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The Geology of Arnhem Land, Northern Territory
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K A Plumb and H G Roberts*

*formerly Bureau of Mineral Resources, Geology and Geophysics

DEPARTMENT OF PRIMARY INDUSTRIES AND ENERGY

Minister for Resources: The Hon. Alan Griffiths

Secretary: G.L. Miller

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Executive Director: R.W.R. Rutland AO

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FOREWORD

The province now known as the McArthur Basin was geologically mapped by BMR between 1959 and 1962. Arnhem Land, the less accessible northern part of the province, was mapped in 1962. 1:250 000 Geological Sheets and Explanatory Notes were published through the late 1960's, but detailed Bulletins, widely quoted as Dunn, Smith and Roberts - Roper River-Queensland border (in prep) and Roberts, Dunn, and Plumb - Arnhem Land (in prep.), were never completed.

The southern McArthur Basin has been the subject of continuing studies and major revision through the 1960's to 1980's. The comprehensive synthesis by Jackson and others (1987) details these data and interpretations and incorporates, as appropriate, data from the unpublished manuscript of Dunn and others.

No systematic surveys, other than company exploration programs, have been carried out in Arnhem Land since 1962. The 1962 survey remains the fundamental source of data from that area. The unpublished data have been utilised, reinterpreted, and integrated with summaries of southern McArthur Basin data in several interregional syntheses (e.g., Plumb and Derrick, 1975; Plumb and others, 1980, 1981, 1990), but the detailed manuscript has remained unavailable to workers outside BMR. This report presents that unpublished manuscript of Roberts and Plumb, updated and revised as appropriate to accord with latest concepts and knowledge from the southern McArthur Basin.

Dramatic advances in geological concepts and models in recent years render much of the interpretative sections of the original Roberts and Plumb manuscript obsolete. These superseded sections have been omitted or replaced by discussions which place the original data into a modern context, both in terms of recent concepts from the southern McArthur Basin and elsewhere in northern Australia. The younger Mesozoic and Cainozoic cover is not discussed herein. The major advances in mining and economic geology have taken place since 1962 and are discussed in various published sources outside of BMR, and so they are not be discussed in detail herein.

At the time of publication a new project has commenced in Arnhem Land, under the National Geoscience Mapping Accord (NGMA), which is expected to significantly enhance knowledge of this area, particularly in the fields of sedimentology, petrology, geochemistry, geochronology, structure, and stratigraphic correlation. Publishing this manuscript at this time formalises the original stratigraphic nomenclature definitions and documents the original basic data, both as a prelude to the new NGMA project and as detailed background to the interregional syntheses referred to above.

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SUMMARY

Previously unpublished results from the 1962 geological survey of Arnhem Land are detailed, in the context of modern concepts of North Australian geology . Access problems to aboriginal land has prevented any further major work in the region since 1962. Stratigraphic units are formally defined for the first time.

Arnhem Land occupies the northwestern part of the prospective, Proterozoic McArthur Basin. The McArthur Basin unconformably overlies a basement of Palaeoproterozoic metamorphic rocks and a post-tectonic felso volcano-plutonic suite in the Arnhem Block, formed during the Barrumundi Orogeny and probably continuous in the subsurface with the Pine Creek Inlier. Both tectonic units are unconformably overlain by the flat-lying Arafura Basin succession, of Cambrian age.

The basement rocks range from greenschist to granulite facies metamorphism. The volcano-plutonic suite is unusual in containing fayalite, and may be part of an A-type suite.

Equivalents of the principal sequences of the McArthur Basin in the prospective McArthur River region are identified and described. The evolution of the McArthur Basin may be modelled in terms of asymmetric rifts, formed by oblique extension along major strike-slip fault systems. Arnhem Land is highly prospective for lead-zinc, bauxite, and manganese.

The principal geological features and economic geology are succinctly outlined in a special 'Geological Outline' section.

INTRODUCTION

In 1959 the Bureau of Mineral Resources (BMR) began a program of regional geological mapping of some 235,000 km^2 of country bordering the Gulf of Carpentaria, in the northeastern part of the Northern Territory. It followed similar mapping programs in the adjoining northwest Queensland and Katherine-Darwin regions (Carter, Brooks and Walker, 1961; Walpole and others, 1968). Field work was completed in 1962 with the mapping of Arnhem Land, the subject of this report.

Prior to 1954 little was known of the geology of the area; indeed along parts of the coast the only recorded observations on the geology had been made by Flinders (1814) and King (1827) during their exploratory voyages. Other observations had been made by various geologists and explorers but these dealt mainly with small isolated areas. Regional reconnaissance surveys carried out by mineral exploration companies between 1954 and 1959 established the essential geological unity of the area extending along the Gulf of Carpentaria from the Queensland/Northern Territory border to the north coast of Arnhem Land; this area, which contains extensive exposures of Proterozoic rocks, encompasses essentially of all of the outcropping area now known as the McArthur Basin, and its scattered basement inliers.

1:250 000 Geological Sheets and Explanatory Notes covering the whole of the McArthur Basin were published through the late 1960's, and those covering Arnhem Land were synthesised into a 1:500 000 map (Plate 1). However, proposed BMR Bulletins covering the basin, widely quoted in early publications as Dunn, Smith and Roberts - Roper River-Queensland border (in prep) and Roberts, Dunn, and Plumb - Arnhem Land (in prep.), were never completed. This report presents the unpublished manuscripts of Roberts and Plumb, updated as appropriate to accord with revised concepts and knowledge from continuing studies in the more easily accessible southern McArthur Basin.

Location

Arnhem Land lies in the northeastern part of the Northern Territory; in the north it is bounded by the Arafura Sea and in the east by the Gulf of Carpentaria. The southern and western limits of Arnhem Land are taken as latitude 14°S and longitude 133°30'E respectively. This area coincides for the most part with the boundaries of the Arnhem Land Aboriginal Reserve. Arnhem Land is covered by nine Sheets of the Australian National Grid; the three easternmost areas (Truant Island, Gove, and Port Langdon) have been combined in the 1:250 000 Geological Series with their respective westerly adjoining Sheet areas (Wessel Island, Arnhem Bay, and Blue Mud Bay).

Access and infrastructure

At the time of the BMR survey, in 1962, the only permanent settlements were coastal settlements established to cater for the predominantly aboriginal population of the Arnhem Land Aboriginal Reserve. These were Maningrida (government settlement) and Milingimbi and Elcho Island (mission stations) on the north coast, Yirrkala (mission station) on Gove Peninsula, and Angurugu and Umbakumba (mission stations) on Groote Eylandt. Most aboriginals lived in these mission stations and just a few percent, totalling a few hundred people, were estimated to be nomadic aboriginals in bush camps. The only road to enter Arnhem Land terminated near the Bulman waterholes; it connected the Bulman district with Mainoru homestead, Beswick homestead, Maranboy, and Katherine, 305 km distant. Within Arnhem Land, tracks had only been constructed in the immediate vicinity of the several coastal settlements; they rarely extended more than 15 km from the settlements.

Crohn (1954) of the Broken Hill Proprietary Co Ltd had negotiated a vehicular route from Bulman to the northeast; he travelled along Annie Creek until it met the Goyder River, which was crossed near latitude 13°S. From this point he travelled eastwards to Ritarango Gap, which gave access to areas east of the Mitchell and Parsons Ranges. The 1962 BMR party followed Crohn's route and, from the Ritarango Gap, were able to travel, without great difficulty, to points as far afield as Caledon Bay, Yirrkala, the Flinders Peninsula, Bath Range, Walker River, and Rose River.

Since 1962 two new townships, with predominantly European populations, have been built to service new mining operations - Alyangula on Groote Eylandt in late 1965 and Nhulunbuy in 1969 on Gove Peninsula. In response to evolving government policies on self determination and return to traditional culture, major aboriginal-governed townships have been established at Yirrkala, Gapuwiyak (Lake Evella), Maningrida, Elcho Island, and Bulman, and at Numbuwah (Rose River) and Ngukurr (Roper River) to the south of the area covered by Plate 1, while nomadic bush camps have been replaced by numerous small permanent settlements for the traditional owners throughout Arnhem Land.

Activity by mineral exploration companies through the 1960's-1970's established an extensive network of tracks suitable for four-wheel drive vehicles. These tracks have continued to be used and extended by aboriginal communities, so that a network now links all bush communities and townships from the Roper River to Nhulunbuy, and thence westward to Manigrada and Bulman. In 1991 all-weather gravel roads linked Nhulunbuy to Katherine via Bulman, Ngukurr to Katherine via Mataranka, and Maningrida to Darwin via Kakadu.

Substantial sealed airstrips are available at Gove (Nhulunbuy) and Groote Eylandt (Alyangula). Major unsealed or sealed airstrips are maintained at the other townships, and substantial graded dirt strips are available at many of the bush settlements. Regular interstate air services are available to Gove and Groote Eylandt via Darwin and Cairns. Light aircraft commuter services connect the townships to Darwin or Katherine. Numerous charter aircraft are available throughout the area. Port facilities have been established at Gove and Groote Eylandt capable of holding large ore-carriers, and bulk goods are supplied to the townships by ship. Commercial barges regularly service other coastal settlements.

Permits to enter: The area under discussion lies wholly within the Arnhem Land Aboriginal Reserve, except for exemptions applying to special leaseholds around the townships of Alyangula, Groote Eylandt and Nhulunbuy, Gove Peninsula. All persons of non-aboriginal descent must obtain permits from the Northern land Council in Darwin before entering any part of the aboriginal reserve. In addition entry to any specific area must be negotiated with appropriate local land councils and traditional owners.

Climate and Vegetation

Arnhem Land lies between latitudes 11°S and 14°S and has a monsoonal climate, with distinct wet and dry seasons. The wet season extends from December to April and the dry season from May to November. January, February, and March are the wettest months; April, December, and November less so, and negligible amounts of rain fall between May and October.

Along the north and east coast an average of up to 1300 mm of rain falls annually, but in the southwest the average is only about 900 mm. The potential average annual evaporation is about 1800 mm in the northeast and 2200 mm in the southwest.

During January the normal daily maximum temperature ranges from about 31°C on the north coast to 35°C inland; the daily minimum is around 25°C throughout the area. During July the normal daily maximum temperature is around 30°C, but the daily minimum ranges from 18°C on the north coast to 15°C inland. During the dry season however the area east of the Parsons Range has a noticeably higher humidity than farther west due to the influence of southeast trade winds blowing across the Gulf of Carpentaria.

Southeasterly winds are predominant during the dry season. Winds are more variable during the wet season, but northwesterly and northerly winds predominate. Periods of calm are more frequent in the wet season, but are punctuated by violent storms and cyclones.

Despite the high annual rainfall, vegetation in Arnhem Land is rarely sufficiently dense to prevent vehicular travel. Most of the area east of the Mitchell and Parsons Ranges is covered by open *Eucalyptus* woodlands; stands of Cyprus pine *(Callistris)* occur along the eastern margin of the ranges, and small palm-like trees *(Livingstonia spp.)* are abundant to the east. In the Mitchell and Parsons Ranges and Arnhem Land Plateau spinifex grass *(Triodia spp.)* and low scrub predominate. To the west of the ranges vegetation is more sparse: tall *Eucalypts* and paperbarks *(Melaleuca spp.)* line the major watercourses, but elsewhere open grassy patches alternate with areas of low scrub and open woodlands. The geological control of vegetation is pronounced in the western area: the areas underlain by dolerite are well grassed and devoid of trees; the carbonate rocks give rise to poorly grassed areas with stunted scrub and occasional trees; and arenites are covered with spinifex and scattered low scrub. Most of the coastal tidal flats are fringed by mangroves.

PREVIOUS GEOLOGICAL INVESTIGATIONS

The first recorded geological observations on Arnhem Land were made by Matthew Flinders, who, in 1803, charted the eastern and northeastern parts of the Arnhem Land coastline (Flinders, 1814). He described the geological and physiographic features of parts of the mainland and many of the islands and made collections of the rocks encountered. In 1818-19 King (1826) completed the charting of the coasts and added to the rock collections. King's and Flinders' specimens and physiographic data were studied in London by W H Fitton who constructed a remarkably accurate account of the geology of the Arnhem Land coast (Fitton, *in* King, 1826).

For well over a century, indeed until 1962 when the present survey was completed, Fitton's account contained the only published information on the geology of many of the islands off the Arnhem Land coast. It is paradoxical that one of the earliest geological accounts of a part of Australia described the fringe of an area which was destined to remain one of the least known parts of the continent. Remarkably, Fitton recorded 'ferruginous oxide of manganese' in the Blue Mud Bay area, an occurrence noted again by Brown (1908) and only in recent years rediscovered.

The establishment of permanent European settlement in the Northern Territory in 1869, and the ensuing discovery of mineralisation in the Katherine-Darwin region, led the Government of South Australia, which was at the time responsible for the Territory, to sponsor geological surveys. One of the first surveys was made by Tate (1882), the Professor of Natural Science in the University of Adelaide. Tate did not visit Arnhem Land, but he was able to show on his map the occurrence of granite near Melville and Caledon Bays, 'metamorphic slates' near Cape Wilberforce and on Morgan Island, and 'Desert Sandstone' on Groote Eylandt and Bickerton Island. The source of his information is not given, but may partly have been interpreted from Fitton's work. Tate regarded the rocks forming the western scarp of the Arnhem Land Plateau as part of his 'Desert Sandstone', and regarded them as of probable Upper Miocene age.

In 1883 the surveyor, Lindsay (1884, 1887) made extensive explorations and recorded notes on the rocks encountered along his course; these provide the first significant record of the geology of the Arnhem Land interior.

Woods (1886) described the geology of the country between Katherine and Darwin, and was critical of Tate's (1882) interpretation of the 'Desert Sandstone'; Woods argued that the 'Desert Sandstone' was not as extensive in its distribution as Tate had supposed, and suggested, in contradiction to Tate, that auriferous rocks might occur to the east within the Arnhem Land Plateau.

In 1894-95 Brown (1895), the Government Geologist, made extensive traverses throughout the Northern Territory and, although he did not visit Arnhem Land, he recommended that an examination of the Blue Mud Bay and Cape Arnhem districts be undertaken 'as it is supposed that there are areas occupied by rocks likely to be auriferous'. Twelve years later Brown (1908) made numerous observations along the Arnhem Land coast; he regarded the 'quartzite, sandstone, grit, conglomerate, and shale' of the Goyder River, Elcho Island, Mallison Island, and Cape Wilberforce areas as Permo-Carboniferous, and the granites of Melville and Caledon Bays as Precambrian. He made mention of manganese oxide on a beach on Groote Eylandt and had a sample of bauxite from the Cobourg Peninsula assayed; The latter was the first discovery of bauxite in the Northern Territory, and attracted the interest of Owen (1954) to the region with the eventual discovery of the deposits at Gove, while economic manganese was discovered on Groote Eylandt in the 1960's (Smith & Gebert, 1969.).

Prompted by Brown's recommendations, and by the discovery of lead-zinc mineralisation at Bulman in 1909, several prospecting parties set out to search for minerals in Arnhem Land. Among these were parties led by Love (1911) and Murphy (1912). Their reports added little to the meagre geological knowledge of the area, although Love can be credited with the discovery of what we now call the Gunbatgari Granite, and perhaps part of the Nimbuwah Complex.

In 1914 Jensen (1914), who succeeded Brown as Government Geologist, landed at several localities on the Arnhem Land coast; he considered the rocks of the Wessel Islands, Cape Wilberforce, English Companys Islands, and Groote Eylandt to be Permo-Carboniferous, with a capping of Tertiary sediments. Gray (1915), an assistant to Jensen, reported on the granites of the present Nimbuwah Complex.

In 1922 the Reverend J C Jennison was sent to establish a mission station on Elcho Island, and while doing so he discovered 'cakes' of bitumen. A company was formed to undertake drilling there, and the Government Warden and Assayer was subsequently sent to examine the occurrence (Bell, 1923). Wade (1924) visited the island and reported that some of the strata were bituminous and that the rocks were 'certainly of Lower Cambrian age, and possibly of Precambrian age'.

Little if any geological work was done in Arnhem Land between 1924 and 1951 due initially to the depression in the 1930's, and later to World War II; during the war numerous airstrips were constructed in Arnhem Land, among them being the 6000-foot sealed airstrip at Gove, which was built (unwittingly) on foundations of Gove bauxite. In 1949 H B Owen of the BMR, in the course of an Australia-wide survey for bauxite, requested members of the Northern Territory Coast Patrol Service to collect specimens of pisolitic material from the Arnhem Land coast (Owen, 1954). Before the end of the year Captain F E Wells and Seaman F J Waalkes, of the Patrol Service, had forwarded specimens of bauxite from Truant Island and Wessel Islands containing between 34.6% and 40.8% available Al_2O_3. It was not until October, 1951 that Owen was able to make a reconnaissance visit to the deposits with Captain Wells. During this reconnaissance they also visited the shores of Melville Harbour but they only found siliceous and ferruginous laterite of granitic origin. As a result of this reconnaissance the Australian Aluminium Production Commission, in 1952, tested the Wessel Islands deposits extensively (Puckey & Richardson, 1952) but while this work was proceeding Captain Wells, in February 1952, collected a specimen of pisolitic bauxite containing 52.6% Al_2O_3 from near Gove airstrip. Owen visited the deposit in August, 1952 (Owen, 1952) and all attention was subsequently directed to Gove instead of Wessel Islands. In 1955 the New Guinea Resources Prospecting Co investigated the deposits at Gove (Gardner; 1955, 1957). The Commonwealth Aluminium Corporation (COMALCO) carried out a detailed survey of the area in 1958 and was granted Special Mineral Lease No. 1 which was subsequently terminated about 1964 (Dunn, 1965). In 1961 the Gove Bauxite Corporation Limited began a survey of areas exclusive of SML No 1 (Dickinson, 1961) and in 1963 was granted SML's 2, 3 and 4. These were subsequently transferred to Gove Mining and Industrial Corporation Ltd but work on the leases has since lapsed. Later assessment of the deposits eventually led to mining of them commencing in 1971.

In 1952 the Enterprise Exploration Co. became interested and reported on the Bulman lead-zinc deposits (King (1952); Sturmfels (1952); Knight (1952); B.P. Walpole of the BMR also visited the area (Opik, 1952)). Patterson (1958) made a helicopter reconnaissance of much of the Mount Marumba Sheet area.

Meanwhile, in 1954, P W Crohn of the Broken Hill Proprietary Co Ltd made an extensive reconnaissance of the central part of Arnhem Land; this was the first attempt at systematic regional geological mapping in Arnhem Land. The maps of Crohn and Patterson provided a useful basis for the present survey.

In 1955 Dixon of Frome-Broken Hill Co Pty Ltd undertook a reconnaissance survey of the Gulf of Carpentaria, during the course of which he visited Groote Eylandt and the islands of Blue Mud Bay (Dixon, 1956).

During 1958 Williams & Waterlander (1958, 1959) of the BMR conducted underwater gravity surveys along the Arnhem Land coast and in 1960 the CSIRO (1963) made oceanographic observations in the Arafura Sea, and Gulf of Carpentaria during the course of a much wider investigation. During 1962 aeromagnetic studies were made by Hartman (1962) over the Gulf of Carpentaria on behalf of the Delhi-Australian Petroleum Co.

In November, 1960 P R Dunn of the BMR noted manganese outcrops near Angurugu mission station on Groote Eylandt, and during further examination with P W Crohn of the Northern Territory Administration Mines Branch recognised their economic potential; the discovery is described by Crohn & Dunn (1965). During 1961 Crohn carried out preliminary testing of the deposits by pitting with the assistance of mission staff, and improved the potential of the deposits (Crohn, 1962). In May, 1962 W C Smith of the Broken Hill Proprietary Co Ltd visited the island and recognised that the deposits may be part of a large sedimentary deposit (Smith & Gebert, 1969). A lease over the deposits was negotiated with the Northern Territory Administration and the mission authorities, and a reconnaissance test program was carried out in late 1962. As a result of more extensive testing between 1963 and 1967 planning for development commenced in 1964 and the first shipment of ore left the island in March 1966.

Since 1962 Rix (1963) has investigated water supplies at Maningrida, Milingimbi, and Elcho Island; a small ironstone deposit was discovered on Elcho Island (Rix, 1964). Arnhem Land was covered by a reconnaissance gravity survey by BMR in 1967 (Whitworth, 1970). There has been a considerable amount of work carried out by mineral exploration companies in many parts of Arnhem Land, and by oil exploration companies in the offshore Arafura Basin, but the details are not known by us; no further significant discoveries have been announced.

PRESENT INVESTIGATIONS

The investigations on which this Bulletin is based were conducted between May and October 1962 by a BMR field party; geologists in the party were P Rix, D Dunnet, P R Dunn, and the authors. The project was under the supervision of D A White and B P Walpole, R A Ruker assisted in the field work for five weeks, and S K Skwarko spent several weeks in the area collecting Mesozoic fossils. Prior to the field mapping the area was photo-interpreted by the Institut Francais du Petrole in association with the BMR; R A Ruker (BMR) prepared photogeological maps of the Milingimbi, Mount Marumba, and Blue Mud Bay/Port Langdon 1:250 000 Sheet areas, and W J Perry (BMR) prepared a photogeological map of the Arnhem Bay/Gove and Wessel Island/Truant Island Sheet areas. These maps were utilised in the field and contributed much to the planning of the field survey.

Survey Methods

Field mapping was conducted from two main base camps; the first, near Bulman waterhole, was used for the mapping of the Mount Marumba Sheet area and the second, on the western side of the Mitchell Range, was used in the mapping of the remainder of the area. A primitive vehicle track between the two camps was established by the repeated use of the same route. The party was equipped with six short-wheel-base Land Rovers, two long-wheel-base Land Rovers, and a Bedford 5-ton 4-wheel drive truck. Vehicle traverses covered most of the Mount Marumba Sheet area, most of the mainland part of the Blue Mud Bay/Port Langdon Sheet area, and the most critical parts of the Arnhem Bay/Gove Sheet area. Traverses were spaced in accordance with the complexity of the geology. A helicopter was used to visit the more inaccessible areas, and landings were made at several hundred points throughout Arnhem Land; Milingimbi, Junction Bay, islands of the Arnhem Bay/Gove and Blue Mud Bay/Port Langdon Sheet areas, were covered almost exclusively in this manner. Over 8000 miles (140 flying hours) were flown during the survey.

Compilation

Mapping was carried out with the aid of air-photographs at a scale of approximately 1:50 000, flown by the Royal Australian Air Force in 1950. The geology was photo-interpreted onto transparent photo overlays and this information was then transferred, in most cases, onto photo-scale slotted template assemblies prepared by the Royal Australian Army Survey Corps, which were subsequently reduced to a scale of 1:250 000. Most of the 1:250 000 Geological Sheets were compiled in this way, but the Milingimbi and Mount Marumba Sheets were compiled directly from reduced photo-overlays.

In addition to the air-photographs, slotted template assemblies, and 1:250 000 planimetric sheets, a series of photomosaics at a scale of about 4 miles to the inch, prepared by the Division of National Mapping, were available in the field for air-navigation and general planning.

Mapping was greatly facilitated by the photo-interpretation, and most of the geological features such as trend lines, faults, and geological boundaries show up clearly on the photographs, particularly in the less thickly vegetated areas.

Related Publications

The six Sheets covering Arnhem Land have been published in the 1:250 000 Geological Series, together with Explanatory Notes. This Bulletin incorporates the information presented in the Explanatory Notes, and presents a more detailed account of the regional geology and structure of the area. The published Sheets and accompanying Explanatory Notes are as follows:

Junction Bay SC/53-14 (Rix, 1965)
Wessell Islands/Truant Island SC/53-14 & 15 (Plumb, 1965)
Milingimbi SD/53-2 (Rix, 1965)
Arnhem Bay/Gove SD/53-3 & 4 (Dunnet, 1965)
Mount Marumba SD/53-4 (Roberts & Plumb, 1965)
Blue Mud Bay/Port Langdon SD/53-5 & 6 (Plumb & Roberts, 1965).

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PHYSIOGRAPHY

Arnhem Land may be conveniently divided into three broad physiographic provinces - the *Gulf Fall,* which comprises the hilly country drained by streams flowing into the Gulf of Carpentaria; the *Arafura Fall,* which comprises the hilly country drained by streams flowing into the Arafura Sea, and the *Coastal Plain,* which lies at lower elevations between the hilly country and the sea. Several subprovinces can be delineated within each province; readers are referred to the Physiographic Sketch Maps in appropriate Explanatory Notes for distributions of these subprovinces, and to Plate 1 for topographic localities.

The Gulf Fall lies to the southeast and the Arafura Fall to the north of a watershed which extends from near Yirrkala along the Mitchell and Parsons Ranges and westwards around the headwaters of the Wilton River to the western margin of Arnhem Land. The watershed rises from sea level near Yirrkala to about 100 m at the foot of the Mitchell Range, with an average rise of about 0.63 m per km. In the Parsons Range it reaches 330 m, but between the headwaters of the Phelp River and the headwaters of Annie Creek it drops to about 180 m. Farther north and west it attains elevations of 360 to 390 m.

Gulf Fall

In general terms the Gulf Fall is a gentle slope descending seawards from the watershed and intersecting the subhorizontal surface of the Coastal Plain at elevations ranging from sea level to about 60 m. The Gulf Fall, however, includes several important areas which are near-horizontal or more elevated than the surrounding country: the Lindsay Tableland, the Walker Plateau, the Bath Range, the Groote Eylandt Plateau, and the Parsons and Mitchell Ranges, all of which have been designated as subprovinces.

The general elevation of the Gulf Fall (excluding the subprovinces) decreases steadily from the watershed to the Coastal Plain, but the differential resistance to erosion of the underlying strata has markedly influenced the topography. Arenites of the Katherine River Group form strong strike ridges and plateaux around the headwaters of the Wilton River, whereas the less resistant lutites, carbonates, and volcanics occupy valleys and depressions; relief is up to 120 m. To the southeast, the Dook Creek Formation, which consists predominantly of carbonate rocks and chert, tends to form low rounded hills. By contrast, the Roper Group between the Wilton River and Parsons Range forms a series of cuestas interspersed with lower gently undulating areas; relief rarely exceeds 30 m. To the south of the Walker Plateau and east of the Parsons Range the topography is generally more subdued and the relief ranges from about 15 to 30 m; both areas are underlain by the McArthur Group. A series of long parallel strike ridges is present where the strata have been folded, but where they are subhorizontal broad rounded hills have been developed. North of Blue Mud Bay, and along the coast to Yirrkala the Gulf Fall is underlain by a thin veneer of horizontal Cretaceous strata or the underlying granitic rocks. The Cretaceous outcrops are bounded by small scarps up to 15 m high. The granitic rocks are rarely well exposed but in places they produce tor-strewn hills and rises. Most of the area is less than 60 m above sea level.

The *Lindsay Tableland*, in the southwest of Mount Marumba Sheet area, is mostly flat and soil covered, but locally low hills and rises of Precambrian and Cretaceous rocks project above the general level. Most of the tableland is underlain by lateritised horizontal Cretaceous strata; exposures occur along watercourses and in small scarps within the tableland and along its eastern margin. The scarp along the eastern margin is higher around the headwaters of the Wilton River (up to 15 m high) than farther south. The general elevation of the tableland is 360 to 390 m in the north, but to the south it decreases to about 300 m.

The *Walker Plateau* is a dissected depressed plateau surrounding the headwaters of the Walker River, to the southeast of the Parsons Range in central Blue Mud Bay Sheet. Horizontal Cretaceous rocks, commonly covered by sand, underlie most of the area but Precambrian strata crop out in inliers along the main watercourses. The elevation of the Plateau ranges from about 100 to 150 m; the minimum elevation of the bed of the Walker River within the plateau is 50 m.

The *Bath Range*, in central Blue Mud Bay Sheet, is an elongate northerly-trending dissected plateau of McArthur Group rocks exposed in the core of a broad syncline; elevations range up to 150 m and the relief above the surrounding country is up to 100 m.

The *Groote Eylandt Plateau* is a rugged dissected plateau of horizontal arenites of the Groote Eylandt Beds. Elevations range up to 120 m and cliffs up to 45 m high are common along its margins.

The *Parsons* and *Mitchell Ranges* form part of the watershed between the Arafura and Gulf Falls and consequently overlap both provinces. The Parsons Range is a series of prominent northeasterly-trending strike ridges of resistant Parsons Range Group arenites separated by valleys and depressions cut into less-resistant beds. Elevations vary from 240 m in the south to 330 m in the north, and the relief is from about 120 m near the Walker Plateau to 270 m around the headwaters of the Koolatong River. The Mitchell Range is a northerly continuation of the Parsons Range. It contains mainly steeply-dipping intensely-faulted arenites of the Ritarango Beds which form a series of fault-bounded northerly and northeasterly-trending strike ridges. Relief is up to 180 m, but is generally less than 100 m. Elevations range up to about 250 m.

Arafura Fall

The Arafura Fall has a generally gentle slope descending from the watershed dividing the Arafura and Gulf Falls, to intersect the sub-horizontal and relatively low-lying expanses of the Coastal Plain along the north coast of Arnhem Land. The Arnhem Land Plateau, Guyuyu Plain, and the Parsons and Mitchell Ranges are identified as separate subprovinces.

The Arafura Fall is generally more subdued than the Gulf Fall. The topography of the northwestern half is largely controlled by the gently-dipping strata of the Arafura Basin (the Wessel Group). The lowermost formation of the Wessel Group (Buckingham Bay Sandstone) forms rocky dissected plateaux, at elevations ranging from 60 to 120 m, in a broad arc extending to the west and northeast of the Mitchell Range, but it is rarely exposed west of the Goyder River where it tends to form low sand-covered rises. The overlying Raiwalla Shale is poorly resistant and forms low rounded hills and rises interspersed with broad soil-covered plains; where it is capped by more resistant rocks it is exposed in cliff faces (e.g. Wessel Islands) or forms hill slopes and scarps (e.g. to the east of the Goyder River). The Marchinbar Sandstone, which overlies the Raiwalla Shale, is the most resistant unit of the Wessel Group and forms a discontinuous arcuate cuesta-form ridge about 300 km long, extending southwest from the northernmost point of the Wessel Islands. The overlying Elcho Island Formation is less resistant to erosion and is mostly obscured by the sand and soil of the Coastal Plain.

Outliers of Cretaceous strata form scattered mesas and plateaux throughout the Arafura Basin; an extensive plateau ranging in elevation from about 60 to 120 m has been preserved to the southwest of Buckingham Bay.

Elevations in the area encompassed by the Arafura Basin rarely exceed 120 m. Relief is seldom more than 30 m, except in the Wessel Islands where it is locally up to 90 m.

The topography of the eastern third of the Arafura Fall, in the area surrounding Arnhem Bay, is varied and is once again strongly influenced by the bedrock lithology and structure. South and southeast of Arnhem Bay lateritic soil, developed over Cretaceous rocks, covers wide flat area; relief rarely exceeds 15 m, and elevations are up to 90 m.

East of Arnhem Bay the relief becomes more pronounced, with elevations up to 150 m in the centre of the peninsula; the Cretaceous strata and accompanying laterite and lateritic soil are more deeply dissected to expose the older rocks.

Northeast of Arnhem Bay and in the English Companys Islands the topography is dominated by differential erosion of northwesterly-dipping Proterozoic rocks. The Spencer Creek Volcanics and Mount Bonner Sandstone form compound strike ridge extending southwest from Mount Bonner. To the northwest the low country around the Peter John River is underlain by the Wilberforce Beds and Cretaceous strata. These are succeeded by a cuesta of

Mallison Sandstone stretching from the Bromby Islands to Mallison Island. Most of the overlying Wigram Formation is less resistant and underlies the strait separating the English Companys Islands from the mainland; the islands are cuesta-form ridges protruding from the sea and are capped by arenites of the Pobassoo Formation and Astell Sandstone. The southeast coasts contain cliffs up to 75 m high and the northwest coasts are parts of dip-slopes which slope gradually down to the sea. Most of the islands rise to about 75 m above sea level, but Cotton Island rises to 125 m.

West of Arnhem Bay the tightly-folded strata of the Habgood Group produce a number of strong hogbacks with intervening low-lying undulating hills.

The *Arnhem Land Plateau*, in the western part of Arnhem Land, is underlain by resistant arenites of the Katherine River Group. The plateau is extremely dissected; the main watercourses form gorges up to 100 m deep and the tributaries are also deeply incised along faults and joints. The northern margin of the plateau is generally marked by a scarp up to 120 m high in the west, but decreasing to only about 15 m high in the east. The elevation of the plateau ranges from 150 m in the east to over 420 m in the west; local relief rarely exceeds 100 m, and in the less dissected southwestern part of the plateau is generally less than 30 m.

The *Guyuyu Plain* to the east of the Arnhem Land Plateau is bounded to the south by the main watershed. It has an elevation of about 200 m in the south, falling gradually to 75 m in the north. Most of the area is covered by sand and soil; the present of numerous sinkholes suggests that the plain is underlain by carbonate rocks of the Dook Creek Formation.

Coastal Plain

The Coastal Plain is a series of disconnected areas with low elevations and low relief bordering the coast; in places it extends up to 100 km inland. The surface slopes gently towards the sea, and elevations range from sea level to about 100 m around the headwaters of the Rose River. Most of the plain is covered by sand. This is in turn underlain by laterite which has been formed on a variety of rocks, but mainly on Cretaceous strata. The laterite is exposed in small scarps up to 10 m high along the coast. The Elcho/Drysdale chain of islands are almost flat; the elevation in the centre of the islands is only about 18 m, and they are almost invariably bounded by small cliffs, from 6 to 9 m high, produced by wave erosion of the soft laterite.

The *Tidal Flats* are most extensive around the estuaries of the major streams and in some cases they extend up to 30 km inland. They are subject to tidal and seasonal flooding and act as repositories for fine sand, silt, and evaporite deposits. Tidal streams meander through the flats.

Extensive *Coastal Dunes* occur along the east coast of the mainland, particularly north of Blue Mud Bay, and along the east coast of Groote Eylandt. The dunes are up to 75 m high and have been built up by wind action on beach-sand deposits stranded by marine regression. Dunes are also common on the north coast but are rarely more than 6 m high. Some are in the form of emerged offshore bars and act as barriers enclosing the seaward edges of the tidal flats; others are normal beach deposits built up at sea level by wave and wind action. Dunes representing ancient strandlines are common up to about 12 m above the present sea level.

Drainage

In the hilly country of both the Arafura and Gulf Falls the major streams are characterised in part by courses which could only have developed on a mature peneplain. The wide distribution of subhorizontal marine Lower Cretaceous strata in Arnhem Land indicates that most, if not all, of Arnhem Land was below sea level at that time. The subsequent epeirogenic emergence of the area during the Late Cretaceous or Tertiary probably provided the surface on which the main elements of the present drainage pattern were established. Continued uplift has led to the dissection and removal of much of the Cretaceous blanket, and the super-imposition of the old drainage pattern on the underlying rocks. Response to the greater lithological and structural diversity of the older rocks has led to some modification of the major streams, and to the development of complex systems of subsequent tributaries. After these features developed a substantial rise in sea level, or epeirogenic downwarp, resulted in the drowning of large areas of the old coastal region; high ridges remained above sea level and formed islands such as the Wessel Island chain. Wave erosion cut extensive shallow platforms and bevelled much of the area encompassed by the present Coastal Plain. The retreat of the sea to the present coastline sponsored the development of the numerous small consequent streams subperpendicular to the coastline on the Coastal Plain.

The Arafura Fall is drained by several major drainage systems. Most of the western area is drained by the Goomadeer, Liverpool/Mann, and Cadell/Blyth River system; these streams have gradients averaging about 2 m per km. The Goyder River system drains the central part of the Arafura Fall and has a general gradient of about 1 m per km. The streams draining the eastern part of the Arafura Fall generally have much steeper gradients and represent the headwaters of formerly more extensive systems; the streams draining into Arnhem and Buckingham Bays, for example, probably formed parts of a single system prior to their drowning.

It is similarly evident in the eastern part of the Gulf Fall that many of the streams, such as the Walker and Koolatong Rivers, were once part of a single system draining through the area now occupied by Blue Mud Bay. Like their northern counterparts they have gradients of 4 m per km or more.

The Rose River, which drains a small area in the central part of the Gulf Fall, is characterised by a low gradient and extensive anastomosing drainage channels. Except in its headwaters, the Wilton River has gradients of about 1 km per km and, like the Rose River, has many anabranchs and is generally bounded by wide alluvial plains.

GEOLOGICAL OUTLINE

TIMESCALE AND AGE CLASSIFICATION

EON	ERA	PERIOD
	(Base of Cambrian)	"Neoproterozoic III"
		650 Ma
	NEOPROTEROZOIC	CRYOGENIAN
		850 Ma
		TONIAN
	1000 Ma	
		STENIAN
		1200 Ma
	MESOPROTEROZOIC	ECTASIAN
		1400 Ma
PROTEROZOIC		CALYMMIAN
	1600 Ma	
		STATHERIAN
		1800 Ma
		OROSIRIAN
	PALAEOPROTEROZOIC	2050 Ma
		RHYACIAN
		2300 Ma
		SIDERIAN
	2500 Ma	
ARCHAEAN		

Figure 1. IUGS-approved chronometric subdivision of Precambrian time and the Proterozoic Eon (after Plumb, 1991).

At the time of the mapping of Arnhem Land described in this report no formal timescale was available for the Precambrian rock units in the 1:250 000 map series (Dunnet, 1965; Plumb, 1965; Plumb & Roberts, 1965; Rix, 1965a,b; Roberts & Plumb, 1965). The proposal of Dunn, Plumb, and Roberts' (1965) scheme for chronostratigraphic subdivision of the Australian Precambrian became available shortly afterwards and was used on the geological map (Plate 1, 1967) which accompanies this report. This scheme was progressively modified and eventually abandoned over the next couple of decades (Table 1). The new chronometric subdivision of Precambrian time, as approved by the International Union of Geological Sciences and formalised for international use (Fig. 1; Plumb, 1991) is now used throughout the text of this report.

Table 1 compares the time classification of Precambrian rock units in Plate 1 with this report, and also the evolving time classifications assigned to Arnhem Land rocks in principal publications since 1965.

REGIONAL TECTONIC SETTING

Arnhem Land occupies the northwestern part of the mildly-deformed, Statherian-Calymmian *McArthur Basin* (Fig. 2); the principal element of the North Australian Platform Cover (GSA, 1971, Plumb, 1979). The McArthur Basin unconformably overlies a basement of Orosirian metamorphic and late-tectonic granitic and volcanic rocks of the North Australian Orogenic Province, exposed within Arnhem Land as the various small inliers of the *Arnhem Block* and, to the northwest, the *Pine Creek Inlier*. In the north and extending offshore beneath the Arafura Sea, the McArthur Basin is in turn unconformably overlain by the Palaeozoic *Arafura Basin*, an element of the Central Australian Platform Cover.

