In the area between The Graveyard and Gibbings Island, silty hematitic sandstones at the top of the Warton Sandstone make the Elgee/Warton boundary difficult to define.

The boundary with the overlying Pentecost Sandstone is marked mostly by a change from a dominantly siltstone sequence to a dominantly sandstone sequence. In most places the topmost siltstone is taken as the top of the Elgee Siltstone. In the area immediately south of Koolan Island (and on the islands of Yampi Sound) siltstone beds are common in Pentecost Sandstone and the boundary with Elgee Siltstone there is uncertain. Since the upper part of the Elgee Siltstone elsewhere is free from thick white sandstone beds, the first thick white quartz-sandstone is taken as the base of the Pentecost Sandstone. This is illustrated in section E8 measured 3 km southeast of Nares Point (see Fig. 18, column 2). Similarly in sections E5, E6, E7 southeast of Wotjulum Mission, where the Pentecost Sandstone consists almost entirely of grey siltstone, the base of a prominent white quartz sandstone is taken as the top of the Elgee Siltstone. In section E4, 7 km north-northeast of Cone Hill, the basal sandstone of the Pentecost Sandstone is missing and the upper boundary of the Elgee Siltstone is tentatively placed at a change from red-brown siltstone to steel grey siltstone of the Pentecost Sandstone. On Koolan Island the Elgee Siltstone is overlain directly by the Yampi Member of the Pentecost Sandstone, e.i. by the upper part of the Pentecost Sandstone, which is thus considered to rest unconformably on the Elgee Siltstone in this part of the area. The stratigraphic relationships of the Elgee Siltstone in and near Koolan Island are shown diagrammatically in Figure 18.

The Elgee Siltstone is extensively intruded by the Wotjulum Porphyry in the area south and east of Yampi Sound, and by the Hart Dolerite in the south around Mount Olivia. Contacts with these intrusives are sharp, with no evidence of assimilation. Where sections of the sedimentary sequence are apparently missing they are believed to have been rafted out of place during intrusion.

Physiography

The Elgee Siltstone crops out in easily eroded escarpments capped by resistant beds of the overlying Pentecost Sandstone and in narrow strike valleys. Exposures are poor since the scarp faces are generally mantled by a thin veneer of detritus from the capping of Pentecost Sandstone.

Lithology and Primary Structures

The characteristic red-brown siltstone and sandstone of the Elgee Siltstone known farther east in the Kimberley region give way in this area to a more varied assemblage of siltstone, sandstone, and conglomerate. Low grade regional metamorphism has been overprinted locally on these sediments in the western part of the area to give schist and phyllite. Carbonates, found in the Elgee Siltstone in the Mount Ramsay (Roberts et al., 1965) and Lansdowne (Gellatly et al., 1965) areas to the east, are absent from this formation in the Yampi Sheet area. Measured sections outlining the lithological variations in the formation are given in Appendix I.

Throughout the area the most characteristic rocks are grey and red-brown siltstone and mudstone. Thin interbeds of fine to coarse-grained pink-brown or grey sandstone are present in most sections: in some they predominate. Conglomerates, which are found north of Mount Nellie and between Kimbolton and Oobagooma (Fig. 16), form the basal part of the sequence in these areas.

The siltstones are fine-grained, thin-bedded to laminated, and flaggy to blocky in outcrop.

Cuspate symmetrical ripple marks are common; asymmetric and interference ripples have also been noted. Flute-casts were seen on Koolan Island and flame-structures, due to post-depositional compaction and intrusion of siltstone into more competent sandstone laminae, were noted near Mount Olivia.

The red-brown colour of some of the unmetamorphosed siltstones is not diagnostic since siltstones of the Pentecost Sandstone in the northern part of the Yampi Sheet area (especially on Koolan Island) are also red-brown. Also, grey-coloured Elgee Siltstone locally becomes red-brown on weathering. For example the Hanging Wall Schist of Koolan Island is red-brown in outcrop with pale-green interbeds, but in drill cores is a uniform grey.

The sandstones are mostly pink-brown or purple-grey, medium to coarse-grained, thin-bedded, flaggy to blocky, and poorly sorted. Fine-grained feldspathic sandstone is present in the Talbot Bay/Mount Nellie area; elsewhere feldspar is rare in the sandstones, and they are coarse-grained, thin-bedded, flaggy to blocky, and poorly sorted.

Trough-type cross-bedding with thin (8cm to 22 cm) fore-set units is characteristic of the sandstones. The current directions, which are variously from north and southeast, are commented on below.

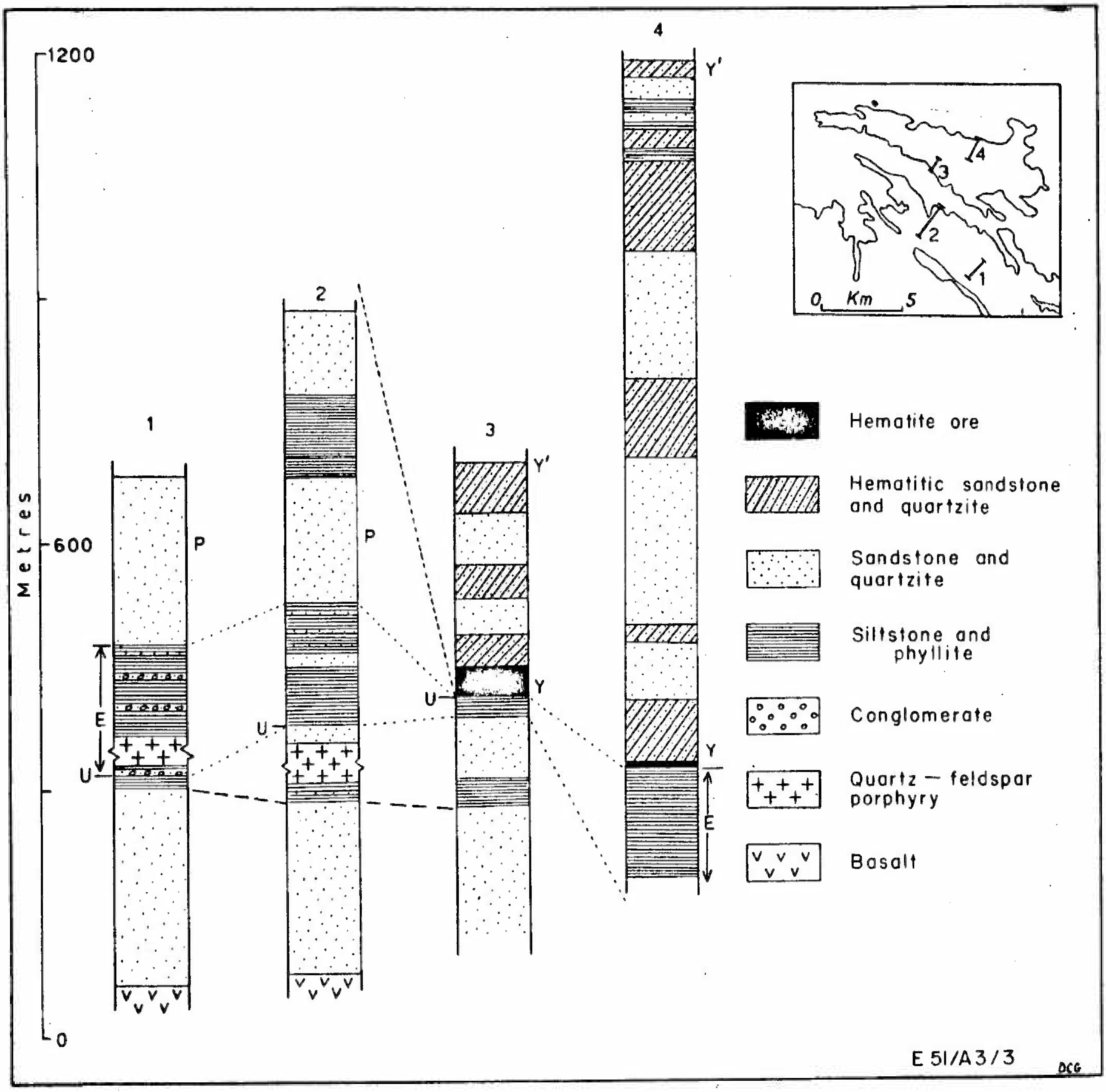


Fig. 18. Comparison of stratigraphy of Koolan Island and adjacent part of Yampi Peninsula. Section 3 from data in Finucane (1939). Other data from this survey. E - Elgee Siltstone; P - Pentecost Sandstone; Y - Y^1 - Yampi Member; U - probable unconformity.

Conglomerates of the Elgee Siltstone are mainly cobble conglomerates with clast size in the range 7 cm up to rare boulders of 60 cm. The most common size range is 10 to 15 cm. The clasts consist entirely of white to very pale-brown, medium to coarse-grained, well-sorted, silica-cemented quartz sandstone and minor pale pink feldspathic sandstone. The matrix consists of poorly sorted granule sandstone. The conglomerate sequences (75 m thick in the south and up to 13 m in the north) contain thin interbeds of coarse-grained pale grey granule quartz sandstone.

With the westward increase in metamorphic grade found in the Yampi area, siltstone gives way to silvery-grey sericite phyllite and muscovite schist, and pale-green chlorite phyllite. Andalusite-bearing hornfelses with 5 mm porphyroblasts of andalusite are characteristic of the Elgee Siltstone in the Graveyard/Whirlpool Pass/Gibbings Island areas, and chloritoid and hematite pseudomorphs after magnetite are found locally in the vicinity of Yampi Sound.

Pseudomorphs after magnetite occur in the phyllites as disseminated grains up to 2 mm and are accompanied locally by thin hematite veins in joints (e.g. Gibbings Island). Small (8 cm) blocks of massive hematite have been noted in detritus from the Elgee Siltstone south of Shoal Bay (Section El), but nowhere has hematite been found in the Elgee Siltstone in quantities comparable to that in the Pentecost Sandstone around Yampi Sound.

Thickness

Over most of the area the thickness of the Elgee Siltstone is between 120 m and 180 m and shows a gradual thinning northwestwards and thickening southeastwards (Fig. 17). The northwestward decrease reaches its extreme on Koolan Island, where the average thickness (from cross-sections of Finucane, 1939) of the Elgee Siltstone (=Hanging Wall Schist) is 30 m (range 13 m to 57 m).

However, it thickens rapidly northwards and attains a thickness of at least 180 m on Koolan Island about 1 km north of the main ore body. This rapid change in thickness, which is unrelated to lithological variation, is thought to be due to erosion.

In the southeast the formation is 255 m thick near Kimbolton Homestead and 480 m thick 6 km west of Oobagooma. This latter section contains conglomerate, sandstone, and grey siltstone, and is separated from other outcrops of Elgee Siltstone by folding and faulting. It may be correlated with a similar, though thinner, sequence of known Elgee Siltstone 9 km north of Mount Nellie. The order of thickness near Oobagooma, although greatly exceeding that found elsewhere in the Elgee in this area, does not differ greatly from the thickness of 370 m that might be expected from extrapolation of the isopachs. Most of this difference can be accounted for by the presence of a 75 m thick basal conglomerate.

There is a general increase in the content of clastic material both southwards and eastwards which appears to be responsible, at least in part, for the thickness variations.

Petrography

Two thin sections have been examined. One of these, a phyllite from the southeastern end of the Graveyard, consists mainly of small quartz grains and small well oriented flakes of muscovite, and a platy opaque mineral (?specularite) along with minor accessory tourmaline and zircon. The other, an andalusite phyllite from Gibbings Island, is notable in that it contains tabular goethite pseudomorphs after ?chloritoid, and inclusions of fresh chloritoid within 5 mm poikiloblastic andalusite crystals.

The heavy mineral assemblages of two sandstones from the Elgee Siltstone show relative concentrations: tourmaline>rutile>zircon. This preponderance of tourmaline over rutile and zircon is a feature characteristic of most of the Kimberley Group sandstones of the area which show southerly current directions.

Discussion

The palaeocurrent data for the Elgee Siltstone in the Yampi Sheet area and their relationship to the distribution of conglomerates and erosional breaks in the sequence form an important key to the provenance of the Kimberley Basin Sediments. Over most of the area the dominant current direction deduced from cross-beds in the Elgee Siltstone is from the north. However where conglomerates are present in the sequence, there is a marked reversal, with currents from the southeast (Fig. 17). The fact that conglomerate deposition and northwest-flowing currents prevailed in localities both to the north and south of the present 'basement' outcrop suggests that both are the result of a single uplift movement of the core of the King Leopold Mobile Zone (which probably lay to the south of present outcrops of older Precambrian rocks). There is no evidence that the older Precambrian rocks were exposed at this time: on the contrary, the uniform quartz sandstone and minor feldspathic sandstone composition of the megaclasts of the conglomerates suggests that they were derived entirely through erosion of the underlying Kimberley Group sandstones.

PENTECOST SANDSTONE

The name 'Pentecost Sandstone' was first used by Harms (1959) as a subdivision of the Warton Beds of Guppy et al. (1958). The name is derived from the Pentecost Ranges of the Cambridge Gulf Sheet area of the East Kimberley. It is the topmost formation of the Kimberley Group and in the Yampi Sheet area it includes the Yampi Member in which the iron ore deposits of Koolan and Cockatoo Islands are found. The Pentecost Sandstone occurs throughout the Kimberley Basin: the Yampi Member is confined to the Yampi Sheet area.

Distribution

In the Yampi Sheet the Pentecost Sandstone is found in narrow northwest-trending fold belts between the basement complex and the coast, and is more or less continuous from Doubtful Bay along the coastline of Collier Bay, Talbot Bay and Yampi Sound, to Strickland Bay. A separate elongate basin of Pentecost Sandstone is present near the Kimbolton Range, extending southeastwards from Mount Olivia. It also crops out on most of the outlying islands in the north, (e.g. Wood Islands) and northwest (e.g. Bathurst Island) of the Sheet area.

Stratigraphic Relationships and Correlations

The Pentecost Sandstone overlies the Elgee Siltstone conformably in most places. However, between Walcott Inlet and Secure Bay and locally near Doubtful Bay the Pentecost Sandstone overlies the Warton Sandstone unconformably. At these localities the Elgee Siltstone has been completely eroded prior to deposition of the Pentecost Sandstone. The formation elsewhere in the Kimberleys is overlain conformably by the Bastion Group, but in the Yampi Sheet area the top of the unit is not preserved. The boundary between the Elgee Siltstone and Pentecost Sandstone is generally defined as the base of the lowermost white or grey quartz sandstone above the Elgee Siltstone, but the contact is usually concealed.

Three informal members (lower, middle, and upper) have been recognized in the Pentecost Sandstone in the eastern part of the Kimberley Basin.

The base of the middle member was taken to be the base of a thin siltstone and glauconitic sandstone unit. In the Yampi Sheet area at least two different glauconite-bearing horizons are present, correlations are uncertain, and the three-fold division cannot be recognized. It is likely that the lower of the two glauconite-rich units (Fig. 20, sections 8,9) correlates with the glauconite-bearing beds to the east. That in the Graveyard Section (Fig. 20, section 3) possibly also correlates with those to the east, but that in the Yampi Member on Cockatoo Island is probably higher in the sequence. Stratigraphic relationships and correlation of the Pentecost Sandstone are illustrated in Figures 18 and 20.

The Pentecost Sandstone is overlain unconformably by Palaeozoic conglomerate in the Kimbolton Range area, and is intruded by Hart Dolerite north of Walcott Inlet and locally by Wotjulum Porphyry in the Yampi Sound area.

The Yampi Member forms the topmost part of the Pentecost Sandstone. In the northeast the Yampi Member lies conformably on up to 800 m of Pentecost Sandstone, but in the northwest it apparently overlaps the lower beds, and on Koolan Island lies directly on Elgee Siltstone.

Physiography

Where folding is gentle or moderate the formation develops cuestas and hogbacks, which are most prominent in the lower, more arenacous parts of the formation. The siltstone units in the formation give rise to poorly developed rounded cuesta and hummocky forms in which closely-spaced drainage is characteristic. Where the formation dips steeply, flat-topped ridges are developed and the rapid alternation of thin resistant sandstone beds with siltstone produces a banded photo-pattern due to alternation of sandstone ridges and siltstone valleys.

Lithology

The Pentecost Sandstone is mainly a sequence of sandstone, siltstone, and minor conglomerate (Appendix, P-3). Three broad divisions of the formation* are recognized.

The lower part is predominantly quartz sandstone. It is white, grey or pale brown, massive, thick-bedded, coarse to medium-grained, and strongly cross-bedded. It is best developed in the Shoal Bay area, where it is about 1200 m thick. The upper part of this basal sequence is generally pale purple, blocky, and thick to thin-bedded, and appears bimodal and relatively poorly sorted in the hand specimen.

Rare thin beds of pebbly sandstone and pebble conglomerate are present within the basal part of the sequence. The pebbles are of quartzite, vein quartz, and jaspilite. Coarse conglomerates with cobbles and small boulders up to 15 cm diameter are present between Secure Bay and Walcott Inlet, where local faulting could have contributed coarse material to the section.

* The Pentecost Sandstone other than the Yampi Member.

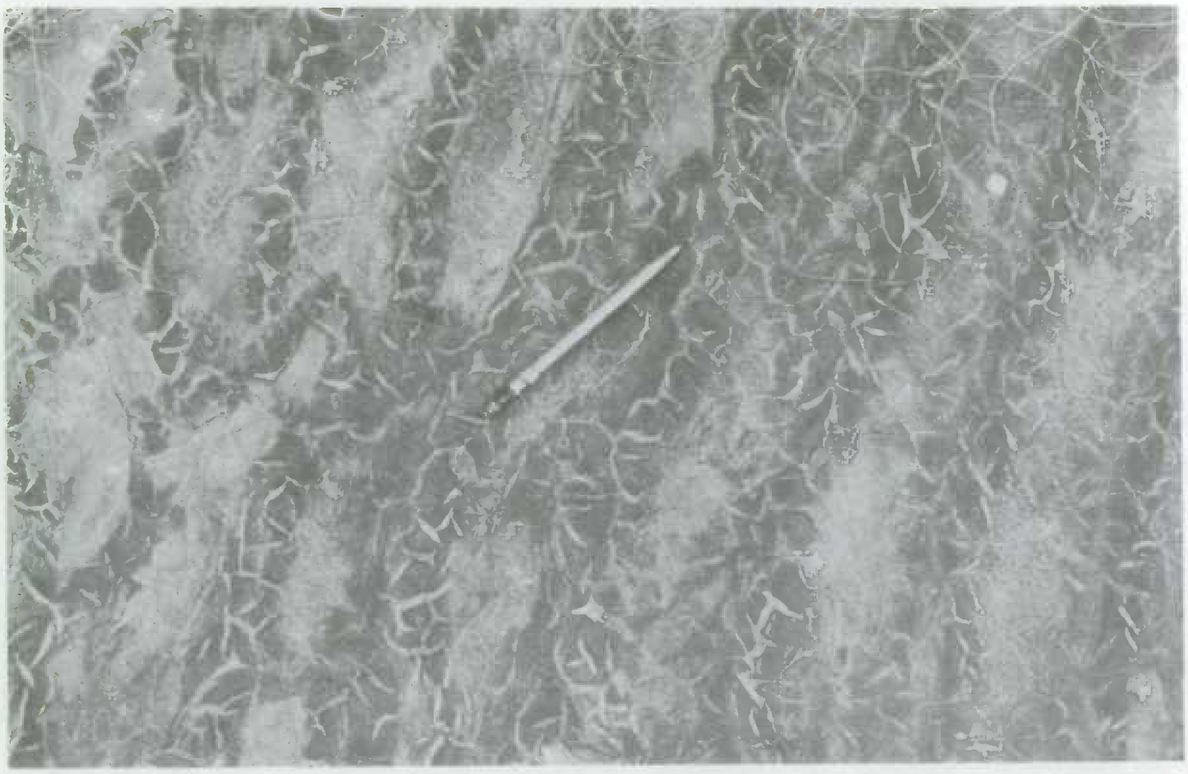


Fig. 19a Trigonal sand casts, Pentecost Sandstone, 3 km southwest of Yule Inlet. (Neg M 753/6) GMD

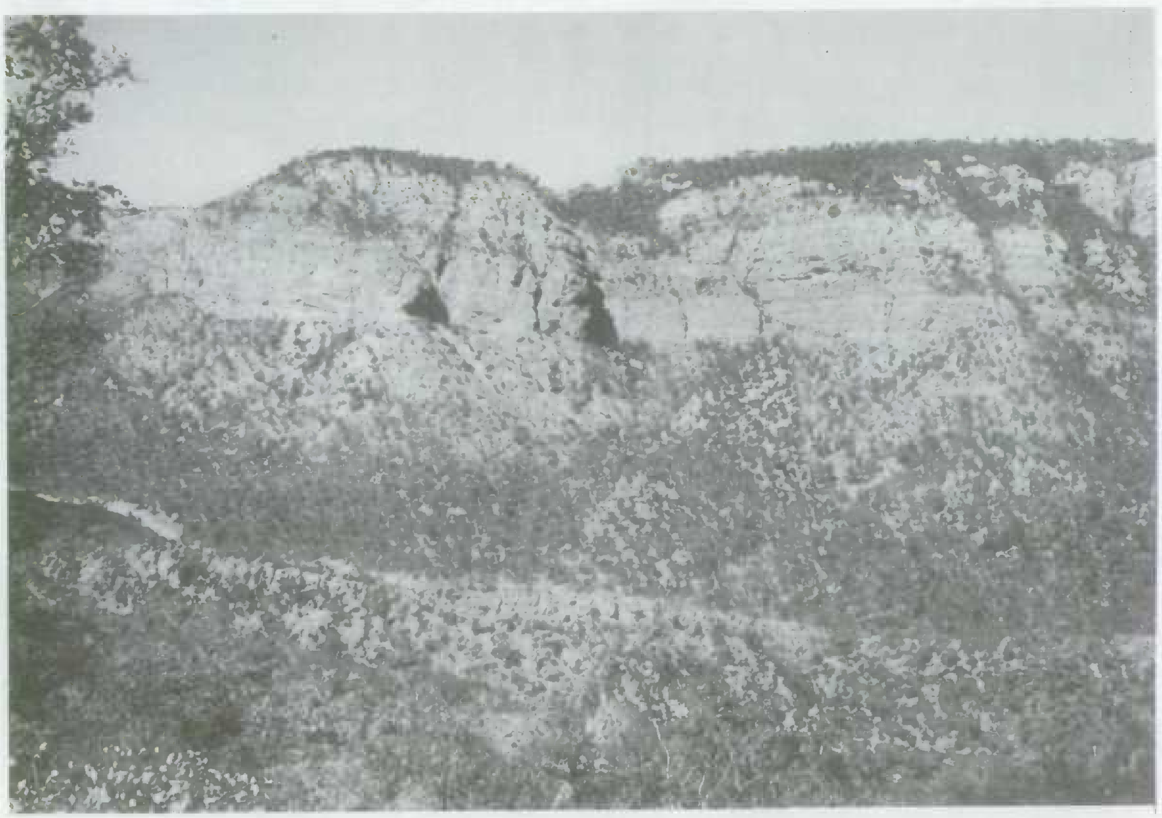


Fig. 19b Cliff-forming basal beds of Pentecost Sandstone overlying easily eroded Elgee Siltstone forming debris slope. Position of contact between the two formations is arrowed. Low bench in foreground is sandstone of Warton Sandstone. 8 km east-southeast of Slug Island. (Neg G9664) GMD

In the northeastern part of the Sheet area, north of Walcott Inlet, three separate units can be recognized in the lower part of the Pentecost Sandstone. They comprise two cuesta-forming units of hard white to buff quartz sandstone and an intervening unit of pale brown cliff-forming, friable, slightly feldspathic sandstone containing scattered mud pellets. These three units can be correlated with similar ones which comprise the lower member of the Pentecost Sandstone in the northern part of the Kimberley Basin, e.g. in the Drysdale-Londonderry Sheet area in the northern part of the Kimberley Basin (Gellatly & Sofoulis, 1966).

Southwest of Shoal Bay the upper 210 m (and near Eagle Point the upper 60 m) of the basal unit contain rare glauconite grains, and these beds may be transitional to the Yampi Member.

A siltstone facies, consisting predominantly of siltstone, mudstone, minor glauconitic sandstone, and abundant thin feldspathic and quartz sandstone interbeds, which is present in the western part of the area is best developed immediately northeast of The Graveyard, where it is up to 1200 m thick. This facies is essentially a lateral equivalent of the sandstone sequence elsewhere in the area. The siltstone and mudstone are generally steel grey to pale grey, less commonly buff, pale green and red-brown. They are massive to blocky, and thin-bedded to laminated, and contain abundant bedding plane irregularities. The siltstones etc. are micaceous, and in folded terrains phyllite and mica schist are common.

Interbeds of quartz and feldspathic sandstone from 0.3 to 12 m thick are widespread through the section. These interbeds are usually fine-grained, blocky and ripple-marked (Graveyard section), or medium to coarse-grained and strongly cross-bedded (e.g. Traverse Island).

Thickness Variations and Facies Changes

The thickness of the measured sections of the Pentecost Sandstone ranges from 420 m to 1260 m. In no place in the Sheet area is a top to the formation found, and thus variations in total thickness are less important than thickness variations of units within the formation. The lower part of the sequence, which is absent locally (e.g. on Koolan Island) is up to 600 m thick. Maximum thickness of this unit occurs in the Shoal Bay area, while the minimum values occur in the Graveyard sequence. The thickness variations in the basal unit are indicated by the position of the principal glauconitic sandstone bed which defines the top of the basal unit. At three localities (The Graveyard, Shoal Bay and Eagle Point), the principal glauconite bed occurs at 225 m, 800 m, and 500 m above the Elgee Siltstone respectively.

Sandstones from the Pentecost Sandstone are quartz-rich, well compacted, and invariably bimodal. The coarser grained fraction is well rounded and ranges from 0.3 to 0.5 mm diameter, whereas the finer fraction is subrounded to subangular and 0.03 to 0.07 mm diameter.

In most specimens the quartz grains show overgrowths, and these, together with ferruginous coatings in some samples, form the rock cement. Small amounts of sericite and fine-grained epidote also occur along the grain boundaries. Most of the sandstone contains some rounded rock fragments, mainly fine-grained siltstone and chert, and in upper parts of the sequence they form up to 15 percent of the rock. Feldspar throughout the sequence is rare or absent (except in the Yampi Member) and exceeds 1 percent in only one specimen.

Common accessory minerals are zircon and olive-green tourmaline and rutile. Epidote, muscovite and limonite fragments are less common.

The siltstones, all of which are from the Graveyard area, are metamorphosed at least to the greenschist facies. They are mainly phyllitic siltstone or mica schist, and consist of a fine-grained recrystallized mosaic of quartz associated with abundant muscovite and iron ore. In the mica schists the mica is highly crenulated. Calcareous clay pellets in some samples are metamorphosed to an aggregate of epidote and limonite. The epidote forms prisms up to 0.3 mm long, and contains abundant ferruginous dust inclusions.

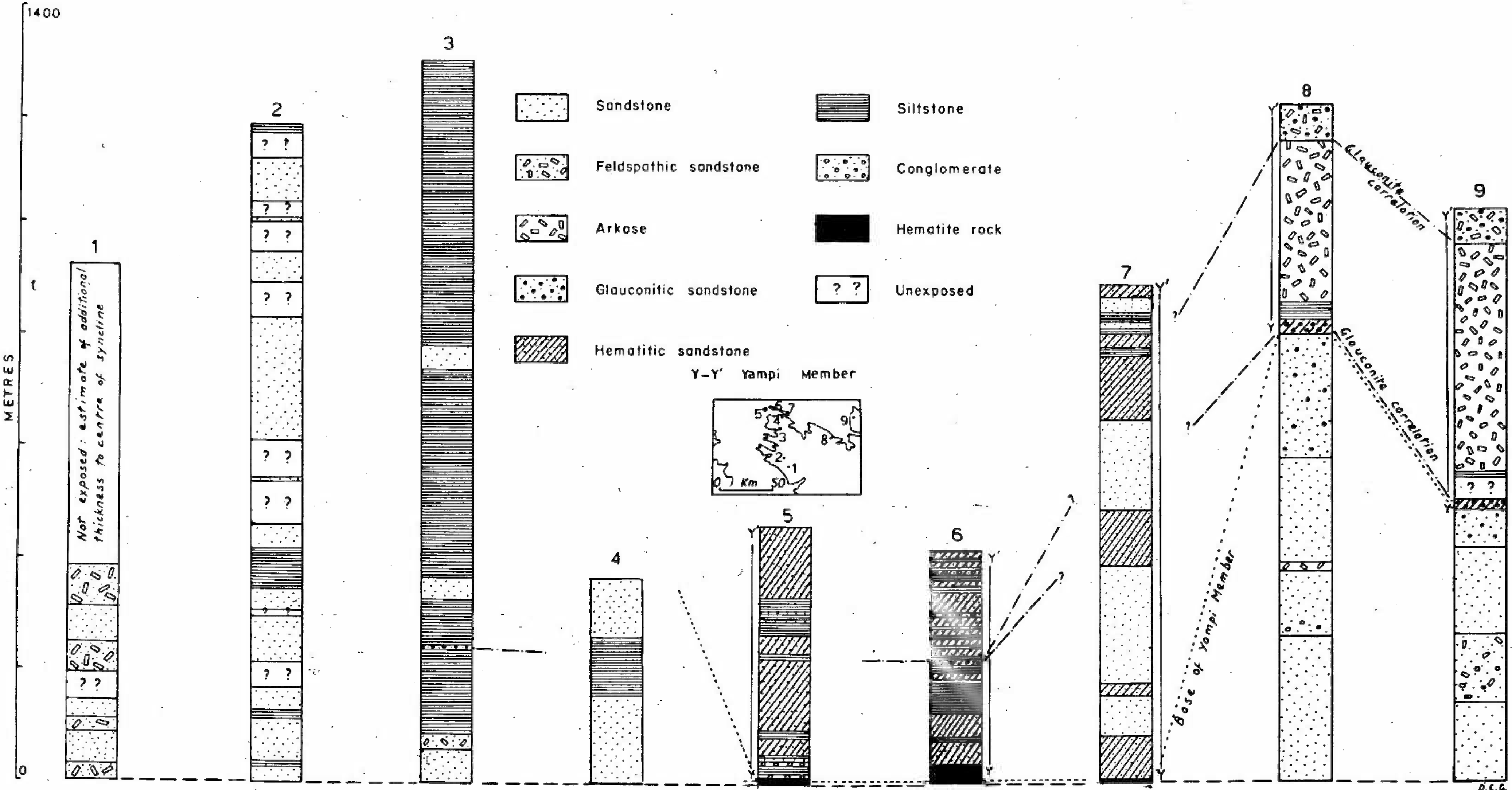
Accessories are mainly tourmaline and zircon. The tourmaline is a blue-green variety, and commonly shows secondary euhedral overgrowths.

YAMPI MEMBER (new name)

The Yampi Member of the Pentecost Sandstone is a sequence of hematitic and feldspathic sandstone forming the upper part of the Pentecost Sandstone in the Yampi Sheet area, and includes the iron ore beds of Cockatoo and Koolan Islands. It was previously termed 'Yampi Beds' by Harms (1959). Reference sections are on the south side of Shoal Bay (1962E, 29290N) and on Cockatoo Island (Reid, 1958, Table 2).

Distribution and Topographic Expression

The Yampi Member forms a discontinuous zone of outcrops on the north coast and northern offshore islands of the Yampi Peninsula from Eagle Point to Bathurst Island.



To accompany record 1971/1

E51/A3/17

FIG. 20 Pentecost Sandstone Stratigraphy and Correlations

FIGURE 20

In the east the Yampi Member forms rounded hills and generally has an even dark grey tone on air-photographs. On the islands in the northwest it forms rockly steep-sided plateaux which have a striped photo-pattern due to the rapid alternation of quartz sandstone, hematitic sandstone, and siltstone.

Stratigraphic Relationships

The stratigraphic relationships of the Yampi Member are illustrated in Figure 20. The Yampi Member is a readily recognizable lithological variant of the Pentecost Sandstone and its base is defined by the first appearance of appreciable amounts of hematite in the sequence. As so defined, the base of the Yampi Member exhibits an overlap, from the east where it is conformably on and partly gradational from the lower part of the Pentecost Sandstone, to the northwest where it lies directly on the Elgee Siltstone. There is no obvious discordance with the Elgee Siltstone and the Yampi Member is considered to be unconformable or paraconformably on it. In places, e.g. the northern part of Koolan Island, the Yampi Member probably overlies the upper beds of the Elgee Siltstone, whereas on the southern part of Koolan Island, where the Elgee Siltstone is only 35 m thick, the Yampi Member probably rests on beds near the base of the Elgee Siltstone.

The Yampi Member is overlain only by superficial Cainozoic deposits, and is intruded by the Wotjulum Porphyry.

Lithology

Lithological details of the Yampi Member given in sections P5 to P9 of Appendix I are representative of the rock unit.

The best known rock types are those of Cockatoo Island and Koolan Island, particularly of Cockatoo Island, which has been mapped in detail (Reid 1958). There the principal rock types are quartz sandstone, hematite sandstone, hematite, phyllitic siltstone, and quartz pebble conglomerate. The sandstones are silica-cemented and all the rocks have undergone low grade metamorphism, and the terms 'quartzite' and 'schist' have been applied to them. However, the effects of metamorphism are slight and confined to a small area and the appearance of the rocks is sedimentary rather than metamorphic, consequently sedimentary rock names are used here.

On Cockatoo Island, Reid (1958) has recognized the presence of fhythmic sedimentation sequences in which the rocks show a progressive upwards increase in grain-size and in the amount of hematite present. Thus within such rhythms, gradations have been recognized from siltstone through quartz sandstone and hematite sandstone to hematite, although not all rock types are present in the one rhythm. Although the gradation is the reverse to that normally found in sediments, small-scale normal graded bedding (e.g. within individual fore-set laminae) has been noted locally. The 'reverse-graded' rhythmic sequences have been attributed (Gellatly, in press) to the effects of winnowing.

In the central and eastern parts of the north coast of the Yampi Peninsula hematite is rare and is formed only in the basal glauconitic sandstone of the Yampi Member. Above this glauconitic sandstone the Member consists largely of fine-grained pale pink-brown to red-brown arkose, and minor siltstone and mudstone. Farther north, and probably higher in the sequence, arkose gives way to feldspathic sandstone, e.g. as on Wood and Viney Islands.

From the limited palaeocurrent data available it appears that currents (as indicated by cross-beds) come from the south and east in contrast to the more general northwesterly and northeasterly current source directions found in the lower part of the Pentecost Sandstone.

Heavy mineral suites from the Kimberley group rocks (including those from the lower Pentecost Sandstone) are predominantly zircon, rutile, or anatase-rich, whereas those from the Yampi Member (except those from the iron ores which have been subjected to intense winnowing) have predominant tourmaline.

Thicknesses of 470 m (south side of Shoal Bay), and of 400 m to 540 m on Cockatoo Island have been measured. The full thickness, however, is almost certainly much greater than this. Measured dips and width of outcrop on the islands in Shoal Bay suggest a further thickness of about 1000 m there.

POST KIMBERLEY GROUP

HART DOLERITE

The name 'Hart Dolerite' was first used by Harms (1959), who redefined the term 'Hart Basalt' used by Guppy et al. (1958). Sills of this unit intrude the Kimberley Basin Succession throughout the Kimberley region. The unit was named after Mount Hart, on the Charnley Sheet area.

Field Occurrence

Extensive sills of Hart Dolerite are present within the Kimberley Group formations, north of Walcott Inlet, particularly in the High and McLarty Ranges, Dugong Bay/Quartzite Range, and Mount Heytesbury/Kimbolton Range areas. Dolerite is absent between The Drain and The Graveyard, where the Kimberley Group is intruded by the Wotjulum Porphyry.

Most of the Dolerite is confined to the King Leopold Sandstone, Carson Volcanics, and Warton Sandstone, the three lowermost formations of the Kimberley Group. At only a few localities does it intrude rocks higher in the sequence, viz. Elgee Siltstone, on the southwest flank of the Kimbolton Range, and Pentecost Sandstone, north of Walcott Inlet.

Best exposures of the Dolerite are those in the High Range, Quartzite Range, and northeast of the Kimbolton Range. Elsewhere the Dolerite is valley-forming and commonly masked by soil, vegetation, and sandstone debris. On air-photographs it is usually expressed by a smooth dark grey tone. In the High Range, rugged hills covered entirely with dark grey to black boulder scree and outcrop are characteristic.

The Dolerite forms sills of varying thickness which both follow and trangress bedding in the Kimberley Group. In the Kimbolton Range the Hart Dolerite is parallel to the bedding over strike lengths of up to 16 km; elsewhere it follows joint and fault planes, and has commonly displaced rafts of of sandstone more than a square kilometre in area.

Macroscopic Appearance and Lithological Variation

Over all the Sheet area, the Hart Dolerite is dark grey-green and massive. Subophitic texture is evident in some samples, particularly in the northeast of the Sheet, but in the west it is obliterated by extensive amphibolitization. All gradations are found between amphibolite and subophitic dolerite.

The prominent dolerite in the High Range is a composite sill, the lower part of which is coarse-grained and subophitic, and granophyric toward its upper margin. The granophyric dolerite characteristically contains large elongate feathery mafics. The upper part is fine to medium-grained, and lacks ophitic texture. It is dense and apparently strongly chloritised.

The sills locally have a poorly developed flow-foliation which is defined by a sub-planar arrangement of plagioclase laths and mafics.

Maximum thickness of Hart Dolerite is 820 m in the High Range, where the upper and lower sills are 180 m and 640 m thick respectively. Elsewhere in the Sheet area, Dolerite thicknesses range from 240 m to 600 m.

Contact Relationships

The Hart Dolerite intrudes all formations of the Kimberley Group, as well as parts of the Halls Creek Group, Woodward Dolerite, Nellie Tonalite, and Lennard Granite. It is overlain unconformably by Palaeozoic conglomerate.

Contacts with Woodward Dolerite. This unit is in contact with the Hart Dolerite in the Quartzite Range area. The two units are difficult to distinguish since both are sheared, recrystallized, and amphibolitic. However, the Hart Dolerite is a paler green colour there than the Woodward Dolerite.

Contacts with Kimberley Group. All contacts with the Kimberley Group are obscured by scree. In the High Range the King Leopold Sandstone within 6 m of the dolerite is unaffected. Near The Graveyard, cordierite has been found in a siltstone unit of the Warton Sandstone at a contact with the dolerite, but it is uncertain whether this is a result of contact or regional metamorphism. The former is considered the more likely. The Carson Volcanics are difficult to distinguish from the Hart Dolerite in some areas. Amygdales and sedimentary interbeds, where present, are diagnostic of the volcanics.