The basement inliers of the *Arnhem Block* are probably continuous in the subsurface with the Pine Creek Inlier (GSA, 1971, Plumb, 1979), and developed during the ~1900-1840 Ma Barramundi Orogeny of Etheridge, Rutland and Wyborn (1987) or the ~1870-1800 Top End Orogeny of Needham, Stuart-Smith, & Page (1988). Highly deformed basement metamorphic rocks are intruded or overlain by mildly deformed post-tectonic granites and volcanics.

The *McArthur Basin* succession is constrained between about 1800-1400 Ma, with four principal successions separated by regional unconformities and deformation events of similar age to equivalent sequences and events in the Mount Isa Block to the southeast. The palaeogeography and structure of the basin may be modelled in terms of several asymmetric rifts, 30 to 80 km wide by 100 to >300 km long, separated by northwest trending transfer faults and transfer ridges (Fig. 3), and of a pattern and scale comparable with modern extensional basins (Plumb, 1987; Plumb & Wellman, 1987).

In Arnhem Land, 10 km of shallow water sediments accumulated over a period of more than 200 Ma in the central Walker Trough, compared to only about 2.5 km on the stable Arnhem and Caledon Shelves either side (Fig. 4) The 'central uplift' of the Mitchell Range probably originated as synrift tilt blocks during extension. Extension is thought to have been in

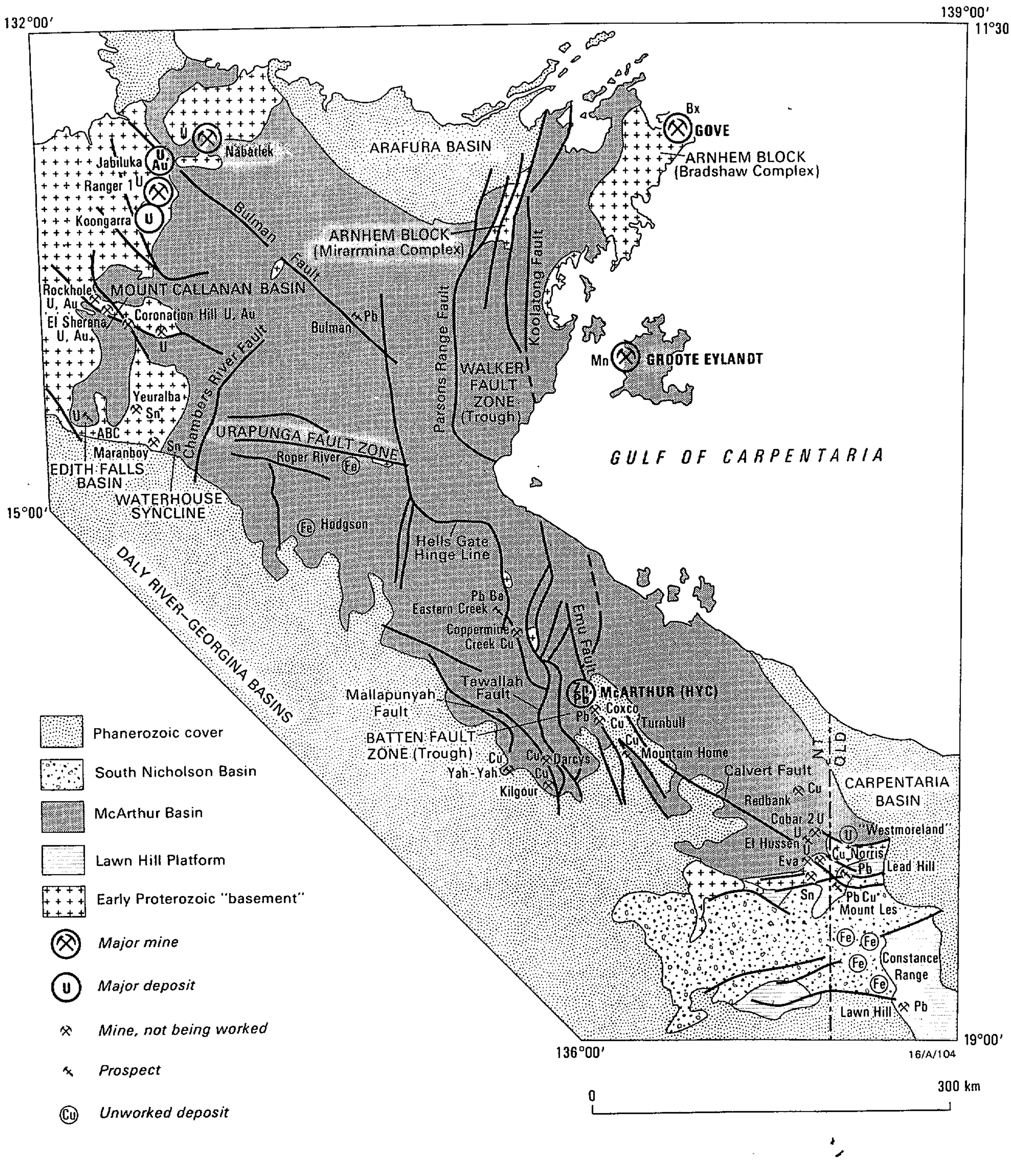


Figure 2. Principal structures and mineral deposits of the McArthur Basin and adjoining tectonic units surrounding Arnhem Land (from Plumb *et al.*, 1990)

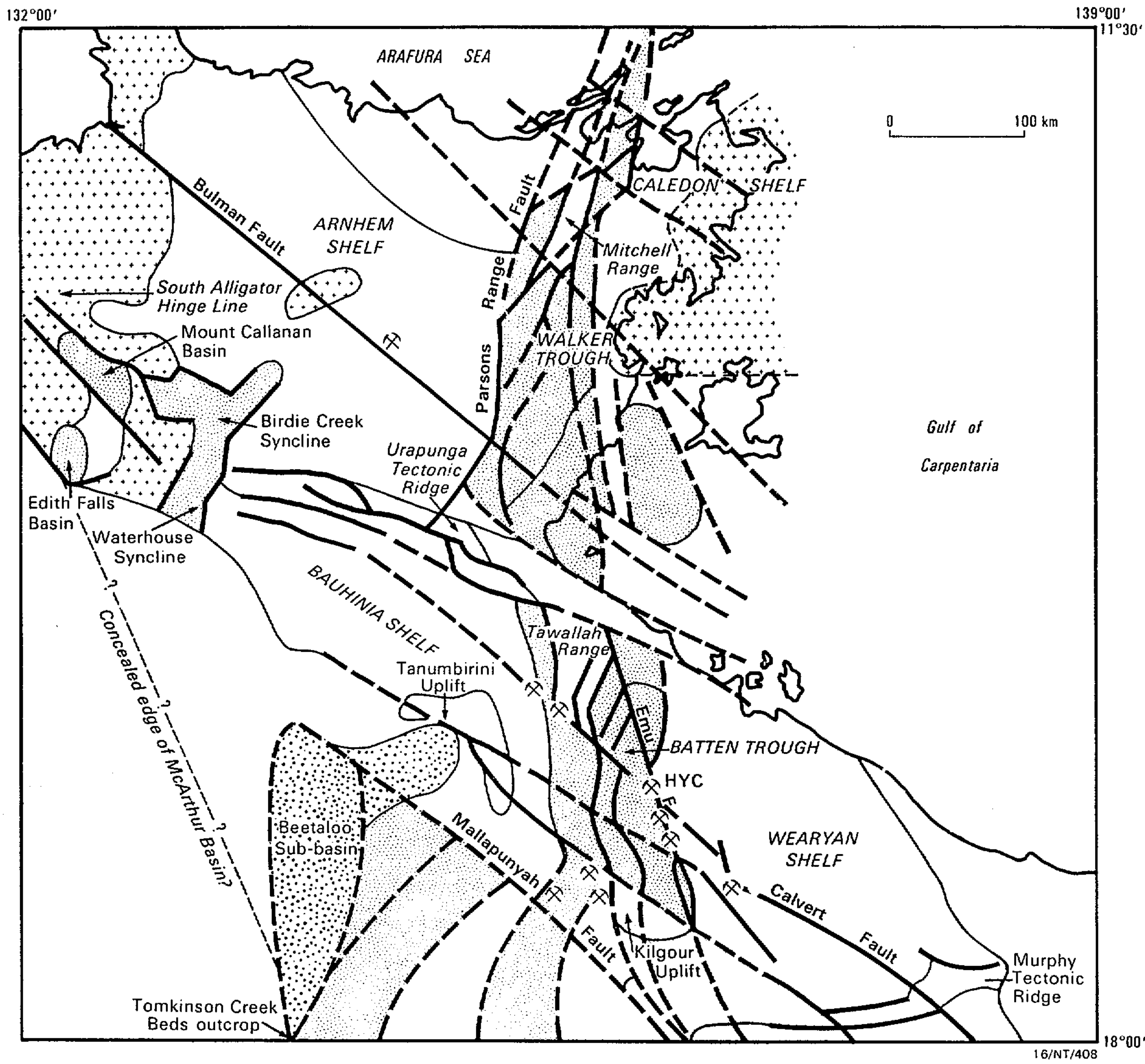


Figure 3. Tectonic setting of Arnhem Land, in terms of the principal tectonic elements of the McArthur Basin (after Plumb, 1987). Patterned areas outline major rifts (stipples), tectonic highs (diagonal lines) and basement inliers (crosses).

Table 1. Evolution of ages and time nomenclature applied to Proterozoic rock units in principal refences on Arnhem Land, with particular emphasis on comparison between this report and the accompanying map (Plate 1, 1967)

<table>
<tr><th>Dunnet (1965), Plumb & Roberts (1965), Roberts & Plumb (1965)</th><th>Plumb & Derrick (1975)</th><th>Plumb (1987)</th><th>Plumb, Ahmad, & Wygralak (1990)</th><th>PLATE 1 (1967)</th><th>THIS REPORT</th><th>ROCK UNIT</th></tr>
<tr><td rowspan="2">UPPER PROTEROZOIC</td><td>ADELAIDEAN</td><td>CAMBRIAN</td><td>CAMBRIAN</td><td rowspan="2">ADELAIDEAN</td><td>CAMBRIAN</td><td>WESSEL GP</td></tr>
<tr><td>ADELAIDEAN or CARPENTARIAN</td><td rowspan="5">CARPENTARIAN (MIDDLE PROTEROZOIC)</td><td rowspan="5">"MID PROTEROZOIC"</td><td>CALYMMIAN</td><td>MALAY ROAD GP</td></tr>
<tr><td>LOWER (?) PROTEROZOIC</td><td rowspan="5">CARPENTARIAN</td><td rowspan="6">CARPENTARIAN</td><td rowspan="2">STATHERIAN or CALYMMIAN</td><td rowspan="2">"Kookaburra Ck Fm"
MOUNT RIGG GP
Wilberforce beds
Mt Bonner Sst
Baralminar beds
Groote Eylandt beds</td></tr>
<tr><td>LOWER PROTEROZOIC</td></tr>
<tr><td>LOWER (?) PROTEROZOIC</td><td rowspan="2">STATHERIAN</td><td rowspan="2">HABGOOD GP
McARTHUR GP
KATHERINE RIVER GP
PARSONS RANGE GP</td></tr>
<tr><td rowspan="5">LOWER PROTEROZOIC</td></tr>
<tr><td rowspan="3">EARLY to MIDDLE PROTEROZOIC</td><td rowspan="6">EARLY PROTEROZOIC</td><td rowspan="6">OROSIRIAN</td><td rowspan="6">Sheridan Fm
Spencer Creek Volc.
Bickerton Volc.
Fagan Volc.
Ritarango beds
Jimbu Gran.
Caledon Gran.
Giddy Gran.
Grindall Mets
Nimbuwah Cplx
Mirarrmina Cplx
Gunbatgari Cplx
Myaoola Gran.
Bradshaw Cplx</td></tr>
<tr><td rowspan="2">LOWER PROTEROZOIC OR CARPENTARIAN</td></tr>
<tr><td rowspan="2">LOWER (?) PROTEROZOIC</td></tr>
<tr><td rowspan="3">LOWER PROTEROZOIC</td><td rowspan="3">EARLY PROTEROZOIC</td></tr>
<tr><td>LOWER PROTEROZOIC (?) & ARCHAEAN (?)</td><td>LOWER PROTEROZOIC(?) & ARCHAEAN(?)</td></tr>
<tr><td>ARCHAEAN (?)</td><td>ARCHAEAN (?)</td></tr>
</table>

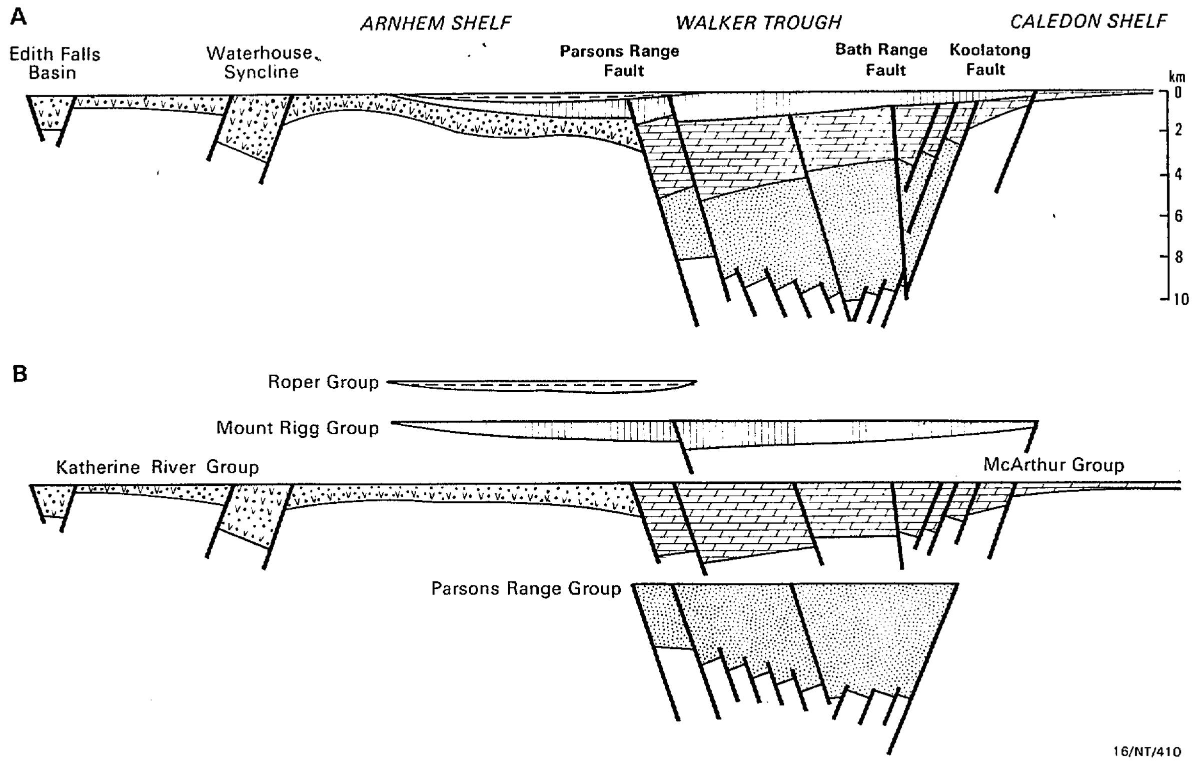


Figure 4. Schematic development of the McArthur Basin in Arnhem Land, from the Arnhem to Caledon Shelves, through the Walker Trough (from Plumb, 1987).

A. Schematic cross section at the close of Roper Group sedimentation.

B. Schematic development of the principal depositional units.

a general NW-SE direction, oblique to the trend of the major rifts. This has produced a major component of dextral strike-slip displacement along the northerly-trending Walker Trough, and sinistral movement along NW-trending transfer faults, such as the Bulman system. Later inversion of the rift has occurred as result of a roughly E-W compressional event.

The exposed Cambrian section of the *Arafura Basin* is only a small part of of a basin succession which extends offshore in a section many kilometres thick, and extends through much of the Palaeozoic and up into the Mesozoic. The onshore part of the basin is essentially undeformed.

OUTLINE OF STRATIGRAPHY

STRATIGRAPHIC SUMMARY

The Proterozoic and Palaeozoic rocks of Arnhem Land are divided into four broad stratotectonic groupings, separated by regional unconformities - mid Orosirian *Basement Metamorphic Complexes*, late Orosirian (Palaeoproterozoic)? *Late Tectonic Granites and Acid Volcanics,* the Statherian-Calymmian (Palaeoproterozoic-Mesoproterozoic) *McArthur Basin Succession,* and the early Palaeozoic *Arafura Basin Succession* (Fig. 5). These units are in turn covered over vast areas, and the relationships between them commonly obscured, by thin Mesozoic and Cainozoic deposits, which are not discussed herein.

The *Basement Metamorphic Complexes,* of the Arnhem Block, comprise greenschist facies (Grindall Metamorphics) and high-amphibolite to granulite facies metamorphic complexes and their anatectic granite equivalents (Bradshaw Complex, Myaoola Granite). The small inlier of Mirarrmina Complex comprises similar low and high-grade metamorphic rocks and granite to the Bradshaw Granite and is considered to be equivalent, but also includes younger mafic intrusives and later dykes of porphyritic granophyre and dolerite, which are interpreted to overlap at least the Late Tectonic Granites and Acid Volcanics in age. The Gunbatgari and Nimbuwah Complexes are eastern extensions of the Pine Creek Inlier.

Within the *Late Tectonic Granites and Acid Volcanics,* the massive Giddy and Caledon Granites are considered to be subvolcanic intrusive equivalents of the adjacent, undeformed Spencer Creek and Bickerton Volcanics; the Fagan Volcanics-Ritarango beds and Jimbu Granite are correlated (Fig. 5). The Giddy and Caledon Granites intrude the Bradshaw Complex and Grindall Metamorphics, whilst the Spencer Creek and Bickerton Volcanics overlie the basement complexes with angular unconformity. The Fagan Volcanics unconformably overlie the Ritarango beds and both are inferred, on structural grounds, to unconformably overlie the Mirarrmina Complex, but no contact is exposed. The small inlier of Jimbu Granite does not contain any older rocks.

The *McArthur Basin Succession* comprises several mildly to undeformed sedimentary sequences, deposited in different tectonic domains and in a variety of depositional environments (Fig. 5). Within the central rift, the Walker Trough, up to 6 km of quartz-rich sandstones and subordinate siltstones and carbonates, the Parsons Range Group, unconformably overlie the Fagan Volcanics. The Parsons Range Group is, in turn, conformably overlain by the McArthur Group; up to 4.2 km of mixed dolomite-lutite-sandstone rocks. The McArthur Group passes up, via a wide gap of no outcrop between, into the "Kookaburra Creek Formation". In the Roper River Sheet area, immediately to the south of the map sheet discussed herein, the "Kookaburra Creek Formation" is overlain with regional unconformity by the Roper Group. In the Flinders Peninsula area of north-central Arnhem Land, about 3.8 km of mixed dolomite-lutite-sandstone rocks, the Habgood Group, are poorly exposed in an inlier, without any stratigraphic top or base; the Habgood Group is confidently correlated with the McArthur Group. The Parsons Range Group is provisionally interpreted as a sequence of shoreline to shallow-marine blanket sandstones, interlayered with subordinate peritidal to lacustrine and alluvial complexes. The overlying McArthur and Habgood Groups are provisionally interpreted to comprise a peritidal to continental carbonate and sabkha facies deposited on a broad marginal-marine shelf, passing up into a regressive alkaline lake complex containing abundant felsic tuffs.

On the Arnhem Shelf to the west, the basement complexes and Jimbu Granite are overlain with angular and onlap unconformity by a flat-lying, complex sequence about 1800 m thick, of alternating sandstone, siltstone, dolomite, and volcanic units, the Katherine River Group, which itself contains several regional erosional unconformities and is of uncertain correlation. Preliminary sedimentological interpretation suggests a basal northwest-derived fluvial sand, passing up into probable peritidal to perhaps shallow-marine and lacustrine facies, via several erosional breaks.The Katherine River Group is overlain with regional unconformity by about 700 m dolomitic siltstones, dolomite, and sandstone, the Mount Rigg Group. The Mount Rigg Group is correlated with the Nathan Group elsewhere in the McArthur Basin, and was probably deposited as a basal alluvial fan facies, passing up into cyclic carbonate complexes deposited in broad hypersaline playas and lakes or peritidal settings. The Mount Rigg Group is, in turn, overlain with regional unconformity by the Roper Group, a cyclic sequence of blanket quartz sandstones alternating with micaceous and glauconitic siltstones and sandstones, less than 1000 m thick in Arnhem Land. The Roper Group was deposited in a variety of marginal, shallow, and deeper marine shelf environments, reflecting alternating transgressions and regressions.The Roper and Mount Rigg Groups are intruded by extensive dolerite sills.

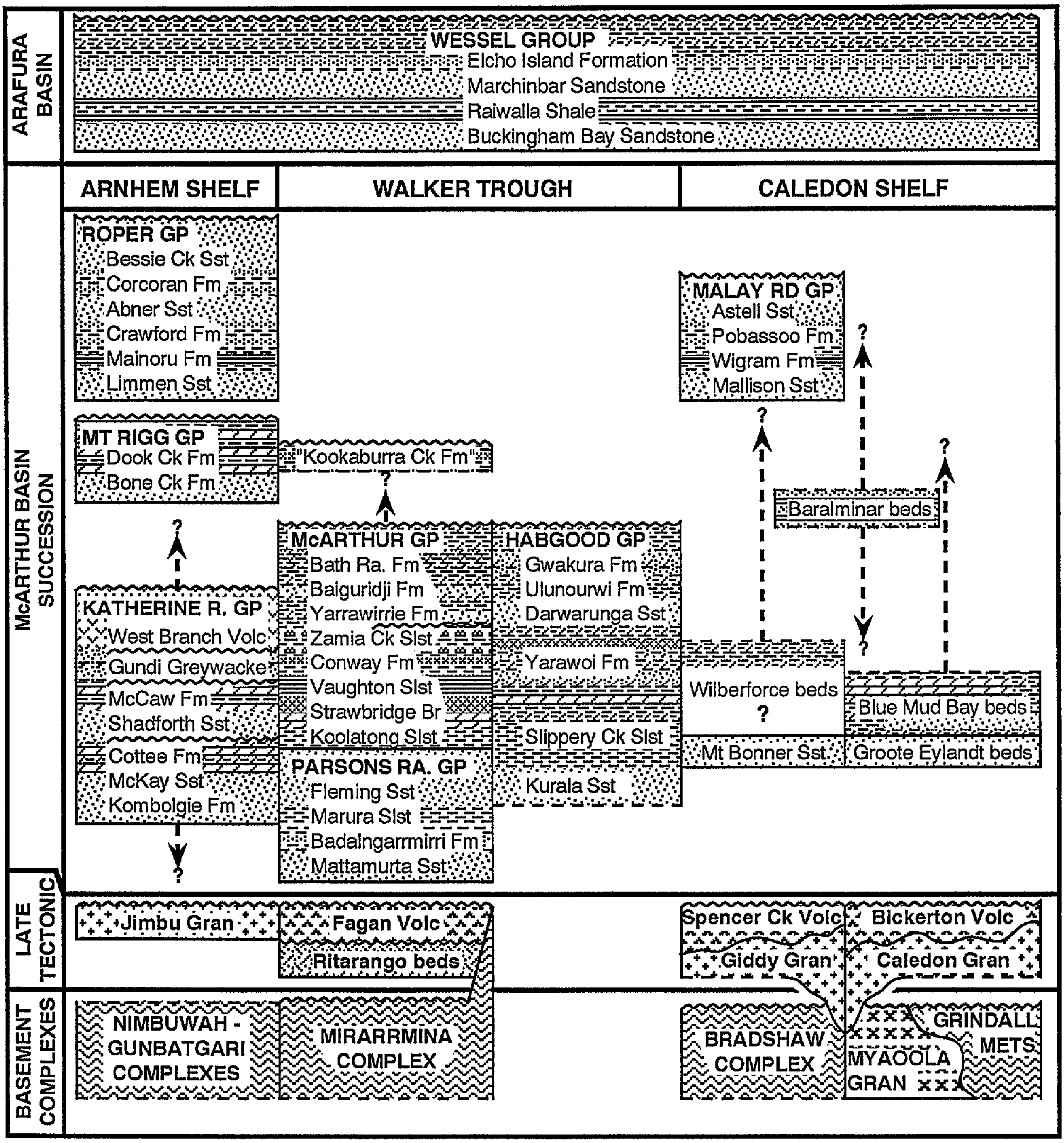


Figure 5. Diagrammatic stratigraphy, stratigraphic relationships, and correlation of Arnhem Land rock units.

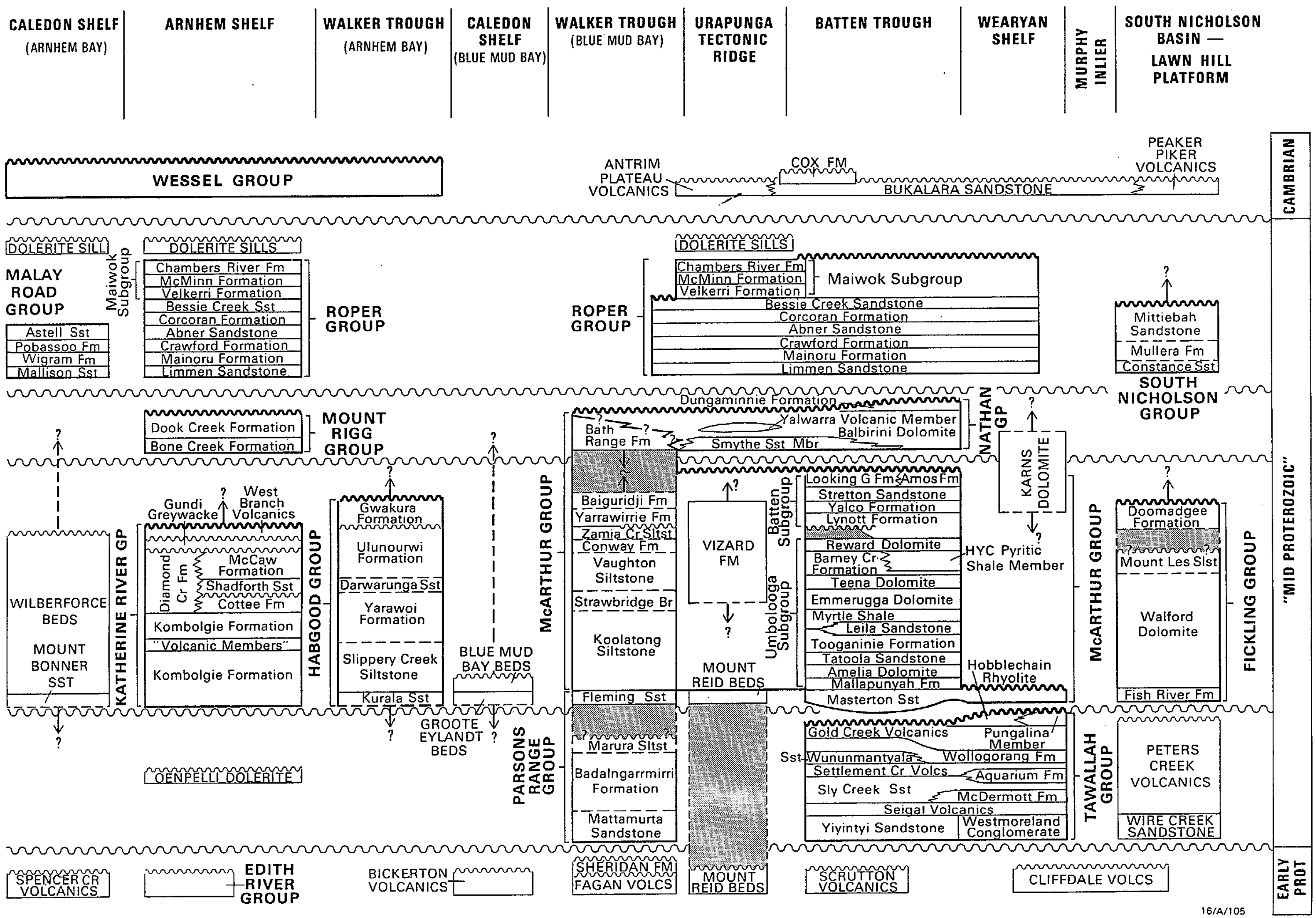


Figure 6. Stratigraphic correlation chart of the McArthur Basin-South Nicholson Region (after Plumb *et al.*, 1990). Patterned areas refer to postulated time gaps within units previously defined as continuous.

Various thin, flat-lying sequences of uncertain correlation are exposed in different areas on the Caledon Shelf of eastern Arnhem Land. In northern Arnhem Land the Spencer Creek Volcanics are unconformably overlain by the Mount Bonner Sandstone, which is turn overlain by the almost totally unexposed Wilberforce beds, of inferred largely carbonate composition. The Mount Bonner Sandstone and lower Wilberforce beds correlate with either the McArthur or Nathan Groups. The uppermost exposed Wilberforce beds resemble the shallow-marine Mantangula Formation, recently discovered at the base of the Roper Group elsewhere in the McArthur Basin. The Wilberforce beds are overlain by the alternating quartz sandstone and micaceous and glauconitic siltstone, sandstone and shale sequence of the Malay Road Group, which is intruded by a dolerite sill. The Malay Road Group may be compared and confidently correlated with the Roper Group, and similar palaeoenvironments inferred. In the area around Blue Mud Bay the basement rocks are overlain with angular unconformity by quartz sandstones of the Groote Eylandt beds, which are in turn overlain conformably by the Blue Mud Bay beds. The Blue Mud Bay beds have been defined as a local equivalent of the basal McArthur Group, but a later suggestion that the Blue Mud Bay beds overlie the McArthur Group elsewhere in Arnhem Land (W.C. Smith, personal communication) places the stratigraphic position of this sequence in doubt. In northern Arnhem Land, a thin inlier of interbedded sandstones and micaceous siltstones, the Baralminar beds, have no exposed relationship with any other Proterozoic unit.

The onshore *Arafura Basin Succession,* the Early to Middle Cambrian Wessel Group, comprises about 1.4 km of flat-lying, alternating sandstone and poorly exposed shale and dolomitic siltstone, which overlies all elements of the McArthur Basin and older rocks in a belt extending around almost all of the northern coast of Arnhem Land. The exposed part of the basin is provisionally interpreted as deposited in a broad shallow, intertidal to subtidal marine shelf setting.

REGIONAL CORRELATIONS AND AGE

Table 1 and figure 5 summarise ages now assigned to rock units in Arnhem Land and their stratigraphic relationships and correlations. These may be compared with the earlier concepts displayed on Plate 1. Figure 6 illustrates the detailed correlations assigned between rock units of Arnhem Land and the rest of the McArthur Basin region, particularly those of the McArthur Basin itself. These differ in some significant details from those of Plumb and Derrick (1975).

The *Basement Metamorphic Complexes* developed during the synorogenic phase of the Barramundi Orogeny, which formed most of the precratonic basement to most of the North Australian Craton

The *Late Tectonic Granites and Acid Volcanics* are generally considered to be part of what is now known as the '1880-1840 Ma felsic volcano-plutonic suite' of the late-tectonic stage of the Barramundi Orogeny. However, geochemistry presented herein for the first time suggests that some of this suite, particularly the Giddy and Caledon Granites and associated Spencer Creek and Bickerton Volcanics, may be part of a younger, post-1820 Ma, A-type suite.

Most of the *McArthur Basin Succession* may be correlated in some detail with units in the 'type successions' of the southern McArthur Basin: the Parsons Range Group with the Tawallah Group; the McArthur and Habgood Groups with the McArthur Group; the Mount Rigg Group with the Nathan Group; and the Malay Road Group with the Roper Group. However, following redefinition in recent years of the stratigraphy of the southern McArthur Basin, it is probable that the top of the defined McArthur Group in Arnhem Land (Bath Range Formation) actually extends up into equivalents of the Nathan Group, although the unconformity cannot be recognised in the data presently available.

The Katherine River Group was originally correlated lithostratigraphically with the Tawallah and Parsons Range Groups (e.g., Plumb & Derrick, 1975; Plate 1, this report) and later, by preliminary magnetostratigraphy and Rb-Sr geochronology, with the McArthur Group (Plumb, 1985). This latter data has now been reassessed, and the age of the Katherine River Group remains an open question. The Mount Bonner Sandstone/Wilberforce beds and Groote Eylandt beds/Blue Mud Bay beds sequences may correlate with either the McArthur or Nathan Groups.

The *Arafura Basin Succession* is Early to Middle Cambrian on the basis of the occurrence of trilobites.

ECONOMIC GEOLOGY

Arnhem Land contains the large Gove bauxite and Groote Eylandt manganese deposits, of Tertiary and Cretaceous age respectively, while the McArthur Basin itself is highly prospective for base metal deposits. However, at the time of fieldwork in 1962 no economic ore bodies had been proven or were in production. The major mining and exploration developments in Arnhem Land have taken place since 1962, and occur in sequences younger than those described herein, and thus this brief summary comprises the only discussion of mineral deposits herein.

Bauxite : In 1949 H B Owen of the BMR, in the course of an Australia-wide survey for bauxite, requested members of the Northern Territory Coast Patrol Service to collect specimens of pisolitic material from the Arnhem Land coast (Owen, 1954). Before the end of the year

Captain F E Wells and Seaman F J Waalkes, of the Patrol Service, had forwarded specimens of bauxite from Truant Island and Wessel Islands containing between 34.6% and 40.8% available Al_2O_3. It was not until October, 1951 that Owen was able to make a reconnaissance visit to the deposits with Captain Wells. During this reconnaissance they also visited the shores of Melville Harbour but they only found siliceous and ferruginous laterite of granitic origin. As a result of this reconnaissance the Australian Aluminium Production Commission, in 1952, tested the Wessel Islands deposits extensively (Puckey & Richardson, 1952) but while this work was proceeding Captain Wells, in February 1952, collected a specimen of pisolitic bauxite containing 52.6% Al_2O_3 from near Gove airstrip. Owen visited the deposit in August, 1952 (Owen, 1952) and all attention was subsequently directed to Gove instead of Wessel Islands.

In 1955 the New Guinea Resources Prospecting Co, a company owned by the Commonwealth Government and British Aluminium Co. Ltd, investigated the deposits at Gove (Gardner; 1955, 1957). The Commonwealth Aluminium Corporation (COMALCO) carried out a detailed survey of the area in 1958 and was granted Special Mineral Lease No. 1 which was subsequently terminated about 1964 (Dunn, 1965). In 1961 the Gove Bauxite Corporation Limited (Duval Holdings Pty Ltd) began a survey of areas exclusive of SML No 1 (Dickinson, 1961) and in 1963 was granted SML's 2, 3 and 4 surrounding SML 1. These were subsequently transferred to Gove Mining and Industrial Corporation Ltd (GOMINCO), who carried out further testing and then relinguished the leases. Between 1966 and 1968 Nabalco Pty Ltd, a joint venture between Swiss Aluminium Ltd and Gove Alumina Ltd, carried out a detailed feasibility study and sampling program, as result of which development of the mining project commenced in 1969. Mining of the major deposit started in 1971 and the alumina plant was commissioned in 1972 (Somm, 1975). Operations continue to this day. In 1975 mineable bauxite occupied a surface area of some 63 km^2 with an average thickness of 3.5 m. Proven reserves were of the order of 250 MT grading 51% Al_2O_3 and 4% SiO_2, and production was planned at a rate of about 4.7 Mt of bauxite and 1 Mt of alumina per annum.

The bauxite overlies a ferruginous laterite conglomerate, which is itself developed on top of a sequence of claystone and arkosic sandstone of the Lower Cretaceous Mullaman beds. This deep-weathering laterite profile is widespread throughout Arnhem Land and is generally developed on a low-level surface which dips gently towards the coast, to lie at or a few metres above seal level at the coast itself. The surface on the Gove Peninsula is distinguished by its elevation, being preserved as undulating erosional plateaux remnants between 30 and 60 m, and locally up to 85 m, above the immediately adjacent sea.

The bauxite itself comprises three distinct layers, from the bottom up: *tubular bauxite, cemented pisolitic bauxite,* and *loose pisolitic bauxite* . The main mineral constituents are gibbsite, hematitie/goethite, and minor boehmite. The base to the ore is defined by a chemical cut-off, and usually lies at the base of the tubular bauxite, but sometimes within it. There is little difference in grade between the three ore types. Contacts between the different layers are sharp and locally unconformities may be identified. The thickness of bauxite is inversely related to the present surface morphology, being thicker in depressions and thinner over gentle ridges and rises. Fragments of the various layers are reworked into overlying layers. Pipe-like vertical root channels penetrate the bauxite form the present surface and may be filled by loose pisolites. Similar fossil root channels in underlying layers are truncated at the tops of those layers. The bauxite almost certainly originated as a residual deposit at the top of the regional laterite profile, and the distinctive elevation of this surface at Gove may have been critical in providing the drainage necessary for bauxite formation. However, the features summarised above point to undoubted local reworking of bauxite to form a mostly sedimentary deposit, as now preserved. The actual distance of transport may have been quite short, and the erosion simply a product of the drainage and relief necessary for bauxite formation (Grubb, 1970; Plumb & Gostin,1973; Somm, 1975).

Lead-zinc : The McArthur Group is host to several lead-zinc deposits to the south of Arnhem Land (Jackson *et al.*, 1987). Most significant are the *shale-hosted (McArthur-type) lead-zinc-silver* deposits, of which the huge HYC deposit is the best known. Deposits are both structurally and stratigraphically controlled. Host carbonaceous-dolomitic shales in the middle of the McArthur Group (Barney Creek Formation) provided favourable receptors or hydrologic traps for epigenetic mineralisation, adjacent to major syndepositional faults during active rifting and, presumably high-heat flow and brine migration, within the extensional Batten Trough (Plumb, Ahmad & Wygralak, 1990). The equivalent tectonostratigraphic setting is provided by the Walker Trough in Arnhem Land. The Vaughton Siltstone has been identified as the most attractive prospect on the basis of lithostratigraphic correlation (Plumb & Derrick, 1975).

BHP Pty Ltd investigated the Vaughton Siltstone over two dry seasons during 1972-73, involving surface geological mapping, ground and airborne geophysics, and limited drilling (interrupted by the onset of an early "wet" season), but discovered only pyritic shale (5%-10% pyrite) associated with an IP anomaly near the Koolatong Fault. Results are reported in Open File Reports at the Northern Territory Department of Mines.

Several small subeconomic deposits of stratabound disseminated lead-zinc, of various types, occur at several levels throughout the McArthur Group. Within western Arnhem Land, small *discordant and karstic lead-zinc (± barite)* deposits are found within the upper Dook Creek Formation at Bulman (Patterson, 1965; Jackson *et al.*, 1987). About 10 tonnes of ore were mined from shallow pits and shafts in the early part of the century. Company exploration during the 1950's and 1970's has revealed further subsurface extensions to the deposits, but have apparently not revealed economic quantities or grades; details are not known to us. The deposits occur in dolomites and oolite beds in the uppermost Dook Creek Formation, and just below the unconformity with the overlying Roper Group.They are further constrained to an area between the major Bulman Fault and a parallel fault 7 km to the northeast. At the surface the deposits consist of coarse-grained galena, oxidised Pb and Zn minerals and, in places, malachite. In the subsurface, the deposits consist of sphalerite, galena, pyrite, and minor pyrrhotite. Identical deposits occur in an identical stratigraphic and structural position in the correlative Balbirini Dolomite at Eastern Creek, in the McArthur district. Two stages of mineralisation are evident: barite,galena, and minor malachite in karstic cavities, and earlier disseminated galena and some chalcopyrite in oolite beds. A mineralisation model involves initiation of fluid movement by local fault movements and then trapping below the Roper group unconformity. Emplacement temperatures were around 170^o to 200^o (Muir *et al.,* 1985).

Manganese : The occurrence of manganese on the shores of Blue Mud Bay was first noted by Matthew Flinders in 1803 (Fitton, 1825), while H.Y.L. Brown (1908) noted manganese on a beach at Groote Eylandt. In November, 1960 P.R. Dunn of BMR, during a reconnaissance visit to Groote Eylandt, collected specimens of manganese from outcrops near Angurugu mission station on Groote Eylandt which assayed better than 50 percent Mn and, during further examination with P W Crohn of the Northern Territory Administration Mines Branch recognised their economic potential (Crohn & Dunn (1965). During 1961 Crohn carried out preliminary testing of the deposits by pitting with the assistance of mission staff, and improved the potential of the deposits (Crohn, 1962).

In May, 1962 W.C. Smith of the BHP Co Ltd visited the island and recognised that the deposits may be part of a major sedimentary deposit (Smith & Gebert, 1970). A lease over the deposits was negotiated with the Northern Territory Administration and the mission authorities, and a reconnaissance test program was carried out in late 1962; at the same time in fact as the BMR regional survey reported herein was in progress. Detailed testing by drilling, pitting, and metallurgical testing, began in 1963, while planning for development commenced as early as 1964. Groote Eylandt Mining Co. Ltd, a BHP subsidiary, commissioned a crushing and screening plant and the first shipment of ore left the island in March 1966. A concentrator was commissioned in 1972 (McIntosh, Farag, & Slee; 1975). Mining from one of the world's major manganese deposits has continued since.

The manganese mineralisation extends over 150 km^2, in an almost continuous stratum 22 km long, 6 km wide, and up to 9 m thick (average 3 m), within the restricted marine, Lower Cretaceous Mullaman beds on the western side of Groote Eylandt. Estimated reserves in 1975 totalled 190 Mt of proven ore and, by 1990, 48 Mt had been mined at an annual production of 3 to 3.5 Mt, and with a proven resource of 152 Mt of plus 40% Mn (McIntosh et al., 1975; Bolton, Berents, & Frakes, 1990).

The manganese oxide ore occurs as primary pisoliths and ooliths, within a sequence of non-volcanic kaolinitic clays and quartz sands, deposited in joint controlled, partly infilled depressions between elongate inliers of the Groote Eylandt beds. The manganese ores are chiefly pyrolusite and crytomelane, with minor amounts of manganite, and various trace minerals. In detail the ore horizon can be divided into a number of sub-units, and passes up into a superimposed laterite profile at the top. The manganese is considered to have been deposited in an organic-rich, oxygen-depleted restricted basin, during the late Albian marine transgression across the irregular surface of the Groote Eylandt beds. The ore has been further modified and enriched by supergene processes during several cycles of exposure and weathering (Bolton, Berents, & Frakes, 1990).

STRATIGRAPHY, PETROLOGY AND STRUCTURE

BASEMENT METAMORPHIC COMPLEXES

OROSIRIAN

INTRODUCTION

The basement rocks are those Palaeoproterozoic granites and metamorphic rocks which unconformably underlie the sediments of the McArthur Basin. Granulites, migmatites, anatectic granites, low-grade metamorphics, and high-level intrusive granites are all represented.

The basement rocks are very poorly exposed. The small inliers generally occupy low-lying country covered by sand, laterite or Mesozoic sediments.

Granitoids fall into two major groupings; old syntectonic granites associated with high-grade metamorphic complexes and young high-level post-tectonic granites, generally sub-volcanic. Minor basic rocks were emplaced between these events.

Since publication of the geological map accompanying this Record, and, also, the various 1:250 000 Sheets, thin section studies have led to a revision of age of some of the units, particularly the Gunbatgari Granite and Nimbuwah Complex. Ages should be taken as stated in the text of this Record.

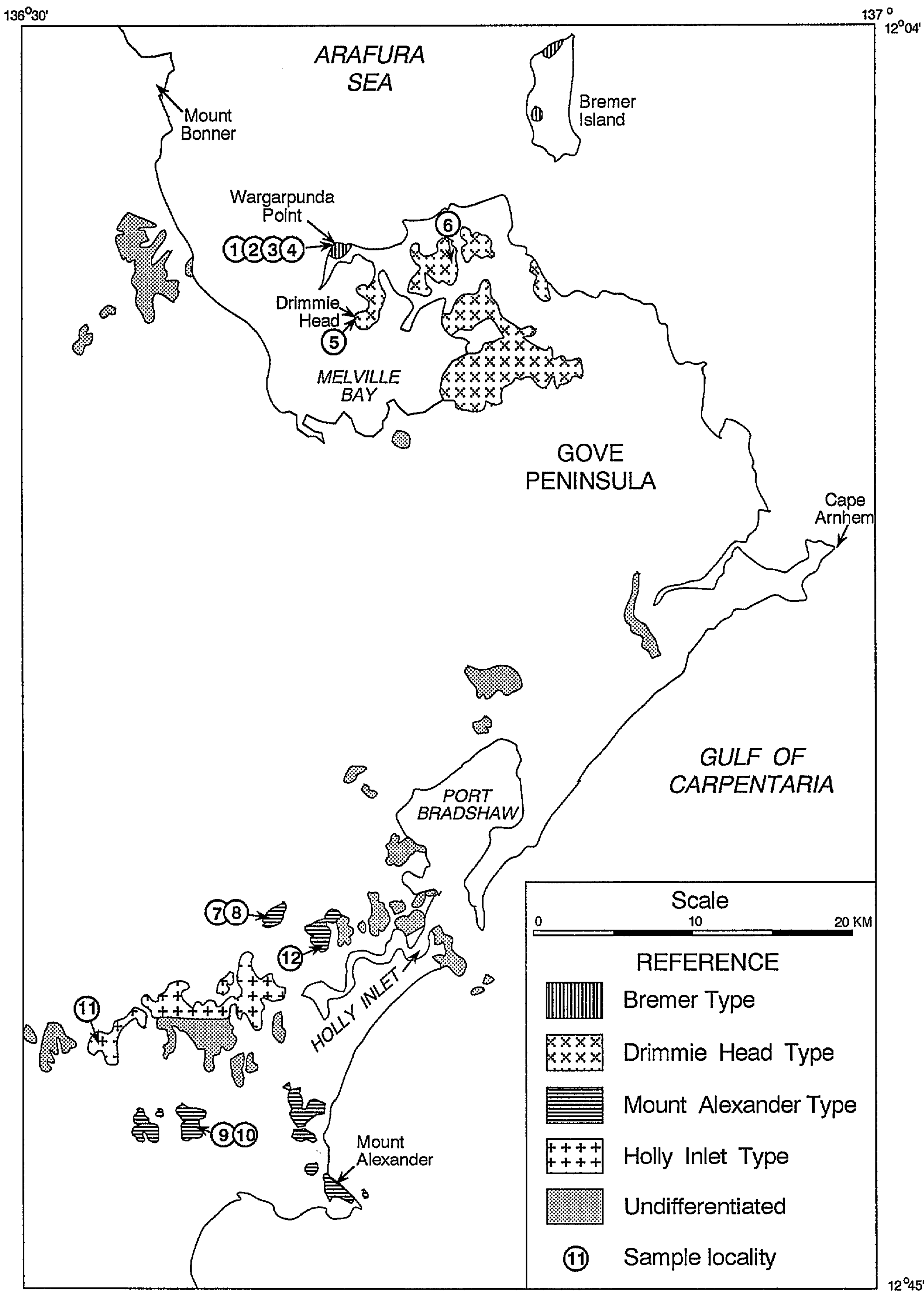


Figure 7. Distribution of exposures, Bradshaw Complex. Numbers refer to localities of specimens in Table **.

Definition

Distribution: Poorly exposed along east coast of Arnhem Land between Melville and Caledon Bays. Main exposures in two areas: a narrow belt south-westwards from Port Bradshaw and along the eastern shoreline of Melville Bay. The two belts total about 500 km but actual outcrop sparse. True extent obscured by widespread cover of Lower Cretaceous sediments and Cainozoic soil and laterites.

Type Locality: The belt of exposures southwest of Port Bradshaw.

Derivation of Name: From Port Bradshaw. Previously named Bradshaw Granite (Dunnet, 1965) because granitoid rocks are the most abundant in outcrop. Complex now considered more appropriate because of metamorphic-anatectic origin of rocks.

Stratigraphic Relationships: Part of the basement complex of Arnhem Land. Intruded by post-tectonic Caledon and Giddy Granites. Unconformably overlain by Spencer Creek Volcanics. Lower Proterozoic isotopic age. Correlated with Myaoola Granite, Nimbuwah and Gunbatgari Complexes, and 'granite gneisses' of Mirarrmina Complex.

Lithology: Cordierite adamellite and granodiorite; massive leucocratic garnetiferous adamellite; (garnetiferous) biotite adamellite and granite; garnetiferous-biotite-plagioclase-quartz and cordierite-biotite-microcline-plagioclase-quartz paragneisses; cordierite rich, banded granulites; leucocratic granulite; quartzite, migmatite.

Age: Orosirian (Palaeoproterozoic)

Description and comments

The Bradshaw Complex is a mixture of granitic, migmatitic, and high-grade metamorphic rocks, with similar pelitic compositions and gradational contacts. The granites formed by anatexis of the metasediments. Many of the rocks are foliated and folded about shallowly plunging west to north-westerly trending axes; the structural history is complex. Only one major metamorphism of low-pressure granulite to upper amphibolite facies can be recognised; retrogressive effects are slight.

The two main areas of outcrop are best treated separately (Fig.7), and in each area two informally named groups of rocks are recognised. The metamorphic grade in the *Port Bradshaw area* is lower (upper amphibolite facies) than the *Melville Bay area* (low-pressure granulite facies).

At Port Bradshaw, the *Mount Alexander Type* is a complex of paragneiss and granitic rocks. Garnetiferous-biotite-plagioclase-quartz and cordierite-biotite-microcline-plagioclase-quartz paragneisses grade through garnetiferous biotite or biotite-cordierite gneissic adamellites and granites (migmatites) into massive biotite adamellites and granites, both with and without garnet. Megacrysts of K-feldspar are common in the latter; the rocks are intimately intermixed in the field; and paragneiss inclusions are common within the granitic rocks. The *Holly Inlet Type* consists of massive cordierite rich adamellite and granodiorite, exposed in a large body to the west of Holly Inlet and surrounded by 'Mount Alexander Type'; hypersthene-cordierite adamellites occur locally. The rocks are comparatively structureless, like a typical 'magmatic' granite. Scattered exogenous xenoliths include paragneiss and amphibolite. The change from the 'Mount Alexander' to 'Holly Inlet Type' is sudden but the contact is not exposed; it is inferred that the 'Holly Inlet Type' is a higher grade anatectic equivalent of, and intrusive into, the 'Mount Alexander Type'.

At Melville Bay the *'Bremer Type'* comprises cordierite-rich banded granulites, interbanded with diopside, cordierite, or biotite-bearing quartzites; all contain scattered porphyroblasts of garnet. These rocks are cut by thin, irregular veins and pods of leucocratic granulite (pegmatite); the first stage of anatexis of the metasediments. The *'Drimmie Head Type'* consists of massive leucocratic garnetiferous adamellite, grading into granite. Inclusions of quartzite, and occasional basic rocks, are common and contaminate the country rock to granodiorite or, locally, tonalite. The rocks are similar to the leucocratic granulites of the 'Bremer Type', except for an overall increase in plagioclase content, and are considered to be the final stage of anatexis of, and intrusive into, the 'Bremer Type'; contacts are not exposed.

The metasediments show at least two periods of deformation, both apparently approximately coaxial. The earliest recognisable phase transposed bedding (S_0) into the metamorphic foliation (S_1); occasional small folds are preserved as tectonic inclusions but the original orientation of the folds is uncertain. The regional structure is now dominated by relatively open folding of the co-planar bedding and foliation about axes plunging 35^o northwest in the Melville Bay area, and about subhorizontal east-west axes in the Port Bradshaw area. Evidence of folding progressively diminishes with increasing grade of anatexis. A third deformation occurs locally in the Port Bradshaw area in narrow shear zones trending east-west and dipping steeply to the south; lineations occur subparallel to the second-phase folds and slight retrogressive metamorphism is present.

The Bradshaw Complex show local retrogressive metamorphism near contacts with the Caledon Granite. Inclusions of Bradshaw within Caledon Granite have been thermally metamorphosed to a leucocratic micrographic granite.

Chemical analyses and Barth Mesonorms of selected specimens are listed in Table 2. Mesonorms were calculated by the C.D.C. 3600 program of Morgan (1965). Rocks containing cordierite were corrected manually by recalculating:

qtz + or. + cor. + biot. = qtz + or. + cord. + (sill. or biot.);

Agreement between observed and calculated mineralogies is good. Localities of analysed specimens are shown on Figure 7.

Table 2. Whole rock silicate analyses and calculated Barth Mesonorms of Bradshaw Complex samples. Oxides expressed as weight percent. Barth Mesonorms recalculated as cordierite + sillimanite + biotite in place of corundum + biotite, to reflect actual observed metamorphic assemblages.

	1	2	3	4	5	6	7	8	9	10	11	12
SiO_2	59.80	70.90	74.80	71.50	69.00	71.92	67.30	66.60	72.10	52.10	69.30	72.00
Al_2O_3	20.60	14.70	13.90	14.20	14.10	15.39	14.80	15.20	14.10	26.20	14.30	14.00
Fe_2O_3	2.65	1.80	0.13	0.89	1.35	1.47	0.73	0.39	0.90	1.50	0.23	0.22
FeO	4.20	3.45	0.89	2.25	3.30	0.80	4.55	5.00	2.80	6.10	3.80	2.95
MgO	2.55	0.48	0.15	1.02	1.43	0.44	1.18	1.26	1.26	3.50	1.35	1.14
CaO	0.73	0.14	1.01	0.93	1.15	1.49	1.98	2.10	0.79	0.63	1.37	0.98
Na_2O	2.10	1.74	2.95	1.85	2.15	2.86	2.25	2.45	2.05	2.10	2.25	2.15
K_2O	4.40	5.25	5.10	5.70	5.20	4.67	5.30	3.85	4.40	5.20	4.70	4.10
H_2O+	1.65	0.61	0.61	0.98	0.89	0.51	1.07	1.55	1.29	1.59	1.47	1.51
H_2O-	0.10	0.29	0.07	0.08	0.18	0.05	0.11	0.15	0.16	0.42	0.02	0.17
CO_2	0.34	0.00	0.25	0.02	1.00	0.00	0.00	0.00	0.06	0.02	0.22	0.00
TiO_2	0.58	0.66	0.05	0.49	0.23	0.08	0.77	0.80	0.24	0.84	0.55	0.43
P_2O_5	0.12	0.08	0.15	0.09	0.23	0.05	0.18	0.16	0.09	0.11	0.11	0.15
MnO	0.11	0.06	0.02	0.04	0.08	0.04	0.06	0.09	0.06	0.04	0.03	0.04
Total	99.93	100.16	100.08	100.04	100.29	99.77	100.28	99.60	100.30	100.35	99.70	99.84
Quartz	13.74	32.01	32.29	30.06	28.20	29.68	27.57	30.39	33.16	0.00	28.87	33.63
Orthoclase	26.86	32.22	30.76	33.75	29.68	28.15	23.74	14.07	25.49	28.68	24.86	23.49
Albite	19.48	16.21	27.03	17.13	20.03	26.21	20.79	22.92	19.03	19.10	20.99	20.08
Anorthite	0.71	0.18	2.32	2.26	0.00	6.93	6.14	6.86	2.19	2.31	2.88	2.48
Sillimanite	3.36	3.15	1.86	0.00	0.00	3.01	5.36	7.83	0.00	0.00	0.00	0.00
Corundum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.73	0.00	0.00
Cordierite	31.46	13.20	4.84	12.97	15.49	4.15	0.00	0.00	16.12	39.26	14.05	16.08
Biotite	0.00	0.00	0.00	1.53	3.51	0.00	13.57	15.41	2.24	3.91	6.40	2.73
Magnetite	2.86	1.95	0.14	0.96	1.46	1.57	0.79	0.42	0.97	1.59	0.25	0.24
Sphene	0.00	0.00	0.11	1.06	0.00	0.17	1.66	1.74	0.52	0.00	1.19	0.93
Ilmenite	0.83	0.95	0.00	0.00	0.33	0.00	0.00	0.00	0.00	1.19	0.00	0.00
Apatite	0.26	0.17	0.32	0.19	0.50	0.11	0.39	0.35	0.19	0.23	0.24	0.33
Calcite	0.44	0.00	0.32	0.03	0.87	0.00	0.00	0.00	0.08	0.03	0.29	0.00
Water	1.75	0.90	0.68	1.06	1.07	0.56	1.18	1.70	1.45	2.01	1.49	1.68
Total	101.7	100.9	100.7	101.0	101.1	100.5	101.2	101.7	101.4	102.0	101.5	101.7

Sample details

1.	"Bremer Type"	Banded sillimanite-garnet-quartz-cordierite-orthoclase granulite. Wargarpunda Point. # D53/4/1. Analyst C.Edmond, AMDL.
2.	"Bremer Type"	Banded garnet-sillimanite-quartz-orthoclase-cordierite granulite. Wargarpunda Point.#R12662. Analyst L.Castanelli, AMDL.
3.	"Bremer Type"	Mobilised leucocratic plagioclase-sillimanite-garnet-cordierite-quartz-orthoclase granulite. Wargarpunda Point.#D53/4/2. Analyst C. Edmond, AMDL.
4.	"Bremer Type"	Mobilised leucocratic biotite-garnet-plagioclase-cordierite-orthoclase-quartz granulite. Wargarpunda Point. #R12664. Analyst L.Castanelli, AMDL.
5.	"Drimmie Head Type"	Masive leucocratic cordierite-biotite-garnet adamellite. Drimmie Head. #R12666. Analyst L. Castanelli, AMDL.
6.	"Drimmie Head Type"	Masssive leucocratic garnetifierous granite. 7 km east of Wargarpunda Point. # D53/3/1. Analyst S. Baker, BMR.
7.	"Mount Alexander Type"	Garnet-biotite adamellite gneiss. 9.5 km west of mouth of Holy Inlet. # R12673. Analyst L.Castanelli, AMDL.
8.	Duplicate of #7 above.	
9.	"Mount Alexander Type"	Porphyroblastic garnet-muscovite-biotite-cordierite granitic gneiss. 9.5 km west of Mount Alexander. #R12683. Analyst L.Castanelli, AMDL.
10.	"Mount Alexander Type"	Sillimanite-cordierite hornfels; inclusion in #9 above. Analyst L.Castanelli, AMDL.
11.	"Holly Inlet Type"	Porphyroblastic hypersthene-cordieriterite-muscovite-biotite-adamellite. 17.5 km north-west Of Mount Alexander. #D53/4/7. Analyst C. Edmond, AMDL.
12.	"Holly Inlet Type"	Massive Biotite-cordierite granodiorite. 7 km west of Holly Inlet. #R12677. Analyst L. Castanelli, AMDL.
Note	#R......	Refers to registered number of samples in BMR collection.
	#D53/4/..	Refers to registered number of BMR age determination samples.

Port Bradshaw area

'Mount Alexander Type': Three divisions are recognized, paragneisses, gneissic adamellites or migmatites, and massive porphyroblastic adamellites, representing progressive stages of granitisation and recrystallization. They interfinger and contacts are gradational. All types are frequently present in outcrops only a few metres across. Limited outcrops immediately west of Holly Inlet suggest an increasing proportion of paragneiss towards the east.

The *paragneisses* are pale-grey, fine to medium-grained, and banded. Bands range from a few millimetres to several centimetres in thickness and reflect differences in both composition and grainsize. The bands are thought to mainly reflect primary bedding (S_0) and are reasonably continuous, but have been transposed by a schistoscity (S_1), and both S_0 and S_1 are folded. Some of the finer banding may result from metamorphic segregation in S_1.

The gradation into the *gneissic adamellites* is marked by:

(1) increased grainsize

(2) disappearance of primary banding (S_0) and development of compositional homogeneity

(3) metamorphic foliation (S_1) predominant; defined by biotite schistoscity or by metamorphic-segregation layering into biotite-rich and quartz-feldspar layers a few millimetres thick (migmatite).

(4) Decrease in biotite and marked increase in K-feldspar contents

(5) Two feldspars distinctly visible to the naked eye.

Further recrystallization, shown by:

(1) disappearance of strong foliation

(2) slight increase in grainsize and development of a massive granitoid fabric

(3) further decrease in biotite content,

(4) increase in size and quantity of K-feldspar megacrysts,

give rise to the *massive porphyroblastic adamellites.*

The gneissic adamellites are intermediate between the homogeneous and banded gneisses of Berthelsen (1961). The foliation is folded about the same axis (F) as the paragneisses. Intrafolial inclusions of paragneiss commonly lie in S_1, with the major axes of elongate inclusions or the axes of rootless intrafolial folds apparently parallel to F. With increasing recrystallization porphyroblasts of K-feldspar appear, lying within S_1 in one of two ways:

(1) where S_1 is shallowly dipping (such as fold crests) the porphyroblasts are random,

(2) where S_1 dips steeply and is strongly schistose the porphyroblasts show marked lineation (L_1) parallel to F.

The massive porphyroblastic adamellites sometimes show a slight foliation, either:

(1) a faint platy orientation of grains, particularly megacrysts, parallel to the foliation in the gneisses, or

(2) post-crystallization cataclasis (S2).

Abundant lenses of gneissic adamellite, up to a few metres long and maintaining their original foliation direction, are preserved as relicts in the massive rocks. Inclusions of paragneiss, amphibolite, and garnet-mica schlieren are also common. Feldspar megacrysts range up to 10 cm long.

Pink garnet megacrysts, up to about 1 cm, are common, but not ubiquitous, throughout the 'Mount Alexander Type'.

The following mineral assemblages were seen in the *paragneiss:*

R12676	(quartz-biotite-plagioclase-(orthoclase-garnet) *(fine band)*
	(quartz-plagioclase-orthoclase-biotite-cordierite *(coarse band)*
R12675	plagioclase-biotite-quartz-garnet-(K-feldspar - hornblende)

The *gneissic adamellites* have:

R12673	quartz-plagioclase-K-feldspar-biotite-garnet
R12683	K-feldspar-quartz-cordierite-plagioclase-biotite-garnet-(muscovite)

The *massive porphyroblastic adamellites* show the following mineral assemblages:

R12674	K-feldspar-plagioclase-quartz-biotite-garnet (-cordierite)
R12680	K-feldspar-plagioclase-quartz-biotite-(muscovite-garnet)
R12681 }	K-feldspar-plagioclase-quartz-biotite (-muscovite)
R12682 }	

In thin section the bands in the paragneiss show wide variation in composition and fabric, reflecting its primary origin, while in the gneissic adamellites the banding is a simple segregation into biotite-rich and quartz-feldspar bands. In the gneisses biotite is schistose and quartz and feldspars are drawn out into small augen, with granulated margins. In contrast, the massive adamellites show a typical granitoid fabric-allotriomorphic granular quartz and K-feldspar, and randomly oriented clusters of biotite.

The K-feldspar is orthoclase in the paragneiss, but has a structure intermediate between orthoclase and microcline (strain extinction and patchy cross-hatch twinning) in the gneissic and massive adamellites. It is perthitic (fine hair, bleb, or string perthites), and poikiloblastic relative to most other minerals in the rocks. Large porphyroblasts are euhedral; smaller groundmass grains are ragged.

Plagioclase is oligoclase or andesine in composition. In the adamellites it is sericitised and forms myrmekitic intergrowths with K-feldspar.

Biotite is pleochroic from deep red-brown to orange-brown or pale yellow-brown. It is sometimes chloritised or intergrown with muscovite. Muscovite also occurs intergrown with cordierite at contacts with biotite and K-feldspar.

Garnets form porphyroblasts within biotite bands. Cordierite occurs as xenoblastic grains, enclosing aligned inclusions of, and rimmed by, biotite, and is almost entirely altered to pinite.

Zircon and apatite are accessories.

The *'Holly Inlet Type'* is characterized by massive fabric and abundant cordierite (up to 30%). The cordierite is now largely altered to pinite, and is clearly visible in hand specimen as black to dark green ragged grains, 1 to 2 mm in size, uniformly distributed throughout the rock. The rocks are generally medium to coarse-grained and pale grey. Euhedral feldspar laths about 2 to 3 mm, quartz, and cordierite are the chief minerals visible. Scattered feldspar megacrysts are present, but are not very common. Cordierite is locally porphyroblastic. The rocks are uniform throughout their outcrop. A weak foliation may be seen parallel to that of the paragneisses, and xenoliths tend to parallel F. The rocks are chemically similar to the rest of the Bradshaw Granite. Mineral assemblages observed in thin section are:

R12677	Plagioclase-quartz-cordierite-biotite-K-feldspar-(andalusite)
R12679	Cordierite-K-feldspar-quartz-plagioclase-biotite-(muscovite-sillimanite-andalusite)
D53/4/7	K-feldspar-plagioclase-quartz-biotite-muscovite-cordierite-hypersthene-(sillimanite)

The rocks show a typical massive, coarse-grained, granitoid fabric. Plagioclase tends to be euhedral; quartz, K-feldspar, and cordierite are sub- to anhedral.

Cordierite shows polysynthetic twinning. Variable replacement by pinite occurs along fractures and grain boundaries; some grains are wholly pseudomorphed. An unusual feature is a comparative lack of inclusions: quartz and small clusters of fibrolite sometimes occur; other inclusions are lacking. Clusters of small biotite flakes are commonly concentrated around cordierite grains, muscovite is intergrown with both biotite and cordierite, and idioblastic sections of andalusite are closely associated with the biotite and cordierite. It seems apparent that the biotite, muscovite and andalusite are all products of alteration of cordierite.

K-feldspar is apparently orthoclase; some patchy cross-hatch twinning suggests an intermediate form. It shows a string perthite structure and is sericitised. Plagioclase has a composition of oligoclase. Both feldspars commonly enclose grains of quartz and biotite.

Biotite is pleochroic from deep red-brown to pale yellow-brown and occurs as small flakes both clustered around cordierite grains and scattered throughout the rock. Symplectic intergrowths with quartz have been observed. Minor alteration to chlorite is present.

Sillimanite clusters are scattered through the rock, as well as fibrolite inclusions in the cordierite.

Specimen D53/4/7 contains the significant assemblage cordierite-hypersthene. Hypersthene is present as small, sparsely scattered, anhedral grains. Polysynthetically twinned grains of cordierite are replaced to varying degrees by pinite, muscovite, and biotite. Muscovite and biotite are the most abundant mafic minerals. Biotite occurs as sub-oriented flakes, frequently associated with muscovite, and appears to replace cordierite and hypersthene. Muscovite has mainly formed from cordierite. Sillimanite tufts are enclosed by feldspar or associated with biotite. It is inferred that the rock originally contained hypersthene, cordierite, and sillimanite in equilibrium with K-feldspar and plagioclase, and has been subsequently partially retrogressed during intrusion of the nearby Caledon Granite.

Rhodes (1966) has studied feldspars from this specimen (Table 3). The K-feldspar is a film perthite with moderately low triclinicity; a monoclinic orthoclase. The plagioclase has an intermediate structural state and shows two distinct compositions, An_{30} and An_{36}. Both occur as separate grains but An_{30} also rims An_{36}. The feldspars are typical of those considered by Rhodes to be associated with granulite facies rocks.

Xenoliths: Both the adamellites of the 'Mount Alexander Type', and the 'Holly Inlet Type' have xenoliths of three types:

(1) virtually unaltered paragneiss,

(2) amphibolite, and

(3) alumina-rich hornfels.

The latter two are apparently relicts of rock types no longer preserved in outcrops of paragneiss, but are significant contributors to the final results of anatexis.

Assemblages observed in the amphibolites are:

R12678 Hornblende-(quartz-plagioclase)

R12685 Hornblende-sericite-biotite

Table 3. Feldspar data (after Rhodes, 1966)

			K-FELDSPAR						PLAGIOCLASE			
Unit	Subunit	Sample number	$2V_x$	Triclinicity	Type	Comp. Or	Ab	An	$2V_x$	Comp.	Structural State	Association
BRADSHAW GRANITE	Bremer Type	D53/4/2	62°-70° Av. 65°	0.14		61	35	4				GRANULITE FACIES
	Drimmie Head Type	D53/4/4	60°-72° Av. 65°	0.20	Monocl.	74	24	3	84°	An_{27}	Intermediate	
	Holly Inlet Type	D53/4/7	54°-70° Av.60°	0.15	Monocl.	82	17	1	85°An_{40} 87°An_{36}	An_{30-36}	Intermediate	
GIDDY GRANITE	Cato area	D53/4/5	73°	0.01	Monocl.	67	31	2	100°	An_5	Low	SUB-VOLCANIC GRANITE
	Giddy area	D53/4/6	58°-61° Av.59°	0.07	Monocl.	74	26	1				
CALEDON GRANITE		D53/4/8	58-61°	0.00	Monocl.	71	27	2				

R12678 is an inclusion within cordierite-granodiorite of the 'Holly Inlet Type' while R12685 is from a gneissic adamellite of the 'Mount Alexander Type'. Both have well marked reaction rims of biotite growing perpendicular to the contact. Hornblende in R12678 is pleochroic from pale-brown to brown and shows a decussate structure. The hornblende in R12685 is almost colourless. The minor constituents form a fine groundmass and frequently are enclosed by grains of poikiloblastic hornblende. The sericite in R12685, with very minor zoisite, appears to be after plagioclase.

The assemblage in the alumina-rich hornfels is:

Cordierite-sillimanite-(biotite-quartz-K-feldspar).

Both studied inclusions are from gneissic adamellites. The first (R12684) is a particularly striking rock, composed of symplectically intergrown cordierite and lesser sillimanite. The sillimanite is unusually coarse-grained and has a uniform orientation which imparts a schistose appearance to the hard specimen. The minor minerals occur as scattered inclusions within the cordierite.

The second specimen (R13522) shows similar symplectic intergrowths and sillimanite is clearly forming at the expense of biotite. Sillimanite forms idioblastic grains with inclusions of quartz, spinel and biotite. Biotite flakes show random orientation and well developed pleochroic haloes. Biotite enrichment occurs at the contact of the inclusion with the enclosing sodic granite.

Melville Bay area

Rhodes (1966) has studied feldspars from both the 'Bremer Type' and 'Drimmie Head Type' (Table 3). The plagioclases are intermediate forms and the K-feldspars are monoclinic orthoclases. The association is typical of the granulite facies.

The *'Bremer Type'* is only exposed along the shorelines of Bremer Island and Wargarpunda Point. Three main rock types are recognized. *Cordierite-rich granulites* and diopside, cordierite, or biotite-bearing *quartzites* alternate in regular bands about 30 cm thick; the bands appear to be primary bedding (S_0). These rocks are then cut by irregular discordant veins and pods of mobilized *leucocratic granulite* .

A metamorphic foliation (S_1), defined by metamorphic segregation bands in the cordierite granulites, or by faint mica schistosity in the quartzites, parallels S_0. Quartzite bands are commonly dislocated and preserved as intrafolial inclusions in S_1; rootless folds of S_0 are either intrafolial or have S_1 axial plane to S_0. Both foliations, S_0 and S_1, have been folded about axes plunging about 35^o northwest. Rumples in $S_1$and a mineral lineation defined by stringers of cordierite and garnet are common.

The granulites are medium to coarse and even-grained with a 'sugary' texture. Cordierite, altered to pinite, is clearly visible as dark green, equant grains. Metamorphic banding up to about 2 cms thick is defined by dark cordierite-rich bands and light quartzo-feldspathic layers. The quartzites are fine-medium grained. They range from massive to finely banded, parallel to the coarser banding. A faint schistoscity may be developed, depending on the content of suitable minerals. Both the granulites and quartzites have scattered pink garnet porphyroblasts up to 5 cms in diameter. The leucocratic granulites are characteristically white massive coarse even-grained quartz-feldspar rocks, with scattered fractured porphyroblasts of pink garnet, up to 5 or 6 cms, rimmed by cordierite and lesser biotite.

Thin sections of *cordierite-rich granulites* show the following mineral assemblages:

R12659 Cordierite-orthoclase-quartz-biotite-garnet-plagioclase.

R12662 Cordierite-orthoclase-quartz-sillimanite-garnet.

D53/4/1 Orthoclase-cordierite-quartz-garnet-sillimanite-(ore).

Cordierite content is generally about 30%; K-feldspar varies between about 15% and 45%; biotite, garnet, and sillimanite individually are generally less than 5% but can range up to about 10%.

The *quartzite* shows the following mineral assemblages:

R12661 Quartz-plagioclase-diopside-calcite-tremolite-sphene-(garnet)

R12663 Quartz-plagioclase-garnet-cordierite-sillimanite

Quartz contents range from about 50% to more than 90%.

The *leucocratic granulites* show the following mineral assemblages:

R12664 Orthoclase-quartz-cordierite-plagioclase-garnet-biotite.

D53/4/2 Orthoclase-quartz-cordierite-garnet-sillimanite-plagioclase.

The notable difference between these rocks and the cordierite granulites is the decrease in ferromagnesian minerals, particularly cordierite, and, to some extent, increase in plagioclase. Quartz and K-feldspar comprise more than 80% of the rocks while cordierite is less than 10%.

Reaction rims occur at contacts between cordierite-rich granulites and quartzite inclusions: lime is added to the granulites from the quartzites, and biotite-rich rims about 1 cm thick occur around the quartzites. For example, R12660, at the contact between R12659 and R12661 has the following mineralogies:

Edge of granulite - quartz-plagioclase-orthoclase-cordierite- biotite-garnet.

Biotite-rich rim - quartz-plagioclase-biotite-tremolite-calcite-(sphene-garnet).

The transition between R12662 and R12663 has:

R12665 orthoclase-cordierite-garnet-quartz-sillimanite-(biotite).

The 'Bremer Type' rocks all have a granoblastic fabric. Fine banding in the cordierite-rich granulites is defined by dark cordierite-rich bands and light quartzo-feldspathic bands, enriched in garnet and sillimanite relative to cordierite. The non-quartz minerals in the quartzites occur interstitially to the coarser, more abundant quartz. One quartzite (R12663) shows a micro-banding defined by concentrations of garnet and cordierite-sillimanite.

Orthoclase in the granulites is fine-hair or bleb microperthite, has ragged outlines, and forms mosaic intergrowths with quartz. Plagioclase occurs as small idioblastic grains of andesine, but ranges from andesine to calcic labradorite in the quartzites; it is commonly sericitised. Myrmekite and micrographic intergrowths sometimes occur at grain boundaries in the leucocratic granulites.

In the cordierite-rich granulites cordierite occurs in xenoblastic grains and is commonly twinned. It poikiloblastically encloses, at various times, fibrolite, apatite, zircon, quartz, biotite, opaques and garnet. Intense alteration to pinite occurs along fractures and grain boundaries and K-feldspar and cordierite are intergrown. The cordierite in the leucocratic granulites is almost entirely replaced by pinite. Garnets are fractured and generally porphyroblastic. They have inclusions of quartz, sillimanite, cordierite, opaques and biotite. Alteration to sericite or chlorite is common at the margins. Cordierite and garnet are commonly closely associated in clusters.

Biotite is also common in these clusters, but less abundant in the leucocratic granulites. It is pleochroic from pale yellow-brown to deep red-brown and is both intergrown with or rimming both cordierite and, more commonly, garnet.

Where biotite is absent from the cordierite-rich granulites, sillimanite occurs as coarse idioblastic sections throughout the slide; it is also associated with cordierite and, more particularly, garnet. In the leucocratic granulites sillimanite forms stubby crystals, both as inclusions and scattered individual grains.

Biotite appears to be metastable in the leucocratic granulites and some secondary muscovite is present.

Accessories in the granulites include apatite, zircon, rutile, sphene, and spinel.

Diopside in the quartzites (R12661) forms small ragged grains altering to amphibole at the margins. Some isolated grains of green amphibole are scattered through the slide and are being replaced by carbonate. Calcite forms large, ragged grains interstitial to quartz and feldspar, contains large quartz and feldspar inclusions, and is, in part, replacing feldspar. There is no indication of disequilibrium in the association quartz-calcite-plagioclase-diopside. Accessories observed in the quartzites are opaques, epidote, zircon and spinel.

The *'Drimmie Head Type'* occupies most of outcrop of Bradshaw Granite in the Melville Bay area. It crops out on Drimmie Head, along the road and coast between Drimmie Head and Yirrkala Mission on islands in Melville Bay, and between Melville Bay and Gove Airstrip. Away from the coast the Granite is only exposed in gullys and valleys below the thick laterites of the area.

The rocks are essentially massive in outcrop, except for a faint foliation defined by feldspar and quartz. They resemble the leucocratic granulites: white to pale grey, leucocratic, coarse and even-grained adamellite and granite, with scattered porphyroblasts of pink garnet up to 2 cm, associated with altered cordierite and biotite. They differ from the leucocratic granulites mainly by more abundant pale-green sericitised plagioclase. Inclusions of quartzite and occasional basic rocks, and cordierite-garnet-biotite schlieren, are abundant aligned parallel to the foliation. The foliation varies widely in orientation from outcrop to outcrop. Contacts between the 'Drimmie Head Type' and 'Bremer Type' are not exposed. It is considered that the 'Drimmie Head Type' is an anatectic granite derived from, and intruding, the 'Bremer Type'.