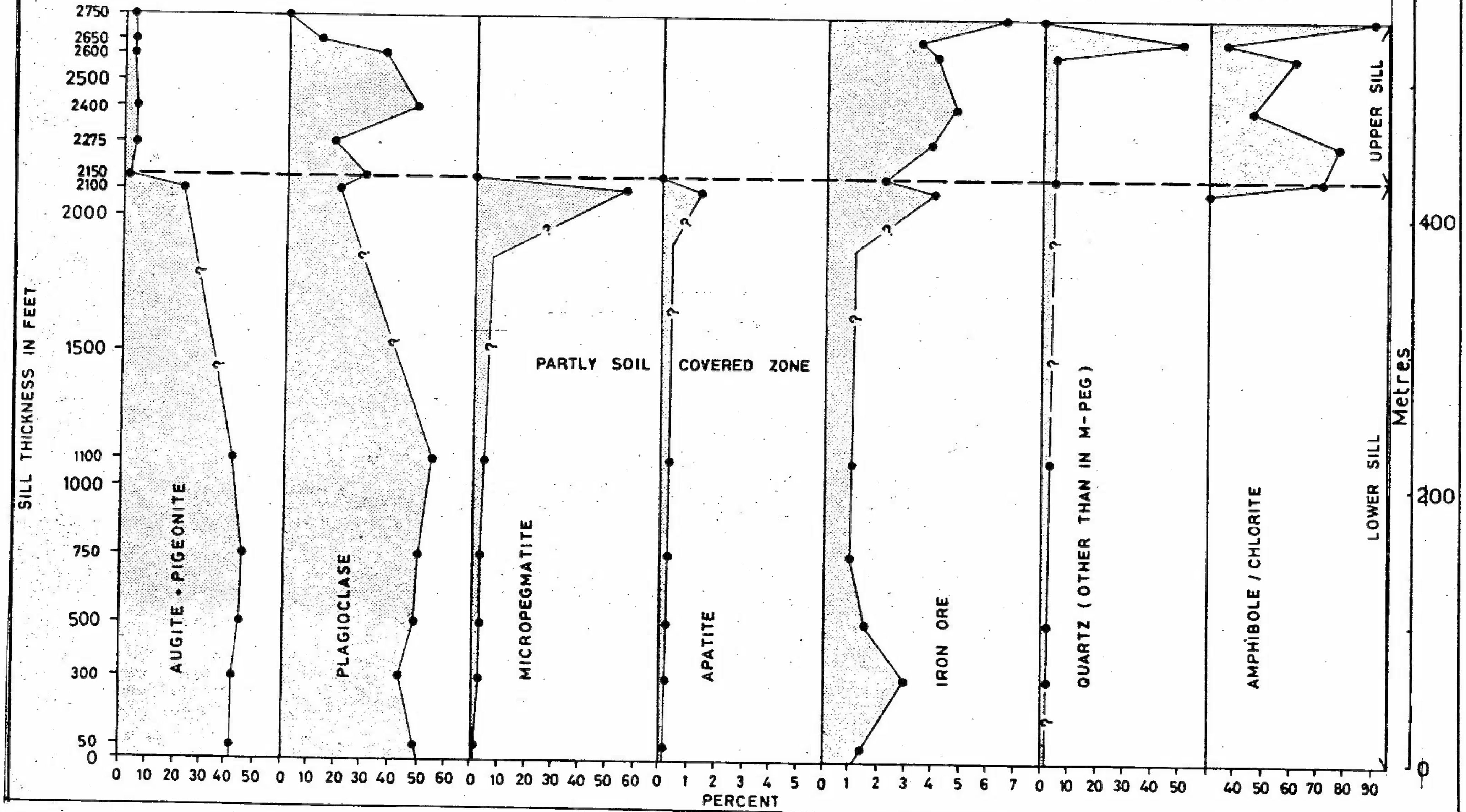
Contacts with the Lennard Granite and Nellie Tonalite have not been seen in the field.

Petrography

Amphibolite. Much of the Hart Dolerite in the Sheet area is amphibolite. Ophitic textures are rarely preserved. Amphibole contents range from 50 to 95 percent. The amphibole is a pale green variety, and in some samples at least two types are present. Clinopyroxene occurs as relict grains in some of the amphibole, and plagioclase is highly saussuritized. Minor accessory minerals are chlorite, iron ore, sphene, quartz, acicular apatite, and, in one case, green-brown tourmaline.

Dolerite. The petrography of dolerite from the High Range is summarized in Figure 21. Two sills appear to be present but no contact was found. The lower sill is moderately fresh and slightly differentiated. It shows good subophitic texture, and contains abundant clinopyroxene, mainly augite (2V greater than 30^{o}) and pigeonite (2V less than 30^{o}). Augite is more common than pigeonite, and usually forms an irregular mantle around a

FIG. 21 MODAL VARIATIONS-HART DOLERITE COMPOSITE SILL-HIGH RANGE, YAMPI 1:250,000 SHEET AREA



E51/A3/25

FIGURE 21

pigeonite core. Rarely it encloses pigeonite poikilitically, and pigeonite itself forms rare discrete grains. Herringbone texture, caused by interaction of (001) cleavage and (100) twin plane is well developed in the augite. Exsolution lamellae are present in the (001) cleavage of the augite, but are too narrow for identification. Plagioclase is variably saussuritized, and is strongly zoned from about An_{66} to An_{25}. The calcic cores are usually more highly altered than the sodic margins. The laths of plagioclase are up to 4 mm long, and are intergrown subophitically with the clinopyroxene. Micropegmatite occurs throughout the lower sill, but is best developed, together with abundant epidote and apatite, in the topmost zone. The mafics in this zone are usually deuterically altered. Accessories throughout the lower sill include iron oxide (?ilmenomagnetite), quartz, apatite, and very rare biotite and zircon.

The upper sill is considered to be a separate sill because of extensive amphibolitization and chloritization, finer grain size (1.5 mm), lack of micropegmatite, and the presence of abundant skeletal iron ore. Augite occurs in the basal part of the sill as ragged cores in pale green amphibole grains. Some of the relict augites show the herringbone texture noted in the lower sill. Plagioclase is completely saussuritized, and composition indeterminate. Chloritization is most intense in the topmost 30 m of the upper sill. Here a sample shows a subophitic texture but a very low colour index. Large colourless chlorite laths are intergrown with altered plagioclase and granular aggregates of clouded quartz. The chlorite laths show a relict (100) twin plane, and probably pseudomorph augite.

At the top of the sill, chlorite forms 90 percent of the rock. It occurs in the groundmass as irregular pale green laths which define a sinuous foliation. Optic properties suggest that the groundmass chlorite is penninite, while some larger pleochroic phenocrysts are composed of a further variety of chlorite. Skeletal iron ore and small muscovite flakes are abundant accessories.

Discussion

Textures in the lower sill suggest that augite and pigeonite crystallized contemporaneously. In some cases the pigeonite core has sharp boundaries with the enclosing augite, which suggests that augite crystallization proceeded for a period after pigeonite crystallization ceased. The exsolution lamellae in augite have not been identified, but since the host is augite and the lamellae are parallel to (001), they are probably pigeonite (Poldervaart & Hess, 1951).

The lower sill is a typical pigeonite tholeiite with limited development of a granophyric residium. The upper sill is a crystallization product of basic magma which apparently was enriched greatly in water, and to a lesser extent, iron.

The aggregates of quartz in the upper sill do not appear granophyric, but are suggestive of metasomatized sandstone. It is possible that the low colour index and the quartz aggregates are a result of incorporation of sandstone xenoliths in the topmost part of the sill.

Age.

The age of the Hart Dolerite is given as 1800 m.y. (Bofinger, 1967, in press), derived from samples of granophyre from Lansdowne Sheet area. In the Yampi Sheet area the Dolerite is folded, metamorphosed, sheared and faulted, and thus appears to be earlier than the main folding and faulting in the area. However, it may post-date an earlier period of faulting, since in many places sills follow pre-existing faults and joints.

WOTJULUM PORPHYRY

The Wotjulum Porphyry (new name) is an acid porphyry found in the northwestern part of the Yampi Peninsula. It was first recorded by Maitland (1919) when he described the Yampi Sound coppermine at Copper Mine Creek. It has also been described briefly by Canavan & Edwards (1938), Finucane (1939), Baker (1954) and Harms (1959).

The porphyry was named the 'Graveyard Porphyry' by Baker (1954) but was not formally defined. Since this name is invalid because of prior usage the porphyry is formally renamed the Wotjulum Porphyry.

The name is taken from the type locality at Wotjulum Native Mission (1259E, 29493N), situated 5 km southeast and upstream from the head of Copper Mine Creek.

Field Occurrence

The Wotjulum Porphyry is a grey quartz-feldspar porphyry forming sills that are essentially conformable with the upper formations of the Kimberley Group. It is confined to the northwestern part of the Yampi Peninsula.

Prominent exposures are found on the mainland, south and southwest of Koolan Island, west of Talbot Bay, and south and southwest of Copper Mine Creek. Minor occurrences intrude the main iron ore horizon on the east side of Phil Cove on Koolan Island. The principal mainland exposures consist of

119

Fig. 22a Wotjulum Porphyry showing flow-banding outlined by variable concentrations of quartz phenocrysts. (GSWA neg.) JS.

Fig. 22b Wotjulum Porphyry (partly oxidised) cut by network of quartz veinlets generally parallel to joints and faults. (GSWA neg) JS.

broad areas and linear belts of undulating rocky hills of massive porphyry, generally with subdued topography and a local relief of less than 60 m.

In shear-zones, the porphyry has been intensely sheared producing phyllonite containing quartz porphyroblasts. In some of the northern exposures the porphyry has undergone varying degrees of alteration and occurs as a grey or white kaolinitic rock studded with prominent rose pink quartz phenocrysts, and cut by numerous veinlets of quartz (Fig. 22).

Contact Relationships

The Wotjulum Porphyry intrudes the Warton Sandstone, Elgee Siltstone, and Pentecost Sandstone, but occurs preferentially within the Elgee Siltstone. It is generally parallel to bedding, but minor dykes intruding the overlying Pentecost Sandstone at Phil Cove (Koolan Island) and on the western side of Water Inlet (Canavan & Edwards, 1937) confirm its intrusive nature.

The Porphyry has commonly intruded the Elgee Siltstone about the middle of the formation (e.g. Sections 5 a, b, 6, Appendix I), and also locally at the upper and lower contacts. It has intruded siltstone of the Warton Sandstone on Yampi Peninsula 2 km south of Koolan Island wharf, and Pentecost Sandstone ca 8 km east of Wotjulum Mission. Sediments adjacent to the contact are mostly unaltered, but on Koolan Island the hematite ore has locally been intimately veined and remobilized by the porphyry producing an irregular melange of the two rock types.

Thickness and Form

The Wotjulum Porphyry is about 420 m thick near Yuraddagi Creek (see Section E6, Appendix I) and it thins to 60 m and less near the Jinunga River, to the southeast and on Koolan Island, to the northeast. These and other thickness estimates, and the absence of porphyry from the Strickland Bay area and Gibbings Island, suggest that the Wotjulum Porphyry is a lenticular sill or laccolith, which reaches a maximum thickness of about 600 m in the Copper Mine Creek area, and thins laterally in all directions from that centre.

Petrography

Thin section descriptions of Wotjulum Porphyry are taken from G.S.W.A. Petrological Report No. 135 (Miss R. Peers).

The Wotjulum Porphyry varies from relatively undeformed dark grey fine-grained massive granite porphyry to light grey and greenish foliated biotite-rich and sheared sericitic varieties.

Quartz phenocrysts, which are commonly rose pink or more rarely pale grey-blue, are abundant throughout. They are generally larger than the feldspars and have an a.g.d.* ranging from 5 mm to 1 cm. Most are fractured, and all show rounded and embayed margins. Recrystallized quartz and groundmass material fill fractures. In sheared varieties the quartz is strained, and partly recrystallized to a mosaic with an a.g.d. of 1 mm. Plagioclase phenocrysts are subhedral or lath-shaped unzoned oligoclase, with an a.g.d. ranging from 3 mm to 1 cm. They are altered to varying degrees, to combinations of sericite, biotite, albite, chlorite, and calcite. Microline phenocrysts (3 mm to 1 cm) are generally unaltered or show only slight alteration to sericite, biotite and calcite. They are perthitic and contain inclusions of recrystallized quartz.

Patches and lenses of green-brown biotite are abundant in much of the porphyry. The biotite is strongly pleochroic with X=pale green, Y=khaki green, and Z=olive green. In strongly foliated varieties (e.g. Y4-21-1) it has X=pale yellow, Y=khaki, and Z=dark yellowish brown. The biotite is usually associated with feldspar breakdown and commonly it contains inclusions of epidote, apatite, sphene, and zircon (with pleochroic haloes).

In some specimens, euhedral brown allanite with an a.g.d. of 0.15 mm is rimmed by secondary colourless epidote. One specimen (Y4-21-1) contained patches of euhedral pink brown and yellow brown allanite crystals averaging 0.5 mm in length.

The porphyry groundmass generally consists of a fine-grained mosaic (a.g.d. 10,660 microns) of quartz and feldspar with one or more of sericite, biotite, and chlorite, in disseminated flakes usually parallel to the foliation or flow banding. Sericite and chlorite are abundant in sheared varieties.

Other groundmass constituents include small quantities of calcite, zircon and sphene. Magnetite granules associated with leucoxenized ilmenite is locally present and concentrated in lenticles within the groundmass.

* Average grain diameter.

PALAEOZOIC

The northwest extensions of the Devonian Napier Range Reef Complexes, mapped by Playford & Lowry (1966), are exposed in the southeastern corner of the Sheet area. Undifferentiated conglomerate beds assigned to the Palaeozoic are found overlying Precambrian rocks in the central parts of the Sheet area, and are possibly of Devonian or Permian age.

DEVONIAN*

Devonian rocks exposed in the extreme southeast corner of the Yampi Sheet form the northwestern end of the Napier Range reef complex and crop out as a rough narrow range of limestone. Formations represented in the complex are the Windjana Limestone, Pillara Limestone, and Napier Formation. There are also a few small exposures of a post-reef unit, the Fairfield Formation. Only the Upper Devonian (Famennian and ?Frasnian) are thought to be represented in these exposures. The maximum thickness of Devonian rocks is not known, but probably does not exceed 240 m in this area.

Details of the Devonian geology of the northern Canning Basin are given by Veevers & Wells (1961) and by Playford & Lowry (1966).

WINDJANA LIMESTONE

This formation is the reef facies of the reef complex. It consists of partly dolomitized massive limestone. The limestone is built up of a framework of calcareous algae (especially Renalcis)and stromatoporoids, with a matrix ranging from calcarenite to micrite. The reef facies is developed in this area as a discontinuous unit between the back-reef and fore-reef facies represented by the Pillara Limestone and Napier Formation respectively.

---

* (by P.E. Playford, G.S.W.A.)

PILLARA LIMESTONE.

This formation is the back-reef facies of the reef complex. The exposures on the Yampi Sheet belong to the birdseye limestone sub-facies (Playford & Lowry, 1966). It consists of well-bedded limestones having a characteristic birdseye texture. Minor dolomitization has occurred in some areas. The unit interfingers with and overlies the Windjana Limestone. In areas where the reef is absent the Pillara Limestone interfingers directly with the Napier Formation.

NAPIER FORMATION.

This formation is the fore-reef facies of the reef complex. It is essentially a talus deposit composed of calcarenite and calcirudite derived from the reef and back-reef facies with contributions from organisms that grew on the fore-reef slope. There is minor dolomitization in some areas.

FAIRFIELD FORMATION.

There are a number of poor exposures of silty crystalline limestone and calcarenite in front of the range that are tentatively referred to the Fairfield Formation. The limestone is thought to be interbedded with calcareous shale and siltstone, but these are not exposed.

The exposures of the Fairfield Formation in this area are believed to be entirely of Upper Devonian (Famennian) age, but elsewhere the unit is known to extend into the Lower Carboniferous (Tournaisian). It was laid down after extinction of the reef complexes as a shallow-water marine deposit.

. . J . (?) PERMIAN(?)

LILLYBOOROORA CONGLOMERATE.

Conglomerates cover approximately 125 sq km of the Yampi Sheet area. The main outcrop occupies part of the headwater region of the Lillybooroora and Townshend Rivers, and stretches to the area south of Dugong Bay. Small exposures occur near the Wyndham range, in the Saddle Hill area, between Mangrove and Sandy Creeks, and a few miles east of Oobagooma.

Their age is uncertain and contact relationships merely indicate a post-Proterozoic age. Palaeozoic conglomerates of similar type and topography are associated with Devonian limestones in other parts of the North Canning Basin (Playford & Lowry, 1966). The conglomerates of the Yampi Sheet are therefore tentatively assigned a similar Palaeozoic age.

The conglomerates form rounded boulder-strewn hills in interfluve areas, low hills in narrow valleys and less commonly elevated benches up to 20 m high on the sides of Proterozoic sandstone ridges. Near-horizontal bedding is distinguishable when the outcrop is viewed from a distance (Fig. 234).

These poorly sorted boulder conglomerates contain coarse sandstone lenses. Boulders, cobbles and pebbles locally constitute 60 to 70 percent of the rock. Boulders have a mean size of 15 cm to 22 cm but may reach 1.2 m diameter. They are well rounded, poorly polished, have surface 'chatter' marks, and usually lack striations. Almost all clastic material is quartzitic sandstone, similar to adjacent Proterozoic types. The matrix is a tough silicified sandstone which is often ferruginized.

Scattered outcrops, e.g. at the northern end of the Wyndham Range, consist of moderately well-sorted coarse cross-bedded sandstones, containing scattered beds of cobbles or boulders. These sandstones, which are friable and kaolin-rich, are similar to rocks described from the Permian Grant Formation by Guppy et al. (1958).

Basal breccia-conglomerates found locally as valley side deposits contain megaclasts of angular quartzite up to 1.2 m long. The matrix consists of angular quartz and quartzite fragments cemented with a ferruginous and siliceous cement (Fig. 23). Distribution of the breccia in the Kimbolton Range area suggests deposition of the clastic material in valleys or stream lines. Contacts tend to be angular and irregular, and the deposits fill channels up to 10 m deep. The surface of the contact is locally controlled by joints or fractures in the parent rock. The orientation of blocks in the breccia within 1 m to 1.5 m of the 'contact' is close to that of the joint or fracture-bounded blocks in the parent rock. Above this 'contact' zone, angularity of fragments decreases and the beds pass upwards into horizontally-bedded conglomerates described above. Maximum thickness of the deposits is around 60 m.

GRANT FORMATION

Restricted exposures of conglomerate and sandstone similar to those described above are found near Limestone Spring flanking the Devonian limestone reef complex. Playford & Lowry (1966) have assigned them to the Grant Formation of Permian age. Low-lying outcrops of probable Grant Formation are present about 30 km south-east of Oobagooma, where they display large-scale trough cross-bedding (with an easterly source direction) visible on air-photographs.

MESOZOIC

Flat-lying Mesozoic rocks rest unconformably upon steeply dipping Precambrian rocks at Apex Island and are exposed below Tertiary rocks in low mesas, buttes, and coastal headlands of Dampier Peninsula.

Table 5 summarizes the known Mesozoic stratigraphy. All the Mesozoic units are assigned to the Lower Cretaceous. A Jurassic (late Tithonian) siltstone formation referred to the Langey Siltstone (Brunnschweiler, 1954) possibly underlies the Mesozoic sediments in the

126

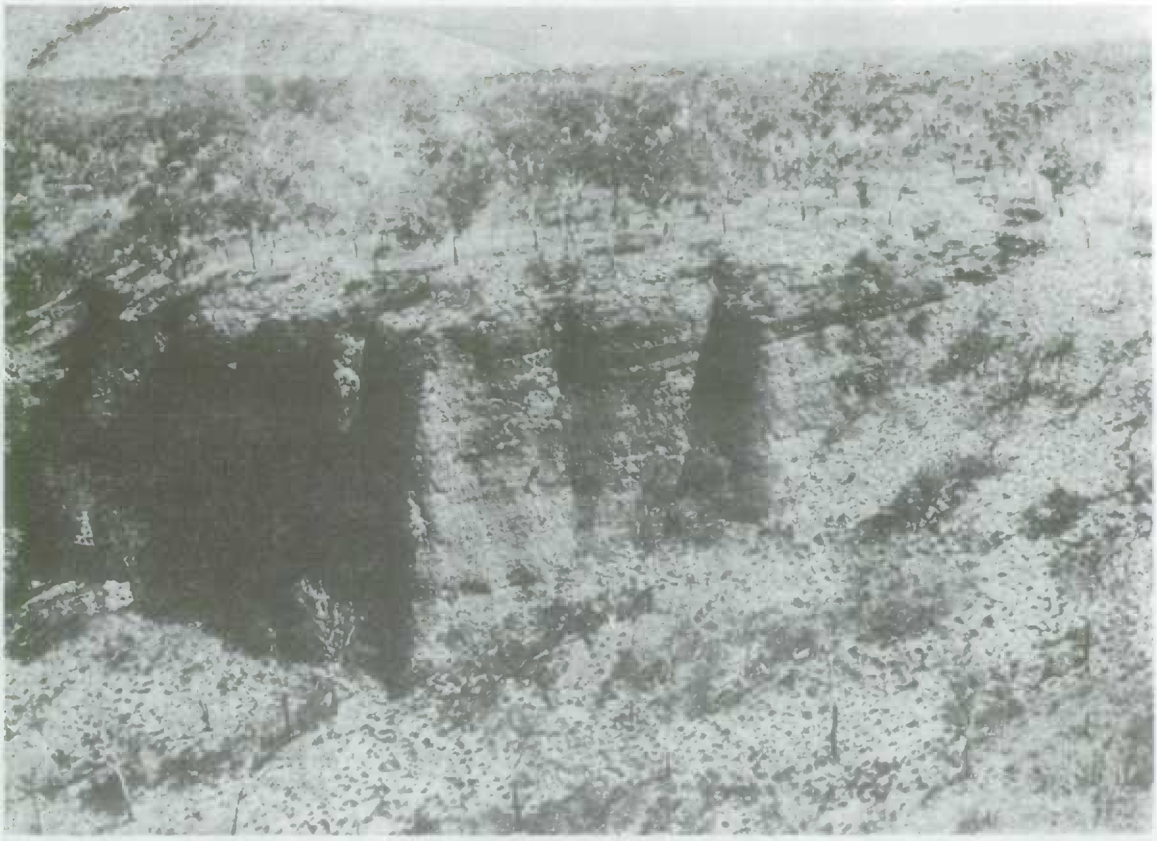


Fig. 23a Flat-lying Lillybooroora Conglomerate, northern end of Wyndham Range. King Leopold Sandstone in distance. (GSWA neg.) RF

Fig. 23b Lillybooroora Conglomerate in the Kimbolton Range, 5 km east-southeast of Mount Olivia, showing angular clasts of quartzite in hematitic-sandstone matrix. (Neg M753/17) GMD

southern part of Dampier Peninsula but is not exposed in the Yampi 1:250,000 Sheet area. The following brief descriptions of the exposed Mesozoic formations are based mainly on detailed work by Brunnschweiler (1951, 1957). Only the Jowlaenga Formation, Melligo Sandstone, and Pender Bay Conglomerate are exposed in the Yampi Sheet area.

TABLE 5

Stratigraphic Table - Dampier Peninsula

TERTIARY?		BORDA SANDSTONE* PENDER BAY CONGLOMERATE* EMERIAU SANDSTONE*	
CRETACEOUS	Aptian - Neocomian	MELLIGO SANDSTONE+	
		LEVEQUE SANDSTONE (E. coast)* BROOME SANDSTONE (W. coast)*	DAMPIER GROUP
JURASSIC or CRETACEOUS		JOWLAENGA FORMATION	
JURASSIC	Tithonian	LANGEY SILTSTONE	
	UNCONFORMITY		
PRECAMBRIAN		KIMBERLEY GROUP	

+ After McWhae, et al (1958).

* After Brunnschweiler (1957).

Whereas Devonian, Carboniferous, Permian, and Lower Jurassic formations are present to the southeast (Guppy et al., 1958) and to the south in Fraser River No. 1 (West Australian Petroleum - unpublished data), Cretaceous rocks north of Cygnet Bay lie directly on Precambrian. This apparently indicates overlap of the Cretaceous rocks over the Jurassic and Palaeozoic rocks subsurface in the southwestern part of the Yampi Sheet area.

JURASSIC OR CRETACEOUS

JOWLAENGA FORMATION.

The Jowlaenga Formation (McWhae et al., 1958) is the lowermost unit of the Dampier Group, and was previously known as the Jowlaenga Sandstone (Brunnschweiler, 1957; Guppy et al., 1958). The type area is at Mount Jowlaenga on the Broome 1:250,000 Sheet area.

The Formation is a fine to medium-grained, poorly-sorted, quartz sandstone, in places ferruginous, and ranges from 80 m to 120 m in thickness (Guppy et al., 1958). The formation is well-bedded and contains scattered cross-beds. Finer-grained beds contain detrital feldspar and mica flakes. Grain size decreases northwards, so that within the Sheet area the beds are represented mainly by fine-grained sandstone or silty sandstone.

The Formation thins northwards and is absent from the islands of the Buccaneer Archipelago. Thickness and grainsize variation suggest it is a nearshore deposit.

Fossiliferous beds in the lower part of the Formation include Meleagrinella, Hibolites, Venus, Pleuromya, Iotrigonia, Crioceras, Pseudavicula, and Belemnopsis spp. Brunnschweiler placed the fauna as Neocomian. Guppy et al., (1958) assign the Formation to the Valanginian part of the Neocomian.

Skwarko (1969), however, stated that the fossil diagnostic of Cretaceous age. Apiotrigonia, (Iotrigonia of Brunnschweiler), occurred not in the Jowlaenga but in the Melligo Sandstone, and that the Jowlaenga Formation should be placed in the Upper Jurassic.

The base of the Sandstone is ill-defined, and consists of passage beds to the underlying or contemporaneous Broome Sandstone.

CRETACEOUS

MELLIGO SANDSTONE

The Melligo Sandstone (McWhae, et al., 1958) is exposed extensively along the coast from South of Chattur Bay northwards to Swan Point. Inland it forms the resistant Lombadina Plateau. The sandstone is clean-washed, medium to coarse-grained, and silicified in places. Minor pebble beds are found locally.

The sand grains are well rounded and commonly cemented with opaline silica. Brunnschweiler (1957) refers to this formation as the Melligo Quartzite, but in view of the superficial nature of the silicification it is now designated a sandstone. Pebbles which include vividly coloured vein quartz and chert cannot be assigned to any known Precambrian source rock.

The base of the Melligo Sandstone in the eastern and central parts of the Peninsula is an erosional unconformity. This unconformity is well exposed at low tide on Apex Island $2\frac{1}{2}$ miles southeast of Swan Point, where flat-lying Melligo Sandstone overlies steeply-dipping Precambrian sediments (King Leopold Sandstone). Its absence in the west part of the Peninsula is attributed to non-deposition.

Marine fossils identified from the Melligo Sandstone by Brunnschweiler (1957) include Fissilunula, Cyrenopsis, Panopaea, and Belemnites spp., the combination of which suggests an Aptian age for the fauna.

CAINOZOIC

Flat-lying formations attributed to the Tertiary Period are present on Dampier Peninsula. High level aluminous and ferruginous laterites found on the Yampi Peninsula and low-level laterites and ferricrete stream conglomerates are also tentatively assigned to the Tertiary.

Cainozoic deposits of probably post-Tertiary age which are widespread in the low-lying parts of the area include various residual and transported soils.

Younger deposits, consisting of alluvium, coastal muds and estuarine sands, are assigned to the Quaternary.

TERTIARY

Several small outcrops of probable Tertiary age are found in coastal sections of Dampier Peninsula. They have been assigned to the Pender Bay Conglomerate and the Borda Sandstone by Brunnschweiler (1957).

PENDER BAY CONGLOMERATE

Brunnschweiler (1957) describes the Pender Bay Conglomerate as a fluviatile deposit occupying the Pender Bay Depression and deposited by a large Tertiary river system that debouched into an ancient Pender Bay. It consists of subrounded and rounded quartz sandstone boulders and pebbles with a few vein quartz pebbles. It is roughly graded, the largest boulders being at the base. The matrix is a medium-grained quartz sandstone, and the whole of the formation is ferruginized to give dark grey or black, well-cemented, indurated beds. Similar ferricrete-conglomerate beds noted along drainages of the Yampi Peninsula (Fig. 24A) are regarded as possible time equivalents. The thickness of these beds varies considerably but seldom exceeds 4 m.

BORDA SANDSTONE

The Borda Sandstone (Brunnschweiler, 1957) which forms outcrops too small to be shown at 1:250,000 scale is an unfossiliferous, light-coloured, soft, mottled, fine-grained sandstone, found on Apex Island and at Cunningham Point. It contains material reworked from the Pender Bay Conglomerate and is probably older than any of the Pleistocene deposits. The Sandstone takes its name from the type locality at Cape Borda where 5 metres of this sandstone disconformably overlies the Pender Bay Conglomerate.

Laterite

Tertiary deposits of the Yampi Peninsula are represented by remnants of a formerly extensive lateritic plateau. Low-level laterites and ferricrete conglomerates which are included in this section possibly belong to a post-Tertiary period of ferruginization. The laterite formations are:

Aluminous Laterite. Only one small outcrop of aluminous laterite has been noted in the mainland in the Yampi Sheet area. It occurs as a thin capping about 50 m in diameter on top of a hill of Nellie Tonalite in the Mangrove Creek Valley, 8 km west-northwest of Mount Nellie. This outcrop probably represents the only remnant on the mainland of this area of a formerly extensive lateritic plateau.

It consists of yellow-brown porcellaneous material containing scattered 0.25 to 0.5 cm pisolites of dark brown goethite showing concentric zoning and marginal alteration to light brown material. It is similar to much of the laterite found in the northern part of the Kimberley Plateau (Sofoulis, 1966) and is tentatively classified as an aluminous laterite.

Ferruginous Laterite. Pisolitic, limonitic, and partly detrital iron ores of Koolan Island and Cockatoo Island, commonly referred to as 'canga' deposits, are probably also remnants of the same laterite plateau or of a separate but possibly contemporaneous one.

The canga on Cockatoo Island has now been mined, but some of that on Koolan Island remains. Descriptions have been given by Canavan & Edwards (1938), and I.W. Reid (1958); only brief notes on it are included here.

The canga, which consists mainly of cellular limonitic iron ore, contains concentrically banded pisolites of limonite with a core of hematite in a matrix of limonite cement plus rounded grains of quartz, tourmaline, and zircon. Boulders of hematite are present locally. Analyses of the canga presented by Canavan & Edwards (1938) show that it is richer in TiO_2, P_2O_5, MnO, and Al_2O_3, (up to 4.63%) than the hematitic ores and hematite schist from which it has been derived. The enrichment in these oxides, particularly in alumina, suggests that the canga has formed as a result of lateritization similar to that responsible for the development of laterites in the northern part of the Kimberley Basin, except that the starting product in Koolan and Cockatoo Islands was highly ferruginous. Like the laterites in the northern part of the Kimberley Plateau (Gellatly & Sofoulis, 1966) the canga of this area is at least partly a transported deposit. The amount of transport, however, is apparently minor.

The uppermost part of these formations is commonly represented by a ferricrete crusting 0.3 to 0.6 m thick consisting of red-brown to black pisolites in a cemented red-brown friable limonitic matrix similar and possibly equivalent to the low-level laterites described below.

<u>Low-level ferricrete</u>. Low-level ferricrete and ferruginous laterites occur in several localities but outcrops are too small to be shown in the accompanying map. They are found on the east bank of the Townshend River a few kilometres north of its confluence with the Robinson River; on the south bank of the Robinson River about 3 km east of Oobagooma Homestead; and near Mondooma. They crop out as jagged, roughly stratified rocks rising only 30 cm or so above soil level. They are dark red-brown ferruginous laterites containing 1 mm pisolites in a friable limonitic matrix.

133

CAINOZOIC - UNDIFFERENTIATED

FERRICRETE AND LATERITIC SOIL (Czl)

Unconsolidated lateritic soil and detritus are associated with, and derived from, the various laterite and ferricrete formations found in the Yampi Sheet area. The deposits consist of variable concentrations of black and orange-brown pisolites and form superficial deposits over red sandy and loamy soils.

Other loose pisolite concentrations are found locally on the landward fringes of the mudflats southwest of Oobagooma, and similar concentrations form patchy veneers over flat to mildly undulating red and yellow soil plains (pindan plains) lying south of the Robinson River and on Dampier Peninsula.

These latter deposits are probably related to the consolidated low-level laterites noted above.

BLACK SOIL (Czb)

Black soils are found east of the Wyndham Range as flood-plain deposits, mainly flanking the Robinson River and the lower reaches of its main tributaries. Other black soils are found in isolated pans in the southern and southeastern part of the Sheet area.

The black soils form gilgai-patterned grass-covered plains. The soils are black, brown, and grey cracking-clays similar to those described from the adjacent Lennard River Sheet area (Gellatly et al., in prep.). The black-soil plains are mainly treeless, although a few isolated trees and tree clumps may grow in sandier parts. Calcareous nodules are a common feature the lower parts of black soil profiles (see Czl of Appendix I).

A black-soil sample taken from an extensive black-soil plain 6 km northeast of Oobagooma contained kaolinite, illite, and montmorillonite clays with abundant fine-grained quartz grains (W.A. Chem. Lab. No. 11676/66).

Dry surfaces of the black-soil plains are usually pock-marked with mounds and depressions up to 1 m across. These produce a rough hummocky terrain over which vehicle access is difficult.

Trough gilgai features (know as tank or melon gilgais) are found within the plain and range in area from 1 to 150 sq m. These have vertical walls walls extending 0.3 to 2 m below the general level of the plain, and are floored by similar cracking-clays. Patchy veneers of quartz fragments and other rock debris are found locally on dry trough floors. Troughs containing water serve as cattle watering-points during the dry season.

Most of the black-soil plains have a closely spaced network of vertical cracks up to 25 cm wide, which extend from a few centimetres to 1.2 m or more below the surface. When saturated by seasonal rains the cracks close and the plain becomes a boggy quagmire.

The rough hummocky appearance of the dried-out surface is attributed to differential swelling and shrinking of the clay soil with seasonal wetting and drying. Hallsworth, Robertson & Gibbons (1955) who have studied similar gilgai-patterned black soils in New South Wales, suggest that the subsoil expands and contracts more than the topsoil and this forces the subsoil to the surface. This theory is considered plausible by Playford & Lowry (1966) who observed gypsum pellets (presumably derived from the lower parts of the soil profile) in some mound features on the adjacent Lennard River Sheet area.

A palynological examination of the black soil sample collected from the Oobagooma area was made by Ingram (1966). The common constituents of the clays were undiagnostic algal cysts with a poor assemblage of spores and pollen containing rare species of *Myrtaceidites*, *Tricolpites*, *Schizaea*, and *?Hoheria*. Although Ingram does not discount the possibility that the palynomorphs were contaminants, the assemblage suggested a non-marine mud of Quaternary age.

UNDIFFERENTIATED SOIL AND ELUVIUM (Czs)

Flat-lying to gently undulating sandplains are extensively developed on Dampier Peninsula and in the plains country of Yampi Peninsula south of the Robinson River.

These sandplains, known locally as 'Pindan Plains', are characterized by a natural vegetation of spinifex and ribbon grasses underlying low scrubby woodlands with a tall scrub layer (mainly acacia sp.). Their soils range from red-brown loamy soils to lighter textured red, brown, yellow and grey sandy soils overlying Precambrian, Mesozoic, and Palaeozoic rocks.

Old and inactive longitudinal sand dunes mainly of easterly trend are preserved locally on the plains. These are attributed to an early reworking of the sandplains, although most of the dunes have now been destroyed or their ridges are bevelled so that relief is generally less than 6 m and their presence may no longer be obvious. Brunnschweiler (1957) considers that the inland dunes of Dampier Peninsula originated in the earlier Pleistocene arid cycles.

Other sandy soils also included with this unit comprise localized small pockets of residual and eluvial sandy, loamy, and stony soils derived directly from Precambrian rocks. The most extensive soil areas derived from the Precambrian are those around the Tarraji and Robinson Rivers. In this area sandy clays form a thin veneer on broad, locally convex, pediments.

QUATERNARY

ALLUVIUM (Qa)

Deposits of alluvium are found in the broad flood-plains associated with the Robinson River and its major tributaries. These flood-plains are cut by braided stream channels incised up to 10 m in yellow, red, and brown sandy or silty alluvium, which shows levee development. The lower part of the alluvial profile is commonly kunkarized (Fig. 24, and Appendix I).

Restricted silty and clayey alluvial deposits are developed locally in valleys floored by basic rocks or silty beds of the Kimberley Group succession. These are found as narrow flood-plain deposits, and, where rivers have eroded down to bedrock, as low terraces.

Alluvial deposits of the sandstone terrains consist of moderately well sorted, coarse to medium-grained sands. They form small discontinuous valley deposits confined to drainage channels and separated by stony stream sections or rock floors.

Two measured sections (Qa_1, Qa_2) are given in the Appendix.

COASTAL DEPOSITS (Qc)

Coastal deposits include tidal marsh and deltaic formations that have accumulated in sheltered bays, inlets, lagoons, and estuaries by progressive siltation.

The larger deposits form mud and salt flats bordering coastal areas and drained by meandering tidal creeks and networks of minor tributaries.

The tidal flats consist mostly of blue grey clay with a thin veneer of heavy textured saline clayey soil. The seaward margin of the flats support dense mangrove communities.

Where mud flats are subject only to occasional inundation, the surface dries out and polygonal shrinkage cracks are developed. The surface mud when dry is 'puffy', and has a surface salt encrustation up to 1 cm thick.

The dry mudflats generally lack vegetation, but samphires and other salt-tolerant plants are established about their landward margins. By contrast, the major tidal channels contain coarse-grained sands which commonly form cross-bedded tidal megaripples (Gellatly, 1970). Intermediate grades of sediment are apparently deposited only farther from land.

Fig. 24a Ferricrete stream conglomerate with rounded and sub-rounded cobbles and boulders set in a sandstone matrix and cemented with iron oxides. Probable time equivalent of Pender Bay Conglomerate and Emeriau Sandstone of Dampier Peninsula. (GSWA neg.) JS

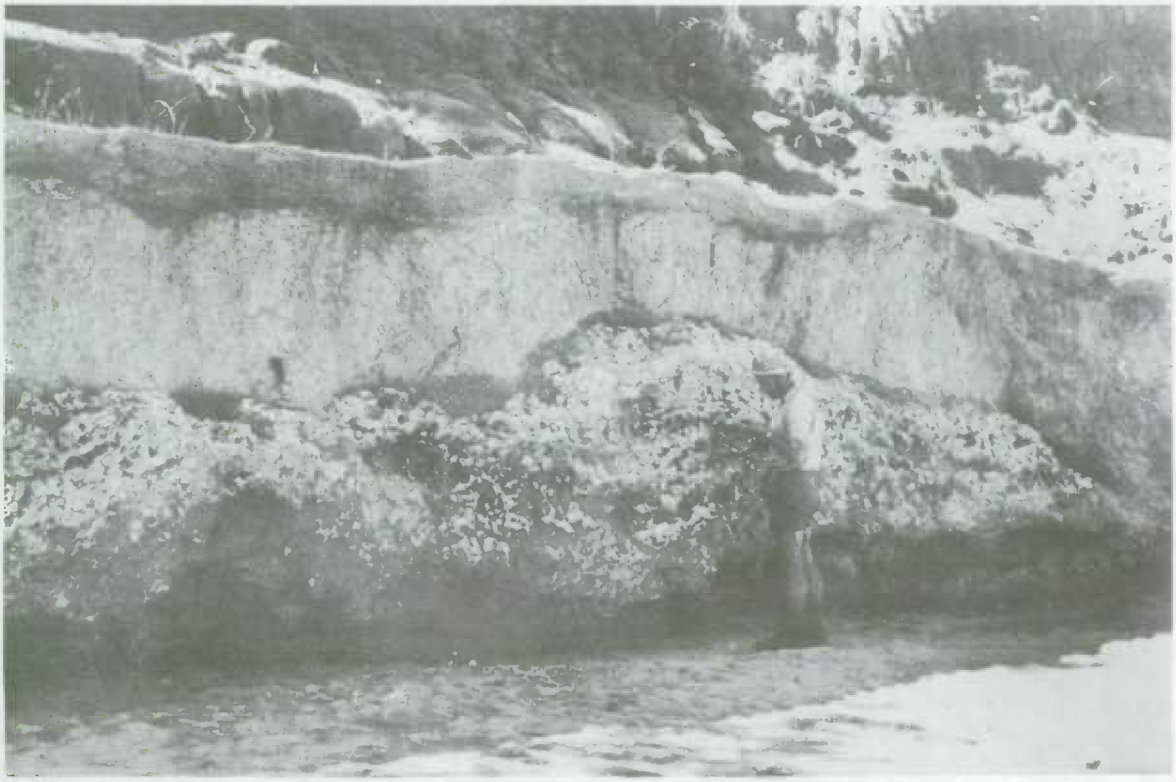


Fig. 24b Alluvium in Townsend River 200 m south of Oobagooma-Kimbolton Road crossing. Profile consists of grey, brown, mottled, sandy, silty and clayey alluvium with local benching at gravel horizons. Underlain by kunkarised layer with irregular upper surface. (GSWA neg.) JS

CORAL REEFS AND COASTAL LIMESTONE

Coral reefs locally fringe parts of the north mainland coast and are extensive about the islands of Collier Bay, Yampi Sound, and the Buccaneer Archipelago. The reefs are generally narrow but in some places they may be up to 60 m or more wide. Some noted in the Graveyard area extend over 10 sq km.

Calcareous beach rocks are found locally as low outcrops on the present day shoreline, especially on gently-sloping sandy shores between maximum and minimum tide levels. Outcrops are too small to show on the accompanying 1:250,000 map. They consist of white-buff coloured well-cemented, fragmental limestone containing poorly-sorted coral and shell fragments and some inclusions of granules, pebbles and fragments derived from Kimberley Group rocks. Brunnschweiler (1957) noted that on Apex Island, the coarse quartz grains of these calcareous sandstones contained parallel idiomorphic accessory mineral inclusions characteristic of the nearby Kimberley Group Sandstones.

BEACH SANDS (Qs)

Sandy beaches are generally confined to small sheltered bays between prominent headlands of the outer coastline and offshore islands. The beaches shelve steeply seawards and are sometimes backed by a narrow strip of sand dunes. The sands of the beaches and dunes consist mainly of clean-washed rounded to subangular quartz grains with lesser amounts of rounded shell and coral fragments.

Localized storm beaches composed of Precambrian and/or beach rock boulders and shingles, together with shell and coral fragments, are piled on the landward side of some sandy beaches (e.g. Apex Island). Scattered sandstones, cobbles and large gastropod shells are also found locally on the landward side of sand bars.

STRUCTURE

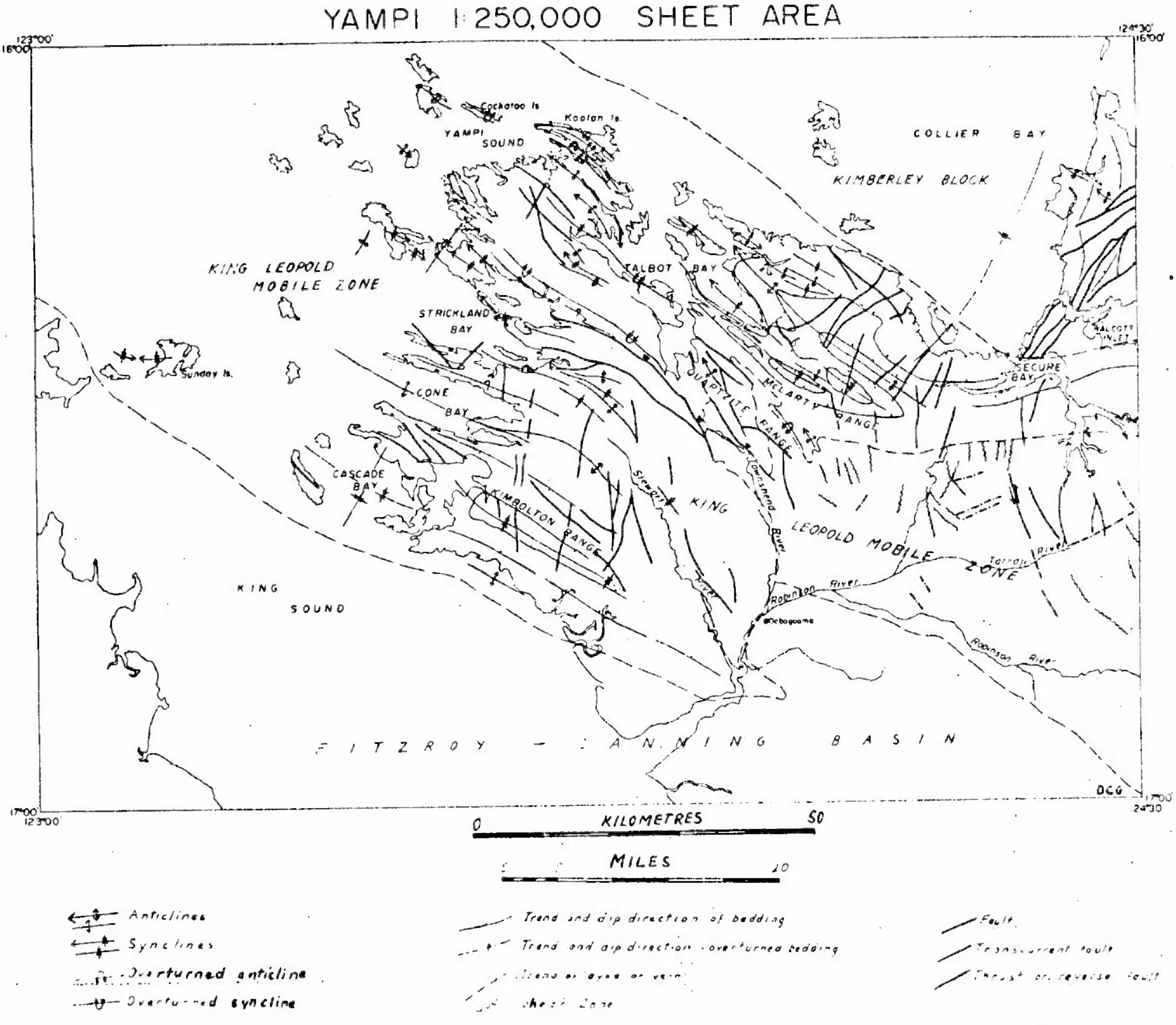
Three basic structural divisions are recognized in the Kimberley region: the stable Kimberley Block to the north, the fringing fold belts to the southwest and southeast, known respectively as the King Leopold Mobile Zone (in the West Kimberley) and the Halls Creek Mobile Zone (in the East Kimberley) (Traves, 1955), and the Fitzroy Trough-Canning Basin to the south (Playford & Johnstone, 1959).

All three basic divisions are present in the Yampi 1:250,000 Sheet area. Their distribution is shown in Figure 25. The King Leopold Mobile Zone, which makes up the greater part of the area, is here subdivided into two parts: the 'basement' core of older Precambrian granites and phyllites in the centre and southeast, and the area of strongly folded younger Precambrian (Carpentarian) sedimentary cover overlying it to the north and west. In the north the Kimberley Block is represented only by a small area to the north of Walcott Inlet. The Fitzroy-Canning Basin forms the southwestern quarter of the Sheet area. Much of the Basin is covered by the waters of King Sound.

The Fitzroy-Canning Basin is distinguished from the adjacent King Leopold Mobile Zone by its younger age and consequent lesser degree of deformation. Similarly the two parts of the Mobile Zone are distinguished by age differences and greater structural complexity of the older part. The Mobile Zone and the Kimberley Block have structures of similar ages but are separated on account of the lesser degree of deformation shown by the Kimberley Block and by the change in character from predominantly folded to predominantly faulted terrain. The boundary between these two divisions is gradational. Since the fold structures that have affected the younger rocks also affect the older, the structural units are described in order of increasing age and deformation.

FIGURE 25

STRUCTURAL MAP
YAMPI 1:250,000 SHEET AREA



E51/A3/18

The two basic fold trends that are recognized throughout the Precambrian rocks of the Kimberley, north-northeast, and west-northwest, are present in the Yampi area. The west-northwest trend predominates; the north-northeast one is only poorly developed, but its effects are nevertheless notable in many places on account of the basin and dome structure it has produced through interference with the dominant west-northwest trend. Faults in the area also follow these two trends and are at least partly related to the folds. The main association of folds and faults is one of tight west-northwest trending folds overturned towards north-northeast, and related high-angle reverse faults that parallel the axial planes of the overturned folds.

FITZROY-CANNING BASIN

The structure of the Fitzroy-Canning Basin in this area is that of a very gentle north-northwest trending anticline on the Dampier Peninsula, and a corresponding gentle downwarp trending northwest forming King Sound (Brunnschweiler, 1957). Dips nowhere exceed 3° and are mainly depositional rather than structural. The prominent fault systems of the Fitzroy Basin are not recognizable on the surface in the Yampi area, but evidence of one prominent structure, the Oscar Range 'high' has recently been traced under King Sound by geophysical means (West Australian Petroleum, 1967).

KIMBERLEY BLOCK

In contrast to the King Leopold Mobile Zone, where steep dips generally prevail, beds within the Kimberley Block are only gently dipping. Dip values rarely exceed 15°. The beds form essentially a straight-dipping sequence with north-northeast trend and dips to the west, and form the eastern limb of a large syncline whose western limb has been modified by west-northwest trending folds within the Mobile Zone. Within this area of dominant north-northeast structures, subsidiary folds (e.g. near Eagle Point) trend west-north-west and are asymmetrical with steeper northern limbs.

The area is intensely faulted by northeast trending faults that have downthrows mainly to the southeast, and cause repetition of the sequence. The amount of displacement on most of these faults is of the order of only 30 to 100 m. One however has a demonstrable displacement of about 800 m about 3 km to 5 km east of the Yampi Sheet boundary (Gellatly et al., 1969).

KING LEOPOLD MOBILE ZONE

Folds

Kimberley Group. Almost the whole outcrop of Kimberley Group rocks in the Sheet area is intensely folded along west-northwest trending axes. The folds have steeply dipping limbs and vary from 'close' to 'tight' (terminology of Fleuty, 1964). 'Open' folds are found only locally e.g. north of the McLarty Range. Many of the folds are asymmetrical, or overturned with axial planes dipping to south-southwest (Fig. 25). Overturning of fold limbs is particularly prominent between Cone Bay and Strickland Bay; 2 km to 3 km north of the Lydarrba River; on the northwestern shores of Dugong Bay; and in the vicinity of Yampi Sound. Overturned limbs in these areas generally have dips of about 50° to 90° while the normal limbs have shallower dips, commonly around 30° to 50°. The wavelengths of the major folds are mostly around 6 km to 9 km and the amplitudes around 3 km to 13 km, but all variations exist from these dimensions down to minor folds which can be observed in individual outcrops.

Most of the major folds have horizontal or near-horizontal fold axes but locally have plunges either to east-southeast or to west-northwest. Angles of plunge are mostly low but in places are 30° or more. Not uncommonly folds with opposing plunges occur in close proximity. Some of the variations in plunge of the west-northwest ttending folds are due to superimposition of north-northeast trending folds but others appear to be the result of a separate, but probably related, system of east-southeast plunging folds.

Fig. 26a Overfolded syncline and anticline in Pentecost Sandstone at Nares Point. Looking southeast. (GSWA neg.) JS

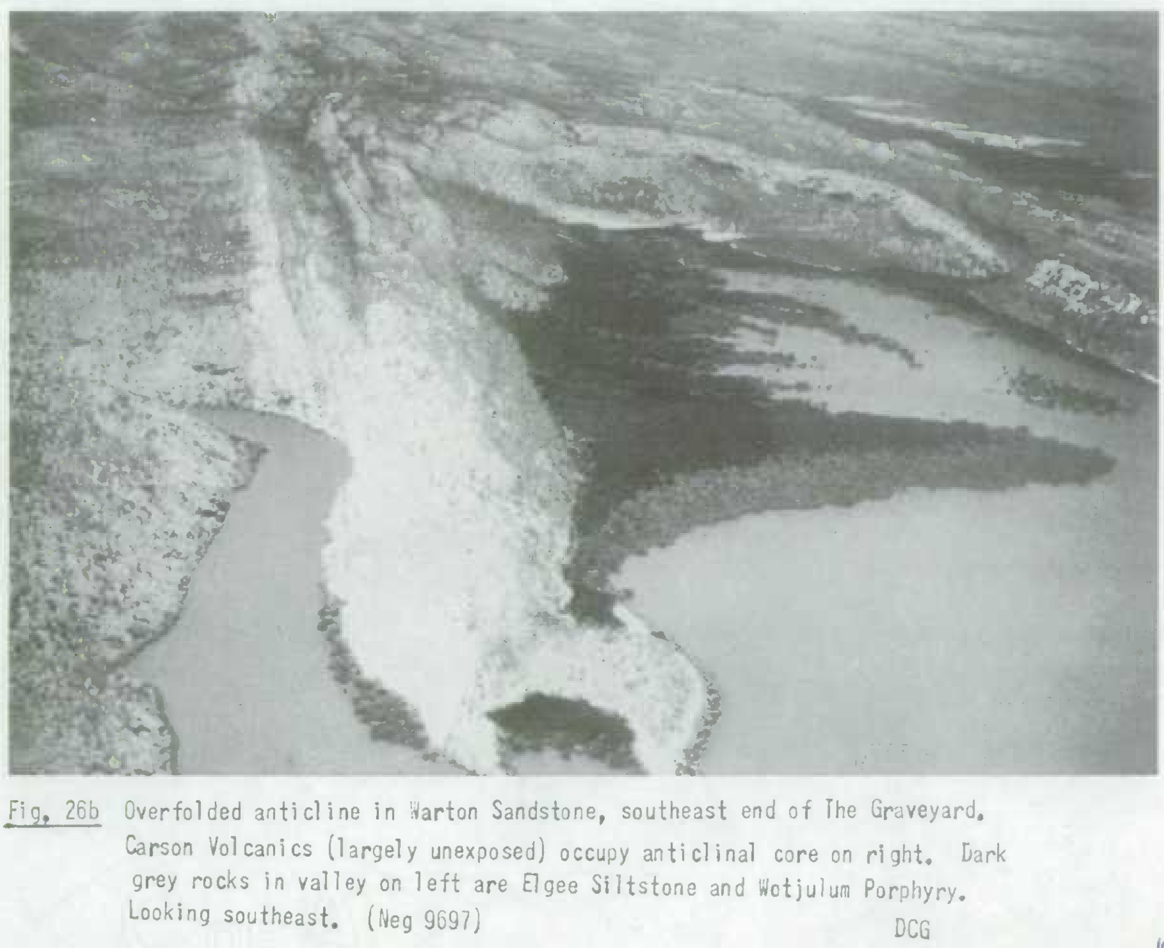


Fig. 26b Overfolded anticline in Warton Sandstone, southeast end of The Graveyard. Carson Volcanics (largely unexposed) occupy anticlinal core on right. Dark grey rocks in valley on left are Elgee Siltstone and Wotjulum Porphyry. Looking southeast. (Neg 9697) DCG

The north-northeast trending folds are scattered in their occurrence, but tend to be more common in the northern part of the Sheet area. The plunge direction of the major ones is to north-north east. Truncation of the broad north-northeast trending folds by the west-northwest trending folds of the King Leopold Ranges in the Charnley Sheet area (Gellatly et al., 1969) suggests that the north-northeast trending system is the earlier of the two.

Minor folds are rare in the Kimberley Group rocks and vary in style from kink folds (similar to those in the Halls Creek Group- Fig. 27). close to the Graveyard-Townshend River reverse fault zone, to relatively plastic sigmoidal types (Fig. 28) in the Elgee Siltstone of Irvine Island.

Halls Creek Group. Folds in these rocks are mostly small-scale, with wavelengths of around 30 m to 60 m. They are mostly isoclinal or nearly so, with axial planes (and strong axial plane cleavage) dipping steeply to the southwest. Bedding is poorly displayed, but in most places can be recognized because of thin psammitic beds in the normal pelitic schists and phyllites. Bedding is generally observed only in the cores of folds where it cuts across the cleavage, and is rarely preserved on the limbs of the folds. Bedding dips are apparently mainly to the southwest and are parallel to the cleavage. Locally bedding is deflected by intrusion of granites and is parallel to the granite contact irrespective of its trend (e.g. in Dingo Creek-Little Tarraji River area).

Fold axes and associated microcrenulation lineations (i.e. cleavage-cleavage intersections) plunge to the southeast at about 50° to 60°. Other lineations and microcrenulations noted plunge gently to west or west-northwest.

Minor folds within the Halls Creek Group vary considerably in style. They include tight chevron folds (Fig. 28.3), open low-amplitude similar folds, gentle drag-folds, and kink-folds. Both the kink-folds and drag-folds are apparently related to post-Kimberley Group movements. The other types appear to be associated with the main pre-Carpentarian movements.

The kink-folds (Fig. 27), which are formed through the sharp intersection of two or more cleavages, are common in the area around the Quartzite Range. They have fold axes plunging gently to east-southeast and cleavages dipping to south-southwest, and are asymmetrical up-dip. Lineations on kink-folded cleavages plunge due south at about 60° and are parallel to lineations noted in the thrust planes on the southern face of the Quartzite Range (i.e. in King Leopold Sandstone). The kink-folds are found only within about a kilometre of the thrusts and reverse faults bordering the Quartzite Range and the southern flank of Mount Nellie. The distribution of the kink folds and the identity of their structural elements with those of the thrusts indicate that the two features are closely related.

Faults

Faults in the King Leopold Mobile Zone are more conspicuous in the Kimberley Group than in the older rocks, and most of the major faults appear to post-date the Kimberley Group.

North-trending shear zones, which are prominent in the granites, are of pre-Kimberley Group age, but may have been reactivated in post-Kimberley Group times. These are described separately.

Two dominant trends are recognized, west-northwest and north. A few north-northeast trending faults are present near Secure Bay and Collier Bay. Some of these form part of a fault arc system described below.

The north-south faults are mostly short and have caused only small displacements. No evidence has been found of the direction of movement. In places the trend of the faults is oblique to the fold trends and they are thus unlikely to be *ac* fractures. They could be secondary faults associated with the thrust movements or could indicate reactivation of north-south fractures in the underlying basement.

FIGURE 27

Fig. 27a Kink-folds with sub-horizontal fold axes in Halls Creek Group phyllite, 11 km northwest of Mount Nellie. (Neg. M 1000/4) DCG

Fig. 27b Kink folds in Halls Creek Group phyllite, 1 km west-northwest of Mount Nellie. (Neg M 1004/7) DCG

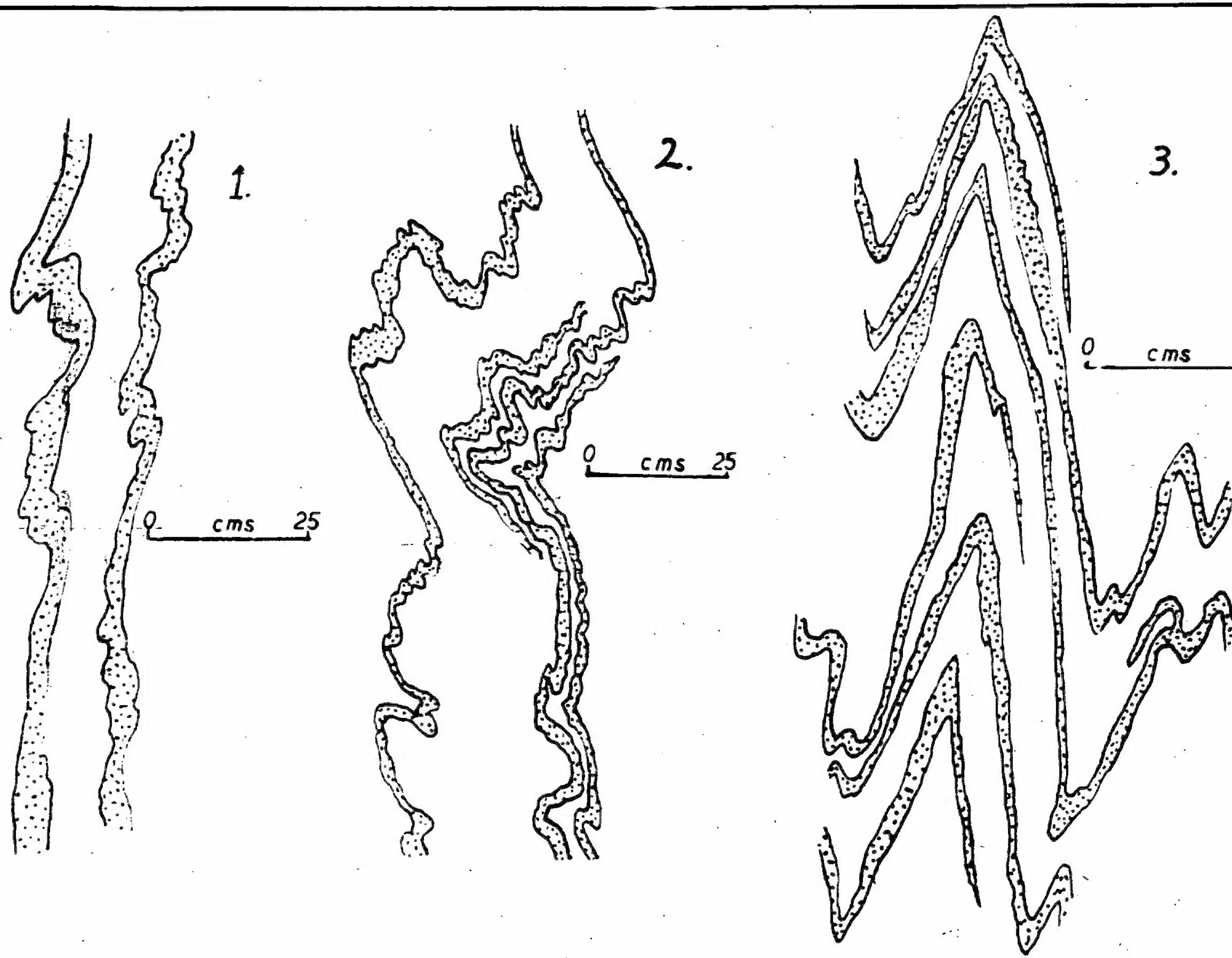


Fig. 28. Minor fold styles in King Leopold Mobile Zone : 1 and 2 from Elgee Siltstone, Irvine Island ; 3 from Halls Creek Group 3 miles south-east of Marboo Pool.

E51/A3/19

FIGURE 28

The west-northwest faults vary slightly in their trend, but almost everywhere are parallel to the strike of the sediments. They are mostly associated with overturned folds and have low-angle fault planes (ca 40° to 50°) parallel to the axial planes of the folds. The most prominent of these faults extends from The Graveyard to southeast of the Quartzite Range.

The nature of these faults as reverse faults and high-angle thrusts is demonstrated 3 km east of Marboo Pool, where Halls Creek Group rocks have been thrust over the King Leopold Sandstone of the Quartzite Range, and at the southern extremity of Dugong Bay, where King Leopold Sandstone overlies Carson Volcanics. Other faults interpreted as thrusts or possibly high-angle reverse faults are found on the southwestern side of the Quartzite Range, and on the southern flank of Mount Nellie. Although individual faults disappear in the soil covered area southeast of the Quartzite Range, further west-northwest trending fault lineaments are found farther to the southeast and probably constitute a continuation of this fault zone. It appears that all of these faults and lineaments are expressions of a broad, major zone of dislocation that cuts obliquely across the King Leopold Mobile Zone from The Graveyard to Limestone Spring and beyond. Evidence of the age of the deformation (Bennett & Gellatly, 1970) suggests that this zone of dislocation is related to the deformation of the Oscar Range in the Lennard River Sheet area.

Shear Zones

Shear zones with a dominant north-south or north-northwest trend have caused intense deformation of the granites of the Yampi area, producing porphyroblastic muscovite schists. All stages can be traced in the field from massive granite to porphyroblastic muscovite schist. The schists formed in these shear zones are more resistant to weathering than the adjacent granites and stand up as prominent ridges. Locally, (e.g., 9 km north of Mount Disaster) they become so abundant that the topography produced is similar to that of the phyllites and schists of the Halls Creek Group. These shear zones are truncated at the unconformity with the overlying King Leopold Sandstone and thus pre-date deposition of the Kimberley Group.

In most of the shears examined the foliation of the muscovite schists is oblique to the trend of the shear zone and makes an angle of up to 45° with it. In all but one example the foliation trends north-northwest and indicates a component of dextral shear movement. Lineations which are strongly developed in those schists plunge to southeast and when considered in conjunction with the dextral shearing suggest a vertical component of movement with downthrow to the east.

Mount Page Fault Arc System.

In the eastern part of the Yampi area an arcuate system of faults, shear zones, joints and dyke trends has been noted. The fault features are discontinuous and cut the Kimberley Block and both older and younger units of the Mobile Zones. This arcuate system of fault features has a radius of curvature of about 40 to 48 km and is centred on Mount Page in the Charnley 1:250,000 Sheet area to the east. The northern part of the arc noted in the Yampi Sheet area continues for a distance of 40 km into the Charnley Sheet area.

One of the faults of this system has a downthrow to the southeast (i.e. towards the centre of the arc) of about 750 m. Another one, occurring about 3 km east of Mount Disaster, has a demonstrable sinistral transcurrent movement of 1.6 km.

Foliation within these faults is parallel to the fault trend and not oblique to it as in the shear zones, and lineations plunge in a general northerly direction. The deformation is of a more brittle type without development of muscovite.

Shear zones within the granite, which are related to this arc, also have a sinistral sense of movement, but the amount of displacement is unknown. Most of the shear zones in the granites, however, show dextral displacement and their initial development is probably unrelated to that of the fault arc, but some of the shears may have been reactivated, and the sense of movement reversed, in post-Kimberley Group times.

Fig. 29a Shear zone in Lennard Granite 9 km southeast of Mount Disaster. En echelon shears (foreground) are oblique to main trend of shear zone. (Neg GA 1883)
DCG

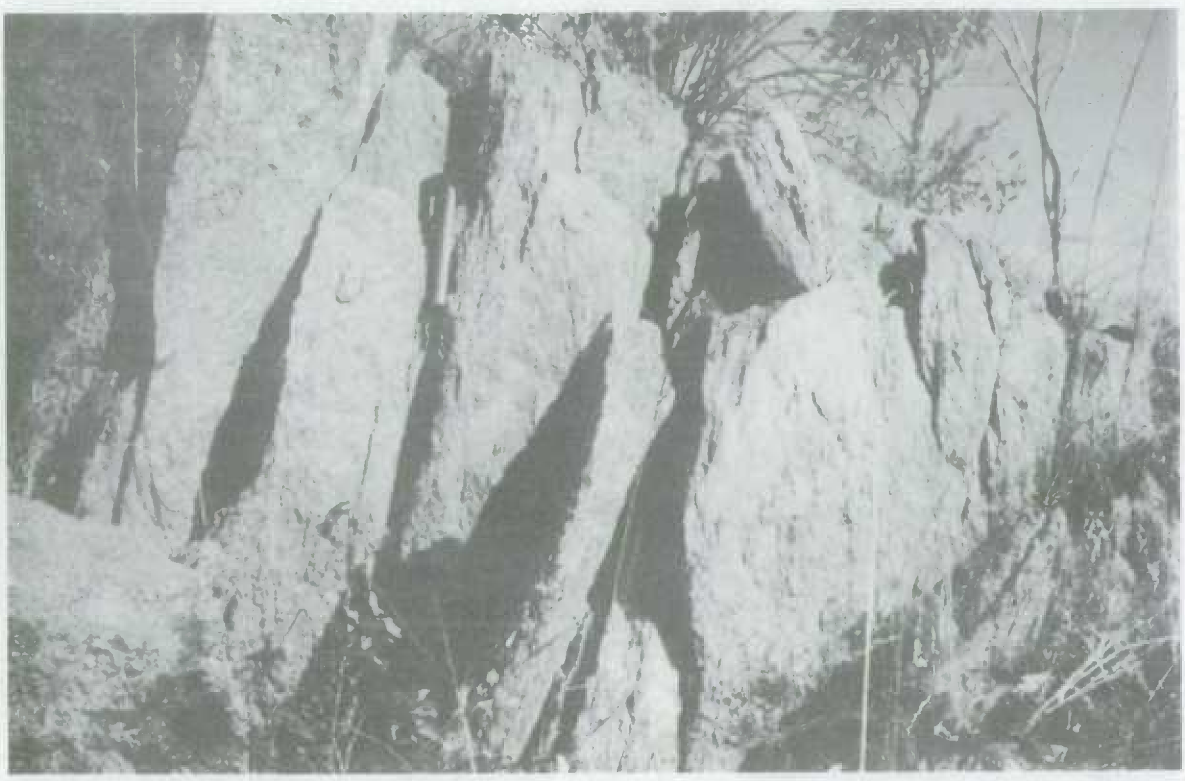


Fig. 29b Flaggy muscovite rich "schisted" granite in shear zone. Locality as above (Neg. G9704)
DCG

Structural Development

Interpretation of the structure of Koolan Island and the nearby parts of the mainland suggest that, if compressional forces have been responsible for the structure of the folded Kimberley Group Cover, then a crustal shortening from 50 km to 23 km has occurred in this area.

This concept, if extended over the whole of the Mobile Zone southwards to Compass Hill, would imply a total shortening of 80 km. There is little evidence in the granites of the Mobile Zone to support this concept for the whole of the Yampi area. The granites appear to have been deformed by shearing and by fracturing to form faults and joints, but apart from this have not been deformed to any great extent and there thus appears to be little if any crustal shortening within them. However, the part of the Kimberley Group cover of the Mobile Zone that is most highly deformed is that overlying the Halls Creek Group (and inferred extensions of Halls Creek Group) where compressional folding and thrusting have been operative, and it is probable that most of the shortening has taken place in the Halls Creek Group.

The present structure of the Kimberley Group rocks of the Mobile Zone probably results from compressional deformation in response to north-south compression, with overturning of folds from the south and localized reverse faulting, combined with shear movement of the granitic basement along pre-existing west-northwest trending faults and joints. It is suggested that the east-northeast trending folds may possibly belong to a conjugate fold system related to renewed movement of earlier east-northeast trending fractures.

METAMORPHISM

The rocks of the Yampi Sheet area have been affected by at least two major periods of metamorphism, one older than the Kimberley Group and the other younger. The earlier period of metamorphism has affected both the Halls Creek Group sediments and the Woodward Dolerite, but is apparently earlier than the granites. The later period post-dates both the Kimberley Group sediments and the Hart Dolerite that intrudes them. The effects of the second metamorphism on rocks affected by the first are difficult to assess, particularly since each may have been polyphase.

The main evidence for a pre-Kimberley Group metamorphism in this area is provided by slightly differing degrees of metamorphism exhibited by the Woodward and Hart Dolerites within the same area (e.g. northwest of Mount Nellie), and by the fact that the area of most intense first metamorphism lies in the southeast corner of the Sheet area, and the area of most intense second metamorphism lies in the west.

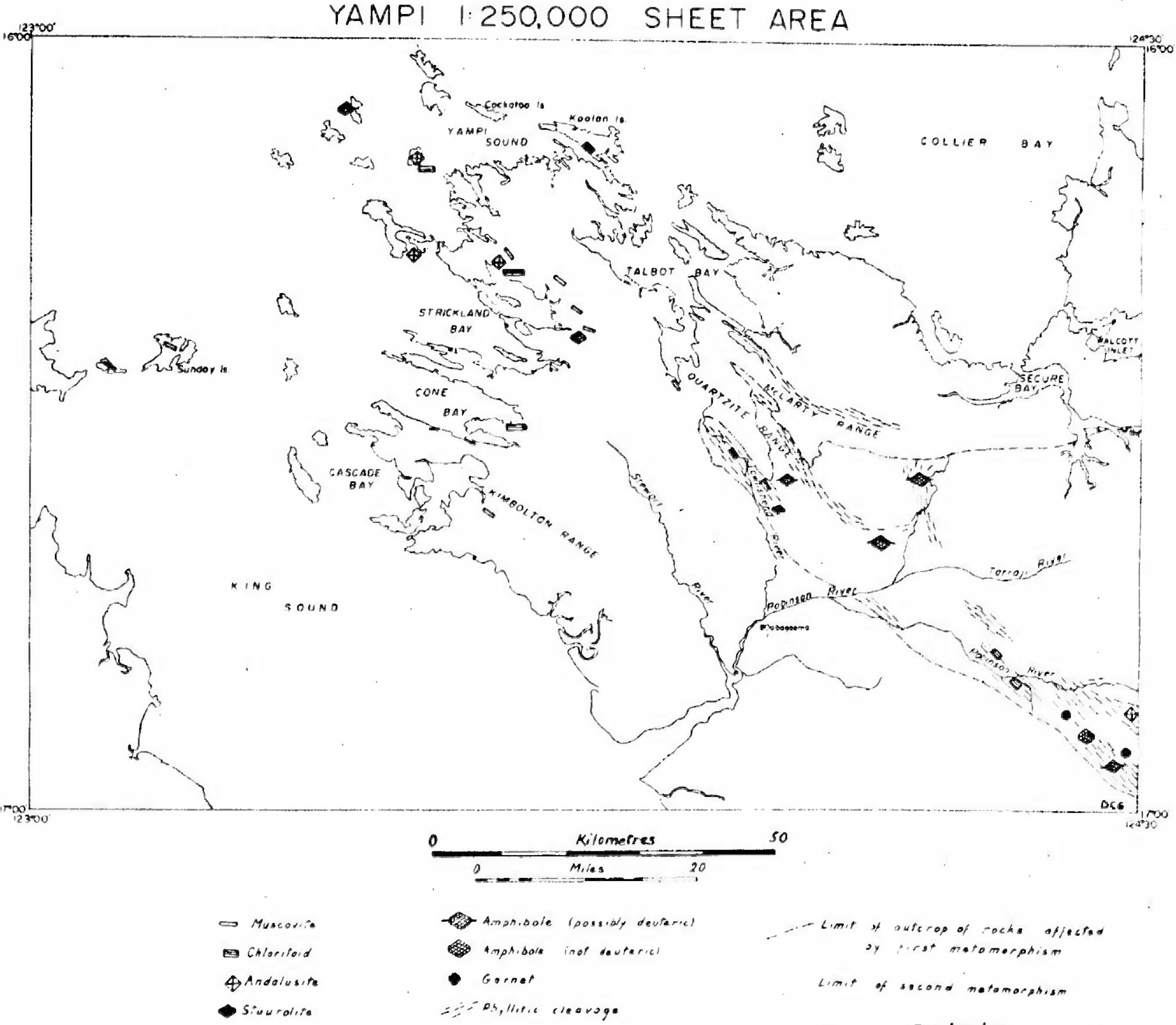
Certain structures common to both the older and the younger rocks may be associated with the second metamorphism, e.g. two sets of distinctive kink-bands with similar trends have been noted in phyllites, one in the Halls Creek Group and the other in the Elgee Siltstone. Alternatively these structural features may belong to a period of deformation that is unrelated to the second metamorphism, which appears to be predominantly a thermal metamorphism without much movement.

First Metamorphism

Over much of the area the first metamorphism was of low grade and resulted in the formation of greenschist facies sericite phyllite and chlorite-sericite phyllite in the Halls Creek Group. Transgressive biotite porphyroblasts (probably pseudomorphing chloritoid) are abundant around Marboo Pool and just east of Boulder Hill, and an isolated occurrence of staurolite has been found near Quiana Pool. Apart from this, the area of moderately high-grade metamorphism is confined to the southeastern corner of the Sheet area (Fig. 30) where amphibolite facies rocks are found. Garnet and andalusite in that area indicate the upper levels of metamorphism. Both fresh andalusite and andalusite pseudomorphs are present.

FIGURE 30

METAMORPHIC MINERALS
YAMPI 1:250,000 SHEET AREA



E51/A3/20

The presence of amphibole-bearing quartzites within the Halls Creek Group (in the southeast) is characteristic of amphibole facies metamorphism of the West Kimberley; similar rocks are found in the Richenda River region of the Lennard River 1:250,000 Sheet area.

Metamorphism of the Woodward Dolerite to amphibolite has taken place throughout the older Precambrian rocks of the area. It is possible that the metamorphism of the Woodward Dolerite may be partly deuteric; consequently the occurrences of amphibole in Woodward Dolerite are distinguished in Figure 30 from those of purely metamorphic amphibole. In the area of amphibolite facies metamorphism in the southeast, amphiboles in the Woodward Dolerite have a brownish-green colour distinct from the pure green colour of those from the Sandy Creek - Mangrove Creek area to the northwest. The brownish amphiboles come from Woodward Dolerite surrounded by garnet-bearing schists and the change in colour of the amphibole thus parallels the change in metamorphic facies outlined by the pelites.

There is little evidence of polyphase metamorphism in the Yampi area, although the presence of chloritoid may represent a retrograde metamorphism superimposed on an earlier higher grade phase. About 6 km east of the Yampi Sheet, Halls Creek Group rocks in the Charnley Sheet area have andalusite pseudomorphs that are replaced by the assemblage muscovite-biotite-staurolite, but still retain cores of unaltered andalusite (or regrown andalusite). This replacement suggests breakdown of early andalusite (possibly in response to falling temperature) plus subsequent development of the staurolite due to a second phase of metamorphism. The first metamorphism in the Charnley Sheet area and thus in the contiguous part of the Yampi Sheet area has thus probably been two-phase.

Second Metamorphism

Because of the quartz-rich nature of the Kimberley Group rocks, effects of the second metamorphism cannot be traced as readily as the effects of metamorphism (mainly first metamorphism) in the older Precambrian rocks. The most sensitive indicators of the second metamorphism are the pelitic rocks of the Elgee Siltstone, and Pentecost Sandstone, and basic igneous rocks (Hart Dolerite and Carson Volcanics).

Over most of the area west of a line from Talbot Bay to Oobagooma pelitic rocks show development of muscovite or sericite. The rocks vary from schist and phyllite to tough hornfelses. The cleavage developed is mostly an axial plane cleavage; locally a bedding cleavage is present. Muscovite has also been noted in the sandstone, particularly in the King Leopold Sandstone of Sunday Island, where it shows good parallel alignment that cuts across bedding (bedding indicated by trains of small tourmaline grains).

Slightly higher grades of metamorphism are indicated by andalusite hornfelses (with andalusites up to 5mm) on Gibbings Island, Dunvert Island (Whirlpool Pass) and on the mainland 6 km south of Wotjulum Mission; by amphibolites derived from Carson Volcanics (at mouth of Lydarrba River) and Hart Dolerite (Powerful Island); and by chloritoid on Koolan Island (Simpson, 1915) on Gibbings Island and in ?Speewah Group sandstone at Cone Hill.

The amphibolite from the Carson Volcanics contains pale brown to blue-green hornblende, plagioclase (An_{30-35}) and only rare small grains of epidote. This assemblage, especially the composition of the plagioclase and the paucity of epidote, indicate that it has reached amphibolite facies grade of metamorphism.

The grade of metamorphism appears to decrease to the north since most of the pelites on Koolan, Cockatoo and Irvine Islands show only inicpient metamorphism. Along strike to the east, e.g. north of Mount Nellie the metamorphism decreases and becomes almost entirely of dynamic nature; the Carson Volcanics (both pelitic interbeds and the basalts) here are strongly sheared to form a series of sericite and chlorite phyllites in which the basic igneous rocks can be distinguished only by the presence of relict, sheared amygdales.

Minor metamorphism of Warton Sandstone adjacent to Hart Dolerite has produced cordierite in the southeast Graveyard area. This, however, is apparently not connected with the regional second metamorphism of the area, but is probably a thermal effect caused by intrusion of the dolerite.

PROVENANCE OF THE KIMBERLEY BASIN SEDIMENTS

During mapping of the Kimberley Basin sediments in the Lansdowne 1:250,000 Sheet area to the west (Gellatly et al., 1965) it was noted that cross-beds indicated consistent current directions - from the northeast in the Speewah Group and the lower part of the King Leopold Sandstone, and from the northwest in higher beds of the Kimberley Group. Observation of cross-bed current directions and other sedimentary features in other areas of the Kimberley Basin has similarly produced consistent results (e.g. Gellatly & Sofoulis, 1966; Derrick, 1966). Ripple-mark trends have also been measured, but previously have given inconsistent results. A summary of the palaeocurrent data for the whole Kimberley region has been presented by Gellatly et al. (1970). The study has continued in the recent work in the Yampi area. In addition to examination of the provenance of the Kimberley Basin sediments on a regional basis, work has also been directed more specifically to problems of genesis of the Yampi iron ores, which appear to be detrital deposits and thus genetically related to the rest of the Kimberley Basin sediments (Gellatly, 1969).

Cross-beds

Cross-bed orientations have been measured in the four principal sedimentary formations from several localities in the Yampi Sheet area. As in previous work in the Kimberleys, 25 cross-beds have been measured from each locality, wherever practicable, in order to provide statistically valid results for the deduced current directions.

The cross-beds in the area are predominantly of the trough or 'festoon' type (terminology of McKee & Weir, 1953) or 'pi' type (Allen, 1963) and mostly range from 10 cm to 45 cm in thickness. Locally planar types ('omikron' type of Allen, 1963) are found and range in thickness from about 30 cm to 1 m. The sets are mostly wedge-shaped, but tabular ones are also found. Dips of fore-sets relative to bedding vary from about 3° to 15° in the trough type, and up to about 30° in some of the tabular ones.

In outcrop the trough cross-beds generally have arcuate intersections with bedding-planes. In flat-lying or gently dipping strata the direction of concavity of these arcs was measured. Where dips were appreciable (in excess of 15^{o}) the dip and azimuth of both fore-set and bedding were measured, and the original dip direction of the fore-set determined on a stereonet using the methods outlined by Ramsay (1961). The results were plotted on rosette diagrams (Fig. 32) and the mean direction of sediment transport plotted on a map of the area (Fig. 31).

Cross-bed directions in the King Leopold Sandstone indicate currents from northeast and northwest. Insufficient work has been done to determine possible variations related to differences in stratigraphic level (as in the Lansdowne Sheet area). Three of the sets of readings K2, K3, and K5 are from the same general stratigraphic level - the topmost beds of the Sandstone; these show a spread equal to that from all stratigraphic levels of the King Leopold Sandstone from which cross-beds have been examined, and it thus appears that the variations present are independent of the stratigraphic level.