Mineral assemblages observed in thin sections of 'Drimmie Head Type' are:

R12666 }	Orthoclase-plagioclase-quartz-garnet-cordierite-biotite.
D53/4/4 }	
D53/3/1 }	Orthoclase-plagioclase-quartz-garnet.
D53/4/3 }	

Adjacent to quartzite inclusions the rocks are contaminated, chiefly by addition of lime. The following were observed:

R12667	Plagioclase-quartz-garnet-biotite (at contact with inclusion).
R12668	Plagioclase-quartz-biotite-garnet-cordierite.

The rocks have a granitoid fabric and evidence of shearing is common: quartz shows marked strain extinction and granulated margins; K-feldspars show some granulated margins and patchy undulose extinction; and plagioclase sometimes has bent twin planes. Myrmekite and graphic intergrowths are present at margins of feldspar grains. Alteration is more marked than in the granulites: cordierite is almost completely replaced by pinite; feldspars (particularly plagioclase) vary from fresh to highly sericitised; biotite is altered to muscovite and leucoxene; and garnets sometimes have sericite along fractures.

Although the K-feldspar is orthoclase (Rhodes, 1966), undulose extinction in some rocks indicates some partial inversion to the triclinic form. The feldspar is a very fine rod or hair perthite, with wide variation in albite content. Rounded inclusions of quartz are present. The plagioclase is andesine and varies widely in degree of twinning; antiperthite has been observed. Quartz has trains of fine needle-like inclusions cutting across boundaries of contiguous grains.

Garnet, biotite, and cordierite are generally closely associated, but do occur independently. Biotite typically occurs rimming or intergrown with garnet or independently in knots (after garnet?). Garnets form relatively large, rounded to euhedral, fractured grains enclosing rounded inclusions of quartz and mica. Cordierite occurs in ragged grains enclosing garnet and biotite. Biotite is distinctively pleochroic from very deep red to pale yellow brown.

Accessories include spinel, apatite, zircon, opaques, and secondary muscovite and carbonate.

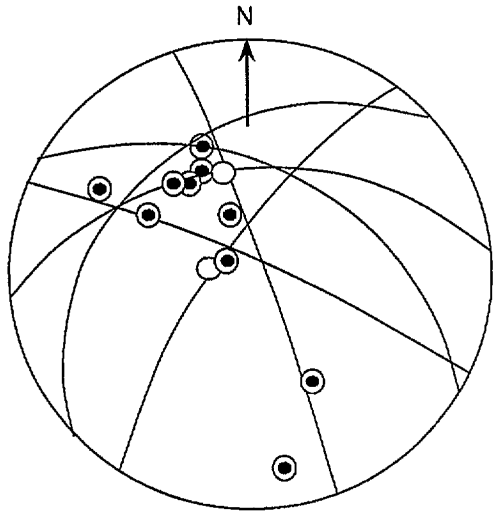
Thermally Metamorphosed Bradshaw Granite

On some islands within Caledon Bay inclusions of Bradshaw Granite are found within the younger Caledon Granite. They have undergone retrogressive thermal metamorphism and are very similar in appearance to the Myaoola Granite.

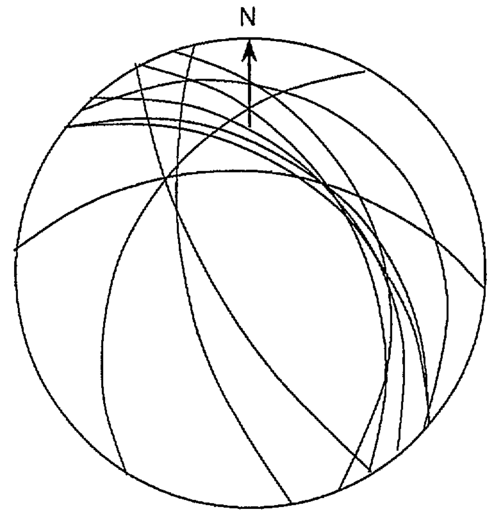
They are now leucocratic granophyric granites. Biotite, the only ferromagnesian mineral, is only present in very minor amounts. The most abundant feldspar is microperthite with strain extinction and incipient cross-hatch twinning; it is apparently an intermediate form resulting from the partial breakdown of monoclinic orthoclase to triclinic microcline. A characteristic feature of the feldspar is the abundance of large round to ameboid intergrowths of quartz within the feldspar producing a granophyric texture (see footnote, page). The feldspar shows slight alteration to kaolin. There is an overall decrease in grainsize from the normal 'Mount Alexander Type' and the fabric is similar to a normal hornfels; the micrographic texture could be described as poikiloblastic.

Plagioclase (albite-oligoclase) is a minor constituent. It occurs as subhedral to euhedral grains and myrmekite is formed at contacts with K-feldspar. Biotite is altered to chlorite; fibrolite occurs rarely as an alteration of feldspar; zircon and opaques are accessory.

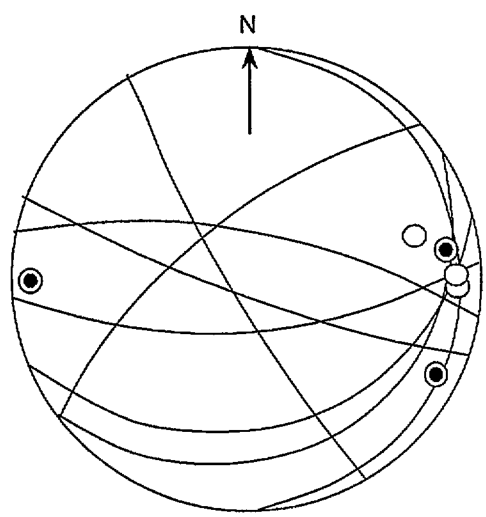
Geochronology: The Bradshaw Complex had been considered to be of Archaean(?) age on the basis of degree of metamorphism and structural trends (Dunnet, 1965), but isotopic age determinations (A W Webb, AMDL Rep. An 1814/73, unpubl.) have indicated a Palaeoproteorzoic (Orosirian) age of metamorphism.



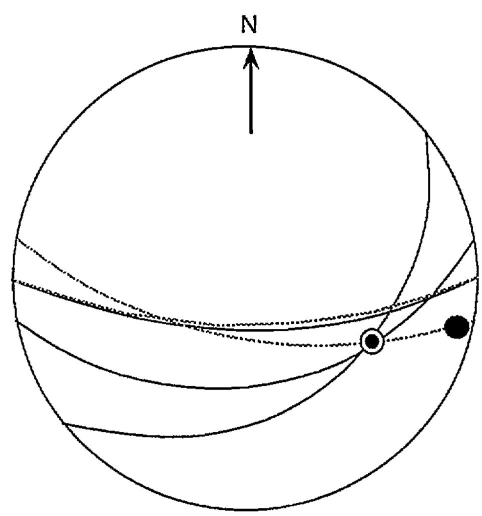
A. BREMER ISLAND
Plot of foliation (S_0, S_1), small folds (F) in foliation, and feldspar lineation (L_1)



B. MELVILLE BAY
Plot of foliation (S_0, S_1)



C. HOLLY INLET
Plot of foliations (S_0, S_1), fold axes in tectonic inclusions (F), and feldspar lineations (L_1)



D. MOUNT ALEXANDER
Plot of foliations (S_0, S_1), small folds (F), cleavage (S_2), and lineation (L_2).

REFERENCE

- Foliation planes (S_0, S_1)
- Late cleavage (S_2)
- Small-scale fold axis
- Feldspar lineation (L_1)
- Lineation (L_2)

Figure 8. Stereograms of principal structural elements, Bradshaw Complex, lower hemisphere Wulff net.

Six total-rock samples define a Rb-Sr isochron with an age of 1832$\pm$143 Ma, but two samples are discordant and exceed experimental error. The remaining four samples define an isochron with an age of 1903$\pm$75 Ma, with all uncertainties attributable to experimental error, and the initial Sr_{87}/Sr_{86} ratio was 0.7057$\pm$0.0050. The low initial ratio suggests that the rocks had a short prehistory, and that they are metamorphosed Orosirian rocks.

The isochron may be compared with the ~1920 Ma isochron originally obtained for the similar Tickalara Metamorphics in the East Kimberley (Bovinger, 1967), but since shown to be a mixing line of uncertain significance, derived during a younger metamorphism at about 1855 Ma (Page & Hancock, 1988). It is thus likely that the age of metamorphism of the Bradshaw Complex is younger than 1890 Ma, and quite likely within the ~1885-1865 Ma range of the Nimbuwah Complex abd othe r units of the Barramindi Orogeny (REFERENCES). A K-Ar age 1775 Ma from biotite (McDougall et al., 1965) may reflect intrusion of the nearby Caledon Granite.

Structure : A polyphase history of intense deformation, too complex to be detailed from the limited observations of sparse outcrop, is indicated for the metamorphic rocks of the Bradshaw Complex. Different fold phases appear to have subparallel trends, plunging moderately to the northwest in the Bremer Island-Melville Bay area, and shallowly to the east in the Holly Inlet-Mount Alexander area (Fig 8). Only one prograde metamorphic event is apparent.

Two foliation types are apparent in the metasediments, but may represent a number of different generations:-

S_0 Coarse compositional banding, interpreted as relic bedding

S_1 Metamorphic foliation of two, coplanar types - fine compositional banding and schistoscity.

S_0 and S_1 are now subparallel, S_0 being transposed into S_1 or preserved only as tectonic inclusions or rootless folds in S_1. These rootless folds and inclusions may be either intrafolial (i.e., S_1 deflects around them) or S_1 may be axial plane to the folds. Both S_0 and S_1 have in situ folds preserved, but without recognisable axial plane foliation. Fold axes (F) in both S_0 and S_1, and of the rootless folds in S_0, are subparallel, and elongate non-folded tectonic inclusions parallel F. The 'Bremer Type' shows rumples in S_1, and a mineral lineation (L_1) defined by stringers of cordierite-garnet, both now parallel to F (Fig. 8A,B). L_1 in the 'Mount Alexander Type' is defined by feldspar phenocrysts lying within S_1; scattered randomly within S_1 on fold hinges or parallel to F in highly schistose S_1 on steep fold limbs (Fig. 8C).

For Figure 8 recorded data is inadequate to reliably differentiate S_0 and S_1, or the different types of F. The relatively simple pattern in all areas, in which F and L_1 are grouped parallel to the main intersections in β diagrams of combined S_0-S_1, show that the structure is now dominated by a set of open folds younger than S_1. In the Melville Bay-Bremer Island area these folds plunge about 35° NW, and axial planes dip 60° NE. In the Mount Alexander-Holly Inlet area axes are subhorizontal to E and W and axial planes are subvertical. One or more intense and probably isoclinal fold events ('F_1') preceded the major 'F_2' because:

1) S_1, a metamorphic foliation associated with folding of S_0 is itself folded;
2) S_0 is transposed into S_1, and intrafolial folds are very tight;
3) The simple pattern of the 'F_2' indicates that S_0/S_1 are now coplanar.

The general coincidence of all measured elements and the shallow plunges and open nature of 'F_2' suggest that S_0/S_1, in common with many high-grade terrains, was probably subhorizontal, and 'F_1' and'F_2' are approximately coaxial. The principle prograde metamorphism is assumed to be associated with 'F_1'/S_1, since S_1 is the principal metamorphic foliation, although continuation of high-grade conditiions into 'F_2' cannot be eliminated.

The only evidence for retrograde metamorphism is late high-strain zones in the Mount Alexander area, in which a cleavage (S_2), defined by biotite, penetrates, dislocate and folds S_0 and S_1. Mild retrogression and granulation of quartz is apparent in thin section. S_2 strikes E-W and dips steeply south. L_2, defined by intersecting quartz veinlets, plunges about 5° E. S_2 could be considered to be axial-plane to 'F' (Fig. 8D), or later.

Structure within the more massive granitic phases is poorly developed. Inclusions within the 'Drimmie Head Type' are randomly oriented. Mobilizates in the 'Mount Alexander Type' and, to a lesser extent, parts of the 'Holly Inlet Type', show a weak but irregular foliation parallel to the metasediments, and inclusions parallel F.

DISCUSSION

It is clear from the preceding descriptions that the rocks of the Bradshaw Complex have all formed within a high-grade metamorphic terrain, and that the massive granitic phases, the *Holly Inlet* and *Drimmie Head* types, are anatectic derivatives of the associated metasediments. The anatectic origin is indicated by:

1. The obvious gradation from paragneiss to massive porphyroblastic adamellite in the *Mount Alexander Type*;
2. The obvious similarity between the *Drimmie Head Type* and the partial-melt veins of leucocratic granulite in the *Bremer Type*;
3. The paragneiss and granitic phases are essentially inseparable, both chemically (Figs 9, 10, 11) and mineralogically;

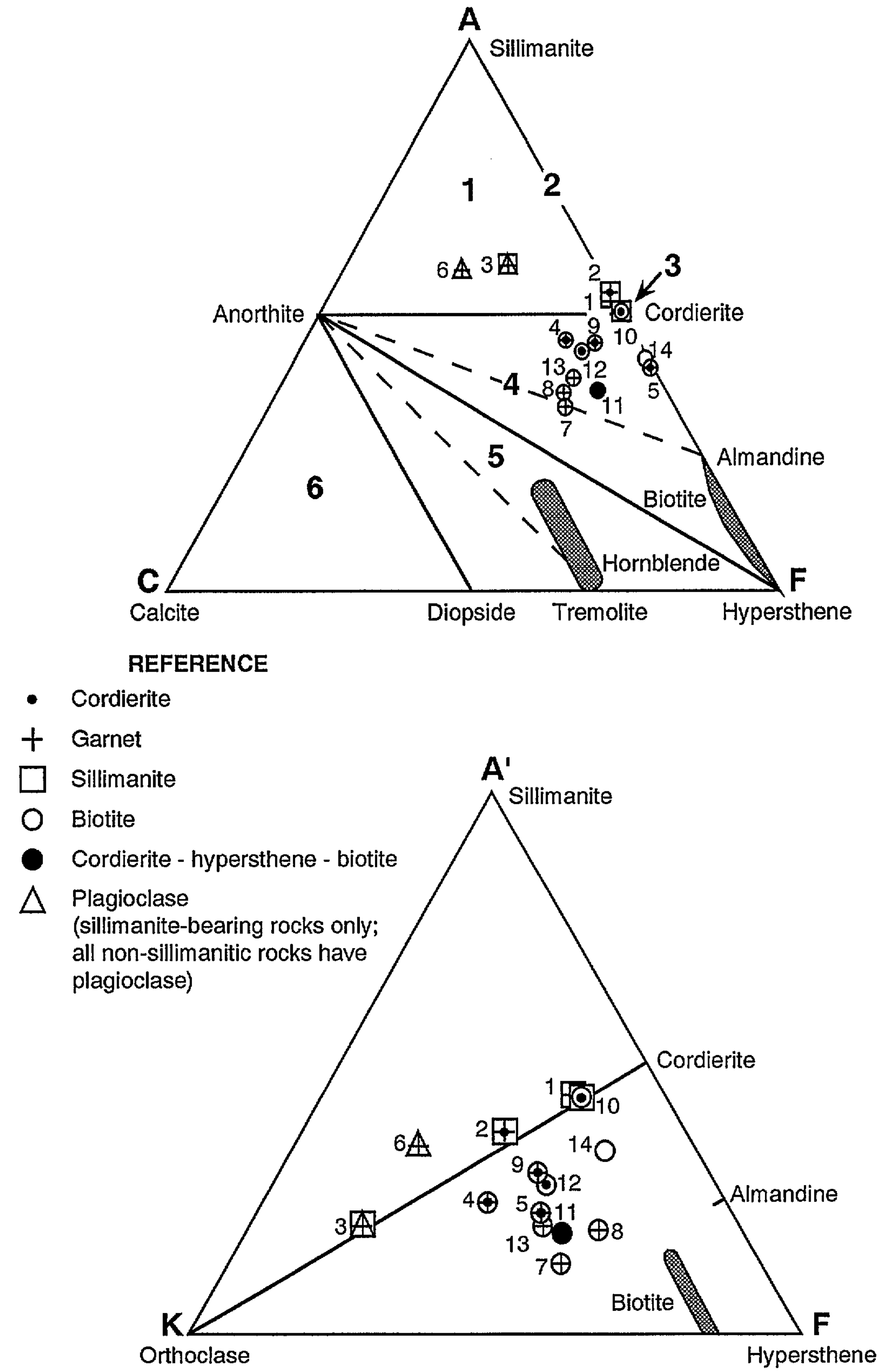


Figure 9. Eskola ACF and A'KF diagrams of analysed metamorphic rocks from the Bradshaw and Mirarrmina Complexes, plotted according to method of Winkler (1976) and using plotting program of Rock & Carroll (1989). A'CF plotted on K-feldspar projection. Mineral assemblages identified by symbol. Sample numbers identified in Tables ** and **. Numbered composition fields refer to actual assemblages observed in this study.

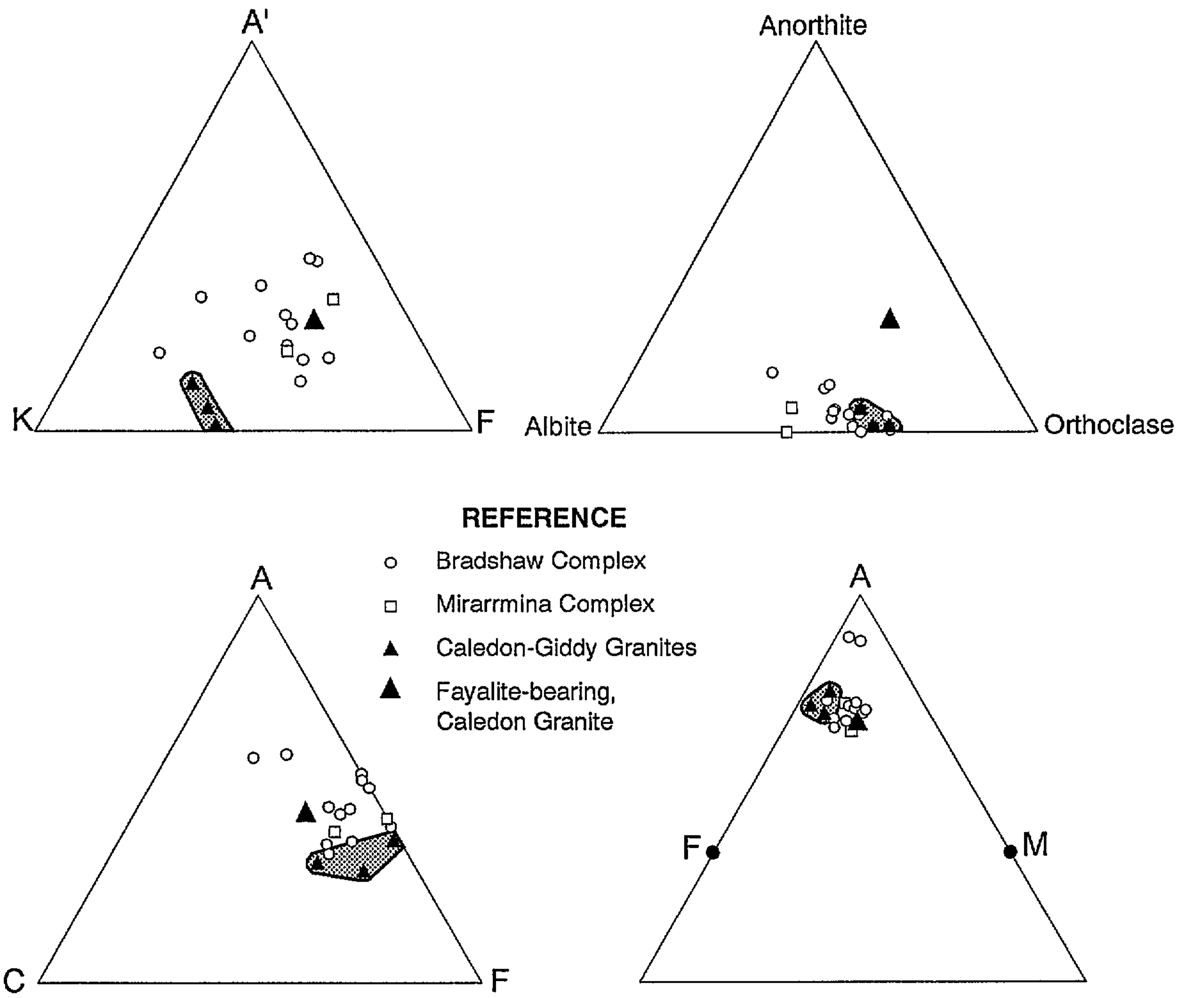


Figure 10. Triangular compositional plots of all analysed 'basement rocks' from Arnhem Land, using plotting program of Rock & Carroll (1989). Eskola A'KF and ACF and Thompson A'FM diagrams plotted according to method of Winkler (1976). A'CF and A'FM plotted on K-feldspar projection.

4. The pelitic composition and abundant cordierite, sillimanite, and garnet in the massive *Drimmie Head* and *Holly Inlet* types are typical of S-type granites.
5. In the $Al_2O_3/CaO+Na_2O+K_2O$ plot of Figure 11, all samples plot above the critical 1.1 line, which separates I-type from S-type granites.

The massive *Holly Inlet* and *Drimmie Head* types have been mobilised to the stage of massive granite intruding their host country rocks, as evidenced in their granitoid fabric, inclusions with reaction rims, and sharp contacts with country rocks. A more hydrous environment is shown by the more abundant retrogressive recrystallisation of cordierite to pinite; breakdown of garnet and cordierite to biotite, muscovite, chlorite, and andalusite; inversion of monoclinic K-feldspar to triclinic; and myrmekitic and graphic intergrowths. The lack of inclusions in cordierite is indicative of a magmatic phase. The extent of granitisation has been such that massive granite phases occupy more outcrop than the host paragneisses.

Figure 9 shows a close correlation between chemical compositions and relatively simple mineral assemblages as represented on ACF and A'KF diagrams. The mineral assemblages of all described thin sections may be grouped into six fields, below.

1.	Sillimanite-cordierite-plagioclase-(garnet):	D/53/4/2, D53/3/1;
2.	Sillimanite-cordierite:	R12683 (inclusion);
3.	Sillimanite-cordierite-garnet -(biotite-plagioclase):	D/53/4/1 R12662, R12679,R12663, R12665;
4.	Plagioclase-cordierite-garnet-biotite:	R12664, R12666, R12673, R12683, D53/4/7, R12677, R12676, R12674, R12680, R12681, R12682, R12659, R12661, R12667, R12668;
5.	Plagioclase-hornblende-diopside-biotite:	R12673, R12678, R12685, R12661;
6:	Plagioclase-diopside-calcite:	R12661.

These fields are typical of low-pressure assemblages in the uppermost amphibolite and lower granulite facies, and may be directly compared with identical assemblages in the East Kimberley, where mafic rocks interlayered with pelites allow precise identification of amphibolite and granulite zones (Gemuts, 1971).

In the Port Bradshaw area biotite is very abundant in the *Mount Alexander Type*, K-feldspar is intermediate between orthoclase and microcline, cordierite is rare, and hornblende is present. It is considered that these rocks crystallised in the sillimanite-cordierite-orthoclase-almandine subfacies of the amphibolite facies.

The feldspars in the *Holly Inlet Type* are typical of the granulite facies (Table 3), biotite is minor and retrogressive after cordierite, cordierite is abundant, and minor hypersthene is present. The *Holly Inlet Type* was therefore mobilised at higher temperature, in the cordierite-almandine subfacies of the granulite facies.

At Melville Bay the gneisses have the typical appearance of pelitic granulites. Feldspars are typical of the granulite facies (Table 3) in both the *Bremer Type* and *Drimmie Head Type* . Cordierite and sillimanite are abundant. Biotite is minor and generally retrogressive. Compared to the Port Bradshw area, all rocks at Melville Bay crystallised in the biotite-cordierite-almandine subfacies of the granulite facies.

MYAOOLA GRANITE

Definition

Distribution: Crops out poorly over about 250 km^2 on peninsula to east of Myaoola Bay, in north-eastern part of Blue Mud Bay-Port Langdon 1:250 000 Sheet area. Outcrops scattered amongst cover of Lower Cretaceous rocks and Cainozoic laterite and soil.

Type Locality: The outcrops found four miles north of Point Arrowsmith.

Derivation of Name: From Myaoola Bay, which bounds western side of the outcrops of Granite.

Stratigraphic Relationships: Inferred to be intruded by Caledon Granite; unconformably overlain by Lower Cretaceous sediments and Tertiary laterites.

Correlated with Bradshaw Granite on basis of lithological similarity and relationship with Caledon Granite; not tested by isotopic age determination.

Lithology: Sheared, white, leucocratic calc-alkaline granite, containing knots of chlorite and biotite (after garnet?).

Age: Orosirian (Palaeoproterozoic)

Description and comments

The Myaoola Granite has only been examined very briefly. It resembles the most southerly outcrops of Bradshaw Granite, with which it is equated. It differs from the Caledon Granite by possessing a large-scale foliation of outcrops and characteristic knots of chlorite and biotite, probably after garnet; no actual garnet was found. Contacts with the Caledon Granite are not exposed; the Myaoola Granite is considered to be older mainly because of its lithological similarity to the Bradshaw Granite. The Myaoola Granite is recrystallised similar to the xenoliths of Bradshaw Granite found within Caledon Granite.

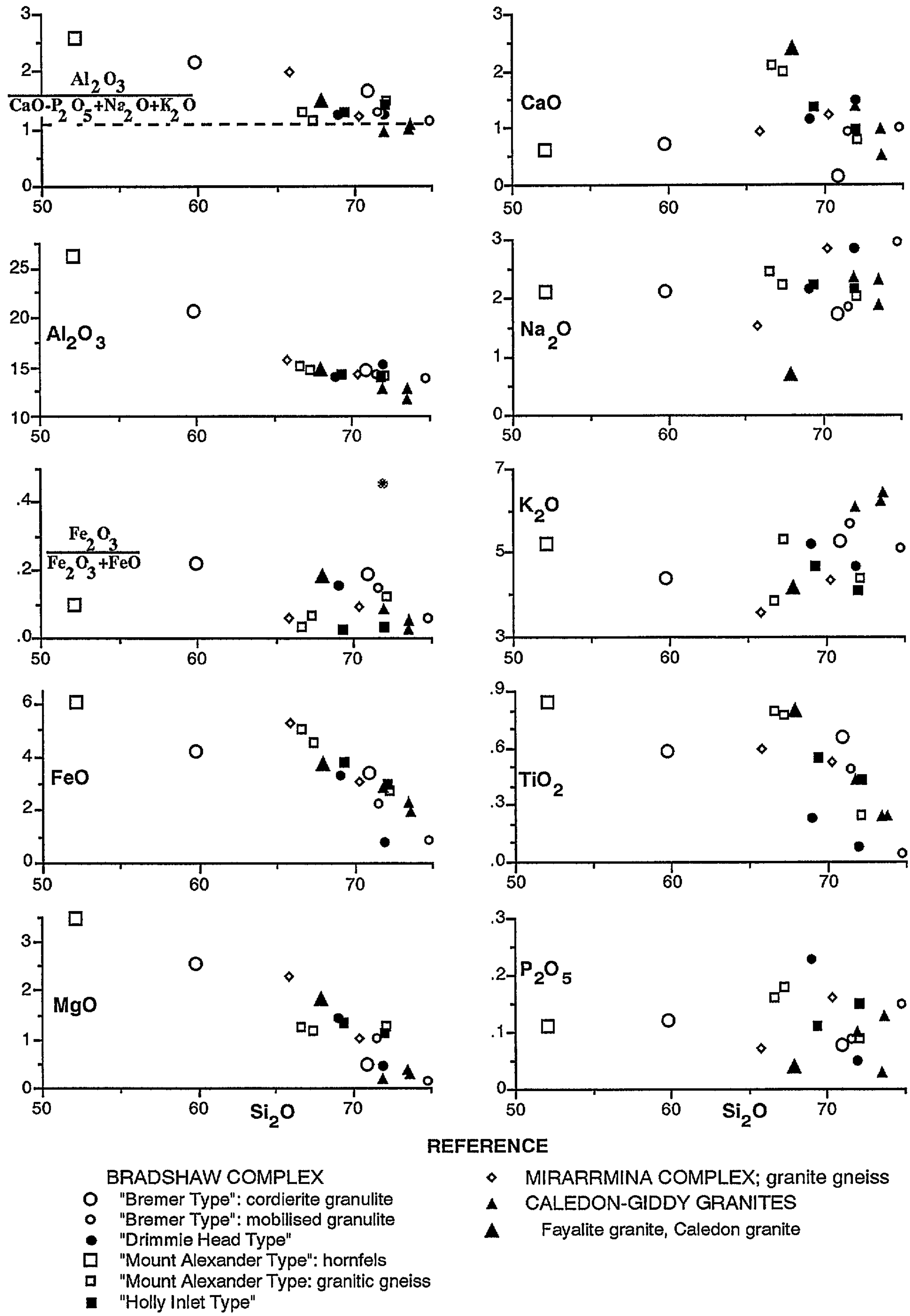


Figure 11. Harker diagrams of selected oxides from all analysed basement rocks from Arnhem Land. Quantities expressed as weight percent.

In thin section the rocks contain orthoclase microperthite, quartz, minor plagioclase and chlorite, and accessory zircon or apatite. They are medium to coarse-grained, have a xenomorphic granular texture, and irregular patches of granophyric intergrowth of K-feldspar and quartz.

The K-feldspar is a string and patch perthite, shows alteration to kaolin, and strain effects are common. Quartz occurs principally as large discrete grains which are fractured, show undulose extinction, and contain numerous opaque inclusions. When intergrown with K-feldspar it is very irregular and has the appearance of poikiloblastic inclusions, rather than micrographic intergrowths. Plagioclase has a composition in the range albite-oligoclase, and occurs in coarse anhedral grains altered to sericite and occasional epidote. Chlorite occurs as clots after biotite, of which a few relict grains remain. Epidote, muscovite, and fluorite occur either associated with chlorite or scattered through the rock. Minor opaques occur as inclusions in the chlorite.

MIRARRMINA COMPLEX

Definition

Distribution: Confined to a fault block, 24 km long and 9.5 km wide immediately west of Mitchell Range, on headwaters of Badalngarrmirri Creek, in south-central part of Arnhem Bay Sheet area. Bounded by fault blocks of Ritarango Beds and Fagan Volcanics to east and Parsons Range and McArthur Groups to west. Complex very poorly exposed; most of area shown on maps covered by sand, soil, and ferricrete.

Type Locality: The whole of the mapped exposures.

Derivation of Name: From Mirarrmina Creek, which flows into Gulbawangay River 19 km west of Complex. Crohn (1954) informally used name McLaren Complex but name is invalid because of prior usage.

Stratigraphic Relationships: Five broad groupings, in order of decreasing age, are recognised:

(1) 'Metasediments'
(2) 'Granite gneisses'
(3) 'Massive gabbros'
(4) 'Quartz-feldspar-porphyry dykes'
(5) 'Dolerite dykes'

' Granite gneisses' anatectic equivalent of, and apparently intrude, metasediments. 'Metasediments' overlain by Ritarango Beds; inferred from structural geometry to be unconformable. By extrapolation Ritarango Beads also unconformably overlie 'granite gneisses'. Part of basement complex of Arnhem Land. 'Metasediments' correlated with Grindall Metamorphics and sediments of Pine Creek Geosyncline. 'Granite gneisses' correlated with Bradshaw and Nimbuwah Complexes.

Younger units have no demonstrable relationships to units outside Complex. 'Massive gabbros' may correlate with Oenpelli Dolerite and Carpentarian dolerites intruding Ritarango Beds and Fagan Volcanics; 'quartz-feldspar-porphyry dykes' have no obvious correlative (except perhaps phonolite dyke swarms in Mirarrmina Complex); 'dolerite dykes' could be as young as dolerite sills intruding Roper Group.

Alternatively 'quartz-feldspar-porphyry dykes' correlate with Fagan Volcanics and 'dolerite dykes' with dolerites intruding Fagan Volcanics (Plumb & Roberts, 1965), in which case 'massive gabbros' represent older event, perhaps Nullaginian dolerites (e.g. Zamu Complex) of Pine Creek Geosyncline. First correlation now preferred (see discussion).

Lithology: Sheared lithic sandstones, tuffites, quartz-sericite slates; garnetiferous gneissic granites, granite gneisses, migmatites; tholeiitic gabbro, quartz gabbro and granophyric gabbro; quartz-feldspar porphyry; pyritic dolerite.

Age: Late Palaeoproterozoic - Orosirian to ?Statherian

Description and comments

The extensive soil cover and poor outcrop of the Mirarrmina Complex prevent accurate mapping of the distribution of the five major rock types. It is thought that most of the subcrop consists of 'metasediments' and 'granite gneisses', although there may be extensive unidentified areas of 'massive gabbros'. Most unidentified dykes are probably dolerite but may include some 'quartz-feldspar porphyry'.

The oldest rocks are the *'metasediments'*, a sequence of medium to coarse-grained sheared lithic sandstones, tuffites and quartz-sericite slates. They are metamorphosed to low greenschist facies in the north and east. Nearer to the 'granite gneisses' thermal metamorphism has produced garnet-microcline-albite-quartz-biotite-sericite and muscovite-biotite-quartz-sericite-plagioclase granofels. Fold axes in the metasediments plunge 50^{o} to 60^{o} to 015^{o} and axial plane cleavage trends 015^{o} and dips steeply to east or west.

The *'granite gneisses'* include garnetiferous porphyroblastic gneissic granites, granite gneisses, migmatites, and minor adamellite and granodiorite. Both orthogneisses and paragneisses are recognised. Foliation types and intensity vary. Primary foliations have a similar trend to those in the 'metasediments'. Post-crystallisation cataclasis has produced a second and more widespread foliation, accompanied by crushing and retrogressive metamorphism. This foliation strikes between 015^{o} and 030^{o}, subparallel to regional shear deformation if the adjacent Ritarango beds. Finally, younger intense shear zones, trending about 060^{o} and apparently related to post-Ritarango Beds faults, have produced local phyllonites and cataclasites in both the 'metasediments' and the 'granite gneisses'.

The 'granite gneisses' are interpreted as having formed by high-grade metamorphism and anatexis of the 'metasediments', but mobilization has locally been complete and the anatectic granite has intruded the 'metasediments' and superimposed a contact thermal aureole on them.

The *'massive gabbros'* form irregular, discordant bodies intruding the 'granite gneisses' and 'metasediments'. Gabbro, quartz gabbro and granophyric gabbro, with tholeiitic affinities, are represented. They are extensively saussuritised and uralitised and have suffered only minor post-crystallization strain.

'Quartz-feldspar-porphyry dykes' intrude all the older rocks; they trend about 015°. The porphyries are characterized by large spherical phenocrysts of K-feldspar up to 2 or 3 cm across, and smaller quartz, in a dark grey granophyric groundmass. Contamination occurs near contacts with gabbro.

The *'dolerite dykes'* also trend at 015°. They contain typical massive, medium-grained, pyritic dolerite and show very extensive secondary alteration.

Metasediments: Data on the 'metasediments' is sparse. They crop out very poorly as the major rock type in the northeast and in a narrow eastern belt adjacent to the Ritarango Beds. Contacts with the 'granite gneisses' or Ritarango Beds are not exposed. They are intruded by 'massive gabbros', 'quartz-feldspar-porphyry dykes', and 'dolerite dykes'.

Although both units are tightly folded, the Ritarango Beds are interpreted as being unconformable on the 'metasediments' because the units show distinctly different orientations of fold axes in adjacent outcrops.

The high-grade metamorphism of the metasediments appears to be thermal in character and is confined to a very narrow zone adjacent to 'granite gneiss'; it is interpreted as a contact thermal aureole adjacent to an intrusive phase of 'granite gneiss'.

The 'metasediments' show consistent fold axes plunging about 50°-60° to 015° and a penetrative axial plane cleavage trends about 015° and dips steeply to east or west. Quartz-sericite phyllonites containing two distinct cleavages occur in narrow shear zones; the first cleavage is penetrative, the second and strongest is less penetrative and apparently continuous with a fault zone in the adjacent Ritarango beds.

Most outcrops consist of deeply weathered sheared quartz-sericite rocks of indeterminate nature in creeks. In fresher exposures the tuffite is a pale grey coarse-grained clastic rock containing angular pale grey, pink and black rock fragments and scattered shale pebbles up to 2 cm long. The sandstones are a spotted pale grey-green and purple-brown colour due to replacement of the matrix by iron oxide.

In thin section the tuffite is poorly sorted (0.16 mm to about 3 mm) and composed almost entirely of rounded volcanic rock fragments (glass, devitrified glass, pumice, and fine porphyry) and embayed quartz grains in a microcrystalline quartz, clay, and sericite matrix. Relict flow texture in the matrix suggests an air-fall tuff.

The sandstones show a rough banding parallel to the schistosity and consist of strained quartz grains and sericitised rock fragments in a sericite-iron oxide matrix. Minor muscovite is developed in a secondary cleavage. The rock fragments were probably originally volcanic.

The quartz-sericite phyllonite is a fine-grained pale-grey, laminated lustrous rock in which the lamination is defined by bands of opaques in the second non-penetrative cleavage. Sericite pods and crushed quartz are drawn out in this foliation. A relict penetrative foliation, defined by individual small flakes of opaques, is oblique to the main foliation; the angle between them is about 30°. Small muscovite flakes occur subparallel to this penetrative foliation; its significance is obscure.

Towards the 'granite gneiss' contact the rocks become brown in colour (dark grey when fresh) and have lustrous surfaces due to development of randomly oriented flakes of muscovite and biotite. Abundant black rock fragments up to 3 or 4 mm are still clearly visible. In thin section the quartz is strained and the rock fragments completely sericitised. Small rounded quartz inclusions in the fragments resemble phenocrysts. Muscovite and biotite are incipient and randomly oriented, but the biotite has retrogressed to chlorite. Acicular epidote is common.

The highest grade 'metasediment' found is a garnet-orthoclase-biotite-plagioclase-cordierite(?)-quartz granofels. Relict axial plane cleavage is visible in outcrop but no foliation is apparent in thin section. Subhedral plagioclase (An_{8-14}) is slightly sericitised. Ragged grains of orthoclase hair perthite and fractured garnets are sericitised. Biotite is chloritised. Some myrmekite is present. Large irregular masses of sericite strongly resemble pinite after cordierite in the Bradshaw Complex although no fresh cordierite can be seen. Biotite flakes are clustered around their margins. Biotite flakes and plagioclase twins are bent and quartz is strained. Zircons occur as inclusions in biotite and apatite is accessory.