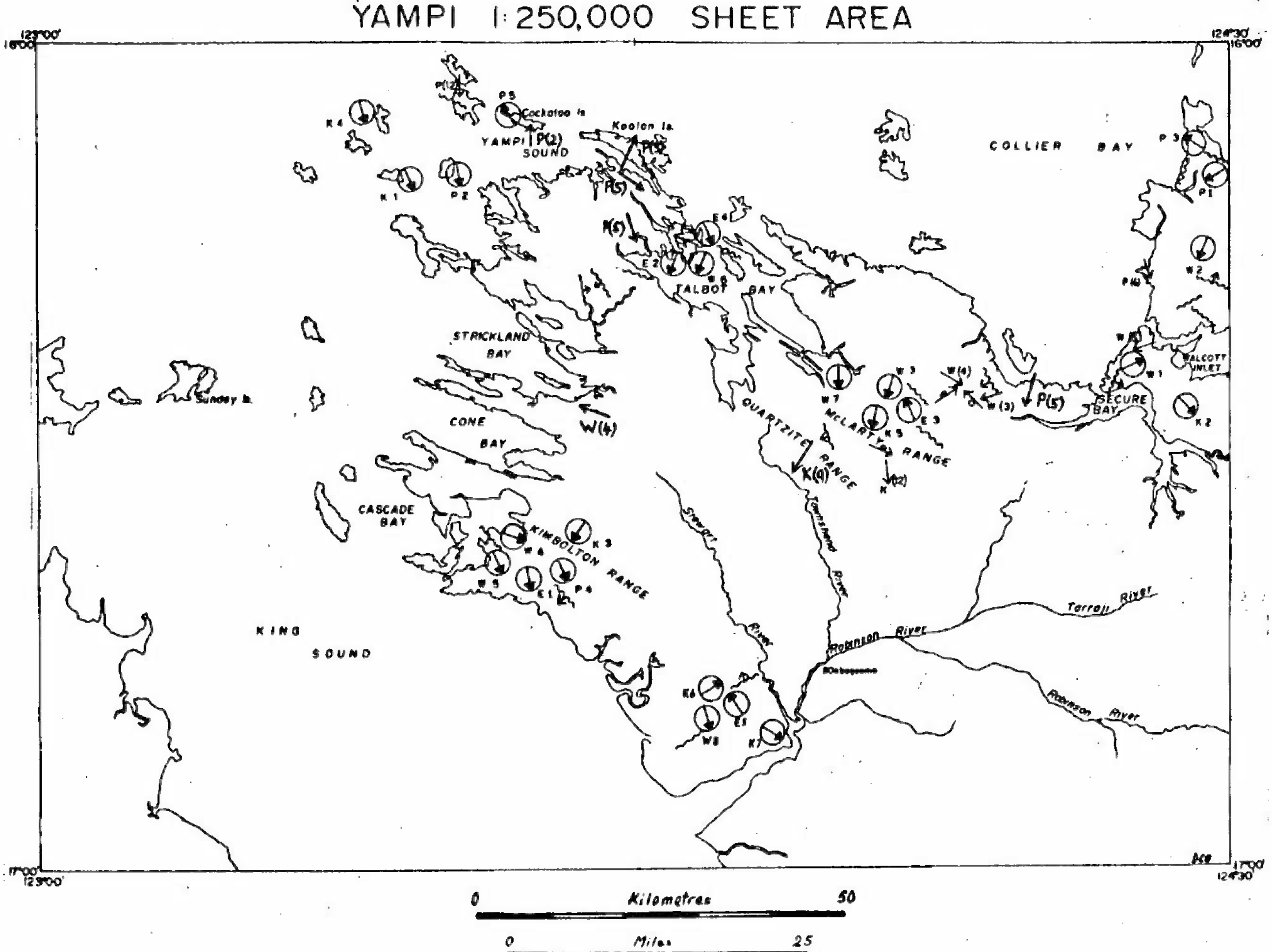
Current directions indicated by cross-beds in the Warton Sandstone similarly show a spread in direction of origin from northeast to northwest. Exceptions are found in the vicinity of Secure Bay where cross-beds indicate currents from west-southwest and east-northeast.

Directions in the Elgee Siltstone are predominantly from northeast and northwest, but directions from south and southeast are found (a) low in the succession to the southeast of Talbot Bay, and (b) from a minor component of the readings in the northwest of Talbot Bay. In the first-mentioned locality these reversals of the normal current directions occur in sandstones immediately overlying the basal Elgee conglomerate, and in the second they are found in beds of equivalent stratigraphic level.

158

FIGURE 31

SEDIMENTARY STRUCTURES
YAMPI 1:250,000 SHEET AREA



Current direction from cross-beds (25 readings)

" " " " " (no. of readings indicated in parentheses)

Trend of symmetrical ripple-marks

Trend of asymmetrical ripple-marks: arrow indicates current direction

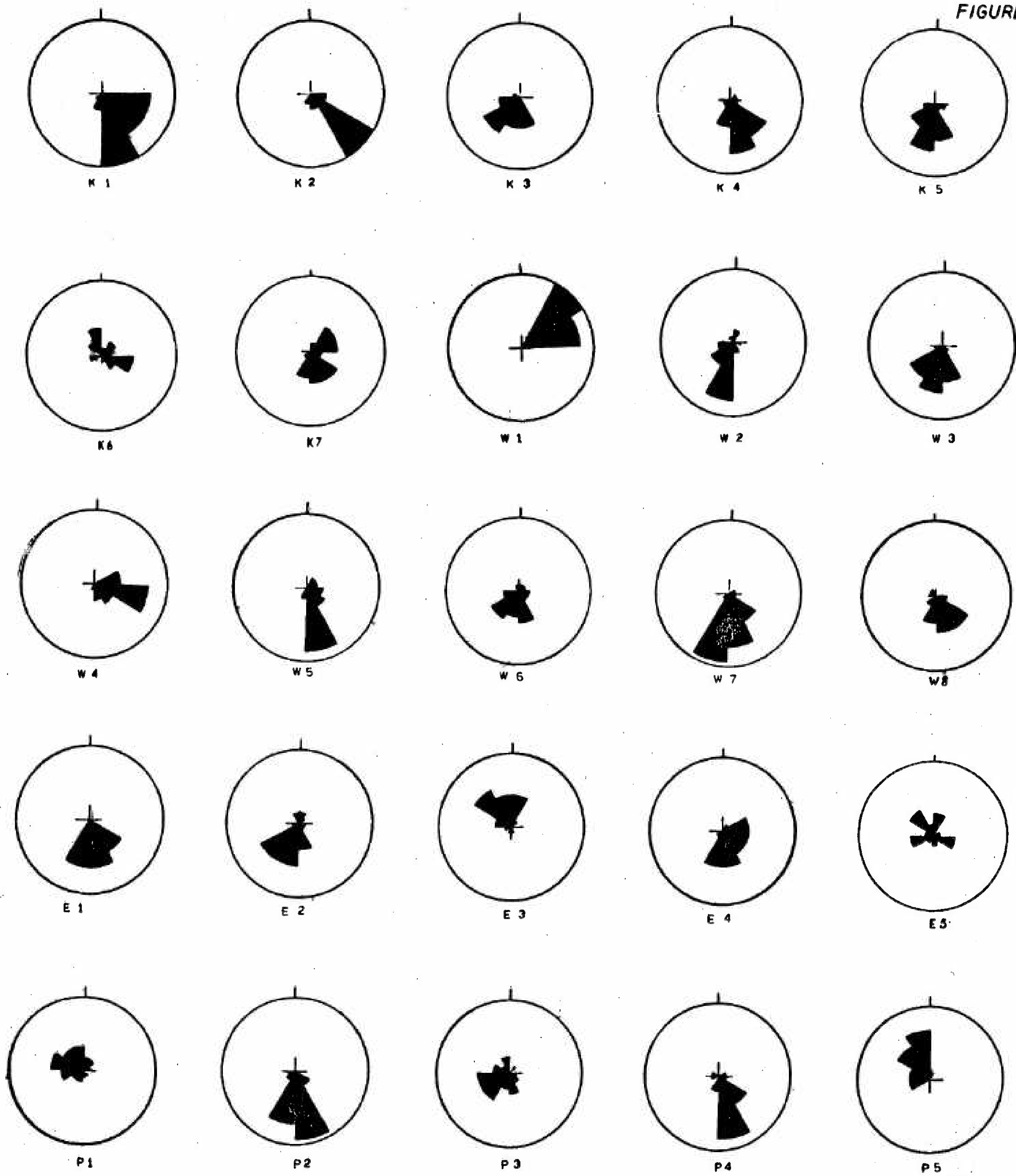
Overturned cross-beds: arrow-head indicates direction of overturning

K – King Leopold Sandstone W – Warton Sandstone E – Elgee Siltstone P – Pentecost Sandstone

Numbers without parentheses refer to rosette diagrams in Figure 32.

E51/A3/ 26

FIGURE 32.



DCG

E51/A3/21

FIGURE 32. Current directions from cross-beds (25 readings per diagram)

Numbers refer to localities on Fig

K - King Leopold Sandstone

W - Warton Sandstone

E - Elgee Siltstone

P - Pentecost Sandstone

In the Pentecost Sandstone the southeasterly current direction indicated by cross-beds in the Yampi iron ores initiates a trend that is evident in the vicinity of Yampi Sound and elsewhere along strike to the southeast and east. Elsewhere in the Pentecost Sandstone, however (Gibbings Island and Kimbolton Range), the more normal northerly direction prevails.

Overturned Cross-beds

Cross-beds that have been subjected to localized intraformational folding are moderately common in the Kimberley Group sediments. A few have been noted in the Yampi area. These are flat-lying U or V shaped intraformational folds confined to a single bed in an otherwise normal sequence. The direction of overturning in each case makes an angle of about 45° or less with the average current direction indicated by the cross-beds in each locality. In view of experimental evidence (McKee, Reynolds, & Baker, 1962) they are considered to have originated through the scouring action of strong sediment-bearing currents immediately after deposition of the beds concerned.

Ripple Marks

Little attention has so far been paid to ripple marks in the Kimberley Basin sediments because of their paucity and their variability. Ripple marks studied in the Yampi Sheet area are partly cuspate asymmetrical ones and partly asymmetrical current ripple marks. They are mainly low amplitude (a = 1cm) low wavelength (2λ = 5 cm to 8 cm) types, but cross-laminated mega-ripples (a = 10 cm; 2λ = 60 cm to 1 cm) have been noted in the Warton Sandstone north of Walcott Inlet.

The ripple marks show a consistent northwest trend over the whole area except in the extreme east, where north-northeast trending ripples have been observed. The dominant trends of the ripple marks are approximately parallel to the directions of the depositing currents. They imply a northeast-southwest trend of wave propagation; asymmetrical ripples indicate formation by currents mostly from the northeast. These directions are approximately normal to those implied from the cross-beds; a similar relationship between cross-bed directions and ripple-mark directions has been noted in the Drysdale Sheet area (Gellatly & Sofoulis, 1966). In other areas (e.g. Ashton Sheet area) the orientation of ripple marks is apparently random. The divergence of trends suggests a differing origin for the two sets of structures. It is probable that the cross-beds indicate the transport direction at the time of deposition and that the ripple marks possibly indicate the trends of wave propagation and related redistributing bottom currents (e.g. undertow).

Grain-size Variations and Conglomerates

For the most part, the Kimberley Group sandstones of the Yampi area are medium to coarse-grained and well-sorted. Grain-size analyses at present are incomplete, but preliminary results indicates that they are similar to the sandstones of the Drysdale-Londonderry Sheet area (Gellatly & Sofoulis, 1966) which have median grain diameters mostly in the range 0.18 mm to 0.64 mm and sorting coefficients (So = $\sqrt{\frac{Q25}{Q75}}$) ranging from 1.24 to 1.46.

In the Yampi Sheet area, sandstones of the Elgee Siltstone are locally coarser than the other sandstones. Also the King Leopold Sandstone appears to be extremely coarse-grained on and around Sunday Island, but the exact grain size there is uncertain due to effects of metamorphism.

Conglomerates are prominent in the succession only at the base of the Elgee Siltstone in a belt that parallels the margin of the 'basement' outcrop and stretches from Secure Bay to the eastern end of the Kimbolton Range. These conglomerates are mainly cobble conglomerates with clasts up to 20 cm in diameter. Localized pebble conglomerates are found also at the base of the Speewah Group (3 km east of Mount Nellie), in the Yampi Iron ores, and in the basal beds of the Pentecost Sandstone on Gibbings Island. An isolated occurrence of boulder and cobble conglomerate has been noted in the Pentecost Sandstone 5 km southwest of Yule Entrance.

Mineralogy

The quartz sandstones (which make up about 80% of the Kimberley Group in this area) consist essentially of quartz, with trace amounts of heavy detrital minerals, and locally with moderate amounts of feldspar. The heavy mineral assemblages consist principally of green tourmaline, and pale pink zircon, rutile, and anatase.

The hematite-bearing sandstones, the hematite ores, and all compositional variations between these, contain the same heavy minerals as the quartz sandstones, but in the hematitic rocks tourmaline is generally much more abundant than in the quartz sandstones. The heavy mineral variations are described in the section on Provenance of the Yampi iron ores.

The siltstones cannot be compared directly to the coarser sediments and their mineralogy has not been studied in detail.

Thickness and Lithological Facies Changes

The Warton Sandstone and Elgee Siltstone show variations both in thickness and composition within the area. Compositional variations are present within the Pentecost Sandstone, but thickness variations in it are difficult to assess because of rapid facies variations, and because nowhere is the full sequence preserved.

Complete sections of Warton Sandstone have been measured 5 km southwest of Shoal Bay, 5 km south-southwest of Coppermine Creek, and in the south near Mount Dawson. The section near Coppermine Creek is 340 m thick, but the other two are about 520 m thick, suggesting a thinning to northwest. A similar northwestward thinning is apparent in the Elgee Siltstone (Fig. 33).

Evidence of lithological changes in the Warton Sandstone are difficult to assess because of lack of outcrop of the softer beds. However, it appears that there is a general increase in silt content northwards and westwards which appears to be related to the thinning of the formation in these directions.

Rock types in the Elgee Siltstone are extremely variable. Conglomerates are found only within about 24 km of the nearest outcrop of pre-Kimberley Group 'basement': they are associated with a reversal of current directions indicating derivation from the southeast. There appears to be a decrease northwards in the sand/silt ratio from Mount Olivia to the Yampi Sound area: no significant westward variations have been noted.

In the Pentecost Sandstone the lower beds consist entirely of white quartz sandstone except in the northwest, where hematitic sandstones and siltstones predominate on the Yampi Sound Islands. A short distance to the south of the ore islands however, e.g. Gibbings Island and southeast of Nares Point, white quartz sandstone forms the basal beds. In the northern part of the Yampi Sheet area the Pentecost Sandstone shows a distinct westward increase in silt content which reaches its maximum development in the area between Talbot Bay and the Graveyard. Silts are also common in the upper beds of the Pentecost in the Kimbolton Range in the south and in the hematitic beds in the Yampi Islands and to the southeast. The hematitic facies of the Pentecost is found on the mainland only in the Talbot Bay/Shoal Bay/Collier Bay area as a narrow belt following the coastline, and paralleling the structural trends. The facies changes noted are summarized on Figure 33.

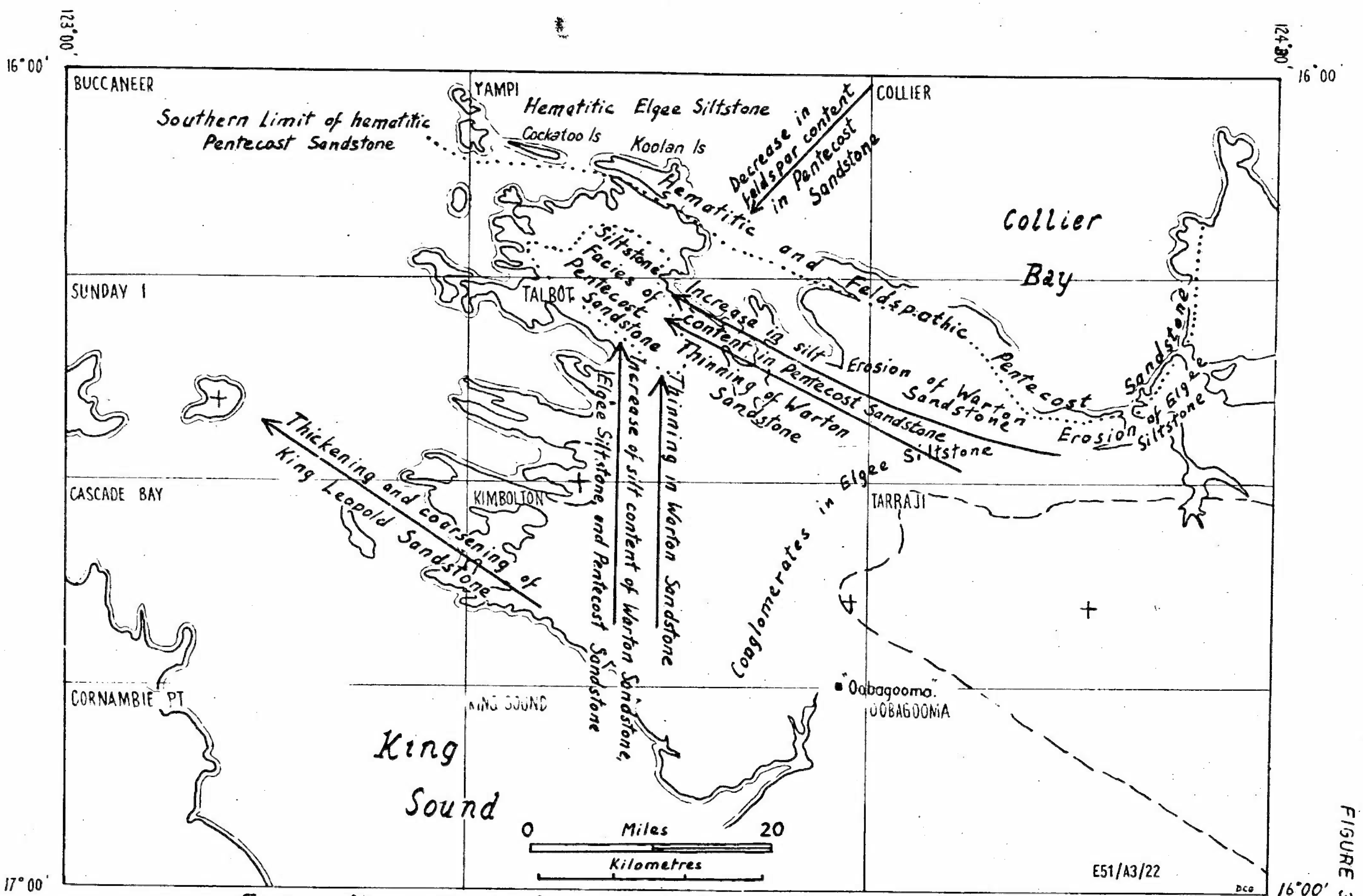


Fig. 33. Diagrammatic Summary of Facies Changes in Kimberley Group.

Provenance

The provenance of the Kimberley Group sediments of the Yampi area is more complex than that of other parts of the Kimberley Basin. This is probably due to the proximity of a temporary shoreline (or shorelines), and to the control of sedimentation by localized uplift and subsidence during deposition. Two sets of folds and faults are apparent in the Yampi area: those trending west-northwest, and those trending east-northeast. The west-northwest trending structures have dominated the post-depositional movements; it appears that they have also been predominant during sedimentation since the majority of facies changes take place along an approximate north-south line, and belts of lithologically uniform rocks tend to be aligned west-northwest. It is possible, however, that the east-northeast structures may have controlled some of the localized contemporaneous erosion (e.g. of the Elgee Siltstone). Evidence concerning the provenance of the sediments is not fully consistent and the location of the source areas and the distribution of shorelines can only be hinted at.

The facies changes detailed are not conclusive in indicating possible source areas. Although the variations in the silt/sand ratio tend to suggest an origin from the south or southeast, this could equally well indicate a localized basin of silt deposition in the Graveyard area. The thickening and coarsening of the King Leopold Sandstone, the variation in feldspar content in the Pentecost Sandstone and the distribution of hematitic sediments in the Pentecost Sandstone suggest a source from the north or west. This latter suggestion agrees well with the evidence of transport directions of the sediments deduced from the cross-beds, and it is probable that the principal source areas lay to the north and west.

Conglomerates of the Elgee Siltstone are interpreted as the products of localized and relatively short-lived erosion of earlier deposited Warton Sandstone due to minor uplift, mainly in the part of the Yampi Sheet area now devoid of sedimentary cover. Apart from the temporary shoreline outlined by the Elgee conglomerates, the only evidence of proximity to a shoreline is provided by the apparent westward thickening and coarsening of the King Leopold Sandstone, and by the belt of hematitic rocks in the north, together with their associated conglomerates.

PROVENANCE OF THE YAMPI IRON ORES

Detailed descriptions of the Yampi Iron Ores have been given in Canavan & Edwards (1938) and I.W. Reid (1958). A short summary, based partly on the earlier work, is given as a background to the present results.

The Yampi iron ores consist of fine to medium-grained hematite rock, hematite-rich quartz sandstone, and hematite-rich phyllite and schist. The ores and associated sediments show all gradations from pure quartzite to pure hematite. They occur as steeply dipping beds that are conformable with the underlying quartz sandstone, schist, and phyllite, and the overlying quartz sandstone and hematite sandstone. Cross-bedding with 5 cm to 8 cm thick fore-set units, and fore-set laminae grading from a hematite-rich lower part to a quartz-rich top, are noted in the ores. Localized conglomerates are present in the area and have either quartzite pebbles, or cavities where the pebbles have been leached out (Fig. 34). Similarly, leaching of interstitial silica from silica cemented hematite ores has produced 'powder' hematite ores consisting of uncemented hematite grains.

Minor accessory detrital minerals present in the ores and associated beds are characteristic of sedimentary deposits. They include tourmaline, zircon, rutile, garnet, plagioclase, and possible monazite.

Canavan & Edwards (1938) note that there are few cross-cutting veins of hematite and that sulphides are absent. In addition, the octahedral form of the hematite grains and relict cores of magnetite noted within them suggest that all the hematite was previously magnetite.

Origin of the ores as clastic sediments possible enrichment by leaching of silica has been suggested by Edwards (1953) and by Reid (1958, 1965). Although this appears to be the most likely mode of formation, the earlier work leaves several problems unresolved, namely:

1. The stratigraphic position of the ores and their lateral relationship to other sediments of equivalent stratigraphic level;
2. The type of source rocks which provided the iron;
3. The environment of deposition;
4. The methods of concentration.

The following information is directed towards the solution of these problems.

Stratigraphic Position of the Ores

Careful mapping of the Kimberley Group on the Yampi mainland and adjoining islands shows that the Yampi iron ore beds are probably lateral equivalents of the basal beds of the Pentecost Sandstone of the mainland, but this cannot be proved with certainty because of lack of outcrop in 'The Drain' between Koolan Island and the critical area of the mainland southeast of Koolan Island.

However, the stratigraphic sequence of the Kimberley Group, as established in the East Kimberley, can be traced more or less uninterrupted to the critical area. The Carson Volcanics, Warton Sandstone, and Elgee Siltstone there are essentially similar to their counterparts in the type areas except that the Elgee Siltstone is thinner and is more arenaceous. It is also noted that the lower beds of the Pentecost Sandstone become gradually more silty and contain traces of hematite when traced northwestwards.

Further evidence for this correlation rests on:

1. The Elgee Siltstone, which is the only relatively thick (i.e. 30 m to 150 m) dominantly siltstone sequence in the vicinity, is lithologically similar to the 'Hanging Wall Schist' found stratigraphically below the iron ore beds of Koolan Island, where the thickness of schist is similar to that of Elgee Siltstone in adjacent areas of the mainland.

2. The Warton Sandstone, which underlies the Elgee Siltstone on the mainland, is the only relatively thick cleanwashed sandstone in the area, and is lithologically identical with and of similar thickness to the quartzite that stratigraphically underlies the iron ore beds and associated schists of both Koolan and Cockatoo Islands.

3. A further point in evidence, although by no means conclusive, is that the Wotjulum Porphyry, which on the mainland is mainly confined to the Elgee Siltstone (but locally intrudes the lowermost Pentecost Sandstone beds), at Phil Cove on Koolan Island intrudes the 'Hanging Wall Schists' and also the lowermost iron ore bed.

This interpretation of the stratigraphic position of the ores necessitates reinterpretation of the structure of the Yampi Sound area presented by Canavan & Edwards (1938). The two cross sections are compared in Figure 35. Canavan & Edwards interpret the ores as belonging to beds about

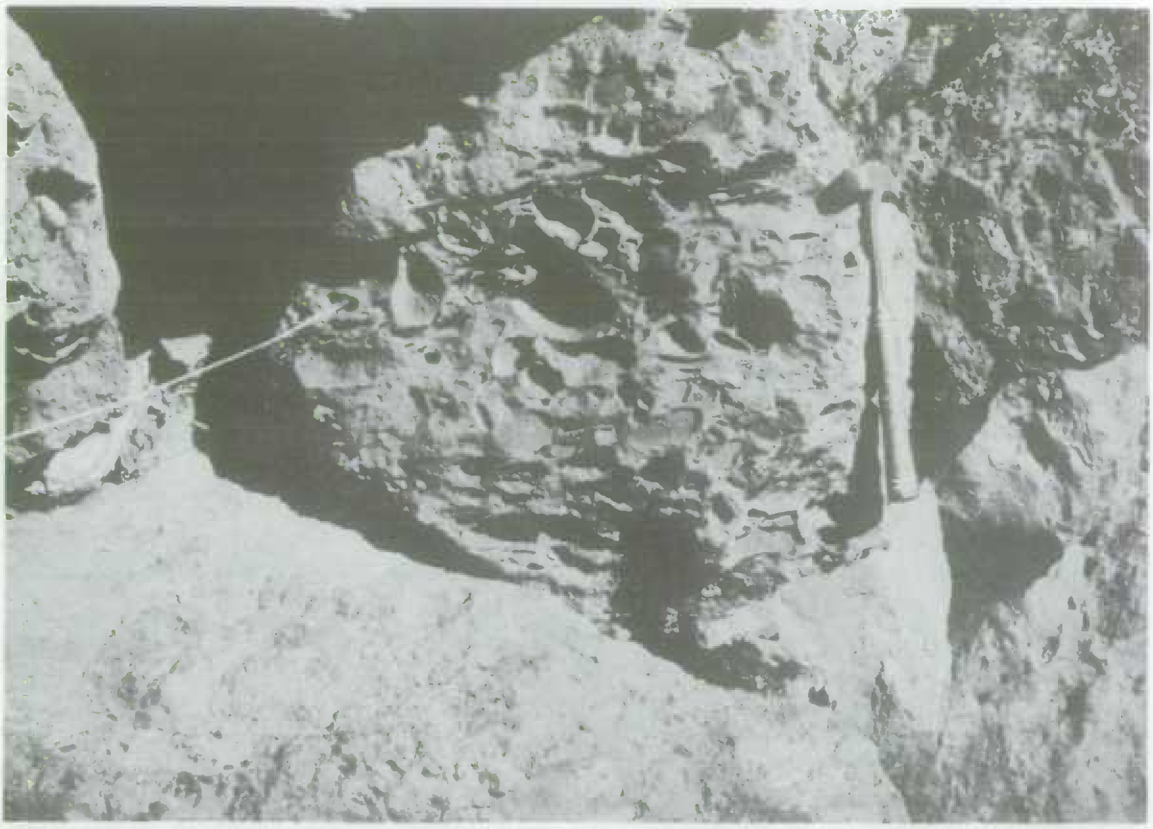


Fig. 34a Leached hematite conglomerate with pebble moulds, Koolan Island quarry.
(Neg. GA 968) DCG

Fig. 34b Hematite conglomerate west end of main ore body, Koolan Island. Pebbles and cobbles of hematite-bearing quartzite are enclosed by a granular hematite matrix. The leached zone consists almost entirely of hematite (Neg. GA 966) DCG

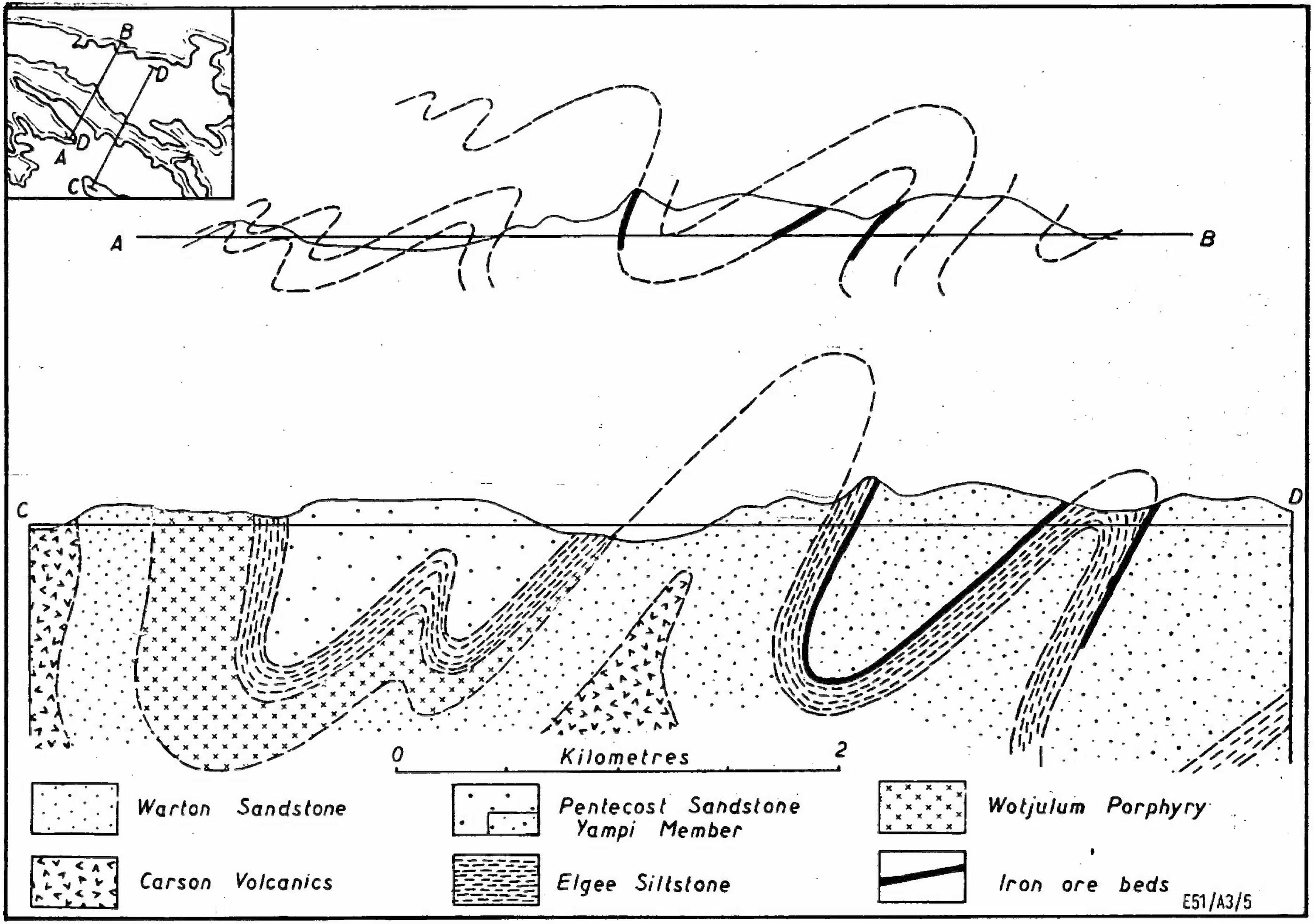


Figure 35. Structural interpretations of Koolan Island and adjacent part of the mainland demonstrating stratigraphic correlation of Yampi iron ores: A-B after Canavan and Edwards 1938; CD this work.

FIGURE 35.

800 m above the Elgee Siltstone, and thus infer that the absence of hematite on the mainland is due to its removal by erosion. According to this interpretation, the quartzite (which we correlate with the Warton Sandstone) underlying the ore beds and 'Hanging Wall Schist' of Koolan Island would be equivalent to the siltstones in the upper part of the Pentecost Sandstone in the mainland area and this would require a considerable thickening as well as facies changes to explain the observed stratigraphy.

According to our work the sandstones on the south side of Koolan Island can be traced almost continuously, around fold structures to the south-east, to outcrops of known Warton Sandstone about 3½ km south of Koolan Island wharf. On the basis of this correlation the ore beds of Koolan Island form the base of the Pentecost Sandstone there and are in a stratigraphic position equivalent to that of the white quartz sandstone at the base of the Pentecost Sandstone sequence on the mainland immediately to the south. Although rapid facies changes are known in the Pentecost Sandstone in this area, they are inadequate to explain the lithological dissimilarity between apparently equivalent sections of Pentecost Sandstone only 2 km apart. The solution to this problem apparently lies in the erosion of the lower beds of the Pentecost Sandstone from Koolan Island (but not from the adjacent mainland), and in the overlap of the Yampi Member on to the Elgee Siltstone on Koolan Island (Fig. 18).

Nature of Original Iron

The iron is now almost entirely hematite, but small amounts of magnetite are found as relict cores enclosed by lamellae of secondary hematite developed along octahedral cleavages (see Canavan & Edwards, 1938, Figures 19, 20). Unabraded octahedral magnetite crystal forms are common in both the ores and the hematite-quartzites, and it is clear that the iron has been recrystallized to form the magnetite octahedra after its deposition. Because of the two processes of recrystallization after deposition, the nature of the original iron remains uncertain.

There is little doubt that the quartzites associated with the ores are of clastic origin, but it has not been proved that the original iron was itself clastic. However, the close association with detrital quartz and the sensitivity to variation in their relative percentages (e.g. as in graded fore-set laminae) suggest that the iron mineral had similar hydraulic characteristics to the quartz and that it was probably present as clastic grains. The other possibility, i.e. that the iron originated as a chemical and biochemical precipitate, seems unlikely in view of the obviously clastic nature of the associated sediments and the absence of cherts and jaspilites normally associated with precipitate-type iron deposits.

Source of the Iron-bearing Sediments

It is necessary to determine whether (a) the ores have formed through derivation from an iron-rich source or whether (b) they represent abnormal concentrations (e.g. as beach sands deposits) of the detrital material that is present in the rest of the Kimberley Group sediments.

The following possible types of source rocks are considered:

Basic igneous

Acid igneous

Metamorphic

Iron-bearing sediments.

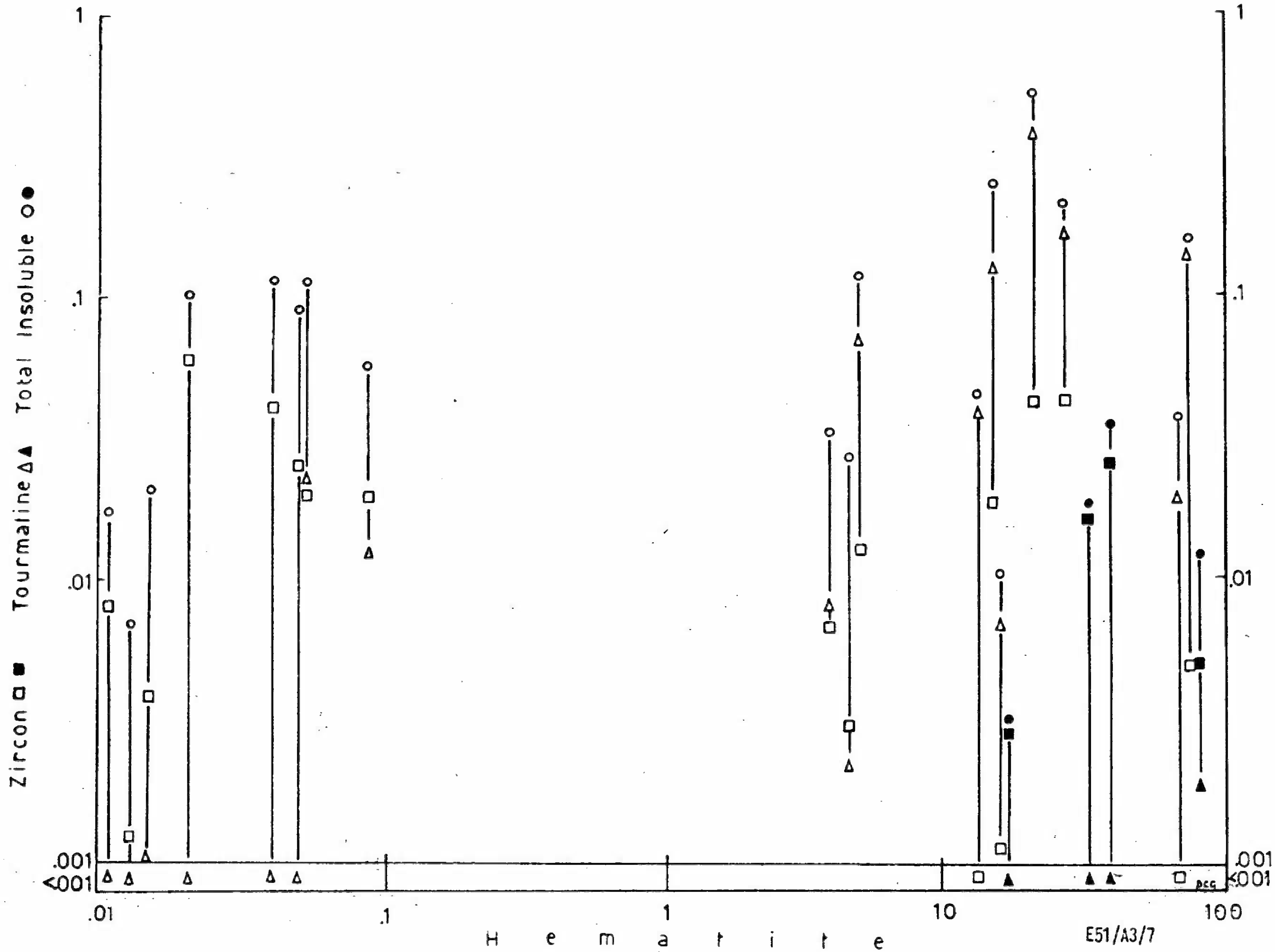
Because of the high temperature of crystallization and composition of the parent magma, iron ore minerals from a basic igneous provenance would invariably be enriched in TiO_2, V_2O_5, Cr_2O_3 and MnO. Thus any clastic sediments derived from them similarly would be enriched in these oxides. Surface weathering or leaching of basic igneous magnetite is unlikely to provide a relatively pure ore of the Yampi type (Table 8) especially with regard to TiO_2, since weathering would result in removal of the iron in solution and would give an enrichment in TiO_2 (Temple, 1966).

In their chemistry, the Yampi iron ores resemble those of the Hamersley area, but are quite distinct from the magnetite beach sands of New Zealand (Table 10), and a basic igneous source can be ruled out.

An acid igneous source could possibly provide magnetite of sufficient purity, but small amounts of other accessory minerals characteristic of granitic rocks (zircon, tourmaline, rutile, apatite, etc.) would be included, and their concentration could be expected to increase with increasing iron content of the ores.

To test this possibility several heavy mineral separations were carried out and the percentages of zircon and tourmaline estimated in the residues after removal of the hematite by dissolving with HCl. Rocks used in this study included clean-washed, iron-free sandstones from the King Leopold Sandstone, Warton Sandstone, and hematitic facies and ore beds of the Pentecost Sandstone. In these tests, the total content of heavy minerals other than hematite (referred to as insoluble heavy minerals) showed only a slight increase with hematite content (Fig. 36). Even if the hematite showed a thousand fold

173



Relative percentages of heavy minerals in Kimberley Group sediments

Solid symbols —Yampi iron ores Open symbols — other formations.

FIGURE 36

174

increase, it is thus unlikely that any abnormal concentration from a granitic source could have resulted in the formation of the Yampi iron ores.

A metamorphic source area is also considered to be unlikely on the same grounds that a granitic one is excluded, namely lack of concentration of the insolubly heavy minerals, and since metamorphic minerals are extremely rare in the ores.

Iron-bearing sediments, possibly of jaspilite type, appear to offer the most likely source on grounds of chemical and mineralogical composition, although the Yampi iron ores are unusually poor in MnO compared to jaspilite type ores from the Hamersley area and from the Biwabik Iron Formation in the USA (James, 1966). Derivation from iron-rich sediments would eliminate the need for extreme concentration of the heavy minerals, although some degree of concentration would be required to explain the variations observed from quartzite and hematite-quartzite through to the iron ores.

Apart from a few beds of hematite-bearing quartzite in the Warton Sandstone there are no known source rocks in the area that could have provided suitable material.

Mechanism of Concentration and Environment of Deposition

Concentration of iron-bearing sediments to produce the ores could have occurred through sorting either during transport and/or by winnowing currents at the site of deposition. Any such concentration would depend principally on size and specific gravity of the minerals concerned, namely quartz, 2.65; tourmaline, 3.1; rutile, 4.2; zircon, 4.7; hematite, 4.9 to 5.3; and magnetite, 5.2.

Removal of quartz through differential transport or winnowing should be accompanied initially by an increase in the content of all the other minerals mentioned and subsequently, with stronger current action, by a reduction in the amount of the next lightest mineral, namely tourmaline.

As noted previously there is little general increase in the total insoluble heavy mineral content. Such increase as is present is mainly due to an increase in tourmaline at hematite contents up to about 25%. In sediments (other than the ores), which have hematite contents ranging from 0 to 73 percent, there is only a very slight decrease in the amount of tourmaline at the hematite-rich end of the scale. However, the ores with a similar hematite content to the richer specimens from the hematite-quartzite succession, are much lower in the solubly heavy mineral content; this can be accounted for entirely by a marked decrease in tourmaline content. Zircon shows no significant variations in abundance through the entire suite.

Thus in the suite of hematitic rocks generally, there is little evidence of general concentration of insoluble heavy minerals with increasing hematite content. The hematite ores are greatly impoverished in tourmaline relative to specimens of equivalent hematite content from higher iron ore beds of the Pentecost Sandstone. This implies that there has been strong concentration, probably due to winnowing, in the ores but not in the rest of the iron-rich succession. This may also account for the thick development of the hematite forming the ore beds, which is in contrast to the rapid alternation of quartzite, hematite quartzite, and hematite, in the overlying beds of the Pentecost Sandstone.

Within the ores and the overlying hematitic Pentecost Sandstone, cross-beds indicate transport from the southeast instead of from the northeast and northwest as in the rest of the Kimberley Group. The implications of this are uncertain since the Elgee Siltstone and the lower beds of the Pentecost Sandstone to the southeast of Koolan Island are not ferruginous. Also the cross-beds examined on Cockatoo Island indicate transport from the southeast, but are of different type viz. very thin (5 cm to 8 cm thick) and lensing, whereas the majority of those measured elsewhere are thicker (15 cm to 0.6 m), are more persistent laterally, and have steeper dips relative to bedding. It is thus possible that those beds indicating currents from the southeast are related to reworking and do not indicate the primary direction of transport as the others probably do. The weight of evidence from the surrounding area indicates derivation of the sediments from a general northerly direction. This is inferred for the ores as well.

Ripple marks within the sequence (e.g. in the Arbitration Cove Sandstone Member of Koolan Island) indicate that deposition took place in relatively shallow water.

Conglomerates in the ores suggest that deposition took place near a shoreline, and it is possible that the ores represent heavy mineral concentrations on a beach or on a near-shore bar. The distribution of the ores in an elongate west-northwest trending belt suggests that the inferred shoreline was also of this trend.

176

TABLE 7

COMPOSITION OF IRON ORES, BEACH SAND AND IRON FORMATION

	(1) Yampi Ore	(2) New Zealand Beach Sands	(3) Hamersley Ore	(4) Biwabik Iron Formation
Fe_2O_3	89.6	81.8	85.6	40.8
SiO_2	3.1	n.d.	3.3	46.1
TiO_2	0.3	7.94	0.06	0.04
MnO	0.01	0.67	0.3	0.66
V_2O_5	n.d.	0.46	n.d.	n.d.
P_2O_5	0.08	n.d.	0.21	0.07

1. Average Yampi Iron ore (Reid, 1965; MnO from Canavan & Edwards, 1938).
2. Average New Zealand titano-magnetite beach sand (Williams, 1965).
3. Average Hamersley Iron ore (complied from MacLeod and Halligan, 1965; Campana, et al., 1964).
4. Average composition of Biwabik Iron Formation (James, 1966).

TECTONIC HISTORY

The tectonic history of the area is summarized in Table 6. Evidence for the age relationships of the various events if not available from the Yampi Sheet area has been taken from other Sheet areas e.g. Charnley and Lennard River.

Notable features of the tectonic history of the Yampi Sheet area include evidence of minor uplifts during deposition of the Kimberley Basin succession. As a result of these minor uplifts unconformities are present at the base of the Elgee Siltstone and the Yampi Member of the Pentecost Sandstone and possibly at the base of the King Leopold Sandstone.

This is the only area in the Kimberley region where significant post-Kimberley Group metamorphism has been found. This metamorphism of 'platform-cover' rocks is unusual. The age of this metamorphism is uncertain: rocks affected by it have given ages of 1550 m.y. and 600 m.y. (Bennett & Gellatly, 1970) but these need to be further substantiated.

The strong overfolding and reverse faulting apparently belongs to a late (ca. 600 m.y.) period of deformation and can be correlated with a period of deformation of similar age and style in the Oscar Range Inlier in the Lennard River Sheet area.

The coastal 'submergence' may be partly tectonic but is probably at least partly a result of glacio-eustary. J.N. Jennings (pers.comm.) by studying the burial by tidal flat muds of longitudinal sand ridges in the Derby area has demonstrated that some of this submergence is as recent as 4000 years B.P.

ECONOMIC GEOLOGY

The only economic mineral produced in the Yampi Sheet area is iron ore, mined at Yampi Sound. Small amounts of copper and muscovite have been mined in the area, but the deposits are not now considered economic. At the time of this survey mineral exploration of the Precambrian basement rocks was being undertaken by Pickands Mather International, and oil potential of the Canning Basin was being investigated by West Australian Petroleum Pty Ltd. Other aspects of economic geology in the region include tidal power resources, ground water, and road construction material.

MINERAL DEPOSITS

Iron Ore

Iron ore, the only mineral mined within the Sheet area, is quarried on Cockatoo and Koolan Islands. Minor iron deposits are also known on adjacent islands, but none have been developed. All of the iron ore bodies are beds of detrital ironsands at the base of the Yampi Member and Pentecost Sandstone formation.

Iron ore has been quarried from Cockatoo Island since 1951 and from Koolan Island since 1965. These operations are administered by the Dampier Mining Company Limited, a wholly owned subsidiary of Broken Hill Pty Ltd. Until recent contracts with Japan were negotiated, all ore produced from Yampi Sound was shipped to BHP's steelworks at Newcastle and Port Kembla.

Table 9 lists the total ore produced from each island to December, 1966. This amounts to a production of 20 million long tons of iron ore valued at $A41 million. The assay value of this ore was approximately 64 percent Fe. Some average assay values of specific Yampi iron ores are given in Table 8.

TABLE 6

SUMMARY OF TECTONIC HISTORY - YAMPI SHEET AREA

ERA	DEPOSITION	IGNEOUS EVENTS	TECTONIC EVENTS	METAMORPHISM	REMARKS
CAINOZOIC	Coastal muds and sands; alluvium	-	Drowning of Yampi Coastline	-	Could be due to glacio-eustasy, Continued until 4000 years B.P.
	Minor detrital deposits mainly on Dampier Peninsula	-	MAJOR PERIOD OF EROSION	-	Development of laterite profile and subsequent erosion
MESOZOIC	Deposition of Mesozoic sediments	-	Gentle warping and submergence	-	In southwest only; overlap on to Precambrian
PALAEOZOIC	Deposition of Devonian to Permian sediments	-	-	-	Mainly in extreme south. Conglomerates probably aquaoglacial in part.
			MAJOR PERIOD OF EROSION		
	-	-	Overfolding and reverse faulting: folds trend northwest	-	About 600 m.y.: Correlates with date of tectonism in Oscar Range
	-	-	MAJOR PERIOD OF EROSION	-	No geological record of period from about 1700 m.y. to 600 m.y.
	-	-	Folding along dominant northwest and subordinate northeast axes; faulting mainly north and north-west	Second Metamorphism	Amphibolite and andalusite granofels in northwest; age uncertain
	-	Intrusion of Hart Dolerite and Wotjulum Porphyry	-	-	-
			Minor north and northeast faulting	-	Cause local fault control of Hart Dolerite
		Deposition of Speewah and Kimberley Groups	Extrusion of Carson Volcanics	-	Minor unconformities at base of Yampi Member, Elgee Siltstone, and possibly King Leopold Sandstone
			MAJOR PERIOD OF EROSION		
	-		Folding and faulting: faulting at least partly transcurrent	-	Foliation and lineation developed locally in granite
	-	Intrusion of basic dykes	-	-	-
	-	Intrusion of plutonic granites: Lennard, Kongorow and Cone Hill Granites, Secure Bay Adamellite etc.	-	-	-
	-	Intrusion of sub-volcanic porphyries: Mount Disaster Porphyry and Mondooma Granite	-	-	-
	-	Extrusion of Whitewater Volcanics			
			PERIOD OF EROSION	-	Cobbles of Woodward Dolerite near base of Whitewater volcanics in Lennard River Sheet area
	-	Intrusion of Nellie Tonalite and early phase of Kongorow Granite	-	-	Uncertain age
	-	-	Folding along steep south-east and southwest axes	First metamorphism: garnet and andalusite in southwest: chloritoid widespread, subsequently converted to biotite	Two phase metamorphism in Charnley and Lennard River areas
	-	Intrusion of Woodward Dolerite	-	-	-
?ARCHAEAN	Deposition of Halls Creek Group	-	-	-	Probable eugeosynclinal sediments

The iron ore deposits of Yampi Sound are described briefly below. This information is taken from Reid (1965). For further details on these iron deposits, reference can be made to the published reports by Campbell (1909), Canavan & Edwards (1938), Connolly (1959), Edwards (1953), Finucane (1939), Harms (1959), Montgomery (1920), and I.W. Reid (1958, 1965).

Cockatoo Island. The Cockatoo Island orebody lies on the southwest side of an overturned syncline (see Frontispiece). The orebody is 2,100 m long at sea level, strikes at 120° and has overturned dips 50° to 60° southwest, except in its upper part where the dip locally increases to 85°. The orebody forms a sea cliff and there are no hanging wall rocks. The orebody is conformable to the footwall rocks and extends for at least 60 m below sea level. Drilling penetrated the normal (northern) limb at a vertical depth of 510 m (about 750 m around the trough of the fold) but intersected only thin bands of hematite in hematite-quartzite.

The orebody has a high-grade zone and a low-grade zone. The former extends the full length of the body and is from 5 m to 40 m thick. It consists of steely blue, almost pure hematite (Table 8), hard in outcrop, but in places below the surface is a friable, uncemented iron sand.

TABLE 8

AVERAGE ASSAYS OF YAMPI IRON ORES

	1	2	3	4
Fe	67.0	58.0	69.0	57.0
SiO_2	1.5	4.6	0.4	6.0
Al_2O_3	1.2	5.5	0.2	6.0
TiO_2	0.2	0.5	Tr	0.4
P	0.02	0.14	0.02	0.05
S	0.002	0.05	Tr	Tr
H_2O	0.6	5.9	0.4	6.0

1. Main Orebody - Koolan Island
2. Canga - Koolan Island
3. High grade zone - Cockatoo Island
4. Low grade zone - Cockatoo Island. The average composition of different parts of this zone varies because of large lateral variation in its hematite content. (Data from Reid, 1965).

The low-grade zone lies northeast of the high-grade zone and is 1400 m long with a maximum thickness of 30 m and a maximum depth of 130 m. It comprises a large number of friable lenticular beds, between 1 cm and several metres thick, which range from hematite to rich hematite-sandstone and hematite-rich schist. The average grade of these beds decreases with increasing distance from the high-grade zone, and also with increasing depth from the surface. Along strike and down dip the beds become harder and more siliceous and pass laterally into hematite-quartzite and hematite-sandstone. In a like manner to minor orebodies on Koolan Island, the low-grade zone has been formed by leaching of silica from hematite-quartzite and hematite-schist, leaving them friable and porous and with a flatter dip near the surface, because of slumping.

The footwall rocks immediately northeast of the low-grade zone are hematite sandstone and hematite quartzite, which do not dip less than 50°. The capping of canga, now removed, was from 6 m to 20 m thick, and lay across high and low-grade zones, and partly on footwall, at about 125 m above sea level.

<u>Koolan Island</u>. The Koolan Island orebodies, which are locally conglomeratic, are folded into an overturned syncline, and a closed overturned anticline. The syncline plunges 8° to northeast and the axial planes strike northwest at 135° and dip at 40° to 45° southwest. This ore bed can be traced with few breaks from sea level on the southwest side of the Island, around the noses of the folds to sea level and to the anticline in the northern part of the island. The ore beds appear again on West Ballast Island.

There is one major and four minor orebodies. The main orebody is 2000 m long, up to 30 m thick, and the dip ranges from 45° southwest at the west end to 65° southwest at the east end. Its highest point is 180 m above sea level and it is known to extend at least below sea level. The ore is high grade (Table 9), and although hard in surface outcrop, much of it is porous and friable in depth. The footwall is hematite quartzite and schist, and the hanging wall is grey chlorite schist. Several hundred feet of non-ferruginous quartzite with minor siltstone and schist structurally overlie (stratigraphically underlie) the chlorite schist conformably. Both walls of the orebody are sharply defined, although the schist is ferruginous close to the orebody and there is some rich hematite quartzite locally on the footwall. The conglomeratic ore is mostly cavernous owing to leaching out of quartzite pebbles. In places, however, the original pebbles remain: these unleached hematite conglomerates are too siliceous to be classified as ore.

TABLE 9

Iron Ore Production - Yampi Sound (to December 1968)

PERIOD	CENTRE	HOLDING	NAME OF LEASE OR HOLDER	QUANTITY (Long tons)	ASSAY % Fe	VALUE $A
1951 - 1965	Cockatoo Is.	M.L.s 10,11,12 & 43	Aust. Iron & Steel Pty Ltd	11,143,111	63.33	24,200,653.38
1965	Koolan Is.	M.L.s 50 to 60	Aust. Iron & Steel Pty Ltd	1,059,648	64.48	
1966	Cockatoo Is.	M.L.s 10,11,12 & 43	Dampier Mining Coy Ltd	1,251,383	63.90	6,226,310.00
1966	Koolan Is.	M.L.s 50 to 60	Dampier Mining Coy Ltd	1,363,778[2]	63.61	
1967	Cockatoo Is.	M.L.s 10,11,12 & 43	Dampier Mining Coy Ltd	678,497	65.15	4,757,806.00
1967	Koolan Is.	M.L.s 50 to 60	Dampier Mining Coy Ltd	1,538,375[3]	65.69	
1968	Cockatoo Is.	M.L.s 10,11,12 & 43	Dampier Mining Coy Ltd	1,364,725	63.99	5,997,493.05
1968	Koolan Is.	M.L.s 50 to 60	Dampier Mining Coy Ltd	1,413,546[4]	65.70	
			TOTAL IRON ORE	19,954,409	63.92	41,182,262.43

Statistics from W.A. Mines Department, Perth

1. Australian Iron and Steel Pty Ltd, a subsidiary of Broken Hill Pty Ltd. Iron ore production now administered by Dampier Mining Coy Ltd, a further subsidiary formed in 1966.
   NOTE: Not included in statistics is 40.50 tons of iron ore valued at $24 produced from Koolan Is. in 1910 for flux purposes.
2. Includes exported to Japan, 141,346 tons, assay 65.79% Fe, value $A1,045,711.09
3. " " " " 64,810 " " 67.27% Fe, " $A 496,729.00
4. " " " " 91,412 " " 67.02% Fe, " $A 697,516.05

The four minor orebodies occur in the anticline on the north side of Koolan Island. Of these the Eastern and Mullet orebodies are considered small and unimportant. The Acacia and Barramundi are the best of the minor orebodies but they deteriorate rapidly in grade and thickness down dip. The Acacia orebody consists of cavernous hematite and rich hematite conglomerate. It is 1800 m long, up to 13 m thick, and dips at 35° to 40° southwest. The Barramundi orebody is of cavernous hematite, 1150 m long and up to 8 m thick. It ranges in dip from 10° to 45° southwest and thins rapidly down dip.

The hematite conglomerate consists of pebbles of quartzite, hematite quartzite, quartz, and jasper, up to 15 cm in diameter, set in a matrix of hematite or siliceous hematite. Most of the pebbles have sharp contacts with the matrix, although some are slightly replaced at the margin. Some contain thin parallel laminae of hematite. This hematite conglomerate is well developed at the west end of the main orebody, and in the minor orebodies, where the pebbles are stretched and rolled in anticlinal noses.

A deposit of canga up to 30 m thick overlies the central part of the main orebody and the adjacent footwall. A similar but much smaller deposit lies on the south side of the Acacia orebody.

An acid porphyry intrusion (Wotjulum Porphyry) cuts across the west end of the main orebody at Phil Cove. This porphyry was intruded prior to the folding of the Pentecost Beds and was subsequently regionally metamorphosed along with the Kimberley Group.

Other Islands. A thin, contorted bed of hematite occurs on an isthmus on the east side of Irvine Island. Hematite is also exposed in a broad anticlinal fold at the foot of a steep cliff, below several hundred feet of hematite quartzite. The ore is also associated with schist and extensive hematite conglomerate. Hematite, canga, and schist occur on West Ballast Island, southeast of Koolan Island. Hematite is also recorded from a small island in the northwest part of Talbot Bay (Harms, 1959).

Reserves. The ore reserves of Cockatoo Island have been estimated at 21 million tons, down to 40 feet above sea level, at an average grade of 66% iron and 5 million tons of canga at an average grade of 58% iron. The Acacia orebody on Koolan Island is estimated to contain 12 million tons of ore averaging 60% iron.

Copper

Minor copper mineralization is widespread in the Precambrian rocks of the Yampi Sheet area. Most of the deposits are associated with veins and reefs of quartz and with silicified, sericitic shear and fault zones. These occurrences are restricted mostly to a belt of Halls Creek Group that extends south and southeast from the Little Tarraji River area. Similar metamorphic rocks in the Townshend River - Mount Nellie area, north of Oobagooma, contain copper mineralization but not in economic amounts.

The only copper ore mined from the younger Precambrian has been at the head of Coppermine Creek near Yampi Sound. This deposit is associated with quartz veins impregnating a sericitized and carbonated quartz porphyry which intrudes the Kimberley Group. There are minor occurrences of disseminated chalcopyrite in the Carson Volcanics and nodular sedimentary copper in the Warton Sandstone.

Copper Production. Table 10 shows the total copper production recorded from the Yampi 1:250,000 Sheet area. This ore was mined during the period 1905 to 1920, when 109.52 tons of copper ore containing 25.92 tons of metallic copper, valued at $A3,418, was produced. Copper ore produced prior to 1914 and not reported to the Mines Department probably amounted to less than 350 tons.

TABLE 10

REPORTED COPPER PRODUCTION - YAMPI 1:250,000 SHEET AREA

CENTRE	LEASE	NAME	PERIOD	QUANTITY Tons	METALLIC Content Tons	VALUE $A
Monarch	ML227H	Holbrook	1915	4.22	0.94	128.00
Group	ML228H	Abagama	1915	8.97	1.82	272.00
Coppermine	ML221H	Yampi Sound	1914	38.50	9.21	852.00
Creek	ML221H	Copper Mine	1915	54.36	13.59	2094.00
		Sundry Persons	1916	3.47	0.36	72.00
		TOTAL		109.52	25.92	3418.00

Geological Investigations. Geological information on the various copper deposits of the area is given by Maitland (1919), Simpson (1952), Harms (1959), and Low (1963). An extensive study of the copper mineralization in the area was made by Western Mining Corporation Ltd, during their tenure of Temporary Reverse 1593H (December 1957 to October 1960). This company conducted a series of reconnaissance and detailed geological, geochemical, and geophysical surveys over the metamorphic rocks and adjacent terrain, and subsequently drilled prospects near the Little Tarraji River, at Grants Find, and at Wilsons Reward.

The various phases of this exploration programme are described in unpublished company reports by Woodall (1957), Triglavcanin (1958), Harper (1959), and D. Reid (1958, 1959).

A compilation of the previous work on the copper deposits of the Yampi area has been published by Sofoulis (1967).

Little Tarraji River Deposits. Copper mineralization was first reported from this area in 1905, the general locality then being referred to as 'east of Mount Nellie'. Abandoned groups of copper workings in this area are shown now on the accompanying geological map as Grants Find, Tarraji, and Monarch Group. Further workings north of the Monarch Group are known also as Wilsons Reward or Berylton.

The copper mineralization of the Little Tarraji River area is associated with veins and reefs of quartz which occupy faults or impregnate sericitized shear zones in steeply dipping sericite-chlorite-muscovite schists, slates, meta-arenites, and amphibolites of the Halls Creek Group. These rocks are intruded, and flanked to the east and west by granite of the Lamboo Complex.

Reid (1959) (reported in Sofoulis, 1967) has estimated reserves of 11,000 tons of $1\frac{1}{2}$ to 2 percent copper ore for the Grants Find prospect and has suggested persistence of mineralization to a depth of at least 120 m.

Townshend River - Mount Nellie Area. Several small copper showings are associated with quartzitic sericitic shear zones in the Halls Creek Group north of Oobagooma. The principal showings are referred to as Mangrove Prospect and Townshend River A, B, and C Prospects (D. Reid, 1958), (Simpson, 1952). None of the deposits are economic.

Some thin quartz veins up to 30 cm thick cutting pelitic and semi-pelitic phyllites of the Halls Creek Group near Marboo Pool on the Townshend River contain up to 10% of malachite. The patchily mineralized veins are very scattered, and none of those found are large enough to warrant further investigation.

Mondooma Copper Prospect. Some copper workings located 5 km west-northwest of Mondooma Yard were described by Harms (1959) as the Mondooma Copper Show. Simpson (1952) and Low (1963) referred to the same workings as the Robinson River Copper Mine.

The workings are in a belt of Halls Creek Group which extends south-easterly from the Little Tarraji River deposits. They are immediately north of the Robinson River, in a prominent northwest trending ridge that rises 50 m above plain level. Lennard Granite flanks the ridge to the northeast.

A prominent quartz reef, sub-parallel to the schistosity of the metasediments, can be traced for about 130 m along the crest of the ridge. Copper staining is visible over about half this length. The major mineralization and workings are near a col about midway along the crest of the ridge. Harms (1959) noted that the reef, where copper-stained, ranges from 1 m to 5 m wide, but is barren over most of this width. Primary copper mineralization is apparently confined to soft ironstained and kaolinized lenses up to 0.6 m wide, from which secondary carbonates have been derived. The vein contains crystal quartz displaying comb-structure. Most of the crystal surfaces are coated with malachite and limonite, particularly on the northwest side of the col. Here blasting of the quartz vein has exposed the southwesterly-dipping hanging wall of friable phyllitic arenites, which are unmineralized.

A shaft has been sunk to about 5 m in the middle of the col, on the northeast side of the ridge. It is apparently following the thickest development of the quartz vein, which here shows small stainings of carbonate. Some small scratchings and pits are present along the ridge to the southeast of the col, but the quartz vein appears to thin rapidly in this direction.

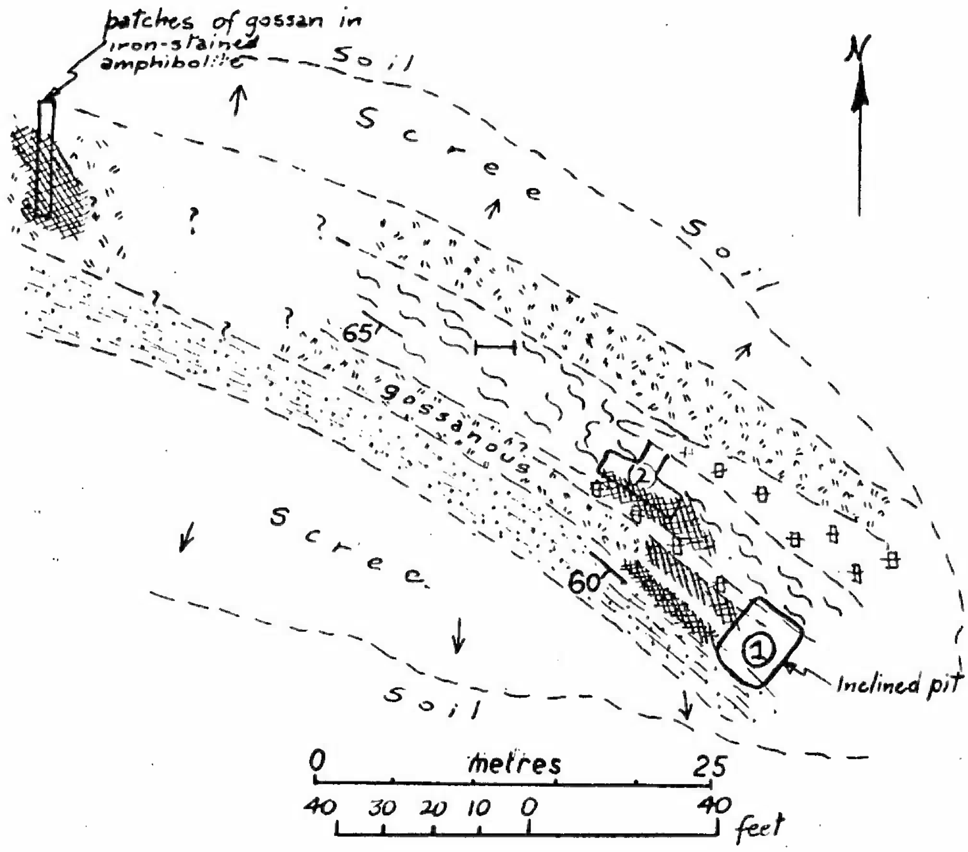
Sporadic quartz-tourmaline veins intrude the arenite sequence a few yards southwest of the ridge, but appear to be unmineralized.

Reconnaissance by Western Mining Corporation Ltd failed to reveal any significant mineralization other than that already known, although a large number of quartz veins with sporadic rich showings of iron oxides occur throughout the belt (D. Reid, 1958).

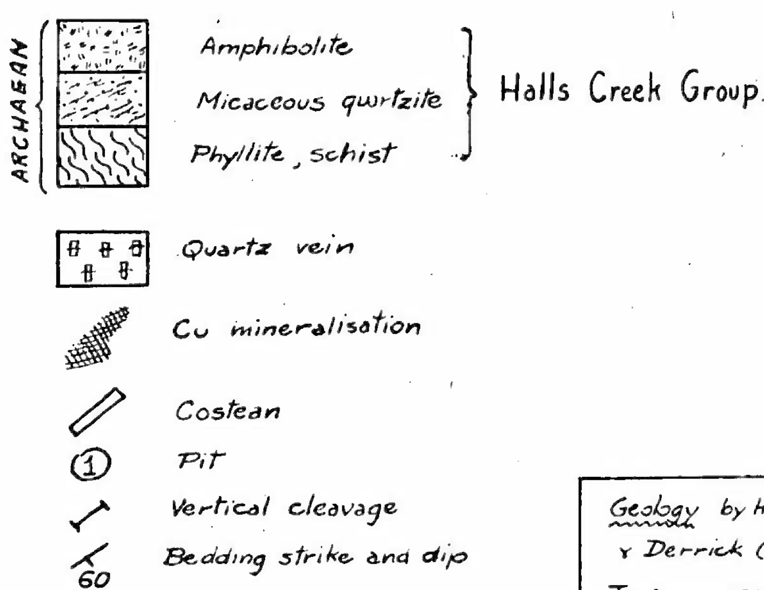
Small shafts near the old Mondooma Yard are reputed to be gold workings of early Chinese in the area, but no further information is available. Exposures are very poor, though quartz veins and quartz rubble are abundant. The country rocks are phyllites of the Halls Creek Group.

FIGURE 37

LIMESTONE SPRINGS COPPER SHOW
WEST KIMBERLEY, W.A.



Reference



E51/A3/23

Geology by Harms (B.H.P), 1953, & Derrick (B.M.R) 1966.

To accompany B.M.R. Record No.

<u>Limestone Springs Copper Prospect</u>. There are shallow workings 3 km north of Limestone Springs in a belt of low bouldery rises consisting of sericite schist, phyllite, micaceous quartzite, and amphibolite. These rocks trend northwest and dip steeply to the southwest, and are a further south-easterly extension of the Halls Creek Group from Mondooma. The sequence is intruded by a vein of massive quartz, which appears to pinch out along strike.

The southernmost amphibolite band (Fig. 37) is gossanous, with an ironstone capping. Copper mineralization is present in this ferruginous boxwork, in a thin ferruginous quartz vein, and also in the micaceous arenites adjacent to the dolerite, over a length of nearly 80 m. The copper is mainly malachite, chrysocolla, and according to Harms (1959), chalcocite, and these minerals are found as chunks or coatings occupying fractures, veins, cracks or interstices in the arenites. Minor pyrite is present. The gangue minerals are quartz and geothite. An inclined shaft or pit (pit 1, Fig. 37) about 6 m deep by 5 m by 2.5 m has been sunk at the southeastern end of this mineralized zone. A smaller pit or trench (pit 2) has been opened 9 m to the northeast of pit 1, and a small costean dug at a point 45 m along strike to the northwest. The quartz vein to the northeast appears to be unmineralized.

There is no official record of production from this area, and from the paucity of mineralization the prospect does not appear to warrant further work.

<u>Warton Sandstone Copper Occurrences</u>. The main siltstone member of the Warton Sandstone carries significant copper mineralization about 9 km north-northwest at the northwest end of a narrow arm of Slug Bay (1583E, 29355N). At the former locality the copper occurs as disseminated spots of malachite in pale grey chert with ferruginous bands, and associated siltstone, and is concentrated mainly in thin nodular hematitic beds up to 20 cm thick which are locally gossanous and have cavities lined with malachite. A chip sample over

a true thickness of 26 m contained the following metal concentrations (in ppm): Cu 1200; Pb 6; Zn 20; Co 40; Ni 15; Sn 2; Ag 0.4; Au 3; Mo 6. Most of the copper in this zone occurs in the top 2 to 3 m.

Since this mineralization occurs over 26 m of section and has been traced about 15 km away along strike, it is one of the most significant copper occurrences in the area, and appears to warrant further investigation.

Copper Mine Creek Deposit. The only copper ore mined from the younger Precambrian has been that from the Yampi Sound copper mine. This mine is on the mainland at the head of Coppermine Creek, about 16 km south of Cockatoo Island. Low (1963) referred to this deposit as Yampi Sound copper deposit, Water Point. Figure 38 is a locality map and plan of the Copper Mine Creek workings.

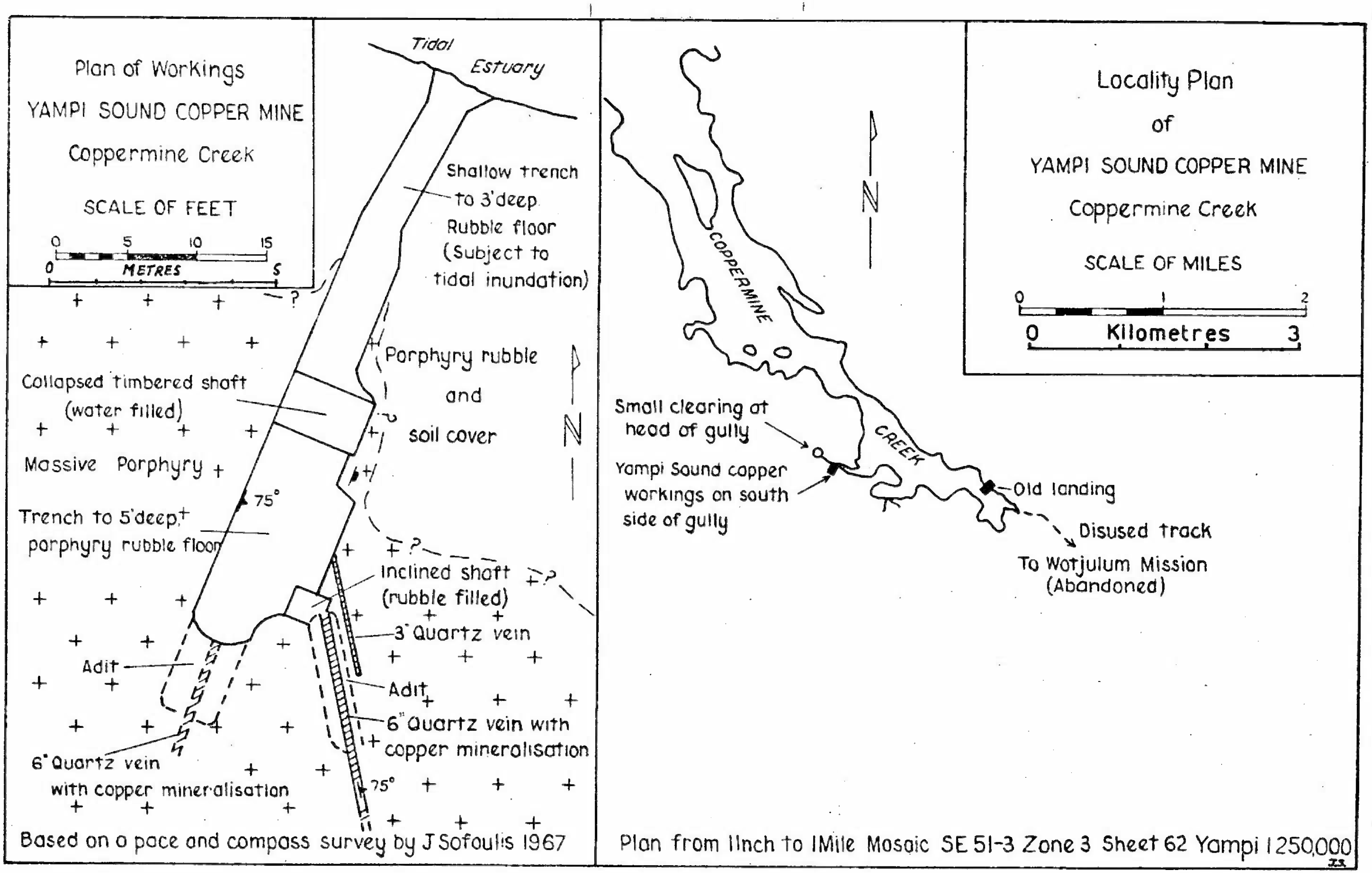
The mineralization is localized in a probable fault zone and consists of copper minerals associated with quartz veins which impregnate sheared, sericitized, and carbonated quartz porphyry. Maitland (1919) recorded that the width of the lode at this deposit ranges between 15 m and 2 m and that it underlies dips to the east. Ore mined from this deposit was described by Simpson (1952) as containing masses of chalcocite, associated with malachite, cuprite, atacamite (copper oxychloride), and brochantite (basic copper sulphate). The deposit has not been worked since 1915. Reported production for the years 1912 to 1915 was 92.86 tons of copper ore containing 22.70 tons of copper valued at $A2,946.

It is possible that the porphyry contains further mineralized zones.

Amphibolite Prospect. Sporadic copper mineralization, associated with iron oxides, is exposed along a shear zone in the younger Precambrian Hart Dolerite north of Rough Triangle prospect. The shear zone is intensely sericitized and contains patchy silicification and minor quartz veins.

The mineralized shear zone is part of a strong fault which can be traced on air-photographs for several kilometres to the north and dies out to

189



E51/A3/27

FIGURE 38

the south in the Rough Triangle area. The line of mineralization has been prospected by three Shallow pits sunk in a gossanous ore consisting of a misture of malachite, bornite, cuprite, and iron oxides. However, no copper production has been reported.

Muscovite and Beryl

Stuarts Mica-Beryl Mine. Muscovite and beryl have been produced from a composite quartz-pegmatite dyke which crops out near the Kimberley Downs-Mondooma track about 6 km south of Mondooma and 9 km north-northwest of Limestone Springs. The mine, known as Stuarts Mica Mine, was last worked in 1949 (as P.A. 58) for mica and beryl.

Production of 31.25 lb of muscovite valued at $A9.24 and 3.5 tons of beryl containing 38.85 units of BeO, valued at $A593.40, was reported to the Western Australian Mines Department. Harms (1959) reported a mica production of about 150 lb.

General Geology. The composite quartz-pegmatite dyke, containing the mica deposit, intrudes a belt of amphibolite (metadolerite), biotite-muscovite quartzite, and garnet-muscovite schist of the Halls Creek Group. Both the dyke and metamorphic rocks trend northwest and dip southwest at 45° to 75°. A large body of granite porphyry of the Lamboo Complex flanks the metamorphic rocks about 1.5 km northeast of the deposit.

This geological setting is almost identical with that of Gussys Mica Mine on the Barker River, about 20 km to the southeast in the Lennard River Sheet area.

Pegmatite and quartz cover an area of about 270 m by 20 m at the deposit locality. The pegmatite phase, which consists of quartz, microline, tourmaline, muscovite, and minor beryl, extends for 180 m southeast of the deposit. There it intrudes amphibolite and psammites, and forms boudings, lenses and veins up to 3 m thick. The muscovite in the pegmatite forms books up to 8 cm diameter.

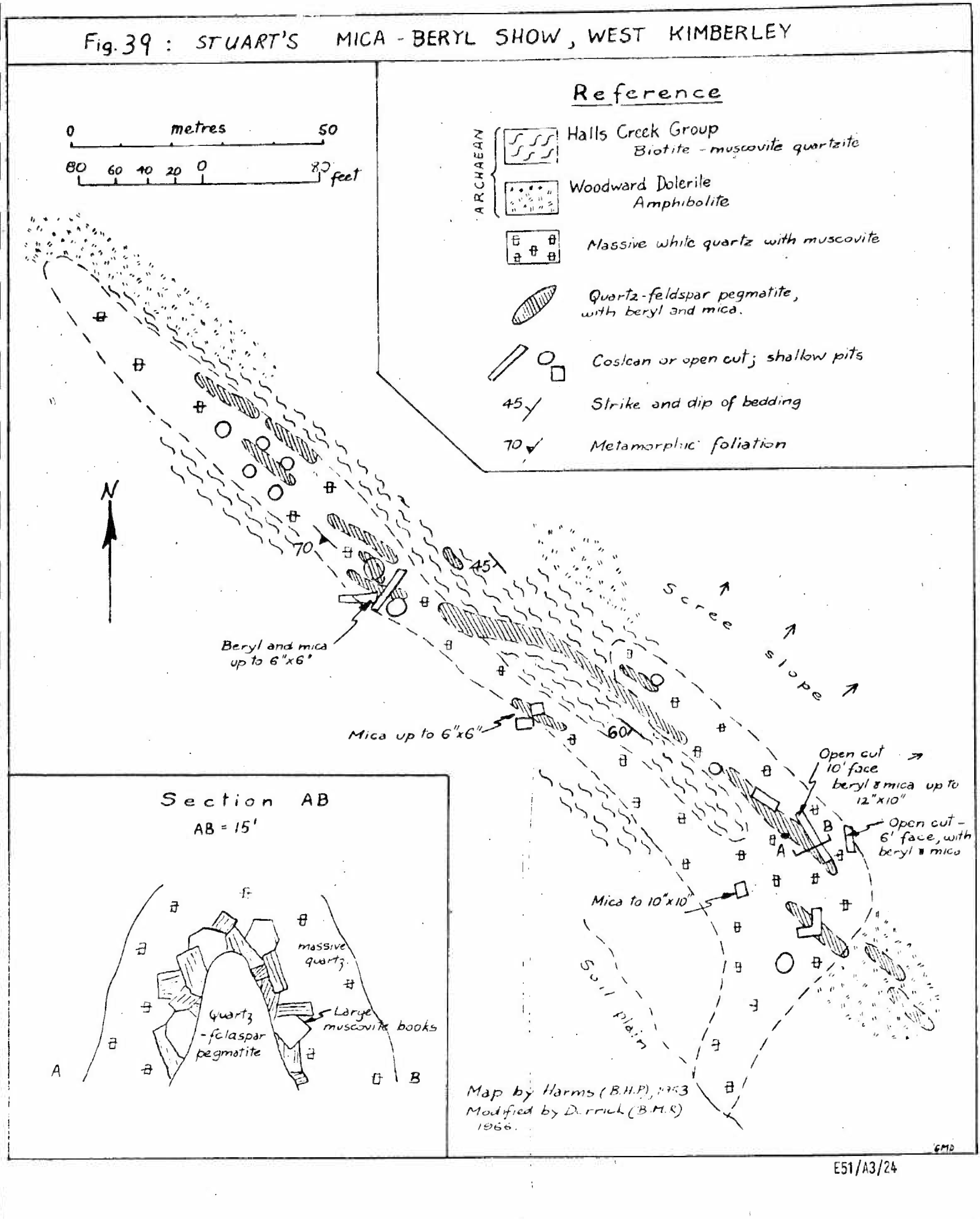
At the southeast end of the mine a dyke 9 m wide of massive white quartz cuts across the strike of the amphibolite-psammite sequence. This quartz vein intersects the pegmatite, and becomes sub-parallel with it (Fig. 39). Very coarse muscovite books appear in the composite quartz-pegmatite dyke from this point of intersection northwestwards. Some of the large books are associated solely with the massive quartz, but the largest and best books of mica are developed at the contact between pagmatite and the quartz vein (see section, Fig. 39). In some areas the wall rock adjacent to the pegmatite is a highly folded psammite intruded by thin veins of quartz and tourmaline.