'Granite gneisses': The most complex group of rocks in the Mirarrmina Complex is the 'granite gneisses' which form the bulk of the outcrop in the southwest and west. They are intruded by the 'massive gabbros', 'quartz-feldspar-porphyry dykes', and 'dolerite dykes'. Contacts with the 'metasediments' and Ritarango Beds are not exposed; they are inferred to unconformably underlie the Ritarango Beds and are interpreted as having formed by high-grade metamorphism and anatexis of the 'metasediments'.

Foliations range from very weak to strong; foliated rocks are generally homogeneous gneisses (Berthelsen, 1961) although banded gneisses do occur. Bodies of massive even-grained granite intrude augen gneisses. Practically all rocks show cataclastic deformation ranging from weak to intense, and commonly this deformation is the source of the only visible foliation. Both paragneisses and orthogneisses are apparent, and intense cataclasites are found locally in narrow shear zones. Relationships between rock types and foliations are obscured by poor outcrop and poorly known. The 'granite gneisses' strongly resemble the 'Mount Alexander Type' of the Bradshaw Complex, and the high-grade phases of the Nimbuwah and Gunbatgari Complexes.

Euhedral or spherical megacrysts of K-feldspar up to 15 cm, but generally 4 or 5 cm long, are present in most outcrops and their orientation ranges from linear to random. Garnet crystals are generally about 0.5 to 1.0 cm. Irregular small veins of pegmatite, generally less than 30 cm thick and often containing tourmalines up to 2 cm long, are common.

Metasedimentary inclusions of fine-grained quartzites or mica-rich pelites and mica schlierin are common. The pelite inclusions form small irregular bodies but the quartzites form tabular bodies up to 30 cm thick and a few metres long. Contacts between host and inclusions are gradational and the granites are contaminated to sodic granites adjacent to quartzite.

The foliations in the paragneisses, which formed during the major period of metamorphism and granitisation, range from a schistoscity (the more common), in homogeneous gneisses and augen gneisses, to lithologic layering (generally alternating coarse and medium-grained layers), in banded gneisses and migmatites. The schistoscity grades into lithologic layering with increased intensity of folding. The layering has been observed as axial plane to a relict fold in a quartzite inclusion and megacrysts can parallel the layering. Schistoscity in the groundmass of the homogeneous and augen gneisses varies from strong to very weak, and is most easily defined by oriented megacrysts in augen gneisses. Even-grained micaceous gneiss grades through augen gneiss into massive porphyroblastic granite, with a decrease in mica content and intensity of foliation. Quartzite inclusions lie in the schistoscity and the schistoscity deflects around pegmatite pods. The schistoscity varies in orientation from subplanar and striking northerly and dipping steeply east to subvertical, to being intensely and irregularly folded by typical migmatitic plastic deformation, with no obvious pattern to the folds.

A later schistoscity has developed in most rocks by retrograde cataclasis. It varies in strike from 010^{o} to 030^{o} and dips at 50^{o} to 70^{o} east, subparallel to the regional shearing trends in teh adjacent Ritarango beds. This cleavage cuts the earlier lithologic layering obliquely, megacrysts are sometimes oblique to the cleavage, and micaceous inclusions are deformed. All minerals are foliated. Crushing is visible in thin section, quartz is smeared out, and mica flakes and feldspar twins are bent.

In the north a younger foliation again has produced intense cataclasites in a shear zone which trends about 060^{o}, dips moderately to steeply north or south, and has a steep east-plunging lineation. It lines up with a shear zone previously described from the 'metasediments', and with an exposed cross-fault in an outlier of Ritarango beds.

Compositionally the 'granite gneisses' are fairly uniform. They typically consist of K-feldspar, albite (occasionally oligoclase/andesine), quartz, biotite, and minor garnet. Deuteric or retrograde alteration is invariably present. Biotites are chloritised, sometimes completely; plagioclase is sericitised and, less commonly, saussuritised; K-feldspars are generally fresh. The alteration suggests that the plagioclase was originally more calcic.

Fabrics range from massive granitoid to foliated, from even-grained to porphyroblastic, and from medium to coarse-grained. Medium and even-grained rocks are generally more micaceous and better foliated than coarse-grained porphyroblastic rocks. Some foliated mica-rich rocks can be identified as paragneiss in thin section. Other mica-rich medium-grained rocks, although not markedly foliated, have abundant micaceous inclusions.

K-feldspar is always microperthitic (fine-hair is more common than patch or string perthite; two periods of development is suggested by hair and string perthite in the same grain) and generally an intermediate variety (usually zonal extinction; varies from uniform, through patchy zonal, to patchy cross-hatch). Inclusions of quartz and plagioclase are common. Groundmass grains, about 2 mm in size, are anhedral. Megacrysts, generally about 2 to 4 cm, are either euhedral or spherical.

Plagioclase is generally about 2 mm in size and anhedral. Myrmekite is sometimes developed at contacts with K-feldspar. Quartz invariably shows undulose extinction, anhedral grains, and varying degrees of crushing and fracturing. Biotite is pleochroic from deep red-brown to pale yellow-orange. It is foliated in some rocks but not in most; two developments are apparent, the older foliation has been destroyed by shearing while the younger parallels shearing. Garnets form amoeboid, fractured grains and are associated with biotite.

Increasing degree of shearing produces undulose extinction in quartz followed by slight granulation of grain boundaries, and, at later states, complete crushing and smearing out in the foliation; feldspars show similar effects but to a lesser extent. The final stage, seen in the latest shear zones, is a cataclasite; a grey, fine-grained rock, cherty in appearance, with faint lamination parallel to the shear direction and scattered small porphyroblasts. A relict foliation is faintly visible oblique to the lamination. In thin section the rock is completely crushed into small angular fragments drawn out in the foliation.

Two quartzite inclusions show different compositions:
quartz-biotite-chlorite-carbonate-epidote
quartz-epidote-tremolite-sphene-albite-carbonate

In the former quartz comprises the bulk of the rock, chlorite is after biotite and carbonate and epidote may be introduced from albitisation of plagioclase in the host rock. Both rocks have a typical hornfels texture and sericite is concentrated near the contact with the host rock.

'Massive gabbros': Irregular discordant bodies of tholeiitic gabbro, quartz gabbro, and granophyric gabbro have intruded the 'granite gneisses' and 'metasediments'. Individual bodies appear to vary up to 6 km long and 1.5 km wide and are elongated along the general structural trend of the Complex. The gabbros are massive and have been saussuritised and uralitised, but do not show the cataclasis typical of the older 'granite gneisses'.

Adjacent to contacts with the 'granite gneisses' the 'gabbros' are finer grained and contaminated; they are more leucocratic and contain quartz, granophyric intergrowths, thin veins of aplite, and small xenoliths of granite. The adjacent granites are pegmatitic and have veins of chlorite-epidote-quartz.

Two main types of gabbro occur. The most common, Type A, is a dark-green, generally even-grained, apparently medium-grained (in hand specimen), mesocratic gabbro and dolerite with scattered pyrite and occasional phenocrysts of pyroxene. Type B is a coarse-grained slightly leucocratic quartz gabbro and granophyric gabbro. Type B is generally less altered than A. The types appear to grade into each other along strike but multiple intrusion is also suggested by xenoliths of gabbro similar to Type A within B; Type A also contains basic inclusions of unknown source at times.

In thin section the Type A rocks are composed principally of clinopyroxene and plagioclase; textures range from ophitic to intergranular. They are medium to coarse-grained and pyroxenes tend to be slightly porphyritic. Pyroxenes are uralitised and the feldspars saussuritised. Widespread alteration to chlorite-epidote-sericite is independent of grain boundaries; vughs and veins containing various combinations of these minerals are common.

Some ferromagnesian minerals may be pseudomorphed by chlorite-epidote masses; an obvious association cannot be established. Interstitial chlorite and scattered euhedral epidote grains are common. Ophitic texture is best developed in the coarser grained rocks (especially the pyroxene phenocrysts) and alteration is most intense in the finer rocks.

Relative grainsizes of the principal minerals is shown by the following samples:

	Pyroxene	*Plagioclase*
(a)	1-3 mms	1 mm
(b)	1-2 mm	1-2 mm
(c)	0.5-1 mm	0.5 mm
(d)	1 mm	1 mm

The pyroxene is colourless to pale pink-brown, faintly pleochroic, and 2V is moderate (about 40^{o}); augite, possibly subcalcic, is suggested. Grains are irregular in shape and some have possible very-fine exsolution lamellae, probably of orthopyroxene. Occasional twinned grains are present.

Although the cores of pyroxene grains are fresh the margins are generally deuterically altered to uralite ranging from a pale brown slightly pleochroic amphibole (hornblende?) to a pale green fibrous form (tremolite); the colour appears to be related to intensity of colour in pyroxene and tremolite is more abundant in the finer grained rocks.

Plagioclase (labradorite) occurs as interlocking euhedral to subhedral grains. Zoning is rare or absent. Alteration to sericite, epidote, and sometimes chlorite, is advanced but patchy.

Some rocks show very minor amounts of granophyric intergrowth. Scattered subhedral opaques associated with pyroxenes are now altered to leucoxene.

Abundant secondary chlorite, sericite, and epidote postdates the uralite and saussurite and follows fine subparallel fracture planes which cut across grain boundaries; commonly only skeletal pyroxenes and feldspars remain. Interstitial chlorite and relatively large epidote grains are scattered through the rock and vugh-like chlorite-epidote masses may pseudomorph on earlier mineral (olivine?).

The only strain effects are:

(a) undulose extinction in plagioclase and quartz

(b) bent twin planes in plagioclase

(c) bent cleavage planes in pyroxene and uralite.

The main differences apparent in Type B rocks, all consistent with their being later-stage differentiates, are:

(1) Scattered patches of granophyric intergrowth and sometimes isolated grains of microcline perthite.
(2) Better development of ophitic texture.
(3) Less intense alteration.
(4) Slightly less pyroxene.
(5) Complex series of uralitic amphiboles.
(6) Occasional myrmekite and secondary biotite.

Grainsize is similar to Type A rocks; the apparent difference in hand specimen is apparently due to the altered nature of A. Feldspars and pyroxenes have similar compositions.

The complex series of uralitic amphiboles is striking; up to three types can rim single pyroxenes:

(1) Pale brown to brown-green, pleochroic hornblende with high 2V forms directly from pyroxene.
(2) A blue-green, pleochroic hornblende with high 2V forms a rim or is irregularly intermixed with (1) and shows parallel optical orientation to (1).
(3) A pale green to colourless fibrous tremolite (?) with low 2V sometimes replaces (1) and (2). In other cases it alone replaces pyroxene.

The chilled contact-zone rocks are intensely altered. Outlines of feldspar grains are almost obliterated by saussurite and pyroxene is almost completely replaced by fibrous pale-green amphibole. Intergranular chlorite is common and contamination by granite is shown by microcline perthite, granophyric intergrowth, and aplite veins.

'Quartz-feldspar-porphyry dykes': Dykes of porphyritic granophyre (definition of Johannsen, 1939) intrude the 'metasediments', 'granite gneisses', and 'massive gabbros'. The dykes all trend about 015°, cut major contacts without change in trend or width, vary in width up to about 100 m, and individual dykes have been traced for up to 8 km.

The porphyries are very striking in outcrop. Large ovoid phenocrysts of white K-feldspar up to 2 or 3 cms in diameter, and quartz up to 2 mms, are set in a fine-grained, dark-grey groundmass and stand out prominently on weathered surfaces. Sometimes the feldspars are finer grained (<10 mms) and sub- to euhedral. Xenoliths up to 15 cm long of metasediment and gabbro are common; micaceous schlieren are sometimes present. Platy flow of phenocrysts, xenoliths, and schlieren parallels the dyke walls.

In thin section the rocks are composed almost entirely of quartz and K-feldspar phenocrysts in a fine-even-grained granophyric* groundmass of the same minerals. Rare albite occurs. Minor groundmass biotite is mostly altered to chlorite. Carbonate is secondary, fluorite and sphene have been observed, and accessory apatite and zircon are included in micas.

The K-feldspar shows anomalous optical properties but a high 2V and patches of very fine, incipient cross-hatch twinning indicate inversion from orthoclase or sanidine. Most grains are microperthitic, some are apparently cryptoperthites, and the perthites have a notable abundance of sodic feldspar. Grain boundaries are ragged and some phenocrysts are glomeroporphyritic. Ragged quartz and granophyric inclusions (secondary?) and veinlets are common; other inclusions include mica, fluorite, and carbonates. Many phenocrysts have reaction rims (clearly visible to the naked eye) of micrographic intergrowth or of albite clusters.

Quartz phenocrysts are subhedral, with rounded corners, and are generally embayed. Glomeroporphyritic grains and granophyric inclusions are common. Albite phenocrysts are small, more euhedral, and patchily sericitised.

In the finer grained rocks (i.e. phenocrysts <10 mms) the groundmass is microgranitic rather than granophyric. Quartz phenocrysts, and to a lesser extent feldspars, are rimmed by cryptographic quartz-feldspar intergrowths.

Highly contaminated hybrid rocks are found near contacts with gabbros. Basic xenoliths are common. Feldspar phenocrysts invariably have micrographic reaction rims and quartz phenocrysts have narrow rims of blue-green hornblende, pleochroic to pale brown; both rims are clearly visible in hand specimen. Abundant hornblende is scattered through the pink,

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* In the Northern Territory the term Arnhem Land is commonly used for a slightly greater area than adopted here. Originally the name was used on Dutch charts for the land discovered by Willem van Colster in the "Arnhem" in 1623.

* Granophyric and micrographic are defined in the A.G.I. 'Glossary of Geology and Related Sciences', 2nd Edition as follows:

"*Granophyric:* A texture in igneous rocks characterised by the irregular intergrowth of blebs, patches, and threads of quartz in a base of feldspar. It is similar to graphic and micrographic but differs from these textures in that the intergrowth of quartz and feldspar is more irregular".

'*Graphic:* A rock texture resulting from the regular intergrowth of quartz and feldspar. The quartz is commonly cuneiform, resembling runic inscriptions on the background of feldspar'..... 'When this kind of intergrowth is reduced to microscopic dimensions the texture becomes micrographic.....'

medium-grained groundmass. The feldspar phenocrysts are mainly turbid microcline and are replaced, sometimes completely, by micrographic intergrowths along fractures. Some cores are replaced by chess-board albite with inclusions of bleb quartz and lesser K-feldspar. Small phenocrysts of subhedral albite occur, replaced along fractures by chlorite.

The groundmass consists of micrographically intergrown quartz and K-feldspar and scattered albite. Hornblende, epidote, chlorite, and biotite occur both as scattered grains throughout the groundmass or as clusters pseudomorphing pyroxene(?).

Contaminated finer-grained porphyries have phenocrysts of saussuritised albite (showing albite, Carlsbad-albite, and pericline twinning) more abundant than orthoclase perthite and quartz. Perthite phenocrysts are the largest, have resorbed margins, and common inclusions of large euhedral albite.

The basic xenoliths are extensively recrystallised. Plagioclase phenocrysts are saussuritised and mafic phenocrysts are replaced by decussate biotite. Relict hornblende reaction rims are preserved and chlorite replaces both feldspars and biotite.

Euhedral opaques are common. The groundmass has a fabric typical of hornfels. A quartz and K-feldspar mosaic poikiloblastically encloses small grains of epidote, chlorite, opaques and hornblende, and is symplectically intergrown with large skeletal hornblendes.

'Dolerite dykes': The youngest rocks in the Complex are dykes of massive, medium-grained dolerite which cut the 'quartz-feldspar-porphyry dykes'. They crop out very poorly and generally can only be traced as dark lines on air-photographs. They trend parallel to the porphyry dykes.

They are black medium-grained subophitic highly-altered pyritic dolerites, originally composed mainly of plagioclase and clinopyroxene. Opaques are abundant and quartz is minor.

Feldspar laths, which appear to be labradorite, are now almost completely replaced by epidote and chlorite. Pyroxene occurs as anhedral to subhedral grains and has been identified as augite. Grains invariably have reaction rims of a pale-green pleochroic amphibole, probably hornblende; in some cases replacement is complete. Boundaries between the pyroxene and amphibole are irregular. Secondary chlorite is scattered through the rock and is particularly concentrated with epidote into vughs.

DISCUSSION

The relative sequence of 'granite gneisses', 'massive gabbros', 'quartz-feldspar porphyries', and 'dolerite dykes' are clearly shown by intrusive relationships. The apparent volcaniclastic derivation of the 'metasediments' suggests a correlation with the nearby, similar Ritarango beds, but the orientation of fold axes in adjacent outcrops are distinctly different. The highest grade metamorphism apparently affecting the 'metasediments' has been interpreted to be thermal, and related to the contact with an orthogneiss of the 'granite gneisses', and so the orthogneisses are interpreted as intruding the 'metasediments'. Since the 'granite gneisses' are inferred to be older than adjacent Ritarango beds on metamorphic grounds, the 'metasediments' are therefore interpreted as older than the Ritarango beds.

The widespread retrogressive cataclasis, which has overprinted much of the 'granite gneisses', is accompanied by a pervasive cleavage subparallel to, and therefore presumably related to, the earliest pervasive deformation of the adjacent Ritarango beds (below). Younger shear zones, trending about 060°, are extensions of the youngest faults to overprint the Ritarango beds. However, although these latest (060°) faults also overprint the 'metasediments', there is no evidence of the earlier cataclastic overprint on the 'metasediments'. Indeed, the overall trend of principal cleavage and folds in the 'metasediments' (015°) parallels that of the Ritarango beds as a whole. Since the unexposed contact between the 'metasediments' and Ritarango beds may well be faulted, the local discordance in fold trends between the two units may therefore be of no relative age significance whatsoever.

The grade of regional metamorphism of the 'metasediments' is very lowest quartz-albite-muscovite-chlorite subfacies of the greenschist facies. The apparent contact metamorphism adjacent to the 'granite gneisses' reached sillimanite-cordierite-orthoclase-almandine subfacies, the same as that of the gneisses themselves, and the 'contact granofels' is very similar in mineralogy to some of the paragneisses. The 'granofels' may well be more properly assigned to the 'granite gneisses'. The metamorphic gradient from the low-grade 'metasediments' to the 'granite gneisses' is remarkably steep for a regional gradient, unless they are tectonically superimposed one upon the other; exposure is too poor to identify any such structure. The correct stratigraphic position of the 'metasediments' - a lower-grade equivalent of the 'granite gneisses' or a tectonic outlier of Ritarango beds - remains an open question for the present.

The 'granite gneisses' may be directly compared with the 'Mount Alexander Type' of the Bradshaw Complex, and are considered to have formed during the same Barramundi event. Their chemistries and mineralogies are inseparable (Figs 9, 10, 11). Their principal metamorphisms took place in the same sillimanite-cordierite-orthoclase-almandine subfacies of the amphibolite facies. The outcrop appearances and migmatitic features are similar.

The 'massive gabbros' show no sign of any of the cataclasis which has overprinted the 'granite gneisses', and therefore inferred to be younger. A logical correlation is with gabbro bodies which intrude the Ritarango beds and Fagan Volcanics, althugh the relative age of these latter bodies to the deformation of their host rocks remains to be determined. They are tholeiitic, containing subcalcic augite and a granophyric residium, and no olivine.

The ages of the 'quartz-feldspar porphyries' and 'dolerite' remain uncertain. Their emplacement apparently reflects late extensional events, because both are emplaced into apparently preexisting faults of the regional 015^{o} system.

GRINDALL METAMORPHICS

Definition

Distribution: Small isolated exposures along the coast and islands within Blue Mud Bay. Found on Grindall Point, Round Hill Island, Morgan Island, Burney and adjacent islands, the northern tip of Bickerton Island, and near the mouth of the Walker River.

Type Section: Eastern end of Morgan Island about lat. 13^{o}28'S long. 136^{o}6'E.

Derivation of Name: From Grindall Point, on the northern side of Blue Mud Bay.

Stratigraphic Relationships: At type section and near Walker River intruded by Caledon Granite and unconformably overlain by Groote Eylandt Beds. On Round Hill Island intruded by volcanic neck which is tentatively correlated with Bickerton Volcanics. From this and intrusive relationship of Caledon Granite, and difference in degree of deformation of metamorphics and volcanics, Bickerton Volcanics are inferred to unconformably overlie Grindall Metamorphics, although no contact between them exposed. From rock type and metamorphic style correlated with rocks of Pine Creek Geosyncline. Considered to be low-grade equivalent of Bradshaw Complex and Myaoola Granite.

Lithology: Green to red-brown interbedded, blocky, fine to medium-grained quartz greywacke and shale or slate; minor black quartz greywacke and white slatey siltstone.

Age: Orosirian (Palaeoproterozoic)

Description and comments

The Grindall Metamorphics contain green to red-brown, interbedded, blocky, fine to medium-grained quartz greywackes and shales or slates which have been folded, almost isoclinally, about roughly easterly-trending axes and undergone low greenschist facies regional metamorphism, with recrystallisation of clays to sericite and biotite. The grade of metamorphism generally does not exceed that of the quartz-albite-muscovite-chlorite subfacies, except on Morgan Island where the appearance of biotite indicates the quartz-albite-epidote-biotite subfacies. A slaty cleavage is developed to varying degrees in the shales and a slight schistoscity is sometimes present in the quartz greywackes. Folding is mainly by flexural slip and the cleavage is sometimes axial plane and sometimes parallel to bedding. A second folding about a northerly axis is shown by development of a shallow fracture cleavage (Figure 12).

On *Morgan Island* blocky black fine-grained quartz greywackes are interbedded with flaggy green biotite slates. They are tightly folded about an axis plunging about 30^o to 070^o, and bedding dips very steeply to north and south (Fig. 12A). The slates have a slatey cleavage (S_1) parallel to bedding (S_0) but cleavage in the greywackes is poorly developed. A notable feature is an excellent development of AC joints (S_2). Minor faults parallel this jointing, and are frequently seen as narrow zones of strong cleavage. A second set of very closely spaced joints (S_3) dip about 60^o E and are broadly warped about a N-trending axis, which is probably related to a fracture cleavage (S_4) which dips shallowly to the east (Fig. 12B). S_3 and S_4 become difficult to differentiate as S_3 becomes progressively more closely spaced.

In thin section the quartz greywacke is poorly sorted (0.005 to 0.5 mm) and consists of sub-angular quartz grains in a sparse matrix of very fine biotite and sericite. Some chlorite is present but is being converted to biotite. Some interstitial carbonate occurs and a few euhedral grains of brown tourmaline have probably formed during the metamorphism. A slight schistoscity is present but is best developed in thin zones.

The slates have a grainsize about 0.01 mms and consist of flakes of biotite with scattered subangular quartz grains making up about 25% of the rock. The mica shows an irregular preferred orientation.

On *Bickerton Island* biotite is absent and sericite is dominant. Blocky medium-grained grey to red-brown quartz greywackes are interbedded with lesser flaggy red-brown ferruginous sericitic slatey siltstone and blocky white sericitic slatey siltstone. The fine-grained rocks have a slatey cleavage while the coarser rocks have an easily visible foliation defined by parallel alignment of grains. Bedding (S_0) trends southwest and dips very steeply to the northwest. Penetrative slatey cleavage trends westerly and dips 30^o-40^o south, and fold axes plunge 30^o southwest - the intersection of S_0 and axial-plane S_1. Bedding-cleavage lineation and rumples in slatey cleavage both parallel this fold axis, and AC joints are again prominent (Fig. 12C).

In thin section the rocks resemble those of Morgan Island, except for the absence of biotite. The greywacke contains about 60% subangular quartz grains, 0.05 to 0.3 mm in size, and occasional sericitised feldspar, in a sericite matrix. The red-brown siltstones consist mainly of intergrown quartz, with only about 5-10% sericite and 5-10% hydrated iron oxide. Bedding laminae 0.2 mm thick are defined by iron oxide and the sericite shows a preferred orientation. The most distinctive rock of this area is the blocky white siltstone beds. These consist of quartz

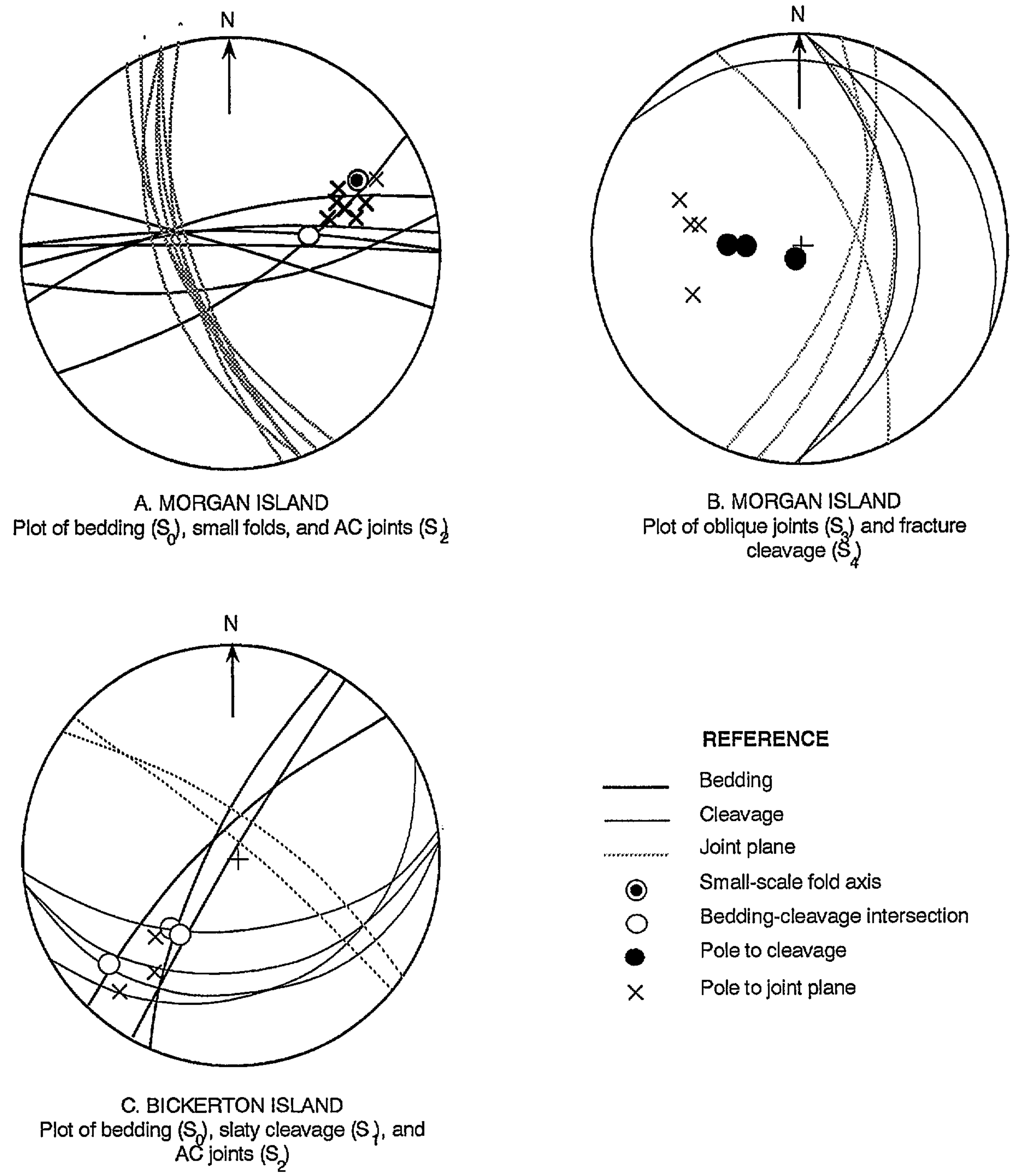

Figure 12. Stereograms of principal structural elements, Grindall Metamorphics, lower hemisphere Wulff net.

about 0.01 mm and less than 30% sericite. Sericite flakes are aligned in the schistoscity and quartz shows a preferred optical orientation.

Near the *Walker River* axial-plane cleavage dips steeply and trends east-west. Small open flexural-slip folds with bedding-cleavage lineation parallel to axes plunge to 290^{o}. Lithology is the usual flaggy to blocky, red-brown to black, quartz greywacke and sericitic siltstone with parallel orientation of mica flakes and parallel optic orientation of quartz.

On *Grindall Point* tightly folded, southerly dipping, sheared quartz-clay-iron oxide rocks and ferruginous siltstones are found. The clay rocks are thought to be of volcanic origin but are too highly altered for this to be verified in thin section.

GUNBATGARI COMPLEX

Definition

Distribution: Only exposed in inlier of about 40 km^2 along Mann River in central part of Milingimbi 1:250,000 Sheet area.

Type Locality: The whole of the exposure along the Mann River about lat. 12^{o}32"S, long. 134^{o}9'E.

Derivation of Name: Gunbatgari District, the aboriginal tribal area in which the complex crops out.

Stratigraphic Relationships: Part of the basement complex of Arnhem Land. Unconformably overlain by the Kombolgie Formation, the basal unit of the Katherine River Group. Correlated with, and probably continuous in subsurface with Nimbuwah Complex.

Lithology: Porphyroblastic migmatite and foliated hornblende-biotite adamellite.

Age: Orosirian (Palaeoproterozoic)

Description and comments

The Gunbatgari Complex crops out poorly in a small inlier beneath the Kombolgie Formation and has only been briefly studied in reconnaissance detail. It most resembles the migmatite zone of the Nimbuwah Complex and may well join up with it in the subsurface.

One sample of porphyroblastic melanocratic hornblende-biotite adamellite contains about 30 percent each of oligoclase-andesine, microcline perthite, and quartz, and about 5 percent each of brown biotite and olive-green hornblende. Apatite and zircon are accessories. The rock shows a granoblastic fabric with grainsize ranging from 1.3-6 mm. Plagioclase is subhedral to euhedral, K-feldspar subhedral to anhedral, and quartz occurs as granular masses or interstitially. Anhedral clots of biotite and hornblende occur both separately and intergrown with each other. Hornblende is occasionally being replaced by biotite and both are being replaced by chlorite.

NIMBUWAH COMPLEX

Definition

Distribution: Poorly exposed along valley of Goomadeer River in north-west corner of Milingimbi 1:250,000 Sheet area, and extends westwards to the East Alligator River area of the Katherine-Darwin region. In detail much of the area shown as outcrop on map is covered by soil.

Type Locality: Needham, Smart, and Watchman (1973) have nominated hill of migmatites, intruded by phonolite and felsite dykes, at lat. $12^{o}9'40"$S, long. $133^{o}35'30"$E.

Derivation of Name: Defined by Walpole et al. (1968). From Nimbuwah, a sandstone monolith in the Alligator River 1:250,000 Sheet area, which has rocks of the complex at its base.

Stratigraphic Relationships: Part of the basement complex of Arnhem Land. Unconformably overlain by Katherine River and Wessel Groups. Lower age limit cannot be defined in Arnhem Land; shown in East Alligator River area to be result of migmatisation of Palaeoproterozoic sediments of Pine Creek Geosyncline (Needham *et al.,* 1973). Orosirian isotopic age. Correlated with Bradshaw and Gunbatgari Complexes and 'granite gneisses' of Mirarrmina Complex.

Lithology: Granitic to tonalitic granitoid, migmatitic, and gneissic rocks; schist, amphibolite, and quartzite; cataclasites locally.

Age: Orosirian (Palaeoproterozoic).

Description and comments

The Nimbuwah Complex crops out poorly as low outcrops surrounded by soils of the Arnhem Land coastal plain and was only briefly studied during the Arnhem Land and Katherine-Darwin surveys. It has been studied in more detail during a detailed survey of the Alligator Rivers uranium province (e.g. Needham et al., 1973; Smart, Wilkes, Needham & Watchman, 1974).

Two types of granite, massive and gneissic, were recognised during the Arnhem Land survey and two ages were suggested (Rix, 1965). Thin section study by the author however suggested a common origin and age for them: they show similar mineralogical compositions and grade texturally into each other.

The later work has shown the complex to be a migmatite dome in which a massive anatectic granitoid core grades outwards through successive zones of migmatite, lit-par-lit gneiss, a transitional zone, and finally into greenschists of the Pine Creek Geosyncline; the outer limit of the complex is defined by the onset of metamorphic differentiation (Smart et al., 1974). Metamorphic grade increases from the staurolite-almandine subfacies (of Winkler, 1967) in the transitional zone to sillimanite-almandine-orthoclase subfacies in the granitoid core. The exposures in Arnhem Land are confined to the granitoid core, and a small area of migmatite in the southwest.

The rocks of the granitoid core are either foliated or nonfoliated homogeneous granites or gneisses. Two types are recognised - medium to coarse, even-grained and coarsely porphyroblastic rocks - with sharp contacts between them. Apophyses of porphyroblastic granite intrude the inner migmatite zone and contain xenoliths of migmatite which retain their original orientation of foliation. Augen gneiss appear in the migmatites near their contact with the lit-par-lit rocks (Smart et al., 1974).

Specimens collected in 1962 contain about 50% plagioclase (oligoclase-andesine), 5-10% K-feldspar, 30-40% quartz, and 5-10% biotite plus hornblende. Accessories include sphene, apatite, iron ore, zircon, epidote, allanite, and calcite. Plagioclase is invariably heavily sericitised and imparts a pale-green colour to many rocks. The K-feldspar is a microcline fine perthite (Needham *et al.,* 1973 record orthoclase and absence of microcline). Biotite and hornblende occur in clots in which hornblende is altering to biotite, and the biotite is, at times, altering to chlorite. Hornblende is pleochroic from dark green to pale green-brown and biotite is a brown variety. Rocks which contain biotite without hornblende contain areas of spherulitic chlorite which may pseudomorph hornblende. Muscovite is sometimes associated with biotite.

The rocks show varying degrees of post-crystallization cataclasis. The final stage, observed in narrow (fault?) zones is a fine-grained thoroughly crushed and granulated cataclasite.

Some areas are extensively intruded by phonolite dykes.

LATE TECTONIC GRANITES AND ACID VOLCANICS

OROSIRIAN

Giddy Granite

Definition

Distribution: Poorly exposed in scattered small inliers, beneath Lower Cretaceous rocks and Cainozoic soil and laterite, over about 340 km^2 inland from south-west of Melville Bay, in Gove 1:250,000 Sheet area.

Exposures can be divided into two areas, one large reasonably continuous exposure about 16 km west-north-west of mouth of Giddy River, and a group of smaller exposures around headwaters of the Giddy River. These two areas have different rock types.

Type Locality: Around upper reaches of Giddy River.

Derivation of Name: From Giddy River, which flows northwards into southern part of Melville Bay.

Stratigraphic Relationships: Only relationship directly observed is that Giddy Granite is unconformably overlain by Lower Cretaceous sediments and Tertiary laterites.

Massive post-tectonic-type granite. Correlated with Caledon Granite on basis of petrology and isotopic age. The western group of Giddy Granite outcrops resemble in rock type, and appear to grade into, overlying Spencer Creek Volcanics and unconformably overlain by Mount Bonner Sandstone. Assigned to the widespread associated post-tectonic granites and acid volcanics, about 1800 Ma old, in northern Australia.

Lithology: Massive pink coarse-grained frequently porphyroblastic granite. Micrographic and granophyric intergrowths common. Grainsize appears to decrease towards margins of body.

Age: Orosirian (Late Palaeoproterozoic)?

Description and comments

The Giddy Granite is best described in two areas. In the area around the Giddy River the Granite is distinguished by the abundance of large porphyroblasts (up to 20 cms across) of alkali feldspar and the presence in the groundmass, of either hornblende-biotite or fayalite-pyroxene-hornblende-biotite. The rocks are calc-alkaline granites or adamellites. Local belts of cataclasis are prominent.

North of the Cato Laterite Deposit the granite is a massive, even-grained leucocratic micrographic granite with occasional chloritised biotite. The rocks are noted for their lack of large alkali feldspar porphyroblasts and paucity of ferromagnesian minerals.

One sample from each area has been chemically analysed (Table 4) and Rhodes (1966) has identified the alkali feldspars as monoclinic forms (Table 3) typical of sub-volcanic granites. The rocks from both areas are chemically very similar, except for higher FeO/MgO ratio and more lime in the Giddy sample, and are similar to the Caledon Granite.

Giddy Area. The granite in this area is typically coarse-grained and massive, pink to grey in colour, frequently has two feldspars visible in hand specimen, and universal large porphyroblasts of alkali feldspar up to 20 cms across. Ferromagnesian minerals, mostly biotite and hornblende, occur in discrete knots, suggesting formation from earlier minerals, and vary in relative abundance from place to place. Two distinct rock types occur in fairly close proximity.

Table 4. Whole rock silicate analyses and calculated Barth Mesonorms of Mirarrmina Complex and Giddy and Caledon Granite samples. Oxides expressed as weight percent.

	13	14	15	16	17	18
SiO_2	70.30	65.80	73.50	71.90	73.60	67.90
Al_2O_3	14.20	15.80	11.80	12.70	12.70	14.60
Fe_2O_3	0.67	0.76	0.27	0.57	0.13	1.88
FeO	3.05	5.25	2.30	2.85	1.95	3.75
MgO	1.02	2.30	0.38	0.18	0.29	1.82
CaO	1.22	0.93	0.96	1.36	0.51	2.40
Na_2O	2.85	1.52	1.88	2.35	2.30	0.68
K_2O	4.35	3.60	6.25	6.10	6.40	4.15
H_2O+	1.32	2.55	1.29	0.87	0.99	1.14
H_2O-	0.04	0.11	0.19	0.05	0.15	0.43
CO_2	0.00	0.68	0.62	0.18	0.16	0.00
TiO_2	0.53	0.60	0.24	0.43	0.24	0.80
P_2O_5	0.16	0.07	0.03	0.10	0.13	0.04
MnO	0.04	0.07	0.03	0.04	0.02	0.07
Total	99.75	100.04	99.74	99.68	99.57	99.66
Quartz	33.79	42.38	37.27	31.76	34.03	42.69
Orthoclase	20.39	10.85	35.09	33.38	36.21	17.41
Albite	26.41	14.45	17.69	21.86	21.39	6.44
Anorthite	3.26	0.00	0.68	3.58	0.69	9.35
Corundum	4.11	10.87	1.95	1.09	1.97	6.62
Biotite	9.82	18.68	5.78	6.32	4.73	13.56
Hornblende	0.00	0.00	0.00	0.00	0.00	0.00
Hypersthene	0.00	0.00	0.00	0.00	0.00	0.00
Wollastonite	0.00	0.00	0.00	0.00	0.00	0.00
Magnetite	0.72	0.84	0.30	0.62	0.14	2.07
Hematite	0.00	0.00	0.00	0.00	0.00	0.00
Sphene	1.14	0.00	0.00	0.93	0.00	1.76
Ilmenite	0.00	0.89	0.35	0.00	0.35	0.00
Rutile	0.00	0.00	0.00	0.00	0.00	0.00
Apatite	0.35	0.16	0.07	0.22	0.28	0.09
Calcite	0.00	0.88	0.82	0.24	0.21	0.00
Water	1.36	2.66	1.48	0.92	1.14	1.57
Total	101.35	102.66	101.48	100.92	101.14	101.56

Sample details

13.	Mirarrmina Complex	Garnetiferous-biotite gneissic adamellite. #D53/3/12. Analyst L. Castanelli, AMDL.
14.	Mirarrmina Complex	Muscovite-biotite-quartz-plagioclase granulite. #D53/3/7. Analyst C. Edmond, AMDL.
15.	Giddy Granite	Graphic biotite-chlorite granite. #D53/4/5. Analyst C. Edmond, AMDL.
16.	Giddy Granite	Hornblende-biotite adamellite. #D53/4/6. Analyst C. Edmond, AMDL.
17.	Caledon Granite	Graphic muscovite-hornblende adamellite. #D53/4/8. Analyst, C. Edmond, AMDL.
18.	Caledon Granite	Weathered fayalite granite. #R12442. Analyst L. Castanelli, AMDL.
Note	#R......	Refers to registered number of samples in BMR collection.
	#D53/4/..	Refers to registered number of BMR age determination samples.