The southeastern part of the deposit has been tested with pits and trenches over a length of 100 m. The largest trench measures 8 m by 3 m and exposes fresh mica books, quartz, and pegmatite. The coarse books have random orientation and in some instances are slightly deformed. The largest books seen measured 60 cm by 30 cm and books 25 cm across were common. Smaller books averaging 15 cm across are scattered around all of the excavations, but are generally weathered and slightly stained.

Little beryl was found during 1966. However, Harms (1959) recorded that beryl crystals up to 15 cm across have been recovered from the deposit, although most beryl production was derived from adjacent eluvial soils. Some of the beryl was semi-transparent and, according to Harms, could yield gem-quality stones.

The mica deposit is far from exhausted. Small-scale production of high-quality mica would be possibility from this prospect if warranted by demand and price.

FIGURE 39



E51/A3/24

PETROLEUM

One test well for petroleum (Lennard Oil, N.L. - Napier No. 4) has been drilled in the Sheet area. This was a dry hole. Other test wells for petroleum have been drilled to the south (West Australian Petroleum Pty Ltd - Fraser River No. 1) and southeast (Lennard Oil Napier Nos 1, 2, 5) of the Yampi Sheet area. No significant indications of hydrocarbons have been found in any of these wells.

The suggested overlap of Cretaceous rocks on the Precambrian has important implications in the search for petroleum, especially in the Dampier Peninsula and offshore areas to the west. The absence of upper Palaeozoic and lower Mesozoic beds means that some of the possible hydrocarbon source beds are absent, but the overlap increases the possibility of stratigraphic traps.

An aeromagnetic survey carried out over King Sound (West Australian Petroleum Pty Ltd, 1967) indicated a probable northwesterly extension of the Oscar Range structure ('The Oscar Ridge') and also a series of closely-spaced northwest-trending anomalies which probably reflect the structure of the underlying Precambrian.

ENGINEERING GEOLOGY

Tidal Power Resources

A large tidal range coupled with suitable physiographic conditions has led to the investigation of some bays and inlets of this area as possible sites for the generation of electricity by tidal power.

Gibb Maitland (1921) earlier commented upon the possibility of harnessing the energy of some rivers and of utilizing tidal flow as a means of providing the cheap power requirements needed to develop the iron ore deposits at Yampi Sound. These requirements were subsequently met by conventional methods.

In recent years the technical aspects of a Kimberley tidal power scheme were examined by the Public Works Department. These investigations were directed by Lewis (1962), who assessed the various sites along the Kimberley coast and suggested that such a scheme was feasible although not economic at the present time.

His investigations were prompted by the potential of a big power demand caused by mineral discoveries in the Pilbara, Kimberley, and Northern

Territory. It was also foreseen that such a scheme could eventually supply peak load requirements to industrial centres in other parts of Australia.

A possible tidal power site is shown in Figures 45 and 46. Of the various sites examined, the most promising in terms of power outlet per mile of dam was Walcott Inlet (Lewis, 1962). This site has an area of 250 square km and a maximum mean effective tide of 11 m. The adjacent site at Secure Bay with an area of 63 square km and a similar mean effective tide was also considered as a further possibility.

Geological aspects of these two sites are contained in a preliminary report by Gordon (1964), who concluded that most of the problems associated with the development of such a tidal power scheme appear to be engineering questions involving the constraint of tidal forces, rather than geological difficulties.

A major practical problem to overcome would be the economic conveyance of electricity from such a remote area.

HARBOUR FACILITIES

Deep-water port facilities catering for the iron ore industry of Yampi Sound are established at Cockatoo and Koolan Islands. With a mean effective tide of about 10 m and a variation up to 2.5 m between empty and loaded position of ore ships, loading facilities have been designed to cope with a maximum variation of about 14 m. This is effected by means of a hinged shuttle boom which can be extended over the ship's hatches and elevated $14\frac{1}{2}^{\circ}$ or depressed 5° to cope with the variation. Jetties consist of steel dolphins interconnected with walk-ways. They are treated electrochemically to prevent rust and corrosion, which in these parts would present a constant problem because of tidal variation giving alternate exposure of piles to salt water and air.

Derby and Broome, the only ports serving the mainland of this West Kimberley region, are south of the Sheet area. Many natural harbours which are found along the coast could provide good anchorage. However, these natural sites are situated in isolated areas and are backed by steep cliffs and inaccessible terrain.

The harbour potential of the coastline has been commented upon by Easton (1921). More recently, the possibility of establishing a further deep water port to serve the West Kimberley region was examined for the State Government by G. Maunsell and Partners (1960). Collier Bay, lying in the

Fig. 40a Coastal breaches southeast Talbot Bay (1630 E, 29370 N). Possible tidal power sites. Same sites shown in Figure below. (GSWA neg.) JS

Fig. 40b Coastal breaches southeast Talbot Bay. Ridges of Pentecost Sandstone (to right) and overturned Warton Sandstone (to left). Flooded areas of Elgee Siltstone and upper Warton Sandstone (between ridges) and Carson Volcanics (extreme left). (GSWA neg.) JS

northeastern part of the Sheet area, was regarded tentatively as a possibility, in particular Secure Bay which had the advantage of deep-water as well as weather protection. Detailed bathymetric data for this Bay were subsequently recorded by the Public Works Department during their investigations for a tidal power scheme in this area.

Bathymetric data as shown on the map Sheet are taken from Admiralty Charts prepared by the Hydrographic Service of the Royal Australian Navy. Tidal charts for the mainland ports and Yampi Sound are available from the Harbour and Lights Department, Fremantle.

WATER SUPPLIES

Mean annual rainfall in the Yampi Peninsula increases from 75 cm in the south to 100 cm to 112 cm in the north. Consequently, surface water is abundant and is adequate for the present limited pastoral development. Few bores exist and little is directly known of groundwater potential.

Surface water is common in the area of Kimberley Group rocks, and occurs in waterholes, rock pools, and spring-fed streams. Springs emanate mainly from fractured sandstone, and from junctions of sandstones with dolerite. In their lower reaches, the major watercourses contain large pools which are rock-bound or are maintained by underflow from river channel alluvium. Steep-sided sandstone plateaux and islands with limited catchments have streams which dry rapidly after the 'wet'. It is thus difficult to obtain fresh water in such places, especially upon the islands of the Buccaneer Archipelago.

Salinites of all waters are between 100 and 300 ppm. The area of metamorphic and igneous rocks has little surface water, although major rivers (e.g. Robinson River) contain semi-permanent pools. The metasediments and granite outcrops are locally mantled with eluvial debris. The junction of sheet joints in granite with this eluvial material is often the site of a low salinity soakage.

The southern part of the Sheet and the Dampier Peninsula is an undulating sand plain with little permanent surface water. Springs occur in low topographic situations, possibly drawing water from Palaeozoic Mesozoic sediments.

Three bores are recorded. Oobagooma Station bore is shallow and obtains water from alluvium, Hamilton Bore cuts sub-artesian Permian aquifers, and a bore some 6 km west of it, also in Permian strata, artesian shallow wells in Cretaceous sandstones supply the Mission stations on the Dampier Peninsula.

Possible subsurface Permian sandstones to the south of the Robinson River may yield usable water.

Groundwater potential in the Proterozoic rocks is untested. It is expected that fractured Proterozoic sandstones could yield large supplies. Siltstone beds in Carson Volcanics and dolerite-sandstone junctions are considered worthy of testing.

Successful bore siting in the metamorphic-igneous rocks is difficult. Bores should cut thick alluvial sections, or eluvium mantling low-level sheet joints in granite and weathered metamorphic sandstones.

REFERENCES

ALLEN, J.R.L., 1963 - The classification of cross-stratified units with notes on their origin. Sedimentology, 2 (2), 93-114.

ANDEL, Tj.H. van, and VEEVERS, J.J., 1967 - Morphology and sediments of the Timor Sea. Bur. Miner. Resour. Aust. Bull. 83.

BAKER, G., 1954 - Specimens from the Graveyard Porphyry, Yampi Sound. Sci. Ind. Res. Org., Melb., Mineragr. Inv. Rep. 566.

BASEDOW, H., 1918 - Expedition of exploration in North-Western Australia. Trans. geogr. Soc. Aust. S. Aust. Br., 18, 185-295.

BENNETT, R., and GELLATLY, D.C., 1970 - Rb-Sr age determinations of some rocks from the West Kimberley region, Western Australia. Bur. Miner. Resour. Aust., Rec. 1970/20 (unpubl.).

BOFINGER, V.M., 1967 - Geochronology in the East Kimberley region, Western Australia. Aust. Ass. Adv. Sci., 39th Cong., Abst., 1, 110-1.

BOFINGER, V.M., in prep. - Geochronology of the East Kimberley area, Western Australia. Bur. Miner. Resour. Aust. Bull.

BOUTAKOGG, H., 1963 - Geology of the off-shore areas of northwestern Australia APEA J., 10-19.

BRANCH, C.D., 1966 - Volcanic cauldrons, ring complexes and associated granite of the Georgetown Inlier, Queensland. Bur. Miner. Resour. Aust., Bull. 76.

BRUNNSCHWEILER, R.O., 1951 - Notes on the geology of Dampier Land, North-Western Australia. Aust. J. Sci., 14(1), 6-8.

BRUNNSCHWEILER, R.O.,1954 - Mesozoic stratigraphy and history of the Canning Desert and Fitzroy Valley, Western Australia. J. geol. Soc. Aust., 1, 35-54.

BRUNNSCHWEILER, R.O.,1957 - The geology of Dampier Peninsula, Western Australia. Bur. Miner. Resour. Aust. Rep. 13.

CAMPANA, B. HUGHES, F.E., BURNS, W.G., WHITCHER, I.G., and MUCENIEKAS, E., 1964 - Discovery of the Hamersley iron deposits. Proc. Aust. Inst. Min. Metall. 210, 1-30.

CAMPBELL, W.D., 1909 - Yampi Sound iron ore deposits. Geol. Surv. W. Aust., Ann. Rep. 1908.

CANAVAN, F., 1953 - The iron ore deposits of Yampi Sound, W.A. in Geology of Australian ore deposits (ed. A.B. Edwards): 5th Emp. Min. metall. Cong., 1, 276-83.

CANAVAN, F., and EDWARDS, A.B., 1938 - The iron ores of Yampi Sound, Western Australia. Proc. Aust. Inst. Min. Metall. 110, 59-101; 111, 164

CONNOLLY, R.R., 1959 - Iron ores in Western Australia. Geol. Surv. W. Aust., Miner. Resour. Bull. 7.

DERRICK, G.M., 1966 - The geology of the Ashton 1:250,000 Sheet SD/52-13, Western Australia. Bur. Miner. Resour. Aust. Rec. 1966/81 (unpubl.).

DERRICK, G.M., and PLAYFORD, P.E., in press - Lennard River, Western Australia - 1:250,000 Geological Series. Bur. Miner. Resour. Aust. explan. Notes.

DOW, D.B. and GEMUTS, I.V., 1969 - Geology of the Kimberley region: The East Kimberley. Bur. Miner. Resour. Aust. Bull. 106.

DOW, D.B., GEMUTS, I.V., PLUMB, K.A., and DUNNET, D., 1964 - The geology of the Ord River Region, Western Australia. Bur. Miner. Resour. Aust. Rec. 1964/104 (unpubl.).

DUNN, P.R., PLUMB, K.A., and ROBERTS, H.G., 1955 - A proposal for time-stratigraphic subdivisions of the Australian Precambrian. J. geol. Soc. Aust., 13, 593-600.

EASTON, W.R., 1922 - Report on the North Kimberley district of Western Australia. W. Aust. Dep. North-West, Publ. 3.

EDWARDS, A.B., 1953 - Wave-cut platforms at Yampi Sound in the Buccaneer Archipelago, W.A. Roy. Soc. W. Aust. 41(1).

FARBRIDGE, R.A., 1967 - The hydrogeology of the Yampi and Lennard River 1:250,000 geological sheets. Geol. Surv. W. Aust. Rec. 1967/5.

FINUCANE, K.J., 1939 - The iron deposits of Yampi Sound, Western Australia: Aer. Surv. N. Aust., W. Aust. Rep. 50.

FITTON, W.H., 1825 - IN KING, 1827 - An account of some geological specimens collected by Captain P.P. King on his survey of the coasts of Australia. London, John Murray.

FITZGERALD, W.V., 1907 - Reports on portions of the Kimberleys (1905-6). Perth, W. Aust. Gov. Printer.

FLEUTY, M.J., 1964 - The description of folds. Proc. Geol. Ass., 75, 461-92.

GELLATLY, D.C., 1969 - Palaeocurrents and lithofacies of the Kimberley Basin and their relationships to genesis of the Yampi iron ores. Aust. Ass. Adv. Sci. 41st Sess. Abstr. C, 2-3.

GELLATLY, D.C., 1970 - Cross-bedded tidal megaripples from King Sound, northwestern Australia. Sediment. Geol., 4, 185-91.

GELLATLY, D.C., in press (a) - Possible Archaean rocks of the Kimberley region, Western Australia. Geol. Soc. Aust. spec. Publ. 3.

200

GELLATLY, D.C., in press (b) - Problems of provenance of the Yampi iron ores, West Kimberley region, Western Australia. Bur. Miner. Resour. Aust. Bull. 125.

GELLATLY, D.C., DERRICK, G.M., and PLUMB, K., 1965 - The geology of the Landsdowne 1:250,000 Sheet SE/52-5, Western Australia. Bur. Miner. Resour. Aust. Rec. 1965/210 (unpubl.).

GELLATLY, D.C., DERRICK, G.M., and PLUMB, K.A., 197 - Proterozoic palaeocurrent directions from the Kimberley region, northwestern Australia. Geol. Mag.

GELLATLY, D.C., DERRICK, G.M., HALLIGAN, J., and SOFOULIS, J., 1969 - The geology of the Charnley 1:250,000 Sheet area SE/51-4 Western Australia. Bur. Miner. Resour. Aust., Rec. 1969/133 (unpubl.).

GELLATLY, D.C., and HALLIGAN, R., in press - Charnley 1:250,000 Geological Series. Bur. Miner. Resour. Aust., explan. Notes SE/51-4.

GELLATLY, D.C., and SOFOULIS, J., 1966 - Geology of the Drysdale-Londonderry 1:250,000 Sheet areas, SD/52-5-9, Western Australia. Australia Bur. Miner. Resour. Rec. 1966/55 (unpubl.).

GELLATLY, D.C., and SOFOULIS, J., in prep - Yampi, 1:250,000 Geological Series. Bur. Miner. Resour. Aust. explan. Notes SE/51-3.

GELLATLY, D.C., SOFOULIS, J., and DERRICK, G.M., in prep - Precambrian geology of the Kimberley region: the West Kimberley. Bur. Miner. Resour. Aust. Bull.

GELLATLY, D.C., SOFOULIS, J., DERRICK, G.M., and MORGAN, C.M., 1968 - The Precambrian geology of the Lennard River 1:250,000 Sheet SE/51-8, Western Australia. Bur. Miner. Resour. Aust., Rec. 1968/126 (unpubl.).

GEMUTS, I.V., 1965 - Metamorphism and igneous activity in the Lamboo Complex, East Kimberley area, Western Australia. Bur. Miner. Resour. Aust., Rec. 1965/242 (unpubl.).

GEMUTS, I.V., 1971 - Metamorphic and igneous rocks of the Lamboo Complex, East Kimberley region, Western Australia. Bur. Miner. Resour. Aust., Bull. 107.

GORDON, F.R., 1964 - Secure Bay-Walcott Inlet tidal power scheme. Geol. Surv. W. Aust. Rec. 1964/6 (unpubl.).

GUPPY, D.J., LINDNER, A.W., RATTIGAN, J.H., and CASEY, J.N., 1958 - The geology of the Fitzroy Basin, Western Australia. Bur. Miner. Resour. Aust. Bull. 36.

201

HALLSWORTH, E.G., ROBERTSON, G.K., and GIBBONS, F.R., 1955 - Studies in pedogenesis in New South Wales, pt. VII, the "gilgai" soils. J. Soil Sci., 6, 1-31.

HARMS, J.E., 1953 - Summary Report: West Kimberley area. Broken Hill Proprietary Co. Ltd (unpubl.).

HARMS, J.E., 1959 - The geology of the Kimberley Division, Western Australia, and of an adjacent area of the Northern Territory. Adelaide Univ. M.Sc. Thesis, (unpubl.).

HARMS, J.E., 1965 - Geology of the Kimberley Division, Western Australia, in Geology of Australian Ore Deposits (ed. J. McAndrew): 8th Comm. Min. metall. Cong. 1, 66-70.

HANN, F., 1901 - Exploration in Western Australia. Proc. Roy. Soc. Qld. 16, 9-34.

HARPER, B., 1959 - Geophysical survey of Little Tarraji River area, West Kimberley region, Western Australia. Western Mining Corporation Ltd Rep. K1191 (unpubl.).

HAWKESTONE OIL CO. LIMITED, 1963 - Report on gravity meter survey PE 142H Western Australia for Hawkestone Oil Co., Ltd., by Geophysical Associates Pty Ltd. Bur. Miner. Resour. Aust. Petrol Search Subsidy Act Rep. 62/1934. (unpubl.).

INGRAM, B., 1966 - Geol. Surv. W. Aust. Palaeont. Rep. 40/1966 (unpubl.).

JAMES, H.L., 1966 - Data of geochemistry (6th Edn). Chapter W, Chemistry of the iron-rich sedimentary rocks. U.S. geol. Surv. Prof. Paper 440-W.

JUTSON, J.T., 1950 - The physiography of Western Australia (3rd Edn). Geol. Surv. W. Aust., Bull. 95.

KING, P.P., 1827 - Narrative of a survey of the intertropical and western coasts of Australia performed between the years 1818 and 1822, London, Murray, 2 vols.

LENNARD OIL, N.L., 1969 - Digital seismic reflection survey, Alexander project for Lennard Oil No Liability by Geophysical Service International. Bur. Miner. Resour. Aust. Petrol Search Subsidy Act Rep. 69/3057 (unpubl.).

LEWIS, G.J., 1962 - The tidal power resources of the Kimberleys. (Private publication - limited distribution).

LOW, G.H., 1963 - Copper deposits of Western Australia. Geol. Surv. W. Aust., Miner. Resour. Bull. 8.

McKEE, E.D., REYNOLDS, M.A., and BAKER, C.H., Jr, 1962 - Experiments in intraformational recumbent folds in cross-bedded sand. U.S. geol. Surv. prof. Paper 450D, 115-60.

McKEE, E.D., and WEIR, G.W., 1953 - Terminology for stratification and cross-stratification in sedimentary rocks. Bull. geol. Soc. Amer. 64, 381-90.

MacLEOD, W.N., and HALLIGAN, R., 1965 - Iron ore deposits of the Hamersley Iron Province, in Geology of Australian Ore Deposits (Ed. J. McAndrew). 8th Comm. Min. metall. Cong. 1, 118-25.

McWHAE, J.R.H., PLAYFORD, P.E., LINDNER, A.W., GLENISTER, B.F., and BALME, B.E., 1958 - The stratigraphy of Western Australia. J. geol. Soc. Aust., 4(2).

MAITLAND, A.G., 1919 - The copper deposits of Western Australia. In The Mining Handbook of Western Australia, Pt. 3, Sect. 2 W. Aust. Mines Dep.

MAITLAND, A.G., 1921 - Development of water power for the generation of electricity, Kimberley Division, West. Australia. W. Aust. Dep. Min. Ann. Rep. 1920, 73-4.

MATHESON, R.S., and GUPPY, D.J., 1949 - Geological reconnaissance in the Mt. Ramsay area, Western Australia. Bur. Miner. Resour. Aust. Rec. 1949/48 (unpubl.).

MAUNSELL and PARTNERS, 1960 - Report on deep water port to serve the West Kimberley region. Report to Premier of W.A. (unpubl.).

MONTGOMERY, A., 1920 - Report on the iron ore deposits of Yampi Sound. Dep. Min. W. Aust., Ann. Rep. 1919.

PEERS, R., 1966 - Geol. Surv. W. Aust., petrol Rep. 111 (unpubl.).

PEERS, R., 1967 - Geol. Surv. W. Aust., petrol Rep. 135 (unpubl.).

PERRY, W.J., and RICHARD, R., 1965 - Report on photo-interpretation of the Yampi, Charnley, Prince Regent, Camden Sound, Montague Sound, Ashton, Londonderry-Drysdale and Mount Elizabeth 1:250,000 Sheet areas, Kimberley Division, Western Australia. Bur. Miner. Resour. Aust. Rec. 1965/87 (unpubl.).

PLAYFORD, P.E., and JOHNSTONE, M.H., 1959 - Oil exploration in Australia. Bull. Amer. Ass. Petrol. Geol. 43, 397-433.

PLAYFORD, P.E., and LOWRY, D.C., 1966 - Devonian reef complexes of the Canning Basin, Western Australia. Geol. Surv. W. Aust. Bull. 118.

PLUMB, K.A., (in prep.) - Precambrian geology of the Kimberley region. The Kimberley Basin. Bur. Miner. Resour. Aust. Bull.

POLDERVAART, A., and HESS, H.H., 1951 - Pyroxenes in the crystallisation of basaltic magma. J. Geol., 59 (5), 472-90.

PORATH, H., (in press) - The magnetic anisotropy of the Yampi Sound hematite ores. Pure Applied Geophys.

RAMSAY, J.G., 1961 - The effects of folding upon the orientation of sedimentation structures. J. Geol., 69, 84.

REID, D., 1958 - Tarraji copper prospect, 1958 field season, geological and geochemical work. Western Mining Corporation Limited Rep. K1150 (unpubl.).

REID, D., 1959 - Tarraji copper prospect, 1959 field season, geological and geochemical work. Western Mining Corporation Limited Rep. K1192 (unpubl.).

REID, I.W., 1958 - The geology of Cockatoo Island, Yampi Sound, Western Australia, in Stillwell Anniv. Vol., Aust. Inst. Min. metall. 213-39.

REID, I.W., 1965(a) - Iron ore in Yampi Sound, in Geology of Australian Ore Deposits (ed. J. McAndrew). 8th Comm. Min. metall. Cong., 126-31.

REID, I.W., 1965(b) - Exploration of the iron ore deposits of Yampi Sound W.A., in Exploration and Mining Geology (ed. L.J. Lawrence) 8th Comm. Min. metall. Cong. 2, 317-20.

REID, I.W., 1965(c) - Geology in the quarrying of a steeply dipping tabular iron ore deposit, in Exploration and Mining Geology (ed. L.J. Lawrence) Ibid., 2, 276-9.

ROBERTS, H.G., HALLIGAN, R., and GEMUTS, I., 1965 - Geology of the Mount Ramsay 1:250,000 Sheet area E/52-9, Western Australia. Bur. Miner. Resour. Aust. Rec. 1965/156 (unpubl.).

ROSS, C.S., and SMITH, R.C., 1961 - Ash flows: their origin, geologic relations and identification. U.S. geol. Surv. Prof. Pap.

SHARP, A., 1963 - The discovery of Australia. Oxford. Clarendon Press.

SIMPSON, E.S., 1948 - Minerals of Western Australia. Vol. 1 Perth (Govt Printer).

SIMPSON, E.S., 1952 - Minerals of Western Australia, 3 Vols. Perth, Govt Printer.

SIMPSON, E.S., 1915 - On chloritoid and its congeners, with special reference to the chloritoid of Yampi Sound, West. Australia. Geol. Surv. W. Aust. Bull. 64, 64-8.

SMITH, HAMPTON, 1951 - Oil possibilities Dampierland, Western Australia, Western Australia Ampol. unpubl. Rep.

SOFOULIS, J., 1967 - The copper deposits of the Little Tarraji River and other areas of the Yampi 1:250,000 Sheet area, West Kimberley, Geol. Surv. W. Aust. Ann. Rep. 1966, 65-9.

204

SOFOULIS, J., 1967 - Mica deposits of the West Kimberley area, Western Australia. Geol. Surv. W. Aust., Ann. Rep. 1966, 70.

SPECK, N.H., and LAZARIDES, M., 1964 in Speck et al., 1964 - General report on lands of the West Kimberley area, W.A. Sci, ind. Res. Org. Melb., Land Res. Ser. 9.

STILLWELL, F., 1945 - Quartzite from Yampi Sound. Sci. ind. Res. Org. Aust., mineragr. Inv. Rep. 326.

STOKES, J.L., 1846 - DISCOVERIES IN AUSTRALIA; with an account of the coasts and rivers explored and surveyed during the voyage of H.M.S. Beagle in the years 1837 to 1843, by Command of the Lords Commissioners of the Admiralty. London, T. & W. Boone.

TEMPLE, A.K., 1966 - Alteration of ilmenite. Econ. Geol., 61, 695-714.

TRAVES, D.M., 1955 - The geology of the Ord-Victoria Region, Northern Australia. Bur. Miner. Resour. Aust., Bull. 27.

TRIGLAVCANIN, A., 1958 - Geophysical survey of Little Tarraji River area, West Kimberley region, Western Australia. Western Mining Corporation Limited Rep. K1148 (unpubl.).

VEEVERS, J.J., 1958 - Lennard River - 4-mile Geological Series. Bur. Miner. Resour. Aust. explan. Notes.

VEEVERS, J.J., 1967 - The Phanerozoic geological history of northwest Australia. J. geol. Soc. Aust. 14(2), 253-72.

VEEVERS, J.J., and Van ANDEL, T.H., 1967 - Morphology and basement of the Sahul Shelf. Marine Geol., 5(4), 293-8.

WEST AUSTRALIAN PETROLEUM PTY. LTD., 1965 - Canning Basin digital reflection seismic survey, Permit to Explore 30H, West Lennard Seismic project: Project 153 for West Australian Petroleum Pty. Ltd by Geophysical Services International. Bur. Miner. Resour. Aust. Petrol. Search Subsidy Act Rep. 65/11016 (unpubl.).

WEST AUSTRALIAN PETROLEUM PTY LTD., 1965 - Dampierland Gravity Survey for West Australian Petroleum Pty Ltd by Wongela Geophysical Pty Ltd., Bur. Miner. Resour. Aust. Search Subsidy Act Rep. 65/4816 (unpubl.).

WEST AUSTRALIAN PETROLEUM PTY LTD., 1966 - Dampier Land Seismograph Survey, Canning Basin Western Australia, for West Australian Petroleum Pty Ltd by United Geophysical Corporation. Bur. Miner. Resour. Aust. Search Subsidy Act, Rept 66/11099 (unpubl.).

WEST AUSTRALIAN PETROLEUM PTY LTD., 1967 - An airborne magnetometer survey offshore northern Canning Basin, being part of a W.A. Permit to explore 30H on behalf of West Australian Petroleum. Bur. Miner. Resour. Aust. Petrol Search Subsidy Act Rep. 66/4623. (unpubl.).

WEST AUSTRALIAN PETROLEUM PTY LTD., - in prep - Pender seismic survey. Bur. Miner. Resour. Aust. Petrol Search Subsidy Act Rept.

WEST AUSTRALIAN PETROLEUM PTY LTD, 1970 - King Sound Marine Seismic Project 260 for West Australian Petroleum Pty Ltd by Digicon Inc. Bur. Miner. Resour. Aust. Petrol Search Subsidy Act Rept. 70/218, (unpubl.).

WILLIAMS, F.B., and McKELLAR, M.G., 1958 - The uppermost Devonian and Lowermost Carboniferous sediments of the Canning Basin, Kimberley district. Aust. Petrol. Pty Ltd unpubl. Rep.

WILLIAMS, G.J., 1965 - Economic geology of New Zealand. 8th Comm. Min. metall. Cong. 4, 136.

WILLIAMS, I., and SOFOULIS, J., 1967 - The geology of the Prince Regent and Camden Sound 1:250,000 Sheet areas SD/51-16, 15. Bur. Miner. Resour. Aust. Rec. 1967/38 (unpubl.).

WOODWARD, H.P. 1907 - Mount Nellie copper, Mondooma Copper, Barker River lead deposits. Geol. Surv. W. Aust. Ann. Rep. 1906, 11.

WOODALL, R., 1957a - Little Tarraji River copper prospect. Western Mining Corporation Limited Rep. K1100 (unpubl.).

WOODALL, R., 1957b - The copper prospects of the Little Tarraji area West Kimberley region, Western Australia. Western Mining Corporation Limited Rep. K1112 (unpubl.).

WRIGHT, R.L. 1964 - In Speck et al., 1964 - General report on lands of the West Kimberley area, W.A. Sci. Ind. Res. Org. Melb., land Res. Ser.9.

APPENDIX I - MEASURED SECTIONS

TABLE I

LIST OF MEASURED AND ESTIMATED THICKNESSES OF STRATIGRAPHIC UNITS

Stratigraphic Unit		Thickness in metres (feet)	(Paced - P) (Taped - T) (Estimated - E)	Locality
Speewah Group	S1	135(449)	P	5km east of Mount Nellie (SI a 1763E, 29162N, SI b 1758E, 29194N)
" "	S2	360(1200)	E	Cone Hill (1300E, 9220N)
King Leopold Sandstone	L1	1050(3479)	P	5km north-northwest of Mount Nellie (1748, 9205)
" "	L2	1040(3444)	E	4km north-northeast of Cone Hill (1280E, 9190N)
Carson Volcanics	C1	1140(3796)	T	13km north-northeast of Mount Nellie (1798E, 9259N)
" "	C2	1080(3612)	E	8km north-northeast Mount Nellie (1752E, 9218N)
Warton Sandstone	W1	510(1685)	P	3km southwest of Mount Dawson (1375E, 8982N)
" "	W2	495(1630)	E	8km east-northeast of Compass Hill (1308E, 9026N)
" "	W3	340(1129)	T	6km south-southwest of the head of Coppermine Creek (1214E, 9457N)
" "	W4*	205(700)	E	Koolan Island (1345E, 9630N)
" "	W5*	160(533)	P	10km north of Mt Nellie (1700E, 9246N)
" "	W7	240(794)	T	6km east-southeast of Slug Island (1670E, 9360N)

Warton Sandstone	W8*	520(1723)	T	5km southwest of Shoal Island (1895E, 9270N)
Elgee Siltstone	E1*	490(1610)	P	6km west of Oobagooma (1577E, 8885N)
" "	E2	260(850)	P	3km northwest of Mount Dawson (1368E, 8976N)
" "	E3	200(635)	P	3km west-northwest of Mount Olivia (1185E, 9048N to 1203E, 9047N)
" "	E4	150(481)	P	Mouth of Kyulgam River (1318E, 9250N)
" "	E5	125(425)	P	Mouth of Lydarrba River (1365E, 9340N)
" "	E6	110(384)	T	10km southeast of Wotjulum Mission (1338E, 9415N)
" "	E7	80(268)	T	5km south-southwest of the head of Coppermine Creek (1214E, 9459N)
" "	E8	140(469)	P	2½km southeast of Nares Point (1350E, 9357N)
" "	E9*	33(113)	T	Koolan Island (1365E, 9618N)
" "	E10	150(500)	E	Koolan Island (1382E, 9627N)
" "	E11	85(279)	P	9km east of Wotjulum Mission (1340E, 9470N)
" "	E12	95(315)	P	13km south-east of Koolan Island (1458E, 9487N)
" "	E13	180(601)	T	8km east of Slug Island (1670E, 9368N)
" "	E14*	155(518)	P	11km north of Mount Nellie (1705E, 9254N)
" "	E15	170(572)	T	4km southwest of Shoal Bay (1898E, 9273N)

Pentecost Sandstone	P1*	810(2657)	P	3km west of Mount Dawson (1352E, 8957N)
"	P2*	1280(4264)	P	8km east-northeast of Compass Hill (1312E, 9005N)
"	P3*	1355(4516)	P	10km southeast of Wotjulum Mission (1335E, 9493N)
"	P4*	360(1200)	E	4km south of Koolan Island Wharf (1353E, 9600N)
"	P5*	425(1466)	P	Irvine Island (1119E, 9693N)
"	P6*	410(1375)	T	Cockatoo Island (Composite Section-Reid, 1958)
"	P7*	875(2923)	P	Koolan Island, north side (1385E, 9635N)
"	P8*	1155(3853)	P	South of Shoal Bay (a - 1897E, 9284N) (b - 1958E, 9287N)
"	P9*	980(3210)	E	Southeast of Eagle Point (a - 2181E, 9543N) (b - 2168E, 9565N)
Lillybooroora Conglomerate	PZI*	7(24)	T	5km south of Townshend Yard (1662E, 29003N).
Cainozoic (Black Soil)	CZI*	1.5(5)	T	2km southwest of Mount Nellie (1702E, 9126N)
Alluvium	Q1*	6(20)	T	¼km upstream from confluence of Townshend and Robinson Rivers (1658E, 8893N)
"	Q2*	5.5(18)	T	1km upstream from confluence of Townshend and Robinson Rivers (1645E 8895N)

* Full sequence not preserved.

APPENDIX I (cont)

MEASURED SECTIONS

SPEEWAH GROUP - SI

Measured section (distances paced) 5km east and north-east of Mt. Nellie, (SIa-1763E, 29162N), (SIb 1738E, 29194N). Measured by D. Gellatly.

Overlain by Hart Dolerite (ca 1200 feet)

Thickness (feet)	Speewah Group
272	Sandstone; pale grey to grey-brown coarse-grained, thick-bedded, blocky, poorly sorted quartz sandstone; cross-bedded with 1 to 2-foot thick foreset units.
	Hart Dolerite ca 5200 feet
?	Detritus of weathered purple-brown phyllite.
25	Sandstone; pale purple-grey coarse-grained thick-bedded massive, poorly sorted silica-cemented quartz sandstone.
2	Pebble conglomerate; pebbles of vein quartz and siltstone 1 inch to 2 inch across, in a coarse-grained sand matrix (lenses out along strike).
150	Sandstone; white, pale grey, and red-brown coarse-to medium-grained thin to thick-bedded, blocky, poorly-sorted quartz sandstone; cross-bedded with foreset units 6 inches to 12 inches thick; no basal conglomerate.
449 Total	

Underlain by Lennard Granite

KING LEOPOLD SANDSTONE - L1

Measured section (distances paced) 5km north-east of Mount Nellie (1763E, 29162N), (1748E, 29204N). Measured by D. Gellatly.

*Underlain by Hart Dolerite (ca 1200 ft) (as above)

Overlain by Carson Volcanics

Thickness (feet)	King Leopold Sandstone
1054	Sandstone; white to pale buff, coarse-grained thin to thick-bedded, blocky moderately well sorted quartz sandstone; cross bedded with foreset units 8 inches to 15 inches thick; local overturning of cross beds; current direction from 010°.
1865	Sandstone; white, coarse-grained, thick-bedded blocky to massive well-sorted quartz sandstone.
560	Sandstone; white to pale buff medium to coarse-grained, thick-bedded, blocky to massive rather poorly sorted quartz sandstone.
3479	

KING LEOPOLD SANDSTONE - L2

Paced and calculated section of the King Leopold Sandstone 4km north northeast of Cone Hill, Grid reference: 130E, 29220N. Measures by C.M. Morgan.

Overlain by Carson Volcanics

Thickness (feet)	King Leopold Sandstone
1026	Sandstone; white to light grey, medium-grained, massive, bedding obscure, contains some micaceous material.
	No exposures: probable Hart Dolerite - 158 feet.
983	Sandstone; white, weathers yellow-brown, medium-grained, friable, blocky, no bedding, apparent; contains tourmaline and muscovite.
	Hart Dolerite - 400 feet.
724	Sandstone; white to grey medium-grained, massive, bedding not well defined; contains minor sericite and tourmaline.
	Hart Dolerite - 295 feet.

364	Sandstone; white fine to medium-grained, flaggy - no bedding apparent, contains muscovite.
347	Sandstone; white, coarse-grained, poorly-sorted, thin-bedded, flaggy.

Hart Dolomite - 2000 feet.

CARSON VOLCANICS - C1

Locality, 13km north-northeast of Mount Nellie (1798E; 29259N). Tape and abney section - measured by J. Sofoulis and G. Derrick.

Overlain by Warton Sandstone

Thickness (feet)	Carson Volcanics
127	Tuffaceous agglomerate, sericitic greywacke matrix with interbeds of poorly-bedded pale-purple, phyllitic, silty sandstone, megaclasts to 9" long and 4" across.
137	No outcrop, Scree cover.
86	Agglomeratic and Amygdaloidal basalt, with thin interbeds of tuffaceous siltstone and fine grained silty sandstone.
70	No outcrop, Scree cover.
24	Tuffaceous siltstone, with cherty sandstone and poorly bedded silty sandstone bands.
427	Amygdaloidal basalt, with interbedded agglomeratic bands, some with angular, subangular and rounded megaclasts up to 10cm across, matrix mainly green chloritic schist.
25	No outcrop, Scree and river wash.
200	Tuffaceous agglomerate, with bands of altered amygdaloidal basalt and agglomeratic basalt.
218	Tuffaceous agglomerate scree.
18	Tuffaceous agglomerate, with rounded, angular and subangular megaclasts to 8cm across. Greenish and grey green greywacke matrix with thin sericite and chlorite schist bands.

33	Basalt, fine grained, greenish, generally massive with chlorite schist bands.
172	No outcrop, soil cover.
86	Scree cover of sandstone and silty sandstone.
86	Feldspathic sandstone and silty sandstone, greenish, purple-red and grey sericitic sandstones.
15	No outcrop, soil cover.
61	Siltstone, dark grey, fine grained.
115	Tuffaceous siltstone, dark grey, fine grained, foliated rock.
104	Siltstone, dark grey-green, laminated, thin-bedded and flaggy fine-grained rock.
178	Basalt, altered, fine-grained, greenish-blue massive rock with acicular mafic minerals and abundant epidote. Minor pyrite associated with thin epidote veinlets. Thin chloritic schist partings parallel to bedding prominent in lower part.
47	No outcrop, soil cover.
14	Quartz scree, probably quartz-filled strike fault.
135	No outcrop, soil cover, sandstone scree locally.
51	Feldspathic quartz sandstone, pale green, grey white, massive, blocky, medium-grained and even-grained, current beds locally, thin foresets to 8cm thick.
150	Basalt, amygdaloidal, fine-grained, green, massive rocks with elongated and flattened amygdales to 3cms across, minor quartz lenses and thin veinlets to 1cm thick.
300	No outcrop, soil cover.
98	Basalt, massive fine-grained, greenish, locally foliated and altered to chlorite schist, scattered pyrite grains.
408	Chlorite schist, altered basaltic rocks with thin mudstone and siltstone interbeds. Minor malachite staining in upper part associated with irregular blebs and thin veinlets of quartz.

344	Scree of King Leopold Sandstone cobbles and boulders, schist plates and fragments, occasional basalt cobbles.
67	Amygdaloidal basalt, altered, well foliated, fine-grained grey-green, with elongated and flattened amygdales. Some interbedded green and maroon coloured chlorite schists.
3796 Total	

Underlain by King Leopold Sandstone

CARSON VOLCANICS - C2

Locality, 8km north-northeast of Mount Nellie (1752E, 29218N). Measured by Abney level and distances measured from air photographs. Measured by D. Gellatly.

Overlain by Warton Sandstone

Thickness (feet)	Carson Volcanics
43	Lapilli tuff; pale grey phyllitic lapilli tuff; grades upwards into highly weathered red-brown slightly hematitic lapilli tuff.
389	Sheared basalt(?); grey-green spotted amygdaloidal phyllite; contains streaded out amygdales of quartz and chlorite.
346	Agglomerate(?); relict rounded cobbles and boulders of grey basalt in matrix of red-brown (weathered) amygdaloidal phyllite.
1038	Sheared basalt(?); grey-green to grey-brown non-amygdaloidal phyllite, interbedded amygdaloidal phyllite.
519	Basalt(?); rotten grey-green amygdaloidal basalt with abundant small quartz amygdales.
270	Phyllite; grey, possibly tuffaceous phyllite.
490	Phyllite; grey-brown laminated fissile phyllitic
15	Sandstone; pale pink-brown medium-grained thin-bedded, flaggy to blocky, well-sorted feldspathic sandstone.

43	Sheared basalt(?); grey-green phyllitic non-amygaloidal ?basalt.
22	Sandstone; pale buff fine to medium-grained, laminated to thin-bedded, flaggy to blocky well-sorted quartz sandstone.
389	Sheared basalt; grey-green amygdaloidal phyllite with quartz amygdales up to 2cm long. Poorly exposed.
43	Altered ?basalt; grey-green amygdaloidal brecciated altered basalt; grey-green chlorite phyllite.
3612 Total	

Underlain by King Leopold Sandstone

WARTON SANDSTONE

For correlation of sections, see Fig 15

WARTON SANDSTONE-W1

Paced section of Warton Sandstone from a point 3km northwest of Mount Dawson. (1375E; 28982N). Measured by C.M. Morgan.

Overlain by Elgee Siltstone

Thickness (feet)	Warton Sandstone
270	Felspathic sandstone; fine pink highly feldspathic with 5-10% coarser angular blue quartz grains.
200	Feldspathic sandstone, pale grey as above.
100	No outcrop: soil cover.
215	Feldspathic sandstone; fine-grained, slightly feldspathic, grades down into a more highly feldspathic sandstone.
	Hart Dolerite ca 700ft (partly soil covered)
	Warton Sandstone
900	Sandstone; fine-grained, pale purple-grey, silica-cemented, generally poorly sorted with some large angular quartz grains.
1685 Total	

Underlain by Carson Volcanics

WARTON SANDSTONE -W2

Thickness estimates from air photographs and measured dips. Locality 8km east-northeast of Compass Hill (1308E, 29025N).

Overlain by Elgee Siltstone

Thickness (feet)	
880	Warton Sandstone
	Hart Dolerite
750	Warton Sandstone
1630 ft	Overlies Carson Volcanics

WARTON SANDSTONE-W3

Measured section by tape and abney; 6km south-southwest of the head of Copper Mine Creek. Grid Reference 1214E, 29457N.
Measured by J. Sofoulis.

Overlain by Elgee Siltstone

Thickness (feet)	Warton Sandstone
209	Hematitic quartz sandstone, grey white, pale green, black and red-brown, thin bedded flaggy medium to coarse-grained, poorly sorted sandstone with abundant hematite grains. Sequence locally conglomeratic with granules and pebbles of quartz sandstone. Numerous interbeds of white medium and fine-grained silica-cemented quartz sandstone to 5cm inches thick and spotted andalusite granafels layers to 2 5cm thick.
24	Hematitic siltstone, red-brown, thin bedded and flaggy siltstone with abundant hematite grains. Minor quartz sandstone interbeds of white and grey thin bedded medium to fine-grained silica cemented sandstones to 2 cm thick.
95	Quartz sandstone, white, grey, fine to medium-grained, well sorted, with minor hematite grains and secondary hematite patches to 5cm across.

74	No outcrop, scree and soil cover; probable siltstone bed.
163	Quartz sandstone, white to grey, massive to blocky, thick-bedded, medium to fine-grained, silica cemented sandstone with scattered hematite grains.
76	No outcrop, soil cover, probable siltstone bed.
139	Quartz sandstone, white, grey, purple and pink, blocky, thick-bedded fine to medium-grained, silica-cemented sandstone with scattered hematite grains.
117	No outcrop, soil cover, probable siltstone bed.
55	Quartz sandstone, white, thick-bedded, blocky, coarse-grained, granular, silica-cemented sandstone.
31	Quartz sandstone, white, blocky, medium to fine-grained, clean-washed, silica-cemented, thick-bedded sandstone.
32	Feldspathic sandstone, white, pink, medium-grained, granular, thick and thin-bedded sequence; locally has sericite along parting planes.
114	Quartz sandstone, white, grey and blue-grey, current-bedded, massive, blocky medium-grained, well-sorted, clean-washed silica-cemented sandstone. Minor quartz veinlets to 6mm thick.
1129 Total	

Underlain by Carson Volcanics

WARTON SANDSTONE-W4

Average measured section, Koolan Island (1345E, 29630N). Total thickness from cross sections of Finucane (1939); thickness of Jap Bay Member and Arbitration Cove Sandstone Member are averages of measured sections by BHP (I.W. Reid. pers. comm.).

Thickness (feet)		Overlain by Elgee Silstone (Hanging Wall Schist)
		Warton Sandstone
Arbitration Cove Sandstone Member	220	Sandstone; white to pale buff medium to coarse-grained well sorted silica cemented quartz sandstone; contains feldspar and sericite (derived from feldspar locally.

Jap Bay Member	115	Sandstone; pink to red brown fine-grained, thin bedded, flaggy feldspathic sandstone, with interbeds of buff to yellow brown and pale grey laminated siltstone.
Blinker Hill Sandstone Member	365	Sandstone; white to buff, medium, to coarse-grained, well-sorted, silicia-cemented. Contains minor feldspar.
Total	700 ft	

Base not exposed

WARTON SANDSTONE-W5

Measured Section, 10km north of Mount Nellie. (1700E, 2924N). Distances paced. Measured by D. Gellatly.

Uncomformably overlain by conglomerate of Elgee Siltstone

Thickness (feet)	Warton Sandstone
63	Siltstone, grey fissile clay-pellet-bearing siltstone.
31	Chert, pale grey chert with partings of hematite and grey siltstone.
75	Siltstone, dark grey flaggy to fissile phyllitic siltstone.
82	Siltstone, pale grey and dark grey (red-brown where weathered) fine-grained, thin-bedded to laminated, flaggy siltstone with 1-2 feet interbeds of chert; also malachite-bearing hematite into beds up to 20cm thick.
6	Chert, grey to white chert, fine-grained and hematitic sandstone; hematitic beds contain malachite.
96	Sandstone, white and buff medium-grained, thin-bedded blocky, quartz sandstone.
180	Sandstone, pale red-brown to white, medium to coarse-grained, thin-bedded, blocky, silica-cemented quartz sandstone.
533 Total	

Underlain by Carson Volcanics

WARTON SANDSTONE-W6

Area of complete erosion of Warton Sandstone - 10km northeast of Mount Nellie (1800E, 29220N).

WARTON SANDSTONE-W7

Locality, 16km north of McLarty Range, near south-east coast of Talbot Bay. 1670E, 29360N. Taped section.
Measured by G. Derrick and C.M. Morgan.

Overlain by Elgee Siltstone

Thickness (feet)	Warton Sandstone
300	Feldspathic sandstone and minor arkose, fine to medium-grained, pale pink to buff, blocky, thin-bedded; abundant small holes (2mm - 10mm) due to weathering of limonitic concretions.
40	Feldspathic sandstone, fine-grained, blocky, thin-bedded; hematite-bearing.
35	Feldspathic sandstone, fine-grained to silt grade, blue-grey, blocky, thin-bedded.
50	Siltstone, pale green-grey, flaggy, laminated; small ?hematite specks and small-scale cross-beds.
120	Quartz sandstone, medium-grained, pale to deep purple, massive, poorly bedded; some hematite specks, overturned cross-beds common.
30	Quartz sandstone, coarse-grained, blue-grey, poorly sorted; massive and poorly bedded, some hematite specks.
38	Quartz sandstone, medium-grained, grey-buff, massive, thick, bedded: continues abundant small limonite concretions.
26	Quartz sandstone, coarse-grained, purple morderately sorted, poorly bedded; some overturned cross-bedding.
25	Quartz sandstone, medium to coarse-grained, white to buff, poorly sorted; some granule sandstone.
120	Quartz sandstone, medium to coarse-grained, white to pale buff, massive to blocky. Minor pebble and granule beds. Cross-beds common with some overturned.
794 Total	

Underlain by Carson Volcanics
(massive conglomeratic tuffaceous sandstone)

WARTON SANDSTONE-W8

Locality 5km southwest of Shoal Bay. (1895E; 29270N).
Measured with tape and Abney, by D. Gellatly.

Overlain by Elgee Siltstone (conglomerate)

Thickness (feet)	Warton Sandstone
115	Sandstone, white to pale purple brown, medium to coarse-grained laminated to thin-bedded, well-sorted silica-cemented quartz sandstone.
165	Sandstone, white, medium-grained, thick-bedded, massive, well-sorted quartz sandstone; cross-bedded with current directions from south-west.
107	Sandstone, very pale pink medium to coarse-grained, thick-bedded, blocky, poorly sorted, silica-cemented quartz sandstone.
284	Siltstone, white to pale rust-brown, medium to coarse-grained, thin-to thick-bedded, blocky, well-sorted, friable, silica-cemented quartz sandstone.
484	Feldspathic sandstone, white to pale cream, medium-grained, thick-bedded, blocky well-sorted, silica-cemented feldspathic sandstone; contains 15% to 20% of white to pale cream feldspar, (poorly exposed).
3	Sandstone, pale pink-brown, fine-grained, well-sorted quartz sandstone; contains 1% of feldspar.
130	No exposure; debris of purple-brown and red-brown micaceous shale and siltstone.
46	Sandstone, white to pale cream, coarse-grained thick-bedded, blocky to massive, cross-bedded quartz sandstone; contains 1% feldspar.
122	Sandstone, white to pale cream, coarse-grained thick-bedded blocky to massive well-sorted silica-cemented quartz sandstone.
90	Sandstone, white to very pale rust-brown coarse-grained, thick-bedded, blocky to massive, poorly sorted quartz sandstone.
180	No exposure, debris of sandstone boulders.
1723 Total	

Underlain by Carson Volcanics
(pale grey to dark brown chert and hematitic acid tuff).

ELGEE SILTSTONE

For section localities and isopachs see Fig.17.

ELGEE SILTSTONE-E1

Measured section near Kimbolton track, 6km west of Oobagooma (1577E, 28885N): distances paced. Measured by D.C. Gellatly.

(Axis of syncline: section imcomplete)

Thickness (feet)	Elgee Siltstone
153	Siltstone; dark grey, laminated, flaggy siltstone.
613	Siltstone; dark grey, laminated, flaggy to blocky siltstone with thin interbeds of pale grey fine-grained silty quartz sandstone. Some siltstones have limonitic spots; minor chert bands are ripple-marked and locally contain clay-pellets.
298	Sandstone; pale grey coarse-grained thin bedded blocky to massive slightly feldspathic quartz sandstone; cross-bedded; prominent tourmaline outline foreset laminae.
264	Conglomerate; (Poorly exposed) abundant detritus of rounded and elongate cobbles and boulders of white to pale grey-brown coarse to medium-grained quartz sandstone.
1610 Total	

Underlain by Warton Sandstone

(white, medium-grained, silica-cemented quartz sandstone)

ELGEE SILTSTONE-E2

Paced section of the Elgee Siltstone 3km north-west of Mount Dawson. (1368E, 28976N)

Overlain by Pentecost Sandstone

Thickness (feet)	
180	Soil cover. (Probable Elgee Siltstone)
115	Sandstone, light purple fine to medium-grained with 5-10% angular blue quartz grains.
255	Soil cover.
185	Feldspathic sandstone, light brown fine somewhat feldspathic, interbedded with fine blue sandstone and also a medium to fine-grained highly feldspathic blue sandstone.
115	Soil cover.
850 Total	

Underlain by Warton Sandstone

ELGEE SILTSTONE-E3

Measured section of Elgee Siltstone 3km west-north-west of Mount Olivia (1185E, 29068N) to (1203E 29047N). Distances paced Abney level. Measured by D.C. Gellatly.

Overlain by Pentecost Sandstone

Thickness (feet)	Elgee Siltstone
112	Schist; pale grey laminated psammitic quartz muscovite schist; consists of thin partings of muscovite separating 2 to 5cm thick siliceous layers.
	No exposure - Hart Dolerite - ca 1300 feet
115	Sandstone; grey and red-brown fine-grained laminated to thin-bedded, flaggy, ripple-marked, silty quartz sandstone.
	Hart Dolerite - ca 110 feet
	No exposures - probably Hart Dolerite - ca 85 feet
71	Sandstone; pale red-brown, medium-grained thick-bedded blocky quartz sandstone, with interbeds of fine-grained thin-bedded, flaggy, silty quartz sandstone; cross-bedded; locally slumped.
	No exposures - Hart Dolerite - 318 feet

46	Sandstone, red-brown, fine-grained, thin-bedded flaggy sericitic quartz sandstone.
34	Schist, pale grey to red-brown, flaggy, phyllitic quartz muscovite schist.
78	Sandstone, white to red-brown, medium-grained, thick bedded, blocky, well-sorted quartz sandstone.
	No exposures - probable Hart Dolerite - 14 feet
27	Sandstone, white to red-brown medium-grained, thick-bedded, blocky well-sorted quartz sandstone.
	No exposures - Hart Dolerite - 350 feet
80	Sandstone, white to pale red-brown, fine to medium-grained thin-bedded quartz sandstone, with thin inter-beds of grey muscovite schist; schist has 2 mm magnetite octahedra.
6	Schist, grey semi-pelitic muscovite schist.
58	Sandstone, red-brown fine-grained thin-bedded flaggy quartz sandstone.
8	Schist, pale grey, well-bedded, semi-pelitic muscovite schist.
635 Total	

Underlain by Warton Sandstone

ELGEE SILTSTONE - E4

Measured section at mouth of Kyulgam River (1318E 29250N) Distances paced. Measured by J. Sofoulis.

Overlain by Pentecost Sandstone
(basal beds 160 feet of steel grey siltstone, thin bedded fissile and locally spotted)

Thickness (feet)	Elgee Siltstone
60	Silty Sandstone; chloritic, red-brown, thin-bedded and fissile.
30	Silty Sandstone; red-brown, with scattered magnetite grains.

15	Quartz Sandstone; pink, thin-bedded.
6	Phyllitic Siltstone; red brown.
3	Quartz Sandstone; pink, fine-grained, thin-bedded.
230	Phyllitic Siltstone; grey, green, black and deep red-brown on oxidised surfaces. Distinct thin bedding laminations.
4	Quartz Sandstone; white-grey, thin-bedded, fine-grained, blocky.
15	Phyllite; red-brown, micaceous and fissile, scarp-forming.
21	Phyllitic Schist; red-brown.
1	Sandstone; 10cm, fine-grained white; Phyllitic schist 10cm red-brown; Sandstone 10cm fine-grained white.
21	Phyllitic Schist; red-brown, locally spotted and with magnetite grains. Well foliated parallel to bedding planes.
75	Phyllitic Siltstone, grey-green, red-brown on oxidised surfaces. Well foliated and fissile.
481 Total	

Underlain by Warton Sandstone

ELGEE SILTSTONE -E5

Locality 15km northeast of salt flats at mouth of Lydarrba River (1365E, 29340N). Measured by D.C. Gellatly. Distances paced. Section 5a - on central limb of draf fold.

Overlain by Pentecost Sandstone
(white thick bedded quartz sandstone)

Thickness (feet)	Elgee Siltstone
53	Sandstone, grey fine-grained thin-bedded to laminated flaggy quartz sandstone with tin interbeds of silvery grey micaceous phyllite; grades downwards into;
212	Phyllite, silvery grey thin-bedded, flaggy phyllitic siltstone.

Quartz feldspar porphyry (ca 480 feet)
(Wotjulum Porphyry)

160	Phyllite, grey-brown (weathered) phyllitic siltstone.
425 Total*	

Underlain by Warton Sandstone
(white quartz sandstone)

Section 5b - on southern limb of drag-fold.
Overlain by Pentecost Sandstone (as above)

Elgee Siltstone

Thickness (feet)	
42	No exposure.
4	Sandstone, pale grey fine-grained laminated micaceous silty sandstone with thin (5cm) interbeds of grey and brown medium-grained quartz sandstone.
55	No exposure.
35	Sandstone, grey, fine-grained, laminated to thin-bedded, flaggy to blocky, ripple-marked quartz sandstone with phyllite laminae.
42	No exposure.
45	Sandstone, cream to pale brown fine-grained thin-bedded to laminated sandstones with thin phyllite interbeds.
45	Phyllite, silvery-grey muscovite phyllite with strong cleavage parallel to contact of Warton Sandstone; has well developed kink folds.
	Quartz feldspar porphyry (60 feet) (Wotjulum Porphyry)
22	Phyllite, silvery-grey muscovite phyllite.
290 Total*	

Underlain by Warton Sandstone
(white quartz sandstone)

* The difference in thickness between these two sections from localities only 05km apart is almost certainly due to strike faulting in the southern (overturned limb), The true thickness here is thus taken to be 425 feet (Section 9a).

ELGEE SILTSTONE - E6

Locality 10Km south-east of Wotjulum Mission (1338E, 29415N). Measured by R.A. Farbridge, C.M. Morgan and D.C. Gellatly.

Overlain by Pentecost Sandstone

Thickness (feet)	Elgee Siltstone
173	Siltstone, blue grey to purple-grey fissile thin bedded siltstone with fine grained sandstone interbeds; contain minor muscovite and hematite.
118	No outcrop (siltstone and fine-grained sandstone debris).
	Wotjulum Porphyry Intrusive
23	Siltstone, pale grey and pale brown thin-bedded flaggy interbanded siltstone and sandstone.
70	No outcrop.
384 Total	

Underlain by Warton Sandstone
(white quartz sandstone - forms prominent dip-slope)

ELGEE SILTSTONE - E7

Measured section by tape and abney; 5km south-south west of the head of Copper Mine Creek. 1214E, 29459N. Measured by J. Sofoulis.

Overlain by Pentecost Sandstone
(Lowermost bed of hill forming white quartz sandstone)

Thickness (feet)	Elgee Siltstone
12	Hematitic sandstone, grey, dark grey to black thin bedded flaggy, medium to fine-grained quartz sandstone with abundant hematite grains.
48	Silty sandstone, red-brown, thin bedded, flaggy with hematite grains.

Quartz Porphyry (Wotjulum Porphyry), approximate thickness 1400 feet.

208	Siltstone, pink, grey and red-brown, thin-bedded, flaggy phyllitic siltstone with minor sericite.
268 Total	

Underlain by Warton Sandstone-Section W3

ELGEE SILTSTONE - E8

Measured section, 2½Km southeast of Nare's Point on mainland opposite Koolan Island Wharf. (1352E, 29596N). Distances paced ([illegible]). Measured by J. Sofoulis.

Overlain by Pentecost Sandstone (Section P4)

Thickness (feet)	Elgee Siltstone
15	Grey phyllitic siltstone.
2	White quartz sandstone medium-grained.
4	Grey phyllitic siltstone.
1	White quartz sandstone.
5	Grey phyllitic siltstone.
1	White quartz sandstone.
10	Grey phyllitic siltstone.
8	White quartz sandstone.
10	Grey phyllitic siltstone.
6	White quartz sandstone.
50	Grey phyllitic siltstone.
6	White quartz sandstone.
1	Grey phyllitic siltstone.
1	White quartz sandstone.
9	Grey phyllitic siltstone.
6"	White quartz sandstone.
4	Grey phyllitic siltstone.
1	White quartz sandstone.
8	Grey phyllitic siltstone.

8	Thin and thick bedded medium to coarse-grained current bedded quartz sandstone.
10	Grey phyllitic siltstone.
4	Grey-white medium to coarse grained current bedded quartz sandstone.
40	Grey phyllitic siltstone.
45	White quartz sandstone.
30	Grey phyllitic siltstone.
5	White quartz sandstone.
30	Grey phyllitic siltstone.
4	White current bedded quartz sandstone.
100	Grey phyllitic siltstone.
3	Grey-white quartz sandstone.
40	Grey phyllitic siltstone.
6"	White quartz sandstone.
469 Total	

Overlies Warton Sandstone (76ft of white and grey quartz sandstone overlying Watjulum Porphyry)

Watjulum Porphyry Intrusive

ELGEE SILTSTONE - E9

Koolan Island. (1365E; 29618N). Thickness estimates of from 45ft to 250ft (AU113ft) - from cross sections in Finucane (1939), Plate 6.

ELGEE SILTSTONE - E10

Section on Koolan Island, 2Km east of Arbitration Cove (1382E; 29627N). Thickness estimated from Finvcane (1939) Plate 4; lithological details by R.A. Farbridge.

Overlain by Yampi member of Pentecost Sandstone (P7)

Elgee Siltstone

Thickness (feet)	
80	No outcrop: Debris of pale buff-grey to pink-brown siltstone. Blocky fracture.
188	Siltstone: Blue-grey siltstone with 15cm to 30cm bands of very fine banded sandstone. Scattered outcrop.
232	Siltstone: Poor outcrop. Blue-grey to red-brown siltstone and mudstone. Ribbon banded in part. Sole marks on some bedding surfaces.
500 Total	Base of section not exposed

ELGEE SILTSTONE - E11

Measured section on shore of Talbot Bay about 9km east of Wotjulum Mission (1340E, 29470N). Measured by D.C. Gellatly. Distances paced.

Overlain by Pentecost Sandstone

Thickness (feet)	Elgee Siltstone
3	Siltstone, pale grey micaceous siltstone with 2 cm to 5 cm interbeds of pale grey and grey-green medium-grained laminated quartz sandstone.
238	Siltstone, dark grey to pale grey phyllitic shale and siltstone, red-brown when weathered.
20	Siltstone, grey micaceous laminated sandy phyllitic siltstone, with thin interbeds of fine-grained grey-brown quartz sandstone.
18	No outcrop (?siltstone).
279 Total	

Underlain by Warton Sandstone

(white, medium to coarse-grained thick-bedded blocky to massive quartz sandstone)

ELGEE SILTSTONE - E12

Locality 1458E; 29487N; 13km southeast of Koolan. Distances paced - measured by D. Gellatly.

Overlain by Pentecost Sandstone

Thickness (feet)	Elgee Siltstone
25	Quartz sandstone, pink-brown, medium-grained, thin-bedded to laminated, flaggy to fissile, quartz sandstone, with thin interbeds of pale pink-brown phyllitic siltstone.
8	Quartz sandstone, white to very pale pink grey, medium-grained, thin-bedded, flaggy quartz sandstone, locally conglomeratic with granules and small pebbles of quartz sandstone.
8	Siltstone, buff to grey clayey siltstone with thin interbeds of pink brown quartz sandstone.
46	Quartz sandstone, pale pink-brown medium to coarse-grained, thin-bedded, flaggy, well-sorted quartz sandstone with interbeds of dark grey cleaved sericitic siltstone up to 30cm think; sandstones are cross-bedded with 8cm to 10cm thick forecets; current directions predominantly from north.
77	Siltstone, dark grey fissile micaceous siltstone with rare 8cm to 10cm interbeds of purple-brown coarse-grained quartz sandstone.
32	Quartz sandstone, pale pink-brown, medium to coarse-grained, thin-bedded, flaggy, poorly-sorted quartz sandstone; partings of grey phyllite up to 5cm thick.
48	Siltstone, grey sericitic siltstone and shale with thin interbeds of pale purple-brown quartz sandstone.
16	Quartz sandstone, grey-brown to purple-brown coarse-grained, thick bedded, blocky poorly sorted silica-cemented quartz sandstone.
26	Mudstone, buff to pale red-brown, clayey sericitic mudstone, grades downwards into dark red-brown and dark grey sericitic shale.
18	Quartz sandstone, cream to pale red-brown, coarse-grained, thin to thick-bedded, flaggy to blocky, quartz sandstone.
11	Siltstone, grey-brown phyllitic siltstone, interbedded with red-brown quartz sandstone.
315 Total	

Underlain by Warton Sandstone

ELGEE SILTSTONE - E13

Locality 10 miles north of McLarty Range, near south east coast of Talbot Bay (1670E, 29368N). Taped section - measured by G. Derrick and C.M. Morgan.

Overlain by Pentecost Sandstone

Thickness (feet)	Elgee Siltstone
106	Siltstone, pale purple, flaggy; interbedded with coarse to medium-grained ferruginour quartz sandstone, blocky and thin-bedded; sandstone, coarse-grained, purple, with jasper and clay pellets; small-scale cross-bedding common.
440	No outcrop.
34	Siltstone and Sandstone, fine-grained, blue-grey, flaggy to laminated; coarse-grained mica flakes on bedding planes.
6	Feldspathic sandstone, pale purple grey, very coarse grained, poorly sorted thin-bedded, blocky feldspathic sandstone with scattered clay pellets.
44	Conglomerate, pale purple, well rounded cobbles and boulders up to 20cm across of coarse-grained, well-sorted feldspathic sandstone in a sparse coarse-grained sand matrix.
601 Total	

Underlain by Warton Sandstone

ELGEE SILTSTONE - E14

Partial measured section 11km north of Mount Nellie (1705E, 29254N); Abney level, and paced sections. Measured by D. Gellatly.

Top of formation not preserved

Thickness (feet)	Elgee Siltstone
151	Siltstone; grey laminated flaggy siltstone; ripple-marked locally.

Thickness (feet)	
262	Siltstone; grey phyllitic siltstone with 5cm to 8cm interbeds of white to pale grey, fine-grained, quartz sandstone.
55	Feldspathic sandstone; pale pink-brown, medium-grained thin to thick-bedded, flaggy to blocky, feldspathic sandstone; cross-bedded with tabular foreset units 8cm to 30cm thick; current direction from sotuheast.
9	Conglomerate; scattered pebbles and rare cobbles of white to very pale brown coarse-grained silica-cemented quartz sandstone and pale pink feldspathic quartz sandstone; matrix is poorly sorted granule sandstone.
5	Conglomerate, cobble conglomerate grading upwards into pebble conglomerate.
1	Sandstone, pale-grey, coarse-grained quartz granule sandstone.
30	Conglomerate, cobble to boulder conglomerate with boulders up to 18 feet across.
5	Breccia, angular pebbles and cobbles of sandstone up to 8cm diameter, in a coarse-grained grey poorly sorted sandstone matrix.
518 Total	

Underlain by Warton Sandstone (grey siltstone)

ELGEE SILTSTONE - E15

Locality 4km southwest of Shoal Bay (1898E, 29273N). (Measured with tape and abney). Measured by D.C. Gellatly.

Pentecost Sandstone
(White to pale brown quartz sandstone)

Thickness (feet)	Elgee Siltstone
126	No outcrop, debris slope of sandstone; includes detritals of very fine-grained red-brown silty sandstone.
42	No outcrop, debris of sandstone, and minor grey micaceous siltstone and flaggy hematitic siltstone.

Thickness (feet)	
270	No outcrop, debris of white and red-brown sandstone and deep red-brown micaceous siltstone.
40	Sandstone, pale grey-brown and purple-brown fine-grained, thin-bedded flaggy slightly micaceous quartz sandstone.
24	Siltstone, purple-grey micaceous shale and siltstone, alternating with 2cm to 8cm beds of purple-brown and purple-grey coarse-grained quartz sandstone, and minor clay pellet conglomerate.
90	Sandstone, purple-grey to purple-brown fine-grained slightly micaceous silty sandstone.
6	Feldspathic sandstone, pale purple-grey, very coarse-grained, poorly-sorted, thin-bedded, blocky, feldspathic sandstone with scattered clay pellets.
44	Conglomerate, pale purple-well-rounded cobbles and boulders up to 20cm across of coarse-grained well-sorted feldspathic sandstone in a sparse coarse-grained sand matrix.
572 Total	
	Underlain by Warton Sandstone

PENTECOST SANDSTONE - P1

Paced section of Pentecost Sandstone 3km west of Mount Dawson. (1352E 28957N). Measured by C.M. Morgan.

Thickness (feet)	Pentecost Sandstone
1400	Soil cover. Sandstone and siltstone present along st strike in centre of syncline
	Strike Fault
245	Feldspathic sandstone; light grey, fine-grained, slightly feldspathic, silica-cemented sandstone, passing down into grey highly feldspathic sandstone.
22	Sandstone; cream-white, fine grained.
170	Sandstone; dark-grey.
180	Feldspathic sandstone; light brown-purple, fine-grained.

Thickness (feet)	
165	No outcrop; possibly siltstone bed.
115	Sandstone; dark grey, fine-grained.
75	Feldspathic sandstone; with alternating grey and white beds about 0.5cm thick, and containing a few pale grey angular quartz grains up to 2cm.
195	Sandstone; alternating hard and soft bands thick.
90	Feldspathic sandstone; cream-white, silicia-cemented, poorly sorted with some angular grains up to 2mm.
2657 Total	

Probable Elgee Siltstone

PENTECOST SANDSTONE - P2

Measured section of Pentecost Sandstone 8km east-northeast of Compass Hill (1312E 29005N). Distances paced. Measured by J. Sofoulis

No further exposures - centre of syncline

Thickness (feet)	Pentecost Sandstone
50	Phyllitic siltstone; red-brown, thin-bedded, fissile.
200	No outcrop; soil covered, probable siltstone bed.
255	Quartz sandstone; purple and buff to white, medium to fine-grained, massive and blocky; contains scattered black hematite(?) grains.
104	No outcrop; soil covered, probable siltstone bed.
17	Quartz sandstone; purple, fine-grained, massive blocky, silica-cemented sandstone.
229	No outcrop; soil covered, probable siltstone bed.
187	Quartz sandstone; white to pink, medium to fine-grained, silica-cemented, massive to thick-bedded, blocky.
204	No outcrop; soil covered, probable siltstone bed.

Thickness (feet)	
720	Quartz sandstone, white, fine to medium-grained silica-cemented, massive and blocky. Finer grained towards upper part; ripple marked near top of sequence.
235	No outcrop; soil covered, probable siltstone bed.
10	Quartz sandstone; white, medium-grained massive and blocky.
300	No outcrop; soil covered, probable siltstone bed.
15	Quartz sandstone; white, creamy, and purple-pink clean-washed, silicia-cemented.
120	No outcrop; soil covered, probable siltstone bed.
138	Quartz sandstone; white tp pink thick-bedded blocky, fine to medium-grained.
50	Phyllitic siltstone; grey and pink grey; contains minor quartz sandstone interbeds up to 10cm thick.
15	Quartz sandstone; dark grey, medium-grained, thick bedded, silica-cemented.
102	Phyllitic siltstone; red-brown; contains thin quartz sandstone interbeds up to 5cm thick.
6	Quartz sandstone; white, medium-grained, silica-cemented.
72	Siltstone; red-brown to white flaggy; contains sericitic along bedding plane partings.
130	Quartz sandstone; red, purple and white, fine to medium-grained with thin interbeds (up to 15cm thick); of pink-grey and purple-grey sericitic siltstone, siltstone pellets present locally at upper siltstone contacts with sandstone.
29	No outcrop; soil covered, probable siltstone bed.
98	Quartz sandstone; white to grey, thin to thick-bedded, silica-cemented sandstone mainly fine to medium-grained; locally contains poorly sorted sandstone interbeds up to 1cm thick.

Thickness (feet)	
166	Quartz Sandstone; alternating with friable silty sandstone, white grey pink and red-brown; contains interbeds of sericitic siltstone up to 5cm thick.
5	Quartz sandstone; white, pale-purple and pink fine-grained, silica-cemented.
202	No outcrop; soil and scree cover, probable siltstone bed.
182	Quartz sandstone; white to pale pink, purple-pink, fine to medium-grained, massive, blocky.
55	Phyllitic siltstone; thin-bedded, pale red-brown seritic. Contains spots of possible andalusite.
250	Quartz sandstone; white, pink grey and purple-grey fine-grained massive to thick bedded; blacky; silica-cemented; ripple worked and current bedded locally towards upper part of sequence.
27	Siltstone; red-brown with minor sericite.
91	Quartz sandstone; white, pale, pink grey and purple -grey, massive to thick bedded, blocky, silica-cemented, fine to medium-grained.

PENTECOST SANDSTONE - P3

Measured section about southeast of Wotjulum Mission (1335E, 429493N). Measured by D.C. Gellatly. Distances paced.

Thickness (feet)	(Axis of syncline - top of sequence)
500	Siltstone; dark grey, thick-bedded, blocky to massive siltstone.
233	Siltstone; dark grey siltstone, and minor pale pink-grey slightly feldspathic sandstone.
537	Siltstone; steel grey to mid-grey, slightly phyllitic, cleaved siltstone.
213	Siltstone; steel grey siltstone with 15cm to 30cm interbeds of very pale grey medium-grained feldspar-bearing quartz sandstone; ripple-marked.
185	Siltstone; dark-grey, thick-bedded siltstone.
104	No outcrop

Thickness (feet)	
203	Siltstone; dark grey and light grey, laminated, blocky siltstone.
144	Sandstone; pale grey to buff; fine to medium-grained, thin to thick-bedded, blocky, well-sorted quartz sandstone, with interbeds of laminated, dark grey and light grey, ripple-marked siltstone.
314	Siltstone; dark grey and light grey, laminated, flaggy to massive siltstone.
834	Siltstone; dark grey thick-bedded blocky to massive siltstone, with thin interbeds of pale grey fine-grained quartz sandstone; cross laminated ripple marks well-developed in sandstone.
126	Sandstone; white to pale grey thin-bedded blocky to massive quartz sandstone with thin siltstone interbeds.
192	Siltstone; dark grey laminated massive siltstone with 1 to 2 mm sandstone laminae.
3	Sandstone; pale grey siltstone quartz sandstone.
87	Siltstone; dark grey massive siltstone with thin interbeds of pale grey silty quartz sandstone.
4	Sandstone; white to pale grey coarse to medium-grained quartz sandstone; contains minor hematite and glauconite.
101	Siltstone; dark grey siltstone with thin interbeds of grey quartz sandstone.
2	Sandstone; white to pale grey, medium-grained.
75	Siltstone; dark grey thin-bedded to laminated flaggy siltstone.
109	Siltstone; dark grey siltstone, with thin interbeds or pale grey fine-grained quartz sandstone; sandstone predominates locally.
56	Siltstone; dark grey, thick-bedded, massive to blocky siltstone.
12	Siltstone; dark grey siltstone, with thin interbeds of pale grey, fine-grained quartz sandstone.
123	Siltstone; dark grey, thick-bedded, massive to blocky siltstone.

Thickness (feet)	
79	Feldspathic sandstone; Dark grey, fine-grained, slightly silty feldspathic sandstone, with thin siltstone interbeds.
140	Sandstone; pale grey-brown, fine-grained, thin-bedded, blocky quartz sandstone.
10	Siltstone.
40	Sandstone; pale grey-brown, fine-grained, thin-bedded, blocky quartz sandstone, with thin siltstone interbeds.
4516 Total	

Underlain by Elgee Siltstone (Section E6)

PENTECOST SANDSTONE - P4

Estimated section 4km south of Koolan Island Whart (1353E, 29600N).

No further exposures - "The Drain"

Thickness (feet)	
350	Sandstone; White to pale purple-grey quartz sandstone.
350	Siltstone; grey phillitic siltstone and subordinate interbedded sandstone.
500	Sandstone; White to buff and pale purple, medium to coarse-grained thick bedded, blocky quartz sandstone with rare feldspar grains.
1200 Total	Underlain by Elgee Siltstone - Section E8

PENTECOST SANDSTONE - P5

Measured section of Yampi Member of the Pentecost Sandstone - Irvine Island. (1119E, 29693N) paced distances. Measured by D.C. Gellatly.

Top of formation not preserved

Pentecost Sandstone

Thickness (feet)	
217	Sandstone; pale grey to dark grey, medium to coarse-grained, laminated to thin-bedded, flaggy to blocky, hematitic quartz sandstone.
200	Sandstone; pale grey to dark grey, coarse-grained, thick-bedded blocky hematitic quartz sandstone; cross-bedded and ripple-marked.
117	Siltstone; pale-grey laminated to thin-bedded, flaggy siltstone interbedded with purple-grey to purple-brown fine to coarse-grained, thin-bedded, blocky, hematitic quartz sandstone.
2	Sandstone; purple-grey, laminated to thin-bedded, blocky hematitic quartz sandstone.
75	Siltstone, pale grey, laminated to thin-bedded, flaggy siltstone; forms low escarpment.
59	Sandstone, pale grey fine to medium-grained hematitic quartz sandstone with siltstone inter-beds; forms dip-slope.
29	Sandstone; pale grey to dark grey medium-grained, laminated to thin-bedded blocky to massive well-sorted hematitic quartz sandstone.
35	Sandstone; pale purple-grey fine-grained hematitic quartz sandstone interbedded with dark purple-grey hematitic quartz sandstone.
29	No exposure; detrital yellow-brown to grey-brown laminated flaggy siltstone.
163	Sandstone; very pale grey to dark purple-brown coarse-grained silica-cemented quartz sandstone and hematitic quartz sandstone; minor pink-brown feldspathic sandstone.
265	Sandstone; pale grey to dark grey coarse-grained, thin-bedded to laminated hematite sandstone and hematitic quartz sandstone, scarp-forming; ripple marked.
30	Siltstone; very pale grey, laminated, fissile siltstone, with thin-interbeds of pale grey coarse-grained hematite-bearing quartz sandstone.
20	Siltstone; very pale grey, laminated, fissile.
96	Sandstone; pale grey to dark grey medium- to coarse-grained, laminated, blocky to massive, medium to coarse-grained hematitic quartz sandstone with partings of grey siltstone.

Thickness (feet)	
10	Sandstone; dark grey, medium- to coarse- grained, very thick-bedded, massive hematitic quartz sandstone.
2	Conglomerate; grey siltstone and medium-grained silty quartz sandstone with pebbles and cobbles of fine-grained quartz sandstone, chert, and hematitic quartz sandstone.
15	Siltstone; grey siltstone.
5	Sandstone; slightly silty hematite-rich quartz sandstone.
10	Conglomerate; cobbles of pale grey quartz sandstone in a matrix of coarse-grained hematitic quartz sandstone.
10	Sandstone; grey, very poorly-sorted granule sandstone interbedded with grey phyllite; phyllite contains hematite pseudomorphs after magnetite.
50	Phyllite; grey ferruginous phyllite; contains abundant small magnetite pseudomorphs.
5	Conglomerate; pebbles and cobbles of fine-grained quartz sandstone up to 4 inches, in a matrix of hematitic quartz sandstone and hematite sandstone.
30 ft	Hematite; "medium poor hematite" (along strike to south - Finucane 1939).
1466 Total	

Underlain by Elgee Siltstone
(Hematite ore and red-brown siltstone)

229

PENTECOST SANDSTONE - P7

Measured section of Yampi Member of Pentecost Sandstone, Koolan Island. (1385E, 29635N). Distances paced. Measured by R. Farbridge.

Thickness (feet)	Higher beds not represented
	Pentecost Sandstone
67	Hematitic sandstone; steel grey, medium to fine-grained, minor quartzose hematite bands up to 20 cm thick and laterally impersistent. Thin beds of grey-green medium to coarse sandstones, locally very fine-grained and muscovitic.
56	Sandstone; grey-green, coarse to medium-grained, speckled with hematite and chlorite? Minor pale-grey to pink-grey fine-grained sandstone, siltstone and hematite quartzite.
19	Hematitic sandstone; coarse to medium-grained, thin bedded. Intercalated with grey very fine-grained sandstones.
35	Sandstone; steel-grey, medium to coarse-grained, hematite-rich. Bedding 0.5m to 0.7m thick. Minor quartzose hematite and pale grey silty sandstone.
38	Shaly siltstone; grey, blocky to fissile.
9	Sandstone; pink-grey to steel-grey, coarse to medium-grained, hematite-rich; cut by quartz-hematite veins; contains vugs filled with "kidney" hematite.
27	Shaly siltstone; grey to pale pink-grey, flecked with hematite.
29	Sandstone; grey, with 10-15% hematite. Veined by specular hematite; minor very fine-grained massive sandstone and siltstone with disseminated hematite.
37	Shaly siltstone; grey to pink-grey, muscovitic, flecked with hematite. Minor vughs filled with porous hematite interbedded with coarse to very coarse hematitic sandstone.
74	Hematitic sandstone; coarse to very coarse; quartz grains moderately well rounded; discontinuous hematite-rich veins.
54	Shaly siltstone; grey to purple.