The first is a medium-grained granophyric fayalite-pyroxene-hornblende calc-alkaline granite (R12669). The ferromagnesian minerals are minor and scattered randomly through the rock; fayalite and clinopyroxene occur both separately and associated with each other; fayalite as ragged grains 0.5-1 mm in size and clinopyroxene in masses 1 mm across symplectically intergrown with quartz. Both are partially replaced by hornblende (pleochroic pale brown - green brown - green), which is in turn partially replaced by red-brown biotite; iron ore accompanies the alteration. About 80 percent of the rock comprises a groundmass of granophyric quartz-microperthite, and minor patches of microgranitoid fabric with equant quartz grains poikilitically enclosed by feldspar. The K-feldspar is an intermediate form (strain extinction), forming ragged grains 1-4 mm in diameter and enclosing irregular quartz vermicule inclusions, which show uniform optical orientation over large areas. Set in this groundmass are phenocrysts of subhedral plagioclase (sometimes several centimetres long), lesser anhedral orthoclase and rounded resorbed strained quartz. Plagioclase is occasionally zoned, and invariably has myrmekite at its outer edge and an outer shell of granophyric quartz-orthoclase. K-feldspar shows resorbed outlines within outer micrographic shells. Accessories include apatite, zircon, and opaques.

The second type (analysed specimen D53/4/6) is a hornblende-biotite calc-alkaline granite or adamellite with a relatively even-grained granitoid groundmass of orthoclase microperthite, quartz, plagioclase, biotite, hornblende, and accessory epidote, zircon and apatite. Orthoclase and quartz occur as rounded to anhedral grains 0.3 to 2 mms in diameter; the orthoclases contain abundant film perthite lamellae. Quartz shows slight strain extinction and the smaller grains tend to be enclosed by orthoclase, probably an end product of the clearing of earlier micrographic fabric. Plagioclase is strongly sericitised and occurs as isolated grains, sometimes up to 6.0 mms long. Biotite flakes (pleochroic pale yellow-orange to dusky yellow-brown) occur in small clusters and hornblende as fresh stumpy isolated grains.

A large K-feldspar microperthite megacryst (R12672) from this outcrop is probably intermediate between monoclinic and triclinic (shows strain extinction) and contains abundant inclusions of the following: (1) quartz in granophyric intergrowth with the host K-feldspar; (2) euhedral sericitised plagioclase, generally surrounded by micrographic intergrowth; (3) hornblende, iron ore, and zircon; (4) fayalite and clinopyroxene, altering to hornblende and associated with micrographic intergrowth. The texture of these inclusions is identical to the minerals in the groundmass of the enclosing granite indicating late-stage growth of the megacrysts, i.e. they are porphyroblasts.

Local cataclasis has produced a weak east-west foliation in some outcrops. Initially quartz is strained, elongated, and slightly granulated and K-feldspar inverts to microcline.

More deformed cataclastic granites contain occasional relict phenocrysts of feldspar and quartz in a crushed groundmass about 0.25-0.5 mm in size.

Cato Area: The rocks of this area are characterised by the lack of large alkali feldspar porphyroblasts and paucity of ferromagnesian minerals. In outcrop they are pink leucocratic medium to coarse, apparently even-grained, granites. Outcrops are massive and lack xenoliths.

Under the microscope however the rocks are seen to be porphyritic and the groundmass varies from graphic to hypidiomorphic granular near the margins of the mass. The analysed specimen (D53/4/5) is a leucocratic graphic granite containing euhedral to subhedral phenocrysts, 2-6 mms long, of cryptoperthitic orthoclase and minor albite, and rounded and embayed square quartz phenocrysts, 1-2 mms in size, in a groundmass of graphically intergrown quartz and microperthite. K-feldspar phenocrysts show both Carlsbad and Baveno twinning and plagioclase albite twinning. The graphic intergrowths form masses about 2 mms in size and in places embay phenocrysts. Immediately surrounding phenocrysts the quartz bodies are vermicular, while elsewhere they are triangular, square, or amoeboid. Pods of chlorite after biotite and rare green biotite occur. Sphene is an abundant accessory and zircon is rare.

Nearer the margins of the mass granophyric texture is only patchily developed within the even-grained (0.5-2.0 mm) hypidiomorphic granular groundmass which makes up the bulk of the rock. Feldspar phenocrysts are less common but resorbed quartz phenocrysts are still abundant. Pods of brown and green biotite and chlorite after biotite occur. Sphene is common and secondary carbonate is minor. Alteration of feldspars is quite heavy.

Geochronology: Replicate analyses of biotite from a single sample of Giddy Granite (D53/4/6) gave a K-Ar minimum age of 1760 Ma (McDougall et al., 1965); this is similar to the 1750 Ma age obtained for the Caledon Granite. A single biotite from the same Giddy sample was sufficiently enriched in Rb^{87} to define a Rb-Sr age of 1786 + 50 Ma; a single total-rock sample gives agreement with the biotite with an assumed initial Sr^{87}/Sr^{86} ratio of 0.720, but replicate analyses of K-feldspar give an age of 1705 Ma for the same initial ratio, indicating slight discordance due to some geological effect.

More work is necessary to reliably determine the age of the Giddy Granite but the data may be compared with the range of Rb-Sr minimum ages available for the late tectonic granites suites associated with the Barramundi Orogeny across northern Australia (Bofinger, 1967; Page, Compston & Needham, 1980; Riley, 1980; A W Webb, AMDL Rep. An 1814/73, unpubl.), and since found by precise U-Pb zircon chronology to lie within the range 1850-1870

Ma (Page, 1978; Page & Hancock, 1988; Wyborn, 1988). Alternatively, some fayalite granites in northern Australia have been part of a younger A-type association (L.A. Wyborn, pers. comm., 1992), with ages around 1820-1700 Ma (Wyborn, Page, & McCulloch, 1988).

Caledon Granite

Definition

Distribution: Scattered small exposures over about 675 km^2 around coast of Caledon and Trial Bays and on nearby offshore islands, near boundary of Arnhem Bay - Gove and Blue Mud Bay - Port Langdon 1:250,000 Sheet areas. Small exposures also near mouth of Walker River and on Morgan Island in Blue Mud Bay 1:250,000 Sheet area.

Type Locality: The relatively large exposure on southern side of Caledon Bay, in Gove 1:250,000 Sheet area.

Derivation of Name: From Caledon Bay in Gove 1:250,000 Sheet area.

Stratigraphic Relationships: Intrudes Bradshaw Complex on islands of Caledon Bay, and Grindall Metamorphics on Morgan Island and near mouth of Walker River. Inferred to intrude Myaoola southwest of Trial Bay. At latter two localities unconformably overlain by Groote Eylandt Beds. In most localities overlain by Lower Cretaceous sediments or Tertiary laterite.

Correlated with Giddy Granite on basis of petrology and isotopic age. Inferred to be related to Bickerton Volcanics from occurrence of fayalite in both and universal association of post-tectonic granites and acid volcanics about 1800 Ma old in northern Australia.

Lithology: Massive medium-grained leucocratic pink to white granophyric calc-alkaline granite and minor adamellite containing small amounts of biotite and chlorite. Fayalite and pyroxene in places.

Age: Orosirian (Late Palaeoproterozoic)?

Description and comments

Two ages of granite occur: the older is pink or white in colour; the younger is generally finer grained, red in colour, contains less biotite and chlorite, and intrudes the early type as dykes and small stocks.

Inclusions are rare; the only xenoliths found were fragments of Bradshaw Granite on Bridgland and McNamara Islands, off-shore from Caledon Bay. On Morgan Island and near the mouth of the Walker River the granite is markedly discordant with the structure of the Grindall Metamorphics, and thermal metamorphism is almost negligible; the only observed effect is a slight increase in visible mica in the metasediments immediately adjacent to the contact. Granite collected near the contact at the Walker River has knots of associated andalusite, sillimanite, pinite after cordierite, biotite, and muscovite.

Outcrops are massive except for jointing. Most of the granite shows strain effects; inversion of orthoclase to microcline and strain extinction and slight granulation in quartz. Both phases of the granite are affected and there appears to be a correlation between intensity of micro-strain effects and intensity of jointing.

The *early Caledon Granite* is typically composed of K-feldspar, quartz, and plagioclase (albite-oligoclase). Minor chlorite after biotite, and associated muscovite, are scattered through the rock; relict biotite is rare. Accessories include fluorite, zircon, apatite, epidote and opaques. One sample has been chemically analysed (Table 4), and Rhodes (1966) has identified the K-feldspar of this sample as monoclinic orthoclase, typical of sub-volcanic granites. K-feldspars are invariably string microperthites and, with progressive strain, develop, firstly, strain extinction (form intermediate between monoclinic and triclinic) and, finally, microcline twinning.

Generally, subhedral to euhedral sericitised plagioclase and K-feldspar phenocrysts are set in a granophyric quartz and K-feldspar groundmass, which comprises the bulk of the rock. Typically, the host-feldspar grains have irregular outlines, producing an overall granitoid fabric, and enclose groups of optically-continuous vermicular quartz inclusions, more than one orientation of quartz being possible in single intergrowths. This texture grades into a microgranitoid groundmass in which scattered equant quartz grains, of similar size to ordinary groundmass quartz, are poikilitically enclosed by K-feldspar.

The phenocrysts are commonly subparallel. K-feldspars are sometimes zoned and commonly have outer shells of micrographically-intergrown quartz inclusions, surrounding cores with resorbed outlines. Myrmekite is sometimes present adjacent to plagioclase. Quartz phenocrysts occasionally occur and are invariably rounded and embayed.

The contact rock containing andalusite, sillimanite, cordierite etc. differs in having a granitoid rather than granophyric fabric.

A party from the Broken Hill Proprietary Co. Ltd. collected samples during a reconnaissance survey in late 1962, from near the mouth of the Walker River and from the northern side of Caledon Bay, in which W R Morgan (File Note 120 NT/16) identified fayalite and pyroxene. Only imprecise locations are available and field relationships to the normal granophyric granite are unknown. The sample chemically analysed (Table 4) is weathered and may be misleading (e.g. the high Fe_2O_3).

The rocks are essentially typical Caledon Granites containing K-feldspar, quartz and plagioclase. At Caledon Bay the K-feldspar is orthoclase ($2V_x = 59^o$) while at Walker River it has inverted to microcline. Plagioclase is tabular and K-feldspar is graphically intergrown with quartz. Grainsize ranges between 0.75 mm and 5.0 mm.

At Caledon Bay fayalite ($2V_x = 51^o$) forms pale grey-brown to colourless prismatic or subhedral crystals, partly replaced by iron oxide, iddingsite, biotite, and, in some places, amoeboid intergrowths of augite. Brown biotite also forms mantles around the fayalite. Augite ($2V_x = 40^o$) also forms rare colourless crystals with occasional bleb-like inclusions of what may be exsolved orthopyroxene. Brown biotite is interstitial to quartz and feldspar and tends to form veins in green biotite. Accessory minerals are apatite, zircon and black iron ore.

The Walker River sample has been granulated then recrystallized. Colourless serpentine, stained by hydrated iron oxide, pseudomorphs euhedral to rounded crystals with the plate and vein-like intergrowths characteristic of serpentine after olivine. Biotite is the only other ferromagnesian mineral present and accessory apatite was noted. Micrographic texture is absent.

The *late Caledon Granite* is only very slightly different to the early phase: abundant red or pink iron-stained feldspars and paucity of biotite or chlorite. Most quartz is bound up in micrographic intergrowths and is rarely visible in hand specimen. K-feldspar is microperthitic and plagioclase generally minor. Micrographic texture is very well developed; the rocks are best termed micrographic granites (in stocks) or micrographic (dykes). Early-formed feldspar phenocrysts have resorbed margins around which granophyric rims have been deposited; quartz vermicules show uniform optical orientation over wide areas. Accessories are opaques, sphene, and zircon.

One dyke-rock studied is a hydrothermally-altered sheared adamellite. Albite-oligoclase, with bent twin-lamellae and abundant disseminated iron oxide, is the principal feldspar, plus orthoclase patch-perthite. The rock has a coarse-grained hypidiomorphic granular fabric with only occasional granophyric intergrowth. The contact with the country rock is gradational.

Geochronology: Replicate analyses of muscovite from a single sample of Caledon Granite (D53/4/8) gave a K-Ar minimum age of 1750 Ma (McDougall et al., 1965). This is similar to a K-Ar age of 1760 Ma obtained for the Giddy Granite.

More work is necessary to reliably determine the age of the Caledon Granite but the data may be compared with the range of Rb-Sr minimum ages available for the late tectonic granites suites associated with the Barramundi Orogeny across northern Australia (Bofinger, 1967; Page, Compston & Needham, 1980; Riley, 1980; A W Webb, AMDL Rep. An 1814/73, unpubl.), and since found by precise U-Pb zircon chronology to lie within the range 1850-1870 Ma (Page, 1978; Page & Hancock, 1988; Wyborn, 1988). Alternatively, some fayalite granites in northern Australia have been part of a younger A-type association (L.A. Wyborn, pers. comm., 1992), with ages around 1820-1700 Ma (Wyborn *et al.*,, 1988).

Jimbu Granite

Definition

Distribution: Crops out very poorly in three inliers in McKay Hills, headwaters of Shadforth Creek, and along Jimbu Creek, in north-western part of Mount Marumba 1:250 000 Sheet area.

Type Locality: Inlier within the McKay Hills about lat. 13°15'S, long. 133°58'E.

Derivation of Name: From Jimbu Creek, a tributary of Mann River. Previously called Mann River Porphyry (Patterson, 1954, unpubl.) but invalid because of prior usage. Although most outcrops are porphyritic we prefer Granite to describe mass as a whole.

Stratigraphic Relationships: Unconformably overlain by either Kombolgie Formation or McKay Sandstone of Katherine River Group. No exposed relationship to older rocks. Correlated by lithology with widespread post-tectonic granites of northern Australia; most resembles Grace Creek Granite of Katherine-Darwin region.

Lithology: Massive porphyritic microgranite, granophyre, and rhyolite and coarse even-grained granite.

Age: Orosirian (Late Palaeoproterozoic)?

Description and comments

Most outcrops of Jimbu Granite are of fine-grained rocks, frequently as dykes about one metre thick, but it is thought that very poorly outcropping medium to coarse-grained granite is the major rock type. The rocks are generally red or pink in colour and, to the naked eye, vary from even-grained to markedly porphyritic, but under the microscope many apparently even-grained rocks consist of abundant closely-spaced phenocrysts separated by a fine-grained groundmass.

Phenocrysts are of K-feldspar, quartz, and sometimes albite and (especially quartz) have rounded corners and embayments due to resorption. In the dyke rocks the K-feldspar has been identified (XRD) as probably sanidine while in the country rocks it is nearer to orthoclase. Groundmass material shows various stages of crystallization or devitrification but is generally one of two types. The first is composed of albite and quartz in which the feldspar laths occur either as interlocking grains or as spherulitic growths, and is found in both dyke and country rocks. The second type, found only in the country rocks where it is the more common, is characterized by granophyric K-feldspar and quartz; the rocks are classic granophyres (micrographic porphyritic microgranites, Johannsen, 1939).

The coarse-grained 'country-rock' granites contain more than 50 percent K-feldspar, sometimes as phenocrysts up to 2.5 cm in size, stained red by finely disseminated iron oxide and altered to kaolinite. Corroded quartz phenocrysts are smaller, about 2-3 mm.

Chlorite aggregates either pseudomorph a ferromagnesian mineral, probably hornblende, or replace feldspar phenocrysts. Interstitial groundmass is generally less than 10 percent of the rock and is either spherulitic albite or micrographic quartz and K-feldspar. Small amounts of devitrified glass are also present and accessories include zircon, sphene, anatase, and opaques.

These grade, with decreasing proportion of coarse crystals and increasing groundmass, into a porphyritic sodic rhyolite composed mostly of microcrystalline spherulitic plagioclase and iron oxide, probably devitrified glass.

Phenocrysts of albite and orthoclase up to 1 cm are corroded and rimmed by groundmass material, quartz are about 2-3 mm, and chlorite pseudomorphs hornblende(?) or replaces plagioclase.

Rocks intermediate between these extremes have orthoclase phenocrysts up to 5 cms and abundant chlorite-calcite masses after hornblende(?). Orthoclase has inclusions of plagioclase, quartz, and chlorite as in plutonic feldspars. The abundant groundmass is better crystallized than in the rhyolites. Granophyric quartz-feldspar intergrowths in masses 0.5-1 mm in size form the bulk, although scattered small discrete grains of chlorite, quartz, and feldspar are also visible. The granophyre grades, with decreasing grainsize, into microcrystalline spherulitic growths. Phenocrysts have micrographic rims.

The dyke rocks are, in general, finer grained. They range from even-grained microgranites, of grainsize about 0.5 to 1 mm, down to fine-grained porphyritic rhyolites. The rhyolites consist simply of scattered corroded phenocrysts of quartz and sanidine about 1 mm in size, in an iron-stained microcrystalline groundmass of interlocking laths of albite-oligoclase and minor quartz. Apatite and sphene are accessories.

The even-grained rocks contain anhedral sanidine and lesser corroded quartz in a very minor groundmass. Occasional phenocrysts of feldspar can be seen. The groundmass mainly forms reaction rims around the coarser grains and is composed either of fine acicular albite-oligoclase laths or micrographic quartz and K-feldspar. Some sanidines are perthitic and alteration to kaolin and sericite is common.

A pegmatitic dyke observed consists simply of coarse sanidine crystals enclosing graphic quartz inclusions about 1 to 2 mm in diameter and several mm in length.

Ritarango Beds

Definition

Distribution: Crop out over about 300 km^2 in Mitchell Range, straddling boundary between Blue Mud Bay and Arnhem Bay Sheet areas. Confined to narrow north-trending highly-faulted block, between major faults each side of Mitchell Range.

Type Section: No simple section is available due to the complex faulting. Reference area taken as Mitchell Range about lat. 12°55'S, long. 135°36'E.

Derivation of Name: From Ritarango Gap, an access route passing through Mitchell Range at about lat. 12°52'S, long. 135°36'E.

Informally named Mitchell Range Formation by Crohn (1954); invalid by prior usage. Crohn included sedimentary rocks of overlying Fagan Volcanics and interpreted volcanic flows as intrusives.

Stratigraphic Relationships: Overall relationships, and hence age, not clear. Overlain with local angular unconformity by Fagan Volcanics. Overlie 'metasediments' of Mirarrmina Complex; contact concealed; inferred to unconformable on both 'metasediments' and 'granite gneisses'.

Lithology: Blocky to massive grey or red-brown medium-grained lithic or feldspathic quartz greywacke and quartz sandstone. Medium to coarse-grained lithic greywacke and flaggy fine-grained sandstone and siltstone locally prominent. Scattered pebbles of shale, quartzite, and phyllite, particularly near base. Cross-bedding, ripple marks common. Rocks invariably sheared and silicified.

Thickness: Speculative estimate, 3 km.

Distinguishing Features: Composition, degree of silicification and shearing, uniform grey colour, and massive outcrops distinguish Ritarango Beds. These, combined with stratigraphic and structural position, diagnostic.

Readily distinguished on air-photographs from overlying volcanics or underlying Mirarrmina Complex. Numerous closely-spaced shears and lack of obvious bedding on photos distinguishes them from other sandstone units in region.

Age: Orosirian (Late Palaeoproterozoic)?

Description and comments

Most contacts with Fagan Volcanics are faulted or apparently conformable. Throughout most of their outcrop the Ritarango Beds are much more highly sheared, folded, and faulted than the Fagan Volcanics, but not in areas where both crop out or are in contact. An angular unconformity is exposed in the Fagan Creek area, where the Ritarango beds have been tilted to about 20^{o} or so (Figure 14), but this may not necessarily represent a major time break and may be quite local.

They overlie the 'metasediments' of the Mirarrmina Complex but the actual contact is concealed by soil cover. They are thought to be unconformable on the 'metasediments' and, by inference, the 'granite gneisses' for the following reasons:

(i) The 'metasediments' and Ritarango Beds in adjacent outcrops appear to show different plunges of fold axes.

(ii) There is an apparent difference in structural style between the two units; the Ritarango Beds are mainly faulted while the 'metasediments' are tightly folded.

(iii) The 'metasediments' and granite gneisses appear to have a more complex structural history. Widespread cataclasis which has been superimposed on the earlier metamorphism may be related to deformation of the Ritarango Beds.

(iv) There is a marked difference in metamorphism between the 'metasediments' and 'granite gneisses' and the adjacent Ritarango Beds.

(v) The composition of the sediments in the Ritarango Beds is consistent with the Mirarrmina Complex being a source; in particular the volcanic fragments could be from the 'metasediments'.

(vi) Coarse lithic greywacke, with pebbles of quartzite and phyllite, are most common near the base of the Ritarango Beds.

The age relationship between the Ritarango Bads and the 'massive gabbro' of the Mirarrmina Complex is uncertain.

It was not possible to obtain a simple type section through the Beds because of complex faulting and the thickness estimate (3 km) is highly speculative. Rock types are fairly uniform throughout, the most common being blocky to massive, grey or red-brown, medium-grained lithic or feldspathic quartz greywacke and quartz sandstone. Medium to coarse-grained lithic greywacke and flaggy fine-grained sandstone and siltstone are locally prominent. Much of the section, particularly the lower half, is poorly exposed and this may reflect the presence of beds of siltstone or lithic greywacke. There appears to be a greater proportion of coarse-grained lithic greywacke and pebble bands in the lower part of the section; scattered pebbles of shale, quartzite and phyllite are particularly common near the base. Cross-bedding and ripple-marks are common. The rocks are invariably silicified and almost invariably sheared (commonly only visible in thin section).

In thin section the rocks show sorting ranging from poor in the greywackes, through moderate in the quartz greywackes, to well-sorted in the quartz sandstones. Grainsizes are mainly medium-grained (about 0.3 -0.5 mm), with some coarse greywackes up to 1 mm and scattered grains up to 3 mm. Primary grain shapes are generally subangular in the greywackes, moderately-rounded to sub-angular in the quartz greywackes, and well-rounded in the quartz sandstones. Grain shapes have been severely modified by secondary silica overgrowths and elongation, and granulated margins have developed during shearing.

The dominant constituent is quartz. It invariably shows strain extinction, is commonly fractured, and sometimes granulated. Near fault zones, grains have sometimes been sufficiently elongated to form a quartz schist. Most rock fragments are felsic devitrified acid volcanics; others are chert and vein quartz. Rock fragments are commonly the coarsest grains in the rock and are readily elongated and crenulated. Potash feldspar is more abundant than plagioclase and both are kaolinised or sericitised. The matrix consists of very-fine quartz and minor sericite.

Visual estimates of composition, from single thin sections, are given in Table 5.

Table 5. Percentage compositions of specimens of Ritarango beds.

Registered Number	Rock type	Quartz & Chert	Rock Fragments	Feldspar	Matrix
R12633	Quartz sandstone	100			
R12631	Quartz sandstone	90-95	rare		10
R12634	Lithic quartz greywacke	70	5-10	5	15-20
R13637	Feldspathic quartz greywacke	80-85	5-10	5-10	5
R12632	Lithic-argillaceous greywacke	65	8-10	2	25
R13638	Lithic greywacke	45	45	1-2	10

Structure : Deformation of the Ritarango beds is dominated by intense shearing and faulting along NNE trends, which vary in intensity across the region. Folding is difficult to define from reconnaissance ground observations, because mesoscopic folds are rarely seen. Interpretation of fold patterns from air photographs is obscured by the lithologic uniformity of the beds and overprinting by foliation and shear zones.

The broad structure comprises a large synclinorium, culminating in the centre of the Mitchell Range and plunging about 20° to SSW in the south, and 15° to NNE in the north. The eastern limb is completely faulted off by the major Bath Range Fault. Where folds closures can

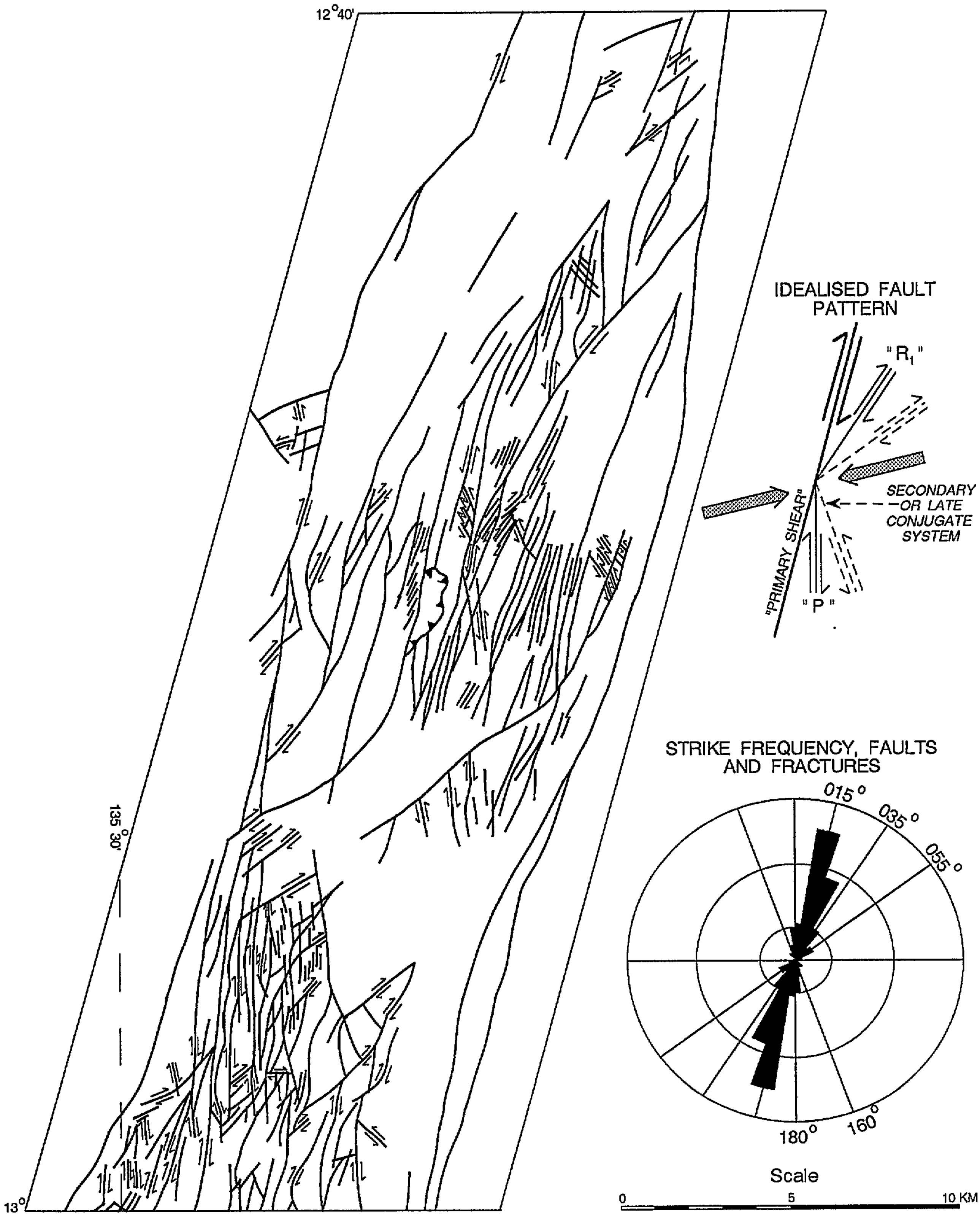

Figure 13. Detailed fault pattern of Ritarango beds in Mitchell Range, plotted from air photo interpretation, including strike frequency of faults and fractures, and interpreted, idealised pattern.

be seen on air photographs they are open in style, but throughout most of the outcrop dips are very steep. A penetrative axial-plane cleavage striking about 350°-030°, but mostly about 015° subparallel to closely spaced shear zones or zones of high strain, and dipping very steeply to east or west, is well developed in the western, central, and northern Mitchell Ranges, but is poorly developed or absent in the southeast, about the Koolatong River and farther south. In the north-east Mitchell Ranges a conjugate set of small shears related to NW-SE compression is developed in the cores of folds - dextral striking about 110° and sinistral striking about 150°, and mesoscopic anticlines developed at the contact between Ritarango beds and Fagan Volcanics have been displaced by a younger set of curved conjugate shears related to E-W compression - dextral striking about 035-055° and sinistral striking about 150-180°. Locally, refolding has been seen on a SSE-trending fracture cleavage, about axes plunging 65° to 160°. This folding is accompanied by sinistral strike-slip displacement along the cleavage, consistent with the young conjugate shears above.

The pattern of faulting within the Arnhem Bay Sheet area, as deduced from air photographs, is summarised in Figure 13. Where faults have been observed on the ground, dips appear to be subvertical, and this is consistent with their appearance and pattern on air photographs. Where displacements can be deduced from photographs, they displace either steeply dipping beds or other faults. They are therefore interpreted as strike-slip displacements on Figure 13. The consistency of the pattern obtained supports their interpretation as strike-slip in nature.

The pattern is clearly dominated by faults striking about 015°, subparallel to the regional foliation. The major movements along this trend, where visible at air photo scale, appear to be dextral; individual displacements of up to 2.5 km have been estimated. A minor set of dextral faults strikes at around 035° and 180°, and a lesser probably conjugate set about 055° (dextral) and 160° (sinistral). The 035°- 180° set is geometrically consistent with Reidel R_1 and P shears, secondary to the primary 015° faults. The conjugate 055°-160° set is geometrically consistent with being R_1-R_2 shears secondary to the 035° faults, but spatially seems to be developed in association with 015° faults. It parallels the young shears which displace anticlines in the NE Mitchell Range. These conjugate faults could be due to a secondary E-W compression field developed by the 015° or 035° faults, or be related to a much younger compressive deformation altogether. One flat-lying thrust fault has been identified, consistent with E-W compression.

The age and nature of some of the deformation is uncertain, and has probably occurred in several episodes. Penetrative cleavage or folding at mesoscopic scale has not been noted anywhere from the overlying Parsons Range Group or younger units, and almost all except the very largest and clearly latest faults in the Ritarango beds and Fagan Volcanics either do not penetrate or die out very rapidly in the lowest parts of the Parsons Range Group. This and the data in Figure 13 was used by Plumb *et al.* (1980) to conclude that the faults along which the McArthur Basin subsequently rifted apart were first developed during a period of intense NNE dextral shear along the the Mitchell Range, before the Parsons Range was deposited.

However, the approximately NW-SE compression described above, from small conjugate shear systems preserved in fold cores, is inconsistent with the approximately NE-SW compressional stress field ideally required for the dextral fault system of Figure 13. Similarly, the regional NNE-trending folds and cleavage are not ideally consistent with the dextral system (they should trend about NW-NNW), but could develop during NW-SE compression, with a component of sinistral strike-slip displacement. The pattern of NNE dextral strike-slip faulting is parallel to that which later extended and then inverted the McArthur Basin, along major structures such as the Bath Range Fault. Furthermore, small subsidiary cross-faults and shears associated with this NNE dextral system are clearly younger than the folding and cleavage development, because they displace folded or very steeply-dipping bedding or steep faults, both at map scale in Figure 13 and the macro scale, above.

Clearly, the earliest identified deformation must be represented by the associated folding, cleavage, and closely spaced shear zones, which likely formed in an approximately NW-SE compressive system, and likely with a sinistral component of shear. The dextral system then probably originated wholly by reactivation of these earlier structures. If any dextral displacement occurred before the development of the McArthur Basin it is not possible at this time to distinguish this from later syn and post-McArthur Basin structures within the Ritarango beds .

Timing is discussed further with the Fagan Volcanics, below.

Fagan Volcanics

Definition

Distribution: Crops out in two areas; main area around headwaters of Koolatong River at southern end of Mitchell Range, near northern boundary of Blue Mud Bay-Port Langdon Sheet area. Lesser exposures at northern end of Mitchell Range in Arnhem Bay-Cove Sheet area. Total area about 120 km^2 confined to narrow highly-faulted uplifted zone bounded by major northerly-trending faults either side of Parsons and Mitchell Ranges.

Type Section: Headwaters of Koolatong River, at southern end of Mitchell Range. Difficult to define a simple reference section due to rapid lateral variations and structural complexity; no accurately measured section. Most representative and best exposed section along unnamed tributary of Koolatong River about lat. 13°15'30"S, long. 135°33'E (shown as Section III in Figure 14).

Derivation of Name: From Fagan Creek, a tributary of Koolatong River which cuts Volcanics about lat. 13°02'S, long. 135°32'40"E.

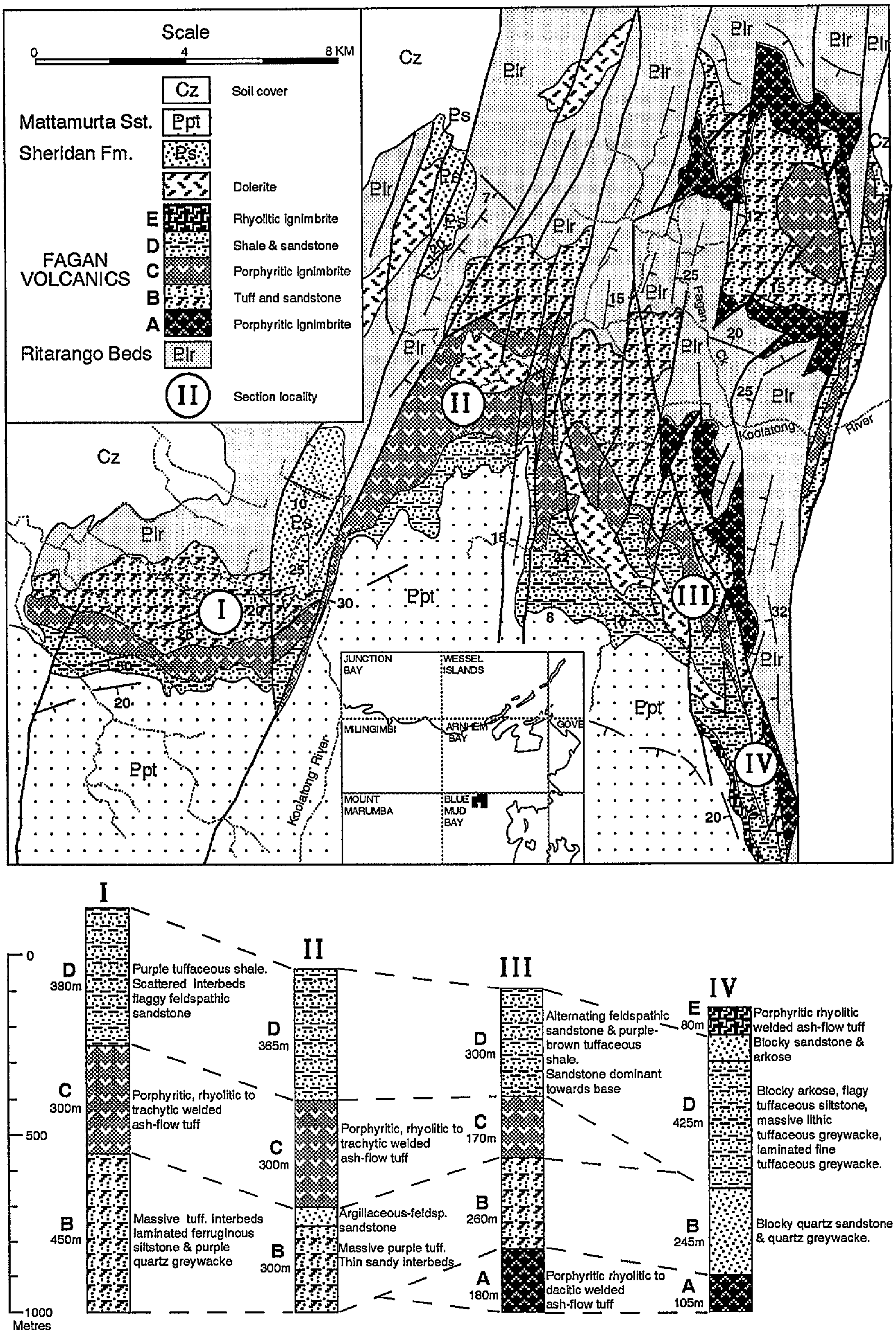

Figure 14. Geological sketch map and generalised stratigraphic sections, Fagan Volcanics, Koolatong River area. Informal members described in text identified by letters. Roman numerals identify general section localities.

Arenites and some lutites of formation were included in informal Mitchell Range Formation of Crohn (1954); other lutites included in Crohn's informed Cypress Creek Formation. Both names invalid by prior usage. Volcanic flows were interpreted as intrusives.

Stratigraphic Relationships: Unconformably overlie Ritarango Beds and in turn unconformably overlain by both Sheridan Formation and Parsons Range Group. In north unconformably overlain by Wessel Group.

Although the Volcanics are considered to be, in general, younger than the Mirarrmina Complex, some of the later minor intrusives of the Complex are considered to be of similar age, and younger than, the Fagan Volcanics.

Lithology: Acid volcanics, associated with tuffaceous siltstone, greywacke, argillaceous quartz greywacke, and feldspathic sandstone.