Thickness (feet)	
132	Hematitic sandstone; grey, coarse to very coarse-grained; minor lenses of massive hematite. Sandstone contains angular cavities filled with hematite. Some hematite-quartz veins sub-parallel to bedding.
237	Sandstone; grey-pink fine to medium-grained, well-sortedsorted; has irregular banding; includes 5cm thick, hematite-rich bands, flecked with hematite-limonite.
270	Sandstone; blue-green, lustrous medium to coarse-grained. poorly-sorted; cross-bedded units up to 4 cm thick. Some coarse to very coarse grained foreset units are truncated by medium to fine-grained sandstone laminae. Poor normal grading in some foresets.
231	Sandstone; purple-grey, coarse to medium-grained. Quartz is clear and well-rounded, with hematite limonite intergranular films; indistinct cross-bedded.
325	Quartz sandstone; grey, coarse-grained, hematitic.
666	Quartz sandstone; grey sand-stone, grains moderately well rounded; poorly cross-bedded in part; several zones of distorted bedding, and brecciation.
60	Quartz sandstone; purple-grey, coarse to very coarse grained, massive with hematite rich clots; strongly cross-bedded units from 4 cm to 30 cm thick; indicative of over-turning. Foreset units, tangential to bounding surface.
228	Sandstone; grey, medium to fine-grained with small scale isolated cross beds 4cm to 8 cm.
117	Quartz sandstone; grey to purple grey, coarse to very coarse-grained moderately well sorting; speckled with hematite-limonite. quartz grains well rounded; isolated cross beds. Stratigraphically lowest bed is a very coarse to granule size quartz sandstone.
137	Hematite sandstone breccia; dark grey to black; matrix of fine to medium-grained hematite-rich sandstone or quartzose hematite. Breccia fragments of grey sandstone and hematite up to 30cm.
15	Siliceous hematite.
2923 Total	(Base of Pentecost Sandstone)

PENTECOST SANDSTONE - P8

Composite section measured to southwest of Shoal Bay (a-1897E, 29284N) and (b-1958, E29287N). Measured by D.C. Gellatly and J. Sofoulis.
(a) distances measured from air photographs.
(b) distances paced; Y-Y' is Yampi Member.

Thickness (feet)	Shoreline - top of exposed sequence
	Pentecost Sandstone
(b) Y 50	Feldspathic sandstone; grey-brown to white, thin-bedded to laminated, flaggy to fissile, fine-grained feldspathic sandstone and arkose; thin (ca 2 cm) inter-beds of hematitic glauconitic sandstone.
41	Arkose; pale grey and dark grey fine-grained thin-bedded to laminated, flaggy, micaceous glauconitic arkose.
74	No outcrop - mangrove swamp.
58	Feldspathic sandstone; grey, fine-grained, thin to thick-bedded, flaggy to blocky, well-sorted, micaceous feldspathic sandstone and arkose; contains minor glauconite.
1240	Arkose; pale grey to pale pink-brown fine-grained thin to thick-bedded, blocky, well-sorted arkose.
16	Siltstone; white, grey and yellow-brown, thin to thick-bedded, blocky to massive, soft clayey siltstone.
3	Siltstone; pale grey and pale buff laminated siltstone and mudstone.
2	Siltstone; purple-grey laminated micaceous siltstone.
38	Mudstone; white, grey-green, grey and pink-grey, thick bedded, blocky to massive soft mudstone.
5	Siltstone; brown and purple-grey thin-bedded, blocky to massive siltstone.
10	Siltstone; white and grey-green massive, banded siltstone; has brown oxidation stains.
9	Siltstone; purple-grey with white and orange liminitic stains.
5	Sandstone; white, maroon and buff thin-bedded fine-grained limonitic and ochreous oxidised silty sandstone.

Thickness (feet)	
(b) Y' 5	Sandstone; purple-brown, fine-grained, thin-bedded silty sandstone.
10	Sandstone; purple-brown, thin bedded, fine-grained, silty sandstone.
32	Glauconitic sandstone; purple-brown and white, thin-bedded, glauconitic silty sandstone.
25	Glauconitic sandstone; dark purple-brown medium to coarse-grained, thin-bedded, friable, glauconitic quartz sandstone.
10	Glauconitic sandstone; purple-grey and red-brown, medium to coarse-grained, thin-bedded, blocky glauconitic quartz sandstone.
(a) 480	Sandstone; pale purple-brown, medium-grained, thick-bedded, massive well-sorted quartz sandstone; contains rare glauconite grains.
40	Sandstone; white, medium to coarse-grained, thick-bedded, blocky to massive, poorly-sorted quartz sandstone.
200	Sandstone; purple-brown, medium-grained, thin to thick-bedded, blocky to massive, well-sorted silica-cemented quartz sandstone; contains rare glauconite grains.
220	Sandstone; white, medium to coarse-grained thin to thick-bedded, blocky to massive, poorly-sorted quartz sandstone.
390	Sandstone; cream, coarse-grained, thin to thick-bedded, blocky to massive, poorly-sorted quartz sandstone.
50	Sandstone; buff, fine to medium-grained, thick-bedded, blocky, cellular clayey quartz sandstone.
375	Sandstone; white to pale buff coarse-grained, poorly-sorted thin-bedded, blocky to massive poorly sorted quartz sandstone; contains scattered 2cm pebbles of vein quartz and rare jaspilite.
300	Sandstone; white, fine-grained, thin-bedded flaggy to blocky quartz sandstone.
(a) 165	Sandstone; white, to pale pink, and pale rust brown, coarse-grained, thin-bedded, flaggy to blocky quartz sandstone; includes thin beds of pebbly quartz sandstone with 1cm pebbles of sandstone.
3853 Total	

Overlies Elgee Siltstone (Section E15)

PENTECOST SANDSTONE - P9

Composite estimated section of Pentecost Sandstone southeast and south of Eagle Point. (a-2181E, 29543N; b-2168E, 29565N). Estimated from air photographs. Lithological details by C.M. Morgan & D.C. Gellatly. Y-Y' is Yampi Member.

Approximate thickness (feet)	Higher beds covered by sea
	Pentecost Sandstone
Y 200	Glauconitic Sandstone; very pale grey, thin-bedded, flaggy, well-sorted, feldspathic glauconitic sandstone.
1300	Arkose; pale pink and pale pink-brown, thin-bedded, flaggy, fine-grained arkose and feldspathic sandstone.
20	Siltstone; pale red-brown soft siltstone.
100	No exposures.
Y' 50	Glauconitic sandstone; dark purple-grey and purple-brown, thin to thick-bedded, blocky, medium-grained glauconitic hematitic sandstone; forms prominent dip slope.
200	Glauconitic sandstone; pale grey, medium to coarse-grained glauconitic quartz sandstone containing 24% of oxidised glauconite grains; glauconite is partly concentrated into 7mm diameter concretions.
500	Sandstone; white, thin to thick-bedded, blocky to massive, medium to coarse-grained, well-sorted, clean-washed quartz sandstone.
350	Sandstone; pale purple-grey, medium to coarse-grained thick-bedded, blocky, friable quartz sandstone containing chocolate-brown clay pellets; also pale pink feldspathic sandstone. These beds form a terraced escarpment.
100	Sandstone; white medium to coarse-grained quartz sandstone. Forms prominent white dipslope.
	(Dolerite: sill about 50 feet thick).
360	Sandstone; white to pale pink, medium to coarse-grained, thin to thick-bedded, blocky, well-sorted quartz sandstone.
3210 Total	
	Overlies Elgee Siltstone

PALAEOZOIC - PZI

Section of Palaeozoic sediments in Townshend River 5km south of Townshend Yard (1662E, 29003N). Measured by D.C. Gellatly.

Thickness (feet)	Overlain by 4½ft of Cainozoic ferricrete
4	Conglomerate; sandstone cobble conglomerate with ferruginous sandy matrix.
2½	Sandstone; red brown coarse-grained pebbly quartz sandstone with thin cobble conglomerate interbeds.
1	Conglomerate; cobble conglomerate with ferruginous matrix.
5	Sandstone; red-brown coarse-grained pebbly quartz sandstone with cobble conglomerate interbeds; sandstone has spherical reduced zones.
4	Conglomerate; cobbles of quartzite and quartz sandstone up to 6 in. in a pale maroon coarse-grained sandy matrix; cross-bedded.
1	Sandstone; white and purple pink mottled medium-grained clayey quartz sandstone.
27 Total	
	(Water level)

BLACK SOIL - CZI

Section measured about 3km southwest of Mount Nellie (1703E, 29126N). Measured by D.C. Gellatly.

Thickness (feet)	
3	Black to dark grey-brown cracking podsol with small scattered 1 cm to 2 cm calcareous nodules; grades downwards into -
1	Pale grey brown to yellow brown clay with scattered 1cm to 2 cm calcareous nodules.
1	Chestnut-brown silt and sandy clay with abundant 2cm to 8 cm calcareous nodules ; nodules increase in abundance downwards to form a calcrete layer.
5 Total	
	(Base of soil sequence not exposed)

ALLUVIUM - Q1

Section of river bank alluvium measured on Townsend River about $\frac{1}{2}$km upstream from confluence with Robinson River (1658E, 28893N). Measured by D. Gellatly.

Thickness (feet)	
1	Grey to red-brown silty loam.
5	Red-brown clayey and silty loam.
6	Red-brown, pebbly gravel and coarse sand; roughly cross stratified; maximum pebble size 1cm to 2cm.
5	Pale red-brown to grey mottled consolidated (dry) cracking clay; contains concretions and fracture veinlets of calcrete, especially near base of layer.
3	Grey to red-brown mottled silty clay; damp and friable.
20 Total	

ALLUVIUM - Q2

Section of river bank alluvium on Townsend River 1 km mile upstream from confluence with Robinson River (1655E, 28897N). Measured by D.C. Gellatly.

Thickness (feet)	
4	Yellow-brown clayey sand.
5	Chocolate brown sandy loam.
4	Grey brown silty clay.
5	Yellow-brown clayey sand; becomes more sandy upwards.
18 Total	

APPENDIX 2.

STRATIGRAPHIC NOMENCLATURE SUBMISSIONS.

Name of Unit	NELLIE TONALITE.
Sheet Area	Yampi 1:250,000
Derivation of Name	Mt Nellie (1721E, 29160N) in the Yampi Sheet area.
Lithology	Dominantly mesocratic hornblende-biotite tonalite; minor granodiorite and diorite; colour index generally exceeds 30 and not uncommonly exceeds 50. Minor amounts of micropegmatite characterise most of the rocks. Generally foliated, and locally migmatitic.
Distribution	Within the catchment area of Mangrove Creek, to the west and north-west of Mt Nellie.
Topography	Mostly low rounded hills and ridges.
Reference Area	(1652E, 29194N) in the Mangrove Creek valley, Yampi Sheet area.
Mode of Occurrence	Uncertain; probably magmatic rocks intrusive into Halls Creek Group sediments. The Nellie Tonalite has undergone at least one period of metamorphism.
Relationships	Because of strong shearing and faulting, relationships with the Halls Creek Group rocks and with the Woodward Dolerite are uncertain. It is overlain nonconformably by the King Leopold Sandstone.
Distinguishing Features	The mesocratic nature of these rocks, their foliation, and the presence of both biotite and hornblende are distinctive. The metamorphosed Woodward Dolerite and Hart Dolerite in this area both differ in being biotite-free. The other acid rocks of the area are more leucocratic.
Petrological Affinities	The Nellie Tonalite is similar to certain of the tonalitic variants of McSherry's Granodiorite, although the former is more mesocratic. It could possibly be related to the more basic constituents of the Tickalara Metamorphics.
Age	Proterozoic.

Name of Unit	MOUNT DISASTER PORPHYRY.
Sheet Areas	Yampi, Charnley, Lennard River, and Lansdowne 1:250,000.
Derivation of Name	From Mount Disaster in the Yampi 1:250,000 Sheet area (2045E, 29040N).
Lithology	Porphyritic biotite microgranite and micro-granodiorite with phenocrysts of quartz (up to 1 cm), and plagioclase and perthitic potash feldspar (both up 3 cm). The groundmass is medium-grained (0.05 mm to 0.5 mm) and consists essentially of quartz, plagioclase, potash feldspar, and biotite.
Distribution	Around Mt. Disaster (Yampi); in the south-western part of the Charnley Sheet area; to the north-west of Inglis Gap, and around Ord Gap in the Lennard River Sheet area; in the south-western part of the Lansdowne Sheet area.
Topography	Mostly prominent hills and tors.
Reference Areas	Mt. Disaster (2045E, 29040N) in the Yampi Sheet area and around Inglis Gap in the Lennard River Sheet area (3035E,28450N).
Mode of Occurrence	Occurs as high level, possibly stratiform intrusions. Intrusive dykes and veins of Mt. Disaster Porphyry are rare.
Relationships	Intrudes Halls Creek Group sediments and Whitewater Volcanics. It is in contact with Bickleys Porphyry, McSherry's Tonalite, but relations with these are uncertain. It is intruded by Lennard Granite, and Secure Bay Adamellite.
Distinguishing Features	The large size of the phenocrysts distinguishes the Mt. Disaster Porphyry from Bickleys Porphyry. The relatively fine-grained groundmass and the presence of large quartz phenocrysts distinguish it from other granitic rocks of the West Kimberley Area.
Petrological Affinities	Appears to be closely related in space and time to the Whitewater Volcanics and to Bickleys Porphyry and Mondooma Granite.
Age	Proterozoic.

Name of Unit	MONDOOMA GRANITE
Sheet Area	Yampi, Charnley and Lennard River 1:250,000 Sheet areas.
Derivation of Name	From Mondooma Creek, in the south-eastern part of the Yampi Sheet area.
Lithology	Grey medium-grained biotite granite porphyritic microgranite and micro-granodiorite; phenocrysts are quartz, alkali feldspar and rarely orthopyroxene. Most varieties are hornblende and biotite-bearing.
Distribution	Extensive outcrops in the southeast corner of the Sheet area, and east from the Tarraji River headwaters.
Topography	High rounded but rugged boulder-strewn hills.
Reference Area	Around Clara Hill: (2240E, 28700N).
Mode of Occurrence	High level plutons, small plugs, and stratiform intrusions.
Relationships	Intrudes Halls Creek Group, Whitewater Volcanics, Mount Disaster Porphyry and Lennard Granite.
Distinguishing Features	Similar to crystal-rich ashflow tuff of Whitewater Volcanics. Generally massive nature and mode of occurrence, and presence of discrete pyramidal and subpyramidal quartz phenocrysts are distinctive. In thin section zones of granular quartz inclusions in alkali feldspar phenocrysts are characteristic.
Petrological Affinities	Textural range from porphyritic microgranite to granite suggests different levels of intrusion and variations in cooling history. Orthopyroxene-bearing varieties unique. Equivalent to Bickleys Porphyry on the Lansdowne and south-eastern part of the Lennard River Sheet area.
Age	Proterozoic.

Name of Unit	SECURE BAY ADAMELLITE
Sheet Areas	Yampi, Lennard, and Charnley 1:250,000.
Derivation of Name	Secure Bay in the eastern part of the Yampi 1:250,000 Sheet area.
Lithology	Coarse-grained, even-grained pale grey biotite adamellite and minor granite and granodiorite. Consists essentially of microcline-microperthite and sedic plagioclase in approximately equal amounts, quartz and biotite. It is locally sparsely porphyritic with 2" to ½" equidimensional potash feldspar phenocrysts.
Distribution	On the west side of the southern part of Secure Bay, to the north and northwest of Mt. Disaster.
Topography	The Secure Bay Adamellite in the Yampi Sheet area forms prominent rocky hills with surrounding low-lying tors and sandy pediments.
Reference Areas	In the south-western corner of Secure Bay in the Yampi Sheet area (2102E, 29023N).
Mode of Occurrence	Occurs as plutonic intrusions. Outcrops are elongate and up to 8 miles across.
Relationships	In the Yampi area contains xenoliths of Lennard Granite but in one locality has apparently been contact altered by the Lennard Granite. Intrudes Mount Disaster Porphyry.
Distinguishing Features	Is similar to Lennard granite, but differs in being mostly non-porphyritic. Where the Secure Bay Granite is porphyritic, the phenocrysts are smaller and sparser than in the Lennard Granite.
Petrological Affinities	The Secure Bay Adamellite is probably related to the Lennard Granite.
Age	Proterozoic.

Name of Unit	TARRAJI MICROGRANITE
Sheet Area	Yampi, 1:250,000.
Derivation of Name	From the Tarraji River in the south-eastern part of the Yampi Sheet area.
Lithology	Pale grey porphyritic biotite microgranite consisting of sparse phenocrysts of potash feldspar (0.5 to 1.0 cm), biotite (2-3 mm) and quartz (3-4 mm) in a fine-grained biotite-bearing matrix.
Distribution	Small scattered outcrops in the catchment area of the Tarraji River to the south of Mt. Disaster; also small areas to the west of Secure Bay.
Topography	Forms small prominent pointed hills which are more resistant to weathering than the surrounding Secure and Lennard Granites.
Reference Area	On the west side of Secure Bay about 6½ miles northeast of Mt. Disaster.
Mode of Occurrence	Occurs mainly as small stocks and plugs within other types of granite. Outcrops range from about 10 m to 12 km across.
Relationships	A part of the Lamboo complex. Intrudes Lennard Granite.
Distinguishing Features	The very fine-grained groundmass, the presence of biotite phenocrysts as well as of quartz and feldspar and their paucity are distinctive.
Petrological Affinities	The close spatial association between the Tarraji Microgranite and the Lennard Granite and Secure Bay Adamellite suggests that the Microgranite may be related to them.
Age	Proterozoic.

Name of Unit	CONE HILL GRANITE.
Sheet Area	Yampi 1:250,000 Sheet area.
Derivation of Name	From Cone Hill at the head of Cone Bay, Yampi Sheet area.
Lithology	A foliated medium-grained porphyritic biotite granite. Contains phenocrysts of potassic feldspar 1 - 3 cm long in a groundmass of quartz, biotite and some muscovite. Some varieties have abundant large tabular phenocrysts 7 - 10 cm long with little groundmass; others are non-porphyritic or gneissic. Contains minor xenoliths and is intruded by tourmaline pegmatites. Muscovitic phases towards granite margin.
Distribution	Cone Hill peninsula.
Topography	Forms low promontory (maximum elevation 190m at Cone Hill). Has rugged rocky surfaces with dissection locally controlled by prominent joint lineaments.
Reference Area	Cone Hill (1260E, 29170N).
Mode of Occurrence	Unknown. Probably occurs as a large stock.
Relationships	Intrusive into Halls Creek Group; out by pegmatitic veins. Unconformably overlain by Kimberley Group sequence and ?Speewah Group.
Distinguishing Features	It is the only granite known in this coastal area. Other promontories and peninsulas in the vicinity consist of Kimberley Group Rocks. Flanked to east by muscovite-rich psammitic rocks. Large and very tabular phenocrysts unique.
Petrological Affinities	Gradational contacts appear between varieties of porphyritic granite. These porphyritic granites resemble the Lennard and Kongorow Granites. Possibly the differences are due only to variations in the size and density of phenocrysts.
Age	Proterozoic.

Name of Unit	BLINKER HILL SANDSTONE MEMBER (of the WARTON SANDSTONE)
Sheet areas	Yampi 1:250,000; Yampi Sound 1:100,000 (Proposed)
Derivation of Name	Blinker Hill on Koolan Island.
Lithology	White to buff quartz sandstone, minor feldspathic sandstone. Topmost beds locally contain hematite.
Distribution	Koolan Island and adjacent parts of Yampi Peninsula. Can be traced southwards to Strickland Bay and eastwards to near Secure Bay.
Topography	Forms a prominent narrow strike ridge and cuestas.
Reference Sections	Koolan Island between Jap Bay and Arbitration Cove: also 3 miles southwest of Shoal Bay
Stratigraphic Relationships	Conformably overlies Carson Volcanics, is conformably overlain by Jap Bay Member.
Age	Lower Carpentarian
Thickness	230 feet (Graveyard) to 440 feet (Shoal Bay). Section incomplete on Koolan Island, where about 400 feet are present at Mangrove Inlet.
Diagnostic Features	The dominantly quartz sandstone lithology and stratigraphic position immediately overlying the Carson Volcanics are diagnostic.
Remarks	The proposed member formalises (and amends slightly) the name "Blinker Hill Quartzite" already in existence in unpublished B.H.P. reports. "Sandstone" is preferred to "Quartzite" since unmetamorphosed sandstone predominates.

Name of Unit	JAP BAY MEMBER (of the Warton Sandstone)
Sheet Areas	Yampi 1:250,000; Yampi Sound 1:100,000 (Proposed)
Derivation of Name	Jap Bay on Koolan Island.
Lithology	Buff to yellow brown and grey siltstone, with interbeds of pale red brown, thin-bedded, flaggy, feldspathic sandstone and arkose.
Distribution	Koolan Island and adjacent parts of Yampi Peninsula. Can be traced southwards to Strickland Bay, and eastwards to near Secure Bay.
Topography	Tends to form narrow easily-eroded strike valley between resistant sandstone members.
Reference Section	On eastern side of Jap Bay, Koolan Island.
Stratigraphic Relationships	Overlies Blinker Hill Sandstone Member, conformably. Is conformably overlain by Arbitration Cove Sandstone Member.
Age	Lower Carpentarian.
Thickness	27 to 45 m (Koolan Island); 39 m south of Shoal Bay 15 m 8 km east-south-east of Slug Island.
Diagnostic Features	The dominantly siltstone lithology and stratigraphic position (about 75 to 135 m above base of Warton Sandstone) are diagnostic.
Remarks	The proposed member formalises a name already in existence in unpublished B.H.P. reports.

Name of Unit	ARBITRATION COVE SANDSTONE MEMBER (of the Warton Sandstone)
Sheet Areas:	Yampi 1:250,000; Yampi Sound 1:100,000 (Proposed)
Derivation of Name	Arbitration Cove on Koolan Island.
Lithology	White to pale grey quartz sandstone, pale buff feldspathic sandstone, minor siltstone, andalusite-bearing quartzite, and sericite quartzite.
Distribution	Koolan Island and adjacent parts of Yampi Peninsula. Can be traced southwards to Strickland Bay and eastwards to near Secure Bay.
Topography	Forms prominent narrow strike ridges and cuestas.
Reference Sections	Koolan Island on eastern side of Jap Bay.
Stratigraphic Relationships	Overlies Jap Bay Member conformably, and is overlain mostly conformably by the Elgee Siltstone. In the region north of Mt Nellie the Elgee Siltstone lies unconformably on the Arbitration Cove Sandstone Member and on lower members of the Warton Sandstone.
Age	Lower Carpentarian.
Thickness	Variable: up to 375 m; mostly around 120-150 m. About 66 m on Koolan Island.
Diagnostic Features	The dominantly quartz sandstone and feldspathic sandstone lithology and the stratigraphic position as the upper part of the Warton Sandstone are diagnostic. Where the Jap Bay Member cannot be recognized the Arbitration Cove Sandstone cannot be distinguished readily from the Blinker Hill Sandstone.
Remarks	The proposed member formalises (and amends slightly) the name "Arbitration Cove Quartzite" already in existence in unpublished B.H.P. reports. Sandstone is more abundant than quartzite.

Name of Unit:	YAMPI MEMBER (of the Pentecost Sandstone)
Sheet Area	Yampi 1:250,000; Yampi Sound 1:100,000 (Proposed)
Derivation of Name	From Yampi Sound.
Lithology	Hematitic sandstone and minor hematite rock; pale brown feldspathic sandstone and arkose; siltstone; minor grey glauconitic sandstone.
Distribution	A semi-continuous belt from Bathurst Island eastwards to Eagle Point. Includes Cockatoo, Koolan and Wood Islands.
Topography	Rocky, steep-sided plateaux on islands to north of Yampi Sound; photo-pattern is striped due to rapid alternation of hard hematitic sandstone and soft siltstone. Rounded hills and cuestas in the east.
Reference Sections	(1962E, 29290N) on south side of Shoal Bay; Cockatoo Island (Reid 1958, Table 2).
Stratigraphic Relationships	Apparently conformable on lower beds (white quartz sandstone) of Pentecost Sandstone in east. Apparently conformable (or para-conformable?) on Elgee Siltstone on Yampi Sound islands.
Age	Lower Carpentarian.
Thickness	480 m on south side of Shoal Bay; 420-540 m on Cockatoo Island (Reid 1958).
Diagnostic Features	The high contents of hematite (in the west) and feldspar and hematite in the east, distinguish rocks of this member from the underlying white quartz sandstone of the Pentecost Sandstone.
Remarks	The proposed member formalises the previously undefined "Yampi Beds" of Harms (1959). Lateral equivalents of both the lower part of the Pentecost Sandstone and of the Yampi Member in the area between Talbot Bay and Strickland Bay comprise a uniform siltstone sequence that has not been subdivided.

Name of Unit:	WOTJULUM PORPHYRY
Sheet Area	Yampi 1:250,000 Sheet area.
Derivation of Name	From the now abandoned Wotjulum Mission which was located within a valley occupied by this sill 5 km southeast from the head of Copper Mine Creek.
Previous References	Referred to by Maitland (1919), Canavan and Edwards (1938), Finucane (1939), and Harms (1959), but not formally named. Specimens described by Baker in unpublished C.S.I.R.O. Mineragraphic Report No. 566 (1954), and porphyry referred to as Graveyard Porphyry. (The name Graveyard has subsequently been used in Queensland (1959) and is thus not available).
Lithology	Dense grey-black quartz feldspar porphyry with micro-crystalline groundmass. The rock is studded with phenocrysts of rose pink quartz 2 and 5 mm across and sporadic phenocrysts of feldspar. Flow-banding is common. Feldspar phenocrysts include oligoclase and orthoclase which show varying stages of alteration to sericite. Altered varieties are well foliated and fissile with abundant sericite. Biotite is present as fine-grained clots and as small flakes marginal to feldspars replaced by calcite. Altered, sheared and kaolinised varieties are commonly pink, pale green or white in colour.
Distribution	Confined to the northwest part of Yampi Peninsula. Occurs principally on the mainland south and southwest of Koolan Island, west of Talbot Bay, and to the south and southwest of Copper Mine Creek. Minor occurrences on Koolan Island.
Topography	Usually as strike valleys flanked by more resistant quartz ridges. Elsewhere as dissected undulating rocky hills, and as low pavements and promontories in coastal waters.
Reference Area	Wotjulum Mission site (1259E, 29493N).
Mode of Occurrence	Forms an extensive sill intrusive into the Elgee Siltstone. Thickness varies from 420 m (calculated) for the sill extending from the Graveyard northwest to the vicinity of Yuraddagi Creek mouth, to 60 m near Jinunga River.

...2

Relationships	Intrudes Kimberley Group, mainly the Elgee Siltstone. Locally intrudes uppermost Beds of Warton Sandstone and lower most beds of Pentecost Sandstone. The porphyry is locally intruded by a network of minor quartz veinlets.
Distinguishing Features	It is the only acid intrusive known within the Kimberley Group sequence.
Petrological Affinities	The only lithological similarity to rocks in the West Kimberley is to the Whitewater Volcanics which are older.
Age	Proterozoic.

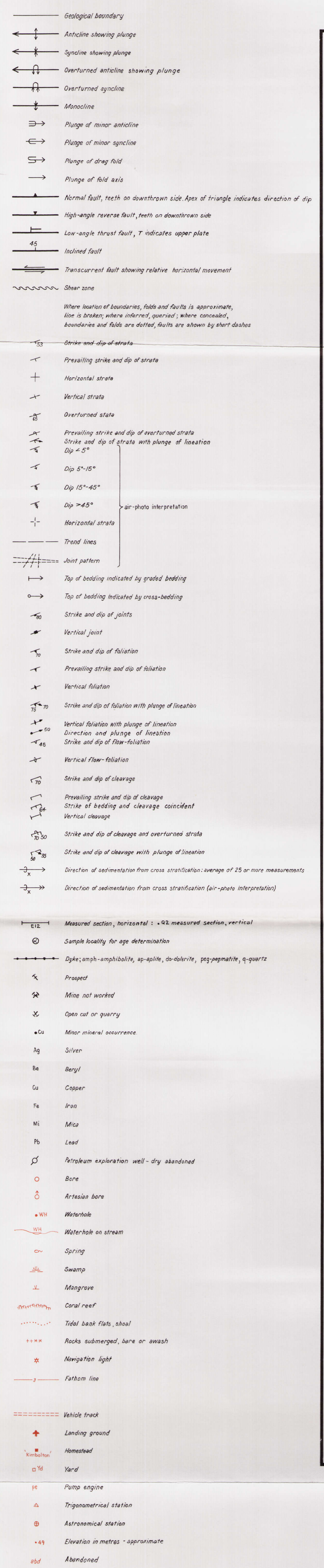
YAMPI

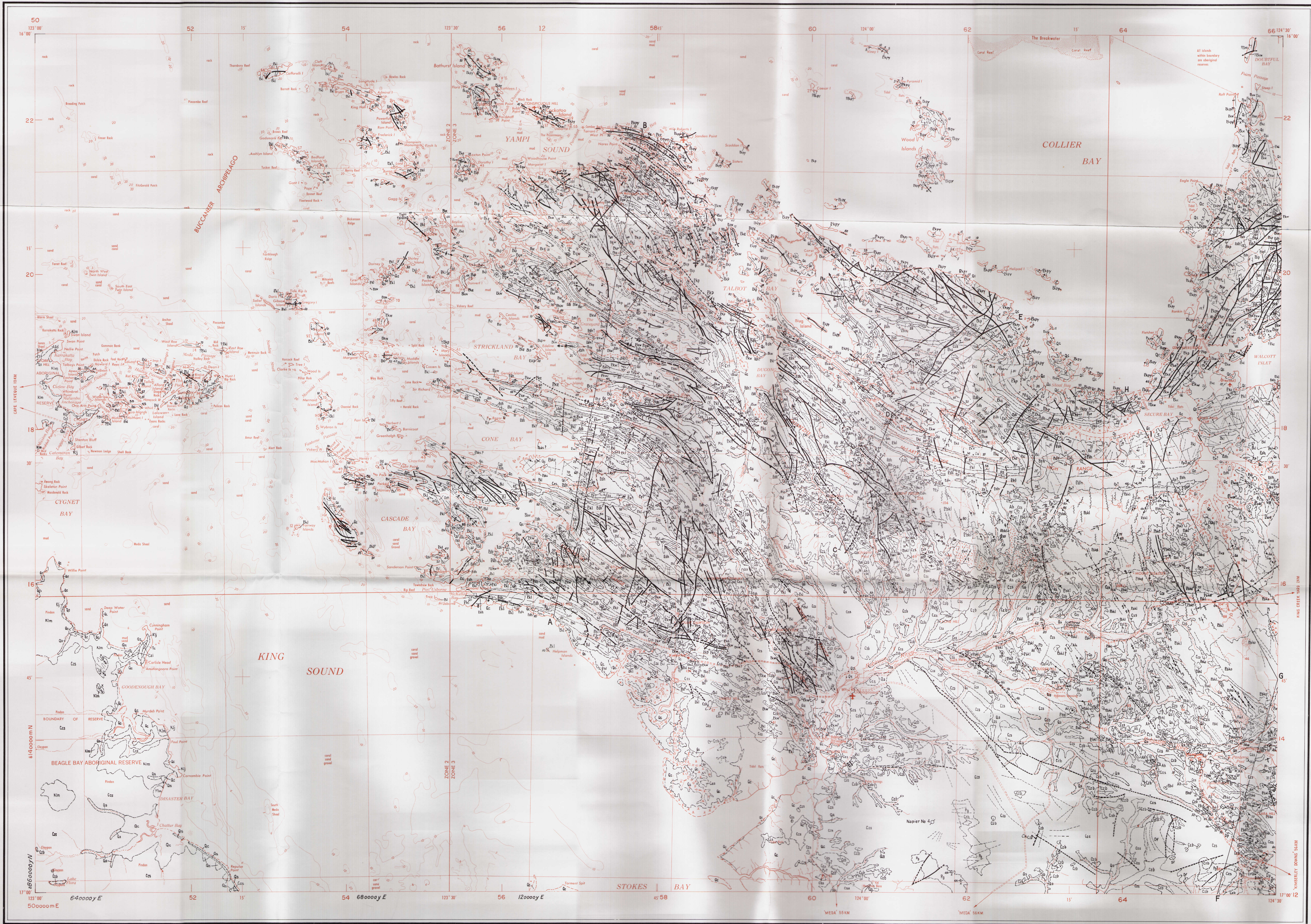
WESTERN AUSTRALIA

AUSTRALIA 1:250,000 GEOLOGICAL SERIES

SHEET SE 51-3

Reference



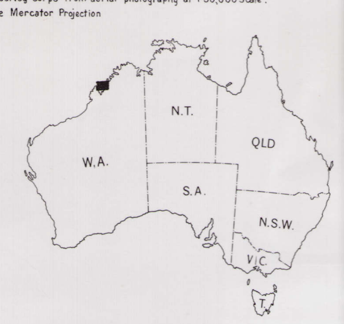


NOTE ON GRID COORDINATES

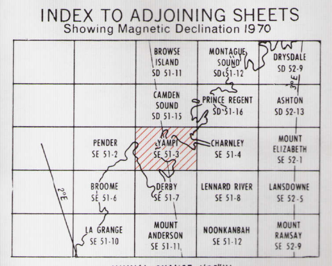
Brown lines with black italic numbers (numbers shown only at SW corner of map and change of zone), indicate the 10,000 yard grid, Zone 2&3 (Australia Series), CLARKE 1858 SPHEROID. Transverse Mercator Projection

Brown numbered ticks (with larger upright numbers), inside the neatline are 20,000 metre intervals of the superimposed Australian Map Grid, Zone 52 AUSTRALIAN NATIONAL SPHEROID. Transverse Mercator Projection

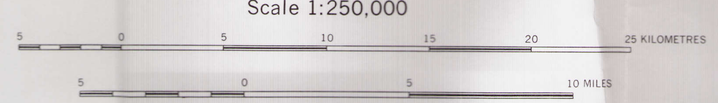
Compiled by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development, in conjunction with Geological Survey of Western Australia. Issued under the authority of Hon. R.W. Swartz, M.B.E., E.D., Minister for National Development. Base map compiled by the Royal Australian Survey Corps from aerial photography at 1:50,000 scale. Transverse Mercator Projection



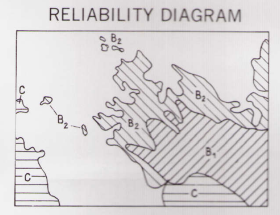
INDEX TO ADJOINING SHEETS



Scale 1:250,000



RELIABILITY DIAGRAM



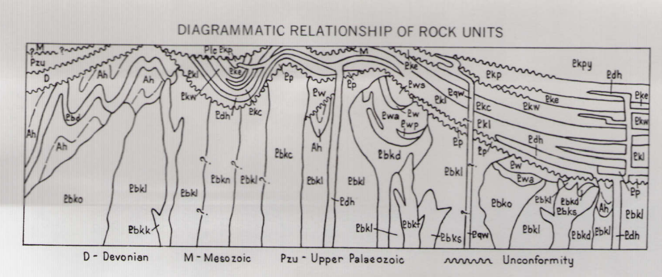
Geology 1948-51 by R.O.Brunnschweiler, D.Guppy and A.Linder (B.M.R.)
1963 by P.E.Playford and D.C.Lowry (G.S.W.A.)
1966-67 by D.C.Gellatly, G.M.Derrick, C.M.Morgan (B.M.R.); J.Sofoulis and R.A.Farbridge (G.S.W.A.)
Compiled 1966-69 by D.C.Gellatly, J.Sofoulis, G.M.Derrick, J.L.McGovern and T.Tatarow
Drawn by T.Tatarow and J.L.McGovern

Reference

CAINOZOIC	QUATERNARY			Qa	Alluvium
				Qc	Coastal mud, silt and sand; thin salt crust locally
				Qs	Beach and dune sand
				Czs	Residual soil, sand, eluvium, colluvium
				Czb	Black soil
				Czl	Ferricrete; ferruginous pisolitic sandy soil
	TERTIARY			Tp	Pisolitic laterite
			Pender Bay Conglomerate	Tc	Dark grey boulder to pebble conglomerate
MESOZOIC	CRETACEOUS	APTIAN	Melligo Sandstone	Klm	White to pale grey, medium to coarse grained quartz sandstone: completely silicified: large scale cross-bedding locally
		VALANGINIAN	Jowlaenga Formation	Klj	Fine to medium-grained quartz sandstone, poorly sorted, commonly ferruginous
PALAEOZOIC	PERMIAN	SAKMARIAN	Grant Formation	Pg	Massive aqueoglacial unsorted silty sandstone, conglomeratic sandstone, tillite, siltstone, shale
	PERMIAN?		Lillybooroora Conglomerate	Plc	Boulder and cobble conglomerate
	DEVONIAN	FAMENNIAN	Fairfield Formation	Df	Silty limestone and calcarenite; calcareous shale and siltstone
		FAMENNIAN TO FRASNIAN	Windjana Limestone	Dw	Reef facies: massive algal and stromatoporoid limestone, dolomitized in part
			Pillara Limestone	Dp	Back-reef facies: bedded stromatoporoid limestone; calcarenite and calcilutite
			Napier Formation	Dn	Fore-reef and inter-reef facies: calcarenite, calcirudite and megabreccia
				p€	Section only
PROTEROZOIC (LOWER PROTEROZOIC*)	CARPENTARIAN	Intrusive into Kimberley Group	Wotjulum Porphyry	Ƥqw	Massive quartz feldspar porphyry: sheared and sericitic locally
			Hart Dolerite	Ƥdh	Dark grey and green-grey tholeiitic dolerite; minor pink-grey granophyre
		Kimberley Group	Pentecost Sandstone	Ƥkp	White well-sorted quartz sandstone, grey siltstone
			Yampi Member	Ƥkpy	Pink-brown arkose and feldspathic sandstone; siltstone, hematitic quartz sandstone, glauconitic sandstone. Iron ore
			Elgee Siltstone	Ƥke	Red-brown and grey siltstone and minor phyllite; thin sandstone interbeds. Basal boulder to pebble conglomerate
			Warton Sandstone	Ƥkw	White well-sorted quartz sandstone and feldspathic sandstone; siltstone interbeds; andalusite granofels locally
			Carson Volcanics	Ƥkc	Tholeiitic basalt and spilite, locally amygdaloidal; tuff, agglomerate. Feldspathic sandstone
			King Leopold Sandstone	Ƥkl	White to buff coarse-grained well sorted quartz sandstone
		Speewah Group		Ƥp	White to pale purple-brown quartz sandstone; micaceous locally; minor phyllite and pebble conglomerate
		Lamboo Complex	Cone Hill Granite	Ƥbkc	Coarse-grained porphyritic biotite granite
			Kongorow Granite	Ƥbkk	Foliated coarse-grained porphyritic biotite granite and adamellite
			Tarraji Microgranite	Ƥbkt	Porphyritic biotite microgranite
			Secure Bay Adamellite	Ƥbks	Coarse-grained leucocratic biotite adamellite; sparsely porphyritic locally
			Lennard Granite	Ƥbkl	Coarse-grained leucocratic porphyritic biotite granite. Xenolith-rich granite. Muscovitic granite. Biotite granodiorite
			Mondooma Granite	Ƥbko	Porphyritic microgranite and microgranodiorite. Non-porphyritic microgranodiorite and microtonalite
			Mount Disaster Porphyry	Ƥbkd	Coarsely porphyritic biotite microgranite and microgranodiorite
			Whitewater Volcanics	Ƥw	Rhyodacite welded ashflow tuff; mainly crystal poor
				Ƥwa	Crystal-rich rhyodacite welded ashflow tuff
				Ƥws	Fine-grained bedded tuffaceous greywacke and bedded tuff
				Ƥwp	Crystal poor rhyodacite ash flow tuff
			Nellie Tonalite	Ƥbkn	Hornblende-biotite tonalite and granodiorite
			Woodward Dolerite	Ƥbd	Dark green coarse-grained metadolerite; porphyritic locally
ARCHAEAN? (ARCHAEAN OR LOWER PROTEROZOIC*)		Halls Creek Group		Ah	Muscovite, sericite, and chlorite schist; phyllitic shale siltstone and greywacke; minor chloritoid, andalusite and garnet schist

* Subdivision of Precambrian time-scale used by the Geological Survey of Western Australia, shown in brown.

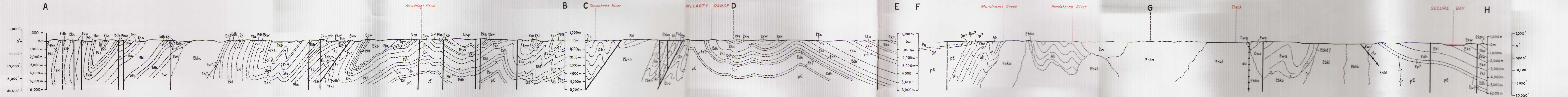
DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



D - Devonian M - Mesozoic Pzu - Upper Palaeozoic Unconformity

Sections

Cainozoic sediments omitted
(Faults shown as vertical where attitude is unknown)



PRELIMINARY EDITION, 1971

SUBJECT TO AMENDMENT

YAMPI

SHEET SE 51-3