Thickness: Estimated 900 m in reference section, thickening to about 1100 m in west. Faulting makes thickness estimates difficult.

Distinguishing Features: Readily distinguished by characteristic succession of volcanics and volcanic derived sediments. Base defined by first volcanic overlying arenites of Ritarango Beds. Unconformity recognised locally but generally contact is faulted.

Top of volcanics marked by unconformity with either Sheridan Formation or Parsons Range Group. Although unconformity below Parsons Range Group cannot be always recognised a thick massive sandstone at its base is readily distinguished from underlying tuffaceous sediments of Fagan Volcanics.

Age: Orosirian (Late Palaeoproterozoic)?

Description and comments

In the Koolatong River area the Fagan Volcanics can be divided into five informal members (Figure 14). They show marked lateral variations. Although most of the igneous rocks are certainly extrusive, intrusive relationships have been observed in places; it has not been possible to map the intrusives separately.

The basal member (A) consists of porphyritic rhyolite, alkaline rhyolite and dacite and outcrops are confined to the eastern edge of the area. They die out suddenly north-westwards near Fagan Creek. The southern limit is faulted out, but the member does appear to be thinning rapidly to the south. Thus the probable strike extent of the unit is about 16 km. The volcanics crop out poorly in valleys between ridges of more resistant sandstones and are difficult to trace accurately due to faulting. Air-photo interpretation suggests marked variations in thickness. In outcrop massive and foliated volcanics alternate in bands about 30 m or more thick. A massive specimen of rhyolitic composition has phenocrysts up to 0.5 cm across of quartz, sericitised orthoclase, and minor acidic plagioclase. Iron oxide and chlorite pseudomorph ferromagnesian phenocrysts. The groundmass is a silicified felsic devitrified glass.

In the foliated rocks phenocrysts parallel the foliation and in weathered outcrop well defined narrow fractures parallel it. The foliation parallels the bedding of surrounding sediments and cannot be related to shear zones or faults. In thin section the sericitised groundmass shows tortuous flow lines swirling around grains. Phenocrysts of albite-oligoclase feldspar, and minor orthoclase and quartz, are shattered and replaced by quartz and sericite.

Near Fagan Creek where a marked angular unconformity is observed the basal rocks consist of volcanic breccia composed of blocks of ferruginised breccia enclosed within an alkaline rhyolite.

In the north-west (Section II), the massive, purple, tuffaceous siltstone of the basal unit (B) has scattered thin sandy interbeds. In outcrop the siltstone itself lacks bedding and contains scattered round vughs, up to 5 mm in size, of fibrous sericite. Occasional shards can be seen. In thin section the rocks consist of angular to rounded poorly sorted quartz and minor feldspar, set in an abundant matrix of very fine sericite, quartz, and iron oxide. Biotite, chlorite and muscovite are accessories. Many of the finer quartz grains have the shape of shards. The larger rounded grains are of sedimentary origin, shown by strain extinction and relict secondary overgrowths.

Relict bedding is contorted into irregular micro-folds or transposed into small clots. The most deformed specimen shows intense autobrecciation and micro-clastic dykes.

Purple laminated, ferruginous siltstone and purple quartz greywacke is interbedded with the tuffaceous siltstone in the Sheridan Creek area (Section I).

In the east (Section III) the tuffaceous siltstone alternates with flaggy to blocky, medium-grained, grey, friable argillaceous quartz greywacke in beds 6-10 m thick; quartz greywacke becomes dominant towards the top. The quartz greywacke contains about 80-85 percent quartz, less than 5 percent chert and volcanic rock fragments, and 10-15 percent sericite matrix. Individual beds are well sorted.

Further south (Section IV) the tuff is absent.

The overlying member (C) is the most consistent volcanic in the formation; it is absent only in the extreme south-east. The rocks are mainly massive, reddish-purple to black, porphyritic volcanics ranging in composition from rhyolites to rhyodacites and alkaline trachytes. They typically contain both scattered and euhedral phenocrysts of pink and white feldspar and quartz in a green to red aphanitic groundmass.

Faint compaction bands have been formed with apparent relict shards parallel to them. Compaction bands are bent around blocks of dark coloured extremely fine-grained material which may be glass, pumice, or included country rock. Jointing perpendicular to bedding is prominent.

Immediately east of the northern tongue of the Parsons Range blocks of sandstone and siltstone up to 0.6 m in diameter have been included within the magma. The rocks here are probably extrusive but in an immediately adjacent area, intrusive relationships have been observed within a narrow fault block.

In thin section the rocks typically contain euhedral to highly fractured phenocrysts of potash feldspar, quartz, and plagioclase (oligoclase-andesine) in varying amounts. They range up to about 5 mm in size. Potash feldspar, generally orthoclase, is commonly perthitic, and is more common than plagioclase. Quartz is usually embayed and corroded. Feldspar, and sometimes quartz, are replaced by sericite and quartz to varying degrees. Clots of opaques and chlorite represent pseudomorphs of ferromagnesians. The very fine-grained (0.01 mm), massive groundmass is either felsic or sericitised. It appears to be a completely devitrified glass.

One porphyritic rhyodacite is distinctive in having a few lenticular or flattened masses of very fine sericite, calcite or quartz, which may be shards. They are bent around phenocrysts. Faint colour variations in the groundmass suggest a possible pyroclastic texture. Larger areas (up to 2 or 3 mm) may be pumice fragments. They parallel the shards and are bent around phenocrysts. Iron filled perlitic cracks can be seen.

Another rhyolite has shards in a devitrified groundmass containing fine, randomly oriented feldspar laths.

The volcanics of Member C have been intruded by a large irregular dolerite sill.

In the reference section (III) the upper member (D) consists of blocky feldspathic sandstone or arkose and flaggy purple-brown tuffaceous shale, alternating in beds about 3-6 m thick. Sandstones predominate near the base while towards the top shales increase in amount and sandstones develop flaggy bedding. The shales sometimes contain thinly interbedded purple-brown and white shales and interbeds, 5-8 cm thick, of sandstone are common. Similarly thin shale interbeds are common within the massive sandstone units.

In thin section a tuffaceous shale contains poorly sorted and sub-angular grains of quartz, volcanic rock fragments, and some feldspar, of coarse silt size, in an abundant very fine matrix of sericite, opaques, quartz and carbonate.

In the west (Section I) tuffaceous shales predominate while in the extreme south-east (Section IV) coarse tuffaceous sediments predominate.

In thin section the latter rocks contain abundant coarse fragments up to 2.5 mm of volcanic rocks, and lesser sodic plagioclase, amongst a finer grained (about 0.1 mm) matrix of quartz and minor plagioclase, orthoclase, muscovite, opaques, chlorite, and sericite. The rocks are generally poorly sorted but some show sorting in well defined bedding laminae.

In Section IV Member D is overlain by a massive, coarsely porphyritic, red, rhyolitic volcanic (Member E). Northwards it passes rapidly into flaggy fine-grained arkose of Member D. The volcanic rock is distinctive due to the abundance (up to 40 percent of the rock) of coarse, severely corroded phenocrysts of pink perthitic orthoclase (up to 10 mm), quartz (up to 3 mm), and green altered ferromagnesian minerals. The groundmass consists of a red fine-grained allotriomorphic granular mass of quartz, spherulitic feldspar, hematite and chlorite and contains abundant irregular patches of chalcedony 0.1 mm in diameter. Occasional thin shard-like splinters of quartz are present.

Along the Parsons Range escarpment, near the headwaters of Sheridan Creek, a slight angular unconformity can be seen between member D and the Parsons Range Group. Elsewhere the contact is structurally conformable.

On the eastern side of the Mitchell Range, 6.5 km north-northeast of the junction of Fagans Creek and the Koolatong River, a massive feldspar porphyry, identical in appearance to the volcanics, has intruded along the contact between the Ritarango Beds and Member B. Similarly in a highly faulted zone adjacent to the Parsons Range, about 5.5 km west-south-west of the Fagans Creek-Koolatong River junction, fine-grained porphyry and porphyritic microgranite has intruded the base of Member C. At one point, a vugh of native copper has been deposited within sandstone at the contact.

These intrusives, of rhyolitic composition, are petrographically indistinguishable from the extrusives. Magmatic corrosion of the phenocrysts is marked. Locally coarser rocks can be found.

North of the Mitchell Range, in the Arnhem Bay-Gove Sheet area, a complete section for the Volcanics cannot be determined; no direct correlation can be made with the reference section further south. The base is usually faulted while the top is concealed. The most complete section observed is given in Table 6.

Table 6. Incomplete stratigraphic section, Fagan Volcanics, northwestern edge of Mitchell Range, precise stratigraphic position uncertain.

Thickness (m)	
240	*Rhyolitic volcanic,* massive, pink to green, coarsely porphyritic, well developed compaction banding.
60	*Alkaline-rhyolitic volcanic,* fine-grained, black, vesicular, porphyritic, flow defined by phenocrysts and vesicles.
60	*Ashstone,* masssive, purple, fine-grained; scattered 30 cm *silt* interbeds.
450	Blocky *feldspathic sandstone* and *quartz greywacke;* interbedded with *tuffaceous siltone* and *shale,* buff, grey and pink.

The base of the Volcanics in the north is exposed in only one place, on the eastern side of the Mitchell Range, where the Ritarango Beds are in contact with a massive porphyritic rhyolitic volcanic. A peculiar scalloped pattern at the contact is produced on air photographs due to the intersections of closely spaced north-striking faults with shallow north-dipping bedding; narrow fault blocks of sandstone form small peninsulas within the volcanics. The pattern is exaggerated by dense, dark coloured vegetation which has grown in sand deposited in hollows between the "peninsulas".

In thin section the volcanics from the north are quite typical of the formation. Two specimens show fine lines and stringers of oriented sericite which are bent around phenocrysts, tail off rapidly away from phenocrysts, and are best developed between crowded phenocrysts; this suggests compaction rather than flow. One contains possible shards, represented by lenticular patches of microcrystalline quartz or calcite, parallel to these lines.

The vesicular alkaline-rhyolitic volcanic shows platy flow defined by oriented phenocrysts of sericitised albite, quartz, and aggregates of quartz and dark green biotite. Small vesicles are filled with carbonate and lined with quartz while the groundmass consists of quartz and orthoclase, with minor sericite and biotite.

At one point on the western side of the Mitchell Range an intrusion is indicated.

Structure: The Fagan Volcanics in the main outcrop area at the southern end of the Mitchell Range are folded into a broad syncline plunging shallowly to the south, cut by broadly northerly-trending faults, and truncated in the east by the Bath Range Fault (Fig. 14). Dips range up to about 30°, or locally steeper near faults. No widespread penetrative cleavage or folding at mesoscopic scale have been noted from the volcanics.

Faults are continuous with the more major ones in the Ritarango beds to the north, but the intensity of shearing and concentration of faults is much greater in the Ritarango beds. Where seen in outcrop, faults are very steep, are marked by narrow zones of breccia, and display sharp boundaries with host rocks. The faults lacks the apparent consistency of strike-slip displacements observed in the Ritarango beds; some appear to be part of a major sinistral system, while others are part of a dextral system (Fig. 14). Dextral faults are most clearly identified adjacent to the Bath Range Fault, which has a large syn to post-McArthur Basin displacement, while the Bath Range Fault in turn truncates a major sinistral fault system. Most of the faults in the Fagan Volcanics either do not penetrate the Parsons Range Group, or die out very rapidly and have only minor displacements.

The more closely spaced pattern of faults and shears in the Ritarango beds compared to the Fagan Volcanics, the apparent lack of penetrative cleavage in the Fagan Volcanics, and the angular unconformity between Ritarango beds and Fagan Volcanics in the Fagan Creek area have been used to propose a period of intense shearing and folding before the Fagan Volcanics were deposited (Plumb and Derrick, 1975), and later correlated with the angular unconformity between the El Sherana and Edith River Groups in the Katherine-Darwin Region (Plumb, 1988).

However, reassessment of data, noted above shows that both the Ritarango beds and Fagan Volcanics have been affected by the same folds and NNE shear zones in the northeast Mitchell Range while, in the far south and southeast, where the main exposures of Fagan Volcanics have been studied, the Ritarango beds themselves lack a penetrative cleavage and are no more faulted than the Fagan Volcanics. Two separate fault systems, one sinistral and one dextral, and probably of different age, are preserved in both; the sinistral system appears to be the older in both cases. The unconformity exposed between the two units in the Fagan Creek area only indicates a period open folding or tilting to no more than 20° or so at that point, and elsewhere, when contacts are not faulted, the units are subconformable. The difference in deformation between the Ritarango beds and Fagan Volcanics involves both a variation in intensity of deformation and a difference in ductility - ductile penetrative cleavage in most of the Ritarango beds, and brittle fault zones in the Fagan Volcanics. This difference may therefore be apparent only, reflecting either regional variations in intensity and style or in depth of burial during post-Fagan Volcanics deformation.

As noted in the field description above, the contact between the Fagan Volcanics and Parsons Range Group is generally subconformable; a clear angular unconformity has been identified in only one locality. However, there is no evidence of the intensity and style of folding and shearing which characterises most of the Ritarango beds, or of significant sinistral fault systems, anywhere in the Parsons Range Group, and few major faults are continuous from the Fagan Volcanics into the Parsons Range Group. The unconformity is exposed at the southern limit of the Fagan Volcanics, where they are least deformed, and overlying the stratigraphically highest members; a reflection once again of depth of burial during deformation.

It is provisionally concluded therefore that the principal deformation of both the Fagan Volcanics and Ritarango beds probably occurred during a single event of folding and, probably, sinistral shearing along the 015° trend of the Mitchell Range. This event probably occurred before deposition of the Parsons Range Group. Later dextral reactivation of these structures occurred, probably both syn and post-deposition in the McArthur Basin. As described below, extensional development of the McArthur Basin involved considerable dextral displacement along broadly northerly-trending faults and uplift of basement tilt blocks, and accommodation of these movements at depth might have been achieved by much of the dextral faulting now seen in the Mitchell Range. Subsequent inversion and folding of the basin was probably more compressive (E-W) in nature, but involved similar dextral displacements, and is probably the origin of most of the small secondary conjugate shear systems described from the Ritarango beds and Figure 13.

Bickerton Volcanics

Definition

Distribution: Crops out in only few small areas on Bickerton Island, Bustard Island, Round Hill Island, and island near Cape Shield, in Blue Mud Bay-Port Langdon Sheet area.

Reference Area: Around the shores of South Bay (lat. 13°46'S, long. 136°10'E) on western side of Bickerton Island.

Derivation of Name: From Bickerton Island.

Stratigraphic Relationships: No base exposed. Inferred to unconformably overlie Grindall Metamorphics; in outcrops less than 2 km apart Volcanics are subhorizontal, while Metamorphics are steeply dipping and intensely folded. Overlain with erosional unconformity by Groote Eylandt Beds. Considered to correlate with Fagan and Spencer Creek Volcanics and to be comagmatic with Caledon and Giddy Granites. Therefore Orosirian? in age.

Lithology: Massive, red-brown to black, porphyritic rocks, probably volcanics, of rhyodacite composition. Fine volcanic breccias locally important.

Thickness: Unknown; no base exposed. Probably greater than 150 m.

Distinguishing Features: Distinguished by presence of volcanics and stratigraphic position. Distribution of outcrop distinguishes it from other volcanic units of similar age.

Age: Orosirian (Late Palaeoproterozoic)?

Description and comments

In outcrop the rocks are massive except for vertical jointing which is sometimes very strongly developed. On Bustard Island compaction banding, 2 to 5 cm thick, is well developed. The banding is irregular in orientation and locally follows swirling flow-like structures.

Phenocrysts are euhedral, pale green feldspar, 0.5 mm to 5.0 mm in size, and rounded and embayed quartz. The microcrystalline groundmass is red-brown in colour.

In thin section the feldspar is mainly sericitised plagioclase (ca. An_{65}), and lesser kaolinised orthoclase, and is sometimes embayed. Ferromagnesian phenocrysts, generally less than 1 mm in size, are completely altered to serpentine and, sometimes, calcite. The pseudomorphs have been identified, in different specimens, as euhedral olivine (?fayalite) and pyroxene. Secondary calcite occurs in pyroxene pseudomorphs. The groundmass is a very fine-grained felsic or micrographic intergrowth of quartz and alkali feldspar with small amounts of chlorite and hydrated iron ore. Accessory sphene, zircon and apatite were noted.

The country rock on Round Hill Island consists of folded volcanics (interpreted as Grindall Metamorphics) intruded by granite. The central core of the Island is a circular mass of fine volcanic agglomerate or fragmental tuff, interpreted as possibly a neck of Bickerton Volcanics. The agglomerate has angular fragments up to 5 mm in size of medium-grained feldspathic igneous rocks and irregular masses of devitrified glass in a felsic groundmass similar to the glass. Iron oxide dust is scattered throughout.

On a small island east of Cape Shield the Groote Eylandt Beds are underlain by a massive, poorly sorted, red-brown lithic-crystal tuff composed of angular fragments of quartz, felsite rock, and felsite rock with quartz phenocrysts, set in a matrix of chlorite, sericite and fine quartz. Extensive alteration has occurred and the rock is cemented by irregular masses of red-brown chalcedony. The very angular nature of the fragments is taken to indicate an explosive origin for the rock.

Definition

Distribution: Crop out as scattered inliers amongst Mesozoic and Cainozoic cover along north-east trending belt about 130 km^2 in area, between Spencer Creek and Mount Bonner on peninsula separating Arnhem Bay and Melville Bay in north-eastern corner of Arnhem Bay-Gove Sheet area.

Reference Area: No complete section exposed in any one place. Taken as being exposures immediately north of Spencer Creek at about lat. 12°18'S, long. 136°26'E.

Derivation of Name: From Spencer Creek (Lat. 12°20'S, Long. 136°25'30"E).

Stratigraphic Relationships: Unconformably overlie Bradshaw Granite and in turn overlain with angular unconformity by Mount Bonner Sandstone. Considered to be comagmatic with Giddy Granite but cannot be demonstrated whether they overlie or are intruded by the Granite. Correlated with Fagan and Bickerton Volcanics and considered to be Orosirian? in age.

Lithology: Massive, red-brown, porphyritic rhyolitic volcanics; blocky, cross-bedded, medium to coarse-grained quartz sandstone.

Thickness: Very poor control. Assuming uniform dip indicated by sandstone member in middle of unit some 1.7 km indicated.

Distinguishing Features: Presence of volcanic rocks readily distinguishes unit from units above and below. Both upper and lower contacts defined by unconformities.

Age: Orosirian (Late Palaeoproterozoic)?

Description and comments

The Spencer Creek Volcanics consist of two volcanic bands, each about 600 m thick, separated by a sandstone member about 450 m thick.

Phenocrysts in the volcanics are predominantly feldspar and range up to about 1 cm in size; smaller quartz and chlorite pseudomorphs after ferromagnesian minerals also occur. Feldspar phenocrysts are generally altered to a pale green colour. The microcrystalline groundmass is coloured red by disseminated iron oxide dust.

Feldspar phenocrysts are kaolinised sanidine and minor sericitised plagioclase. They are generally euhedral or subhedral in form with slight magmatic corrosion of corners. Quartz phenocrysts are highly corroded and embayed. Fracturing of phenocrysts is rare.

The groundmass is composed of fine quartz and alkali feldspar and scattered iron oxide dust. Specimens from the lower volcanic member are notable for the development of spherulitic and micrographic intergrowths; they could in fact be called granophyres. In one specimen the micrographic fabric is quite coarse.

Another distinctive feature of the lower volcanic member is the presence of a flow foliation, revealed in outcrops by subparallel alignment of phenocrysts. In thin section thin

lines of iron oxide dust parallel this foliation and cut across present grains showing that they are a pre-devitrification feature.

The groundmass in the upper volcanic member is different. In one specimen it consists of uniform equant grains up to 0.2 mm in size with scattered chlorite throughout. In another it is very fine devitrified glass; the outlines of developing micrographic or spherulitic intergrowths are just visible. Lines of iron oxide dust show random orientation. K-feldspar phenocrysts are of orthoclase perthite.

The middle sandstone member consists of blocky, white, medium to coarse-grained quartz sandstone with minor granule or pebble zones. The rocks are strongly ripple-marked and cross-bedded. In thin section the rock consists almost entirely of quartz plus a few chert and volcanic rock fragments. The grains are well sorted and rounded and the rock is cemented by secondary quartz overgrowths.

DISCUSSION

The Late Tectonic Granites and Acid Volcanics comprise a single, related subvolcanic suite. The Giddy and Caledon Granites are petrographically identical and are separated only on the basis of geographical distribution. In terms of major elements, they clearly plot together as a single chemical suite (Figs 10, 11); the analysed fayalite granite (R12442) was weathered and should clearly be ignored. The Giddy Granite and Spencer Creek Volcanics are closely related spatially and, indeed, some end-member phases are difficult to distinguish in the field.The presence of altered fayalite in both the Bickerton Volcanics places it is the same characteristic suite as the Caledon and Giddy Granites; altered ferromagnesian minerals in the Spencer Creek Volcanics may well be after fayalite or pyroxene. Feldspar studies shows the Giddy and Caledon Granites to be typical of subvolcanic granites (Table 3). The Fagan Volcanics are inferred to comprise part of the same suite, from petrographic similarity to the other volcanics, although no direct relationship with nearby granite is exposed, and from stratigraphic position beneath the McArthur Basin sequence.

Although the compositional fields for the post-tectonic granites and basement metamorphic complexes cannot be clearly separated for most major oxides on Harker diagrams (Fig. 11), they may be clearly distinguished on most of the triangular 'metamorphic' diagrams of Figure 10. Geochemistry, mineralogy, and petrography clearly support the interpretation of the granites as post-tectonic suite, emplaced after the cessation of deformation of the basement complexes which they intrude.

On the basis of the preliminary geochronological data reported above, and their post-tectonic intrusive relationship to the basement metamorphic complexes, the Giddy, Caledon, and Jimbu Granites, and associated volcanics, have long been considered part of the ~1800 Ma suite of Dunn, Plumb, and Roberts (1966), or the 'Transitional Tectonic' suite of the Tectonic Map of Australia (GSA, 1971; Plumb, 1979), which crops out throughout the North Australian Craton. This suite has been identified more recently as the '1880-1840 Ma felsic volcano-plutonic suite', associated with the closing stages of the Barramundi Orogeny (Etheridge et al., 1987, Wyborn, 1988). Wyborn characterises this suite as having distinctly high levels of K_2O (and various trace elements not available form the analyses herein), and low MgO and CaO; features for which Figure 11 certainly agrees with those of Wyborn (1988) and Wyborn & Page (1983). Wyborn has interpreted this suite as an I-type suite, generated from iintracrustal sources within an intracontinental setting. During an underplating event around 2300-2000 Ma large volumes of mantle-derived material are postulated to have been accreted to the base of the lower crust. The more fractionated part of this source was remelted between 1880-1840 Ma to generate the '1880-1840 Ma felsic volcano-plutonic suite'.

However, the *Caledon* and *Giddy Granites* are distinctive for the unusual presence of fayalite, and seem to have a much more restricted compositional range (only 71.9-73.6% SiO_2 for the three samples analysed) than the 1880-1840 suite. Wyborn (personal communication, 1992) notes that fayalite has been recorded from two sources within the Proterozoic of northern Australia: from S-type granites, and from anorogenic I-type, or 'A-type', granites younger than 1820 Ma. For the diagnostic $Al_2O_3/CaO+Na_2O+K_2O$ ratio, I-type granites always fall below 1.1% and S-type above 1.1%. This certainly applies to the unweathered Caledon and Giddy samples in Figure 11, and distinguishes them from the 'basement metamorphic complexes'.

Wyborn *et al.,* (1988) note that A-type granites at Mount Isa are characteristically pink to red in colour, and rapakivi (granophyric or graphic?) texture is common. These are both certainly characteristic of the Caledon and Giddy Granites. They have high ratio of Fe/Mg, and are more enriched in TiO_2 than the 1870-1840 suite. The Caledon and Giddy Granites do have slightly higher TiO_2 than granites of comparable SiO_2 content from the 1880-1840 suite; they are also marginally higher in K_2O. The FeO/Mg ratio is ~8, compared with ~3 for the average of the Kalkadoon and Ewen Batholiths (Wyborn & Page, 1983). The Caledon and Giddy Granites, in fact, compare very closely with the very restricted composition of the ~1700 Ma Weberra Granite at Mount Isa (Wyborn *et al.,* 1988).

Even without diagnostic trace element data, it does seem very likely that the fayalite-bearing Caledon and Giddy Granites are in fact A-type granites, significantly younger than 1840 Ma. The only field constraint in Arnhem Land is that the Caledon and Giddy Granites are older than the Mount Bonner Sandstone and Groote Eylandt beds; units which are now correlated with either the base of the McArthur or Nathan Groups, and are hence younger than 1700 Ma.

The *Jimbu Granite* occurs far from the other Granites. It is constrained to being older than the Kombolgie Formation, it does have significant petrographic differences to the other Granites, and no chemical analyses are available. It is very similar in field and petrographic characteristics to the Grace Creek Granite of the Pine Creek Inlier; in fact the nearest outcropping granite to the Jimbu Granite. The Grace Creek Granite is part of the 1880-1840 suite.

Field association and common occurrence of fayalite constrain the *Spencer Creek* and *Bickerton Volcanics* as still belonging to the same suite as the Giddy and Caledon Granites.

The *Fagan Volcanics* are constrained to being older than the Parsons Range Group. They occur in a different tectonic setting, beneath the Walker Trough, compared to the Spencer Creek and Bickerton Volcanics beneath or within the Caledon Shelf. They have no associated granite. Petrographic similarity between the volcanics is not supported by any geochemical data. The Fagan Volcanics do differ by the volume of associated sedimentary rocks in the sequence. The Fagan Volcanics need not be the same age as the other units.

Individual volcanic units in the Fagan Volcanics are thick and uniform over large areas; typical features of ignimbrites or ash-flow tuffs. The primary glassy groundmass is now entirely devitrified to the microcrystalline felsic groundmass typical of almost all ancient ignimbrites. Ghost pyroclastic texture, relict shards and flattened pumice fragments, compaction banding, and interbedded pyroclastic sediments, particularly the massive non-welded tuff (Unit B), all support the origin of the Fagan Volcanics as an ignimbrite or ash-flow tuff suite. the same interpretations are applied to the similar Bickerton and Spencer Creek Volcanics.

Sheridan Formation

Definition

Distribution: Occurs in small outcrops, covering only about 25 km^2 between headwaters of Sheridan Creek and Koolatong River, at northern end of Parsons Range in Blue Mud Bay-Port Langdon Sheet area. Small exposures, too small to show on map, occur on eastern side of northernmost tip of Parsons Range.

Reference Area: Exposure between headwaters of Sheridan Creek and Koolatong River at about lat.13^{o}06'S, longitude 135^{o}24'30"E.

Derivation of Name: From Sheridan Creek.

Includes the type area for Crohn's (1954) informal Cypress Creek Formation. His nomenclature is invalid because of prior usage.

Stratigraphic Relationships: Stratigraphic position not clear. Sits unconformably on both Ritarango Beds and Fagan Volcanics but in present exposure not overlain by any rocks. Inferred to be probably older than Parsons Range Group with probable unconformity between them (see discussion).

Lithology: Dark brown to grey, fine to medium-grained, lithic greywacke; massive sandstone-boulder conglomerate; brown to yellow shales; medium to coarse-grained feldspathic sandstone.

Thickness: About 150 m preserved.

Distinguishing Features: "Dirty" nature of sediments and stratigraphic and structural position diagnostic.

Age: Late Palaeoproterozoic (Orosirian or Statherian?).

Description and comments

The lithology of the Sheridan Formation reflects the nature of the immediately adjacent source areas. Thus where the beds overlie Fagan Volcanics the lithology consists of dark brown to grey, fine to medium-grained lithic greywacke. Where they overlie Ritarango Beds they consist of massive sandstone-boulder conglomerate, brown to yellow shales, and medium to coarse-grained feldspathic-quartz sandstone.

The greywackes are either massive or thinly bedded into fine and coarse-grained bands; the bedded greywackes show cross-bedding and graded-bedding. Rock and feldspar fragments are concentrated in the coarse bands while the fine bands are quartz rich. Rock fragments up to 1 cm across have been found.

In thin section the rocks have about 30-50 percent quartz, 20-30 percent rock fragments, less than 5 percent feldspar, and 10-30 percent matrix. Grains are subangular to subrounded and poorly sorted. Quartz grains include a high proportion of strained and vein quartz, probably derived from the Ritarango Beds. Rock fragments are felsic acid volcanics, sometimes porphyritic, derived from the Fagan Volcanics. Feldspars are orthoclase with minor plagioclase and microcline. The matrix consists of sericite, commonly iron-stained or silicified. Zircon, tourmaline and muscovite are accessories.

The boulder conglomerate contains Ritarango Sandstone boulders up to 50 cm across in a sandy matrix.

The rocks of the formation occur in small fault blocks, apparently active during deposition producing a supply of detritus from adjacent areas. The faulted beds dip more steeply than those of the Parsons Range Group. The quantity of volcanic detritus suggests more extensive exposures of volcanics during deposition than are now present near exposures of the Formation. One could expect that in past geological periods, following deposition of the Parsons Range Group, the exposures of volcanics near the present exposed Sheridan

Formation would be much less extensive than at present. Therefore it is concluded that the Sheridan Formation is probably older than the Parsons Range Group. The Formation probably represents deposits which accumulated in small grabens during the faulting and erosion intervening between the development of the Fagan Volcanics and the deposition of the Parsons Range Group.

A younger age cannot be ruled out but the possibility of an age younger than Proterozoic is remote because of the associated faulting.

McARTHUR BASIN SUCCESSION

STATHERIAN

PARSONS RANGE GROUP

Definition

Distribution : Forms the Parsons Range, which trends roughly northeast through the western part of the Blue Mud Bay/Port Langdon Sheet area, and extends for several kilometres north into the southern part of the Arnhem Bay/Gove Sheet area . An isolated exposure occurs west of the Mitchell Range in the Arnhem Bay/Gove Sheet area. Total area of exposure is about 1500 km^2.

Reference Area : Most complete section is along a north-south line through the Parsons Range at longitude 135°30'E. This area is designated as the reference area. The lowermost formation (Mattamurta Sandstone) is incompletely exposed in this area, and is affected by faulting.

Derivation of Name : From the Parsons Range, a prominent series of ridges mainly in the western part of the Blue Mud Bay/Port Langdon Sheet area.

Stratigraphic Relationships : Previously mapped informally as Parsons Range Formation by Crohn (1954). Inferred to rest unconformably on the Sheridan Formation. Rests unconformably on the Fagan Volcanics, and conformably overlain by the Koolatong Siltstone, the basal unit of the McArthur Group. Although no contacts are exposed it is possible that along the western margin of the Parsons Range the Roper Group may, locally, rest directly and unconformably on the Parsons Range Group.

Stratigraphically, the group occupies a position similar to Katherine River Group in the western part of the McArthur Basin and to the Tawallah Group in the southern part of the basin (see pp. 00).

Components : The group contains four formations: Mattamurta Sandstone, Badalngarrmirri Formation, Marura Siltstone and Fleming Sandstone.

Lithology : The group consists mainly of quartz sandstone with subordinate lutites and dolomitic strata.

Thickness : Maximum exposed thickness about 6 km in reference area; to southwest upper parts of group thin markedly and may be accompanied by thinning in lowermost unexposed parts of sequence.

Age : Statherian (Palaeoproterozoic)

Table 7. Summary of stratigraphy, Parsons Range Group.

ROCK UNIT	THICKNESS (m)	LITHOLOGY	TOPOGRAPHY	DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	REMARKS
Fleming Sandstone	60 - (?)450 220 ref. area	Quartz sandstone; sandstone breccia	Moderately resistant; forms cuestas. Sandstone karst in upper beds		Conformably overlies Marura Sltst. Conformably overlain by McArthur Gp (Koolatong Sltst)	Top of Parsons Ra.Gp. Abundant cross-beds and ripple marks
Marura Siltstone	60 - 240 120 ref. area	Fissile siltstone and shale. Minor sandy dolomite	Poorly resistant; forms valleys and gentle slopes	Parsons Range, in Blue Mud Bay/Port Langdon Sheet; west of Mitchell Range in Arnhem Bay/Gove	Conformably overlies Badalngarrmirri Fm	Sandy beds commonly lenticular
Badalngarrmirri Formation	2500 (ref. area) - 1600	Quartz sandstone, ferruginous sandstone, feldspathic sandstone, siltstone.Minor stromatolitic chert, dolomite, dolomitic siltstone	Variably resistant. Alternating cuests and valleys		Conformably overlies Mattamurta Sandstone	Abundant cross-beds and ripple marks
Mattamurta Sandstone	Up to ~3000	Quartz sandstone	Resistant; forms elevated 'core' of Parsons Range	Parsons Range, in Blue Mud Bay/Port Langdon Sheet	Unconformably overlies Sheridan Formation and Fagan Volcanics. Conformably overlain by Badalngarrmirri Fm.	Lower unit of Parsons Ra. Gp. Abundant cross-beds and ripple marks

Description and comments

Detailed descriptions of the lithology of each formation are given under the individual formations and a summary of the stratigraphy of the Group is given in Table 7.

Mattamurta Sandstone

Definition

Distribution : Crops out only in the Parsons Range, in the northwestern and western parts of the Blue Mud Bay/Port Langdon Sheet area. Exposures occupy an area of about 620 km^2.

Reference Area : Designated as northern part of the Parsons Range in the Blue Mud Bay/Port Langdon Sheet area along longitude 135°30'E.

Derivation of Name : From Mattamurta Creek, a tributary of Strawbridge Creek.

Stratigraphic Relationships : Basal formation of Parsons Range Group; inferred to be unconformable on Sheridan Formation and Fagan Volcanics, and conformably overlain by Badalngarrmirri Formation.

Lithology : Predominantly blocky and massive, pink to white, medium-bedded, medium-grained, cross-bedded, ripple-marked quartz sandstone.

Thickness : About 3 km in reference area; probably thins to southwest, as do overlying strata.

Distinguishing Features : The base of the formation is defined by an unconformity with the Fagan Volcanics; the top is marked by a change in lithology from white blocky quartz sandstone to ferruginous sandstone. The latter is much less resistant to erosion than the former and the boundary is well defined by the topography.

Description and comments

The rocks are generally well sorted, but a few pebbly bands are present in the sequence. Beds of fine-grained and coarse-grained quartz sandstone are interbedded with the medium-grained strata. Near the base of the formation the sediments contain minor amounts of feldspar and rock fragments. The rocks are commonly cemented by silica overgrowths.

Badalngarrmirri Formation

Definition

Distribution : Crops out in Parsons Range (Blue Mud Bay/Port Langdon Sheet area) and west of Mitchell Range (Arnhem Bay/Gove Sheet area). Total area of exposure about 800 km^2.

Reference Area : Parsons Range, in northwestern part of Blue Mud Bay/Port Langdon Sheet area, along longitude 135°30'E.

Derivation of Name : From Badalngarrmirri Creek, a tributary of Gulbawangay River in southwestern sector of Arnhem Bay/Gove Sheet area.

Stratigraphic Relationships : Conformably overlies Mattamurta Sandstone and conformably overlain by Marura Siltstone.

Lithology : Medium and fine-grained quartz sandstone, ferruginous sandstone, feldspathic sandstone; siltstone; minor stromatolitic chert, dolomite, and dolomitic siltstone.

Thickness : 2500 m (reference section) in Marura Creek district. 1600 m in Vaughton Creek district.

Distinguishing Features : The contact between the Mattamurta Sandstone and the Badalngarrmirri Formation is generally marked by the appearance of ferruginous sandstone, but in the Vaughton Creek district the ferruginous sandstone is absent and the base is drawn where there is a pronounced decrease in the degree of resistance to erosion. The top of the formation is marked by a lithological change from blocky quartz arenites to lutites.

Description and comments

The formation has been examined in the Marura Creek district in the eastern part of the Parsons Range, the Vaughton Creek district (southern Parsons Range), and in the Badalngarrmirri Creek district (west of the Mitchell Range).

The best section is exposed in the Marura Creek District, where the formation is about 2480 m thick; the sequence is described in Table 8.

Table 8. Stratigraphic section, Badalngarrmirri Formation, Marura Creek district.

Thickness (m)	Overlain by Marura Siltstone
30	*Quartz sandstone*, white, flaggy to blocky, medium-grained.
120	*Quartz sandstone* and *siltstone*, grey, flaggy, fine-grained, cherty towards east.
240	*Quartz sandstone* and *siltstone*, grey and brown, flasggy, thin-bedded, fine-grained, cross-bedded; clay pellet impressions; interbedded with *quartz sandstone* (more common toward base), white, blocky, fine-grained.
165	*Quartz sandstone*, white, blocky, friable, cross-bedded, ripple-marked, medium-grained; purplish (slightly ferruginous) toward top.
165	*Quartz sandstone* and *siltstone*, brown and yellow, flaggy, thin-bedded, fine-grained; *micaceous siltstone*, thin-bedded, flaggy, purple; interbedded with minor *quartz sandstone*, brown, fine-grained.
30	*Quartz sandstone*, hematitic, purple, flaggy to blocky, medium-grained.
120	*Quartz sandstone*, pink and white, silicified, blocky to massive, ripple-marked, cross-beded, medium-grained.
115	*Siltstone*, purple, thin-bedded.

270	*Quartz sandstone,* white, silicified to friable, blocky, medium-grained, minor iron-oxide content
330	*Quartz sandstone,* friable, flaggy to blocky, medium-grained, reddish (slightly ferruginous); interbedded with *quartz sandstone,* fine-grained, and *quartz sandstone,* blocky white, medium-grained.
45	*Quartz sandstone,* blocky, purple to white, medium-grained, cross-bedded.
90	*Quartz sandstone,* fine-grained, flaggy, white; interbedded with ferruginous sandstone, flaggy, purple, fine-grained.
165	*Quartz sandstone,* pink-orange to white, medium-grained, friable to silicified, massive, thick-bedded, some cross-beds, grains well sorted and well rounded.
180	*Ferruginous sandstone,* laminated, cross-bedded, medium-grained, purple; *micaceous quartz sandstone* and *siltstone,* green and pink, fine-grained, and towards the base *quartz sandstone,* white to pink, massive, thick-bedded; abundant weathered clay pellets up to 4 cm long.
150	*Quartz sandstone,* pink, massive, thick-bedded, medium-grained, cross-bedded, well-sorted, pebbly towards top (6mm quartz pebbles).
75	*Quartz sandstone,* silicified, greyish, massive, thick-bedded, medium-grained.
90	*Quartz sandstone,* buff, brittle, medium-grained, originally dolomitic(?).
6	*Chert,* yellow, stromatolitic.
6	*Sandstone,* medium to coarse-grained, cross-beddded; 20% cavities; cavities coated with limonite and manganese oxide - possibly originally dolomitic.
90	*Ferruginous sandstone,* purple, massive, friable, thick-bedded, cross-bedded, medium-grained;up to 30% iron oxides as grain coatings, pisolites, and cement.
2480 total	Underlain by Mattamurta Sandstone

About 50 km to the southwest, in the Vaughton Creek district, the formation is about 1575 m thick (Table 9).

Table 9. Stratigraphic section, Badalngarrmirri Formation, Vaughton Creek district.

Thickness (m)	Overlain by Marurua Siltstone
42	*Quartz sandstone,* purplish (slightly ferruginous), medium-grained; grading downwards into *quartz sandstone,* white, medium-grained, blocky, thin-bedded, conspicuously ripple-marked, cross-bedded, well-sorted; cross-beds from south.
168	*Hematitic quartz sandstone,* purple, pink, and white, medium-grained, flaggy to blocky, thin-bedded, friable, cross-bedded; in places iron oxides form up to 10% of rock; clay pellets common.

21	No outcrop
135	*Hematitic quartz sandstone,* thinly flaggy, fine to medium-grained, slightly micaceous.
162	*Quartz sandstone,* massive to blocky, white to pink, medium-grained, cross-bedded, ripple marked; blocky in middle, massive towards top and base.
45	No outcrop.
330	*Quartz sandstone,* blocky to massive, medium to fine-grained, pink, cross-bedded, ripple-marked; scattered coarser grains.
672	*Quartz sandstone,* massive, thin to thick-bedded, medium-grained, white, friable to silicified, cross-bedded, ripple marked; pebbles of vein quartz (90%) and quartzite or quartz sandstone (1%) up to 2.5 cm in some zones.
1575 Total	Underlain by Mattamurta Sandstone.

In the Badalngarrmirri Creek district, west of the Mitchell Range, the base of the formation is not exposed. The exposed sequence is given in Table 10.

Table 10. Stratigraphic section, Badalngarrmirri Formation, Badalngarrmirri Creek district.

Thickness (m)	Overlain by Marura Siltstone
135	*Quartz sandstone,* white, medium-grained, slightly ferruginous; blebs of specular hematite.
225	Poorly exposed sequence, probably consisting of *siltstone* interbedded with *quartz sandstone,* fine-grained, flaggy.
165	*Feldspathic sandstone,* pink to grey, flaggy to blocky, medium-grained, cross-bedded, ferruginous.
225	*Quartz sandstone* and *dolomitic sandstone,* red, fine-grained, flaggy, thin-bedded; interbedded with *siltstone,* green to white, and minor *dolomite.*
135	*Quartz sandstone,* white, mqassive, medium-grained.
90	*Feldspathic sandstone,* white to pink, thin-bedded, fine-grained.
120	*Feldspathic sandstone,* white, medium-grained, flaggy to blocky; interbedded with *feldspathic sandstone,* pink, fine-grained.
135	*Feldspathic sandstone,* white to buff, medium-grained, with thin interbeds of finer-grained types.
75	*Quartz sandstone,* white, massive, slightly feldspathic, medium-grained.
60	Not exposed (probably fine-grained rocks).
90	*Quartzs sandstone,* white, blocky, medium-grained.
90	Not exposed (probably fine-grained rocks).

105	*Quartz sandstone*, pink, massive, medium-grained.	
15+	*Siltstone*, purple; interbedded with *cherty sandstone* and *micaceous shale*, buff.	
1665 Total	Base not exposed.	

Some beds, notably the arenites, seem to be consistent in lithology and thickness over the area represented by the three sections described, but other beds, particularly the siltstones and shales show considerable variation. In the Vaughton Creek section siltstone and shale are relatively insignificant, while in the other sections they constitute an important part of the stratigraphic column. The iron oxide content shows great lateral variability, and ranges from several percent in once place to negligible amounts in another. The best example is the gradation from the strongly ferruginous sandstone at the base of the Marura Creek section to quartz sandstone at the base of the Vaughton Creek section. The beds in the upper third of each section do, however, contain more iron oxides than the strata in the middle of each section. The lower third of the Marura Creek section contains a number of ferruginous beds, in contrast to the lower third of the Vaughton Creek section which contains none.

The only dolomitic rocks in the Badalngarrmirri Formation are in the Badalngarrmirri Creek area. Here dolomitic sandstone and very thin beds of dolomite are interbedded with quartz sandstone and siltstone in a 225 m sequence near the top of the formation. In the Marura Creek section a 6 m bed of stromatolitic chert occurs near the base; the chert is overlain and underlain by leached sandstones which may have originally contained carbonate minerals. No dolomitic or altered dolomitic beds occur in the Vaughton Creek section.

Marura Siltstone

Definition

Distribution : Crops out very poorly; underlies soil in narrow belt along the southeastern side of Parsons Range, but exposed only in isolated localities around Mount Fleming and in Marura Creek district, in Blue Mud Bay/Port Langdon Sheet area. In Arnhem Bay/Gove Sheet area small exposures occur west of Mitchell Range. Total area exposed about 16 km^2.

Reference Area : No complete section exposed; area immediately northwest of Mount Fleming nominated as reference area.

Derivation of Name : From Marura Creek.

Stratigraphic Relationships : Conformably overlies Badalngarrmirri Formation and overlain conformably by Fleming Sandstone.

Lithology : Consists predominantly of purple, thin-bedded to laminated, flaggy and fissile siltstone and shale, but in places thin brown or green laminae and bands are present. Sandy dolomitic interbeds make up about 10 percent of the formation.

Thickness : About 120 m in reference area, but to east, near Marura Creek probably about 240 m; inferred thickness west of Mitchell Range about same; near southern tip of Parsons Range only about 60 m thick.

Distinguishing Features : The top of the formation is marked by the appearance of blocky quartz arenites; the base is marked by a change from blocky quartz arenites to lutites.

Description and comments

Sandstone occurs as thin (3-5 cm) beds in the middle part of the formation and increase in abundance and thickness towards the top; the beds are purple or brown, fine-grained or very fine-grained, and commonly lenticular.

The dolomitic strata occur mainly in the middle part of the formation as beds from 15 to 60 cm thick. Grey finely laminated sandy dolomite is the most conspicuous of the dolomitic strata in outcrop, but a small proportion of interbeds of stromatolitic dolomite, dolomitic sandstone and siltstone, and cherty siltstone are also present.

Fleming Sandstone

Definition

Distribution : Crops out along southeast margin of Parsons Range and in a fault-bounded block extending southwards from Mount Fleming; other exposures occur to the west of the Mitchell Range.

Reference Area : Designated as area about 6.5 km east of Mount Fleming.

Derivation of Name : From Mount Fleming.

Stratigraphic Relationships : Conformably overlies Marura Siltstone and conformably overlain by Koolatong Siltstone, the basal unit of the McArthur Group.

Lithology : Pink, flaggy to blocky, thin-bedded to laminated, medium and fine-grained quartz sandstone; white or grey, blocky and massive, thick-bedded, medium-grained quartz sandstone; sandstone breccia.

Thickness : Thickness varies considerably: 60 m Vaughton Creek district; 180 m northwest of Mount Ramsay; 220 m around Marura Creek; possibly up to 450 m west of Mitchell Range.

Distinguishing Features : The base of the Fleming Sandstone is marked by the appearance of quartz arenite or sandstone-breccia; the top is marked by a change from quartz arenite to lutite.

Description and comments

In most places two main subdivisions can be recognized, but in the Vaughton Creek/Mount Fleming district a basal unit can also be distinguished. In the latter area a bed of sandstone-breccia marks the base of the formation. The breccia is up to 15 m thick and consists of angular blocks of pink, fine, medium, and coarse-grained quartz sandstone set in a white medium-grained quartz sandstone matrix. The blocks are up to 0.9 m across. Interbeds of sandstone similar to the matrix are present in the breccia.

The overlying strata generally make up about half of the formation. They consist of pink, flaggy to blocky, thin-bedded to laminated, medium and fine-grained quartz sandstone containing abundant ripple marks and cross-beds.

The uppermost beds normally make up about half of the formation. They consist of white or grey, blocky and massive, thick-bedded, medium-grained sandstone. Cross-beds and ripple marks are abundant. The beds generally well jointed and in some areas a 'castle' - topography is produced.

In thin section the arenites consist almost entirely of quartz cemented by minor amounts of secondary silica.

DISCUSSION

The Parsons Range Group has been correlated, on the basis of stratigraphic position and predominance of quartz sandstones, with the Tawallah Group of the southern McArthur Basin, but it differs significantly from the Tawallah Group in the absence of any volcanic rocks. No detailed internal correlations, formation with formation, are possible, except the Fleming Sandstone. The Fleming Sandstone is very similar in lithology and position with the Masterton Sandstone in the south, which is now defined as the base of the McArthur Group, and unconformably overlies the Tawallah Group. The possibility of an unconformity below the Fleming Sandstone has therefore been suggested (Plumb *et al.,* 1990).

No detailed sedimentological studies have been carried out on the Parsons Range Group. Its most striking feature is the vast thickness of predominantly quartz-rich arenites present. It is inferred to probably be of broadly similar facies to the Tawallah Group, which have been interpreted as a sequence of shoreline to shallow-marine blanket sandstones, interlayered with subordinate peritidal to lacustrine and alluvial complexes.

Introduction

The Katherine River Group crops out widely in both the Katherine-Darwin region and Arnhem Land. Some of the constituent units are known only from Arnhem Land, some from the Katherine-Darwin region, and some are common to both.

The following units, first recognised in Arnhem Land, are defined here: Goomadeer and Nungbalgarri Volcanic Members (of the Kombolgie Formation); McKay Sandstone; Cottee Formation; Shadforth Sandstone; McCaw Formation.

Definitions of units defined by Walpole et al. (1968) and common to both areas are repeated here. The units are: Kombolgie Formation; Gundi Greywacke; and West Branch Volcanics.

Development of Nomenclature: Since rocks of the Katherine River Group were first described, the nomenclature of the constituent units has undergone several revisions, both in published and unpublished work.

Table 11. Comparison of nomenclature, Katherine River Group.

<table>
<tr><th>Walpole (1958)</th><th colspan="2">Ruker (1959), Randal (1963)</th><th colspan="2">This work, and Walpole and others (1968)</th></tr>
<tr><td rowspan="4">West Branch Volcanics</td><td rowspan="8">Diljin Hill Formation</td><td>West Branch Volcanic Member</td><td colspan="2">West Branch Volcanics</td></tr>
<tr><td>Unconformity</td><td colspan="2">Unconformity</td></tr>
<tr><td>Gundi Greywacke Member</td><td colspan="2">Gundi Greywacke</td></tr>
<tr><td rowspan="5">Diamond Creek Member</td><td colspan="2">Unconformity</td></tr>
<tr><td rowspan="6">Kombolgie Formation</td><td rowspan="4">Diamond Creek Formation</td><td>McCaw Formation</td></tr>
<tr><td>Shadforth Sandstone</td></tr>
<tr><td>Unconformity</td></tr>
<tr><td>Cottee Formation</td></tr>
<tr><td colspan="2" rowspan="2">Kombolgie Formation</td><td></td><td>McKay Sandstone</td></tr>
<tr><td colspan="2">Kombolgie Formation</td></tr>
</table>

Noakes (1949, p.18) described an 'Upper Proterozoic' succession in the eastern part of the Katherine-Darwin region, and considered it to be an extension of the Buldiva Quartzite described by Hossfeld (1937) in the western part of the region. This correlation was

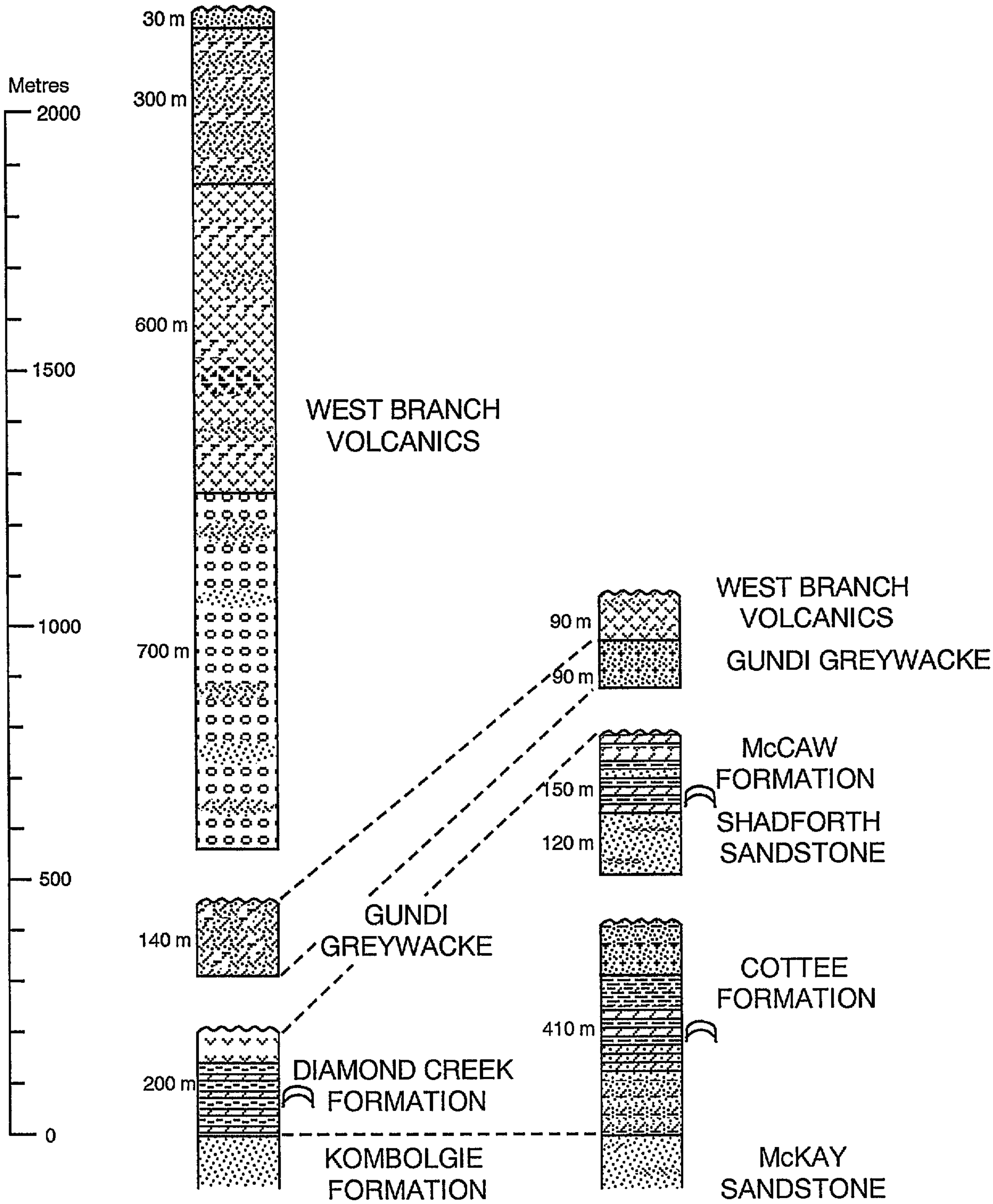

Table 15. Generalised and diagrammatic columnar sections of the upper Katherine River Group, compared between the Waterhouse and Wilton River districts

subsequently shown to be invalid by Walpole & White (1955, unpubl.) and the succession in the eastern part of the Katherine-Darwin region was termed the Katherine River Group by Noakes (1956;, p.229), who wrote 'Walpole has now shown that the sequence in western Arnhem Land is stratigraphically below the Tolmer Group...the Katherine River Group is regarded by Walpole as the lower part of the Upper Proterozoic succession in the area'. Walpole (1958) described the rocks in the Maranboy district, and recognised two formations in the Katherine River Group - the Edith River Volcanics and the Kombolgie Formation; within the Kombolgie Formation he recorded two volcanic members - the McAddens Creek Volcanic Member in the Katherine Gorge area (following Rattigan & Clark, 1955, unpubl.), and the West Branch Volcanic Member, north of Beswick. Although these terms were approved by the Stratigraphic Nomenclature Committee, Walpole refrained from formally defining them.

Subsequently, in the Beswick homestead district (northeastern part of the Katherine Sheet area), Ruker (1959 unpubl.) was able to map twelve rock units in the Katherine River Group.

Randal (1963) adopted most of Ruker's terminology, and applied the term 'Birdie Creek Volcanic Member' to the unit Puk2. Subsequent mapping on the Mount Marumba Sheet area has shown that an unconformity occurs at the base of Ruker's Gundi Greywacke Member and that (in the Mount Marumba Sheet area) a substantial thickness of strata lies between the 'Gundi Greywacke Member' and the equivalents of Ruker's units Puk4 and Puk5. These beds have been divided into three formations - the McCaw Formation, Shadforth Sandstone, and Cottee Formation. The Shadforth Sandstone is unconformable on the Cottee Formation and is overlain conformably by the McCaw Formation. Thus the stratigraphic interval represented in the Beswick homestead area by the Diamond Creek Member of the Diljin Hill Formation is represented in the Mount Marumba Sheet area by three formations, the oldest of which is unconformably overlain by the others. In view of this and the unconformity found at the base of the Gundi Greywacke Member in the Mount Marumba Sheet area, it has been felt necessary to revise the nomenclature of Walpole (1958), Ruker (1959 unpubl.) and Randal (1963); the term Diljin Hill Formation is no longer used and its original constituent members have been raised to formation status. Table 11 and Figure 15 compares the nomenclature used by previous authors with the nomenclature used in this Bulletin, and by Walpole et al (1968).

Definition

Distribution: Crops out over about 13 000 km^2 in western part of Arnhem Land, and similar area in adjoining parts of Katherine-Darwin region. Exposures occur in northern part of Katherine Sheet area; central and eastern parts of Mount Evelyn Sheet; eastern part of Alligator River Sheet; central, western, and southern parts of Milingimbi Sheet, and northwestern and western parts of Mount Marumba Sheet area. Small isolated exposures also occur in the Urapunga, Junction Bay and Coburg Peninsula Sheet areas. Two isolated exposures occur in the Pine Creek Sheet area.

Table 12. Summary of stratigraphy, Katherine River Group.

ROCK UNIT	THICKNESS (m)	LITHOLOGY	TOPOGRAPHY	DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	REMARKS
West Branch Volcanics	90 (Mt Marumba Sheet) 1590 ref area, Katherine Sheet	Tuffaceous greywacke, arkosic sandstone, amygdaloidal basalt, conglomerate, quartz greywacke	Poorly resistant, low slightly undulating country	SW Mt Marumba Sheet, extending into NE Katherine Sheet	Unconformably overlain by Bone Ck Fm. (Arnhem Land) or Margaret Hill Congl., Katherine Sheet. Conformably overlies Gundi Greywacke (Arnhem Land)	Top unit of Kath. R. Gp. Very poorly exposed in Arnhem Land
Gundi Greywacke	90 Mt Marumba Sheet 140 ref area, Katherine Sheet	Tuffaceous quartz greywacke, feldspathic sandstone, quartz sandstone	Resistant - elevated plateaux; commonly dissected into rough hills and sandstone karst	NE trending belt, from Katherine Sheet, across Mt Marumba to S Milingimbi Sheet	Unconformably overlies McCaw and Cottee Fms and Shadforth Sst in Arnhem Land	Large cross-beds and strong jointing (karst) characteristic
McCaw Formation	>150	Siltstone, sandstone, dolomite, basalt	Poorly resistant - low undulating hills	Wilton R. headwaters, NW Mt Marumba Sheet	Conformably overlies Shadforth Sst.	Full sequence broadly equivalent to Diamond Ck Fm. of Katherine Sheet. Glauconite scatterd throughout. Large domal stromatolite bioherms characteristic of Cottee Fm.
Shadforth Sandstone	40 ref. area - 115	Quartz sandstone. Rare conglomarate	Very resistant - strong cuestas	Wilton R. headwaters, NW Mt Marumba Sheet, extending into S Milingimbi Sheet	Unconformably overlies Cottee Fm	
Cottee Formation	~360	Dolomitic siltstone, silty dolomite & silty dolomitic limestone; dolomitic or calcareous sandstone; glauconitic dolomite; quartz & feldspathic sandstone; domal stromatolite bioherms	Poorly resistant - low undulating hills		Conformably overlies McKay Sst or Kombolgie Fm	
McKay Sandstone	360	Ferruginous sandstone, feldsapthic sandstone, quartz sandstone, quartz greywacke	Moderately resistant - undulating hills, occasional strike ridges	NW Mt Marumba and S Milingimbi Sheets, extending into Katherine and Mt Evelyn Sheets.	Conformably overlies and grades laterally into upper Kombolgie Fm. Locally sits unconformably on Jimbu Gr.	Previously mapped as Kombolgie Fm. on Katherine (Randal, 1963) and Mt Evelyn (Walpole, 1963) Sheets

Table 12 (continued).

ROCK UNIT	THICKNESS (m)	LITHOLOGY	TOPOGRAPHY	DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	REMARKS
Kombolgie Formation	630 (Arnhem Land - 1740) 750 ref. area	Quartz sandstone; minor feldspathic sandstone, pebble conglomerate; mafic volcanics	Very resistant (excluding volcanics) - rough elevated hills	Widespread in Mt Marumba, Milingimbi, and Junction Bay Sheets, and adjacent sheets of Katherine-Darwin region	In Arnhem Land, unconformably overlies Jimbu Gr. and Gunbatgari and Nimbuwah Cmplx.	Main bedrock of Arnhem land Plateau; strongly jointed.Several mafic volcanic members. Three broad divisions recognised - 'lower arenite succession', 'median volcanic members', and 'upper arenite succession'.
Nungbalgarri Volcanic Member (of Kombolgie Fm)	~60	Basalt. Minor quartz sandstone	Poorly resistant - soil covered valleys	NW Mt Marumba and W Milingimbi Sheets, extending into adjacent Mt Evelyn and Alligator R. Sheets	Conformably within arenites of Kombolgie Fm. Locally sits directly on Jimbu Gr.	
Goomadeer Volcanic Member (of Kombolgie Fm)	30 (max.)	Mafic volcanics		NW Milingimbi Sheet	Unconformably overlies Nimbuwah Cmplx. Confomably overlain by 'lower arenite succession'	

Reference Area: Walpole et al. (1968) nominate the drainage area of Katherine River but complete section of group is not exposed in any single area. Lowermost part of group (Edith River Volcanics and Kombolgie Formation) best exposed in Edith Falls Syncline, northeast of Katherine, while upper part best exposed in Shadforth Dome and environs although part of section in this area largely covered by soil and can be adequately examined only in Waterhouse River area.

Derivation of Name: Katherine River in Katherine-Darwin region.

Stratigraphic Relationships: In Katherine-Darwin Region rests unconformably on folded rocks of Pine Creek Geosyncline (Walpole et al., 1968). In Arnhem Land rests unconformably on Nimbuwah Complex, Jimbu Granite, and Gunbatgari Granite. Unconformably overlain by Mount Rigg and Wessel Groups, and Mesozoic and younger deposits.

Components: Made up of nine formations. Total of twelve members formally named in two of these formations.

Lithology: Chiefly quartz sandstone. Substantial thickness of carbonate rocks and basic (and locally acid) volcanics also present.

Thickness: Not possible to estimate accurately. Varies considerably. Complete section not exposed in any one area.

Age: Statherian (Palaeoproterozoic).

Description and comments

Over most of their area of outcrop the rocks of the group are sub-horizontal or have very gentle dips to the southeast but in a few places domes and synclines, with limbs dipping at up to 30^{o} or more, are present, and provide the only well exposed sections of significant thickness.

In the Waterhouse River and Upper Wilton River districts the numerous unconformities in the succession bear testimony to repeated tectonic adjustments during sedimentation. The thickness of the various components varies considerably from area to area; nowhere can a complete section of the group be observed and so it is not possible to quote a maximum thickness. It is likely, however, that the maximum preserved section would be east of the Shadforth Dome or southeast of the Waterhouse River area under the Mount Rigg and Roper Groups.

The lithology is discussed under the individual formation headings. The stratigraphy of the group is summarized in Table 12.

Kombolgie Formation

Definition

Distribution: Most extensively exposed unit of Katherine River Group. Bedrock of main part of Arnhem Land Plateau. Crops out over northern part of Katherine Sheet area, central and eastern parts of Mount Evelyn Sheet, eastern part of Alligator River Sheet, central, western, and southern parts of Milingimbi Sheet, and northwestern and western parts of Mount Marumba Sheet area. Small exposures also occur in Pine Creek, Junction Bay, and Coburg Peninsula Sheet areas.

Reference Area: Walpole et al. (1968) nominate Kombolgie Creek, South Alligator River area, latitude 13°30'S, longitude 132°23'E. Best exposures however in Edith Falls Syncline, northeast of Katherine.

Derivation of Name: Kombolgie Creek

Stratigraphic Relationships: In places rests apparently conformably on Edith River Volcanics, in other places they are separated by an unconformity (Walpole et al. 1968). Where Edith River Volcanics are absent Kombolgie Formation rests unconformably on older strata or granite. In Arnhem Land the formation rests unconformably on Jimbu and Gunbatgari Granites and Nimbuwah Complex.

Over most of its strike-length Kombolgie Formation is overlain conformably by McKay Sandstone, but in southern part of Milingimbi Sheet area McKay Sandstone grades laterally into Kombolgie Formation. In this area Kombolgie Formation conformably overlain by Cottee Formation. In the Waterhouse River area Kombolgie Formation is overlain conformably by Diamond Creek Formation.

Lithology: Alternating sediments and volcanic rocks: predominantly medium to coarse-grained quartz sandstone; minor feldspathic sandstone and pebble conglomerate. Purple quartz greywacke, silty sandstone, sandy siltstone, and conglomerate dominant in west (Edith Falls and Mount Callinan Synclines). Volcanics predominantly basic; minor intermediate and acid.

Thickness: Walpole et al. (1968) quote 2500 feet (750 m). However varies from greater than 1740 m (Edith Falls Syncline) to 630 m (Wilton River area).

DESCRIPTION

Excluding the Goomadeer Volcanic Member, at the base of Kombolgie Formation, the formation can, in most areas, be divided into three successions: (i) a basal, dominantly arenaceous succession (lower arenite succession) which is overlain by (ii) volcanics, (median volcanic members), which are in turn overlain by (iii) predominantly arenaceous strata (upper arenite succession).

Goomadeer Volcanic Member

Definition

Distribution: Goomadeer River district, in the northwestern part of the Milingimbi Sheet area. Area of outcrop about 15 km^2.

Reference Area: Here nominated as area in vicinity of latitude 12°13'S; longitude 133°47'E.

Derivation of Name: From Goomadeer River, a major watercourse flowing into Junction Bay.

Stratigraphic Relationships: Unconformable on Nimbuwah Complex; from aerial observation appears to be conformably overlain by arenites of Kombolgie Formation.

Lithology: Not examined on ground due to inaccessibility but from the air they closely resemble in form of exposure and colour, the Nungbalgarri Volcanic Member. We infer that the member consists of basic volcanics.

Thickness: Lenticular. 30 m maximum.

Lower Arenite Succession

In the Wilton River area the lower arenite succession is lenticular and in places the Nungbalgarri Volcanic Member, and younger rocks of the Kombolgie Formation, rest directly on the Jimbu Granite. In the McKay Dome the lower arenite beds vary in thickness from 30 m in the north to zero in the south; in the Shadforth Dome they are over 110 m thick in the south and absent in the north. Some 30 Km west of the McKay Dome the Kombolgie Formation is not preserved and the McKay Sandstone rests directly on the Jimbu Granite.

In the McKay and Shadforth Domes the lower beds of the Kombolgie Formation consist of white, blocky, medium-grained, cross-bedded, ripple-marked quartz sandstone, with occasional discontinuous pebbly bands. The pebbles are exclusively quartz.

In the Goomadeer River area, in the northwestern part of the Milingimbi Sheet area, the basal arenite sequence rests in places on the Goomadeer Volcanic Member, and in other places unconformably on rocks of the Nimbuwah Complex. The sequence is overlain by the Nungbalgarri Volcanic Member. The beds consist of white, blocky to massive, medium-grained quartz sandstone, with thin beds of quartz-pebble conglomerate at the base, and as interbeds. The rocks are cross-bedded and ripple marked.

Median Volcanic Members

Volcanic rocks within the Kombolgie Formation are exposed at widely separated localities in the western part of Arnhem Land and in the adjoining parts of the Katherine-Darwin region. The lack of continuity of the exposures is due mainly to the structural attitude of the Kombolgie Formation, but in places lensing of the volcanics is a contributory factor. The discontinuity of outcrop prevents definite correlation of the volcanic rocks exposed in various localities and they have accordingly been assigned to separate stratigraphic units or left unnamed. In most localities the volcanics are both overlain and underlain by arenites of the Kombolgie Formation; in others the volcanics are known to be overlain by arenites but their base is not exposed. Apart from in the Edith Falls Syncline and Goomadeer River area only one volcanic unit is present where clear sections of the Kombolgie Formation are exposed. This suggests that many of the volcanic units may be stratigraphic equivalents.

Definition

Distribution: Crops out over about 5 km^2 in northwestern part of Mount Marumba Sheet area and over about 260 km^2 in western part of Milingimbi Sheet area; extends into adjoining Mount Evelyn and Alligator River sheets area, but although mapped (Walpole, 1962; Dunn, 1962) they have not been named. The revised edition of the Katherine-Darwin 1:500 000 Geological Sheet indicates the probable westward extent of the unit.

Reference Area: Here designated as area surrounding latitude 12°16'S, longitude 133°47'E (between Goomadeer River and Nungbalgarri Creek in northwestern part of Milingimbi Sheet area).

Derivation of Name: From Nungbalgarri Creek, which flows northeast from northwestern part of Milingimbi Sheet area into Rolling Bay (Junction Bay Sheet area).

Stratigraphic Relationships: Conformably overlain and underlain by arenites of Kombolgie Formation; in places in Wilton River area, the underlying strata lens out and the Nungbalgarri Volcanic Member rests directly on Jimbu Granite. The member is possibly stratigraphically equivalent to the Birdie Creek and Plum Tree Creek Volcanic Members and to un-named volcanic sequences exposed in isolated areas of the Mount Evelyn and Alligator River Sheet area.

Lithology: Basalt, partly amygdaloidal or vesicular. Minor quartz sandstone interbeds locally.

Thickness: About 60 m.

Description and comments

The volcanics are partly amygdaloidal or vesicular. Red, flaggy, fine-grained quartz sandstone interbeds occur in the exposures in the Shadforth Dome; and in the Milingimbi Sheet area an interbed of white medium-grained blocky quartz sandstone up to 50 feet thick occurs in places.

Dykes and sills of dolerite possibly associated with the extrusive activity, intrude the volcanics in places.

W R Morgan (pers. comm.) has described several thin sections of albite basalt from the Nungbalgarri Volcanic Member.

Albite basalt (spilite?) (R13626): Consists of randomly oriented albite laths about 0.3 mm long with a few completely chloritised pyroxene crystals and some magnetite, set in a mass of fine flakes of sericite and chlorite. The sericite and chlorite together form 60 to 70 percent of the rock and probably represent altered basaltic glass.

Albite basalt (spilite?) (R13624): A sparsely porphyritic rock with a basaltic texture. The phenocrysts are mostly rhomb-shaped crystals of slightly sericitised albite and range up to 2 mm in diameter; a few phenocrysts of augite are present. The groundmass contains laths of slightly sericitised albite averaging 0.25 mm long and 0.03 mm wide, together with prismatic to granular, colourless, slightly chloritised augite. Octohedral magnetite is also present in the

groundmass. About 15 to 20 percent of the rock consists of brown devitrified interstitial glass, which encloses small plagioclase microlites.

In other thin sections (R13623, R13625, R13537) the plagioclase is strongly sericitised. In specimen R13623 the pyroxene and the small amounts of olivine(?) present are pseudomorphed by smectite, chlorite, carbonate, and iron oxide.

Upper Arenite Succession

Conformably overlying the Nungbalgarri Volcanic Member and other volcanic units is a succession consisting dominantly of arenites and rudites, lithologically similar, in a broad sense, to these strata underlying the volcanic members. In places where the volcanics are absent, or where their stratigraphic relationships are not clear, it is not possible to map the two separately and the succession has therefore been mapped as part of the Kombolgie Formation.

In both the McKay Dome and Shadforth Dome the upper beds of the Kombolgie Formation as well as the rocks of the Nungbalgarri Volcanic Member and the basal beds each, in places, overlap directly on to the Jimbu Granite. In the northern part of the Shadforth Dome where the upper beds rest on the Jimbu Granite, their thickness is 250 m; in the southern part of the dome, where they overlie the Nungbalgarri Volcanic Member, they are 330 m thick. In the McKay Dome they are about 300 m thick in the north - where they rest on the Nungbalgarri Volcanic Member and 225 m thick to the south - where they rest on the Jimbu Granite. In both domes the upper beds consist of massive to blocky, medium to thin-bedded, white, cross-bedded, ripple-marked, medium to coarse-grained quartz sandstone. Thin pebbly bands are present in parts of the sequence; the pebbles are up to 2.5 cm in diameter and consist solely of quartz.

The rocks are generally well sorted and consist almost entirely of quartz grains cemented by overgrowths of quartz; colourless needles, or round grains and fine opaque inclusions,; are common in many of the grains. Sericite is a minor constituent and zircon is the only accessory observed in thin section (R12027).

To the north, in the Milingimbi Sheet area, the upper beds of the Kombolgie Formation are extensively exposed. Isolated observations in this rugged and poorly accessible area show the beds to consist predominantly of white, pink, and purple, massive, and occasionally flaggy, medium to coarse-grained quartz sandstone, with minor interbeds of feldspathic sandstone and pebble conglomerate. The rocks are prominently cross-bedded and oscillation and current ripple marks are abundant. The purple quartz sandstone noted above owes its colour to the presence of iron oxide as grain coatings; interbeds of this type are more common towards the top of the unit, where the strata are generally flaggy, in contrast to the underlying massive strata. The thickness of the upper part of the Kombolgie Formation in the Milingimbi Sheet area is uncertain, but is probably well in excess of 300 m. The regional dip is to the southeast and the elevation of the outcrops ranges from 60 m in the north to over 375 m in the south.

McKay Sandstone

Definition

Distribution: First recognised in the northwestern part of Mount Marumba Sheet area and southern margin of Milingimbi Sheet. Exposures cover about 210 km^2.

In the Katherine Sheet area (Randal, 1963), rocks now known to belong to the McKay Sandstone were mapped as part of Kombolgie Formation, in Mount Evelyn Sheet (Walpole, 1962), the beds were mapped as part of Diljin Hill Formation. Distribution in these areas is shown on the revised Katherine-Darwin 1:500 000 Geological Sheet (Walpole et al., 1968). Outcrops cover about 1100 km^2 in southeastern Mount Evelyn Sheet and 26 km^2 in northeastern Katherine Sheet.

Reference Area: McKay Hills, around latitude 13°12'30"S, longitude 133°58'E.

Derivation of Name: From McKay Hills, in northwestern sector of Mount Marumba Sheet area. The hills were named after Mr Jack McKay, of Mainoru Station, who was one of the first Europeans to settle in the region.

Stratigraphic Relationships: In McKay Dome rests conformably on Kombolgie Formation, but to the west, in Jimbu Creek district, rests unconformably on Jimbu Granite. In southern part of Milingimbi Sheet area is thought to grade laterally into upper part of Kombolgie Formation because locally rocks of Cottee Formation rest, with apparent conformity, on Kombolgie Formation. In Katherine Sheet formation grades laterally into upper part of Kombolgie Formation. In both Katherine and Mount Evelyn Sheet areas rests conformably on Kombolgie Formation and is overlain conformably by Diamond Creek Formation (formerly Diamond Creek Member of Diljin Hill Formation of Randal, 1963).

Lithology: Flaggy to blocky, fine to medium-grained, purple-brown ferruginous sandstone; feldspathic sandstone; blocky, white quartz sandstone; quartz greywacke.

Thickness: 360 m.

Distinguishing Features: Distinguished from Kombolgie Formation by ferruginous feldspathic sandstone interbeds. Inferred lateral contact between McKay Sandstone and Kombolgie Formation cannot be mapped because it is covered by soil. Top of McKay Sandstone marked by appearance of yellow leached dolomitic or calcareous arenites.

Description and comments

Quartz sandstone is predominant in the reference area but ferruginous and/or feldspathic sandstones are predominant over much of the outcrop area, and account for the generally poor exposures. It is probable that there is a pronounced lateral variation in the lithology of the McKay Sandstone.

Ruker (1959) has noted similar lateral lithological variations in the Katherine Sheet area. Northeast of Waterhouse Waterfall the quartz sandstone of unit Puk3 is succeeded by a lens of laminated micaceous sandstone interbedded with grey siltstone (Puk4), which to the north, in the area east of Eva Valley homestead is represented by 190 m of purple fine-grained quartz greywacke. Overlying unit Puk4 is a bed of quartz sandstone from 90 to 135 m thick (Puk5) which is regarded by Ruker as stratigraphically equivalent to the upper part of unit Puk3 in the Gundi Creek area.

Cottee Formation

Definition

Distribution: Crops out over about 130 km^2 in northwestern Mount Marumba Sheet area and similar area in southern Milingimbi Sheet.

Reference Area: The McKay Dome, where the best exposures occur, is designated as a general reference area.

Derivation of Name: From Cottee Creek, a newly named tributary of Wilton River. Cottee Limestone used by Patterson (1958, unpubl.) to describe same unit. Patterson named unit after K Cottee, a helicopter pilot.

Stratigraphic Relationships: In most areas conformable on McKay Sandstone, but in Milingimbi Sheet area apparently conformable on Kombolgie Formation. In McKay Dome formation is overlain with slight angular unconformity by Shadforth Sandstone; unconformity probably extends over wider area, but poor exposures preclude its recognition.

Lithology: Interbedded dolomitic siltstone; silty dolomite and silty dolomitic limestone; dolomitic or calcareous sandstone; glauconitic dolomite; quartz sandstone; feldspathic sandstone.

Thickness: About 370 m.

Distinguishing Features: The base of the Cottee Formation is marked by the appearance of yellow leached dolomitic or calcareous sandstone. The top is marked by an unconformity.

Description and comments

A generalised stratigraphic section of the Cottee Formation in the McKay Dome, is given in Table 13.

In the dome to the east of the Shadforth Dome representatives of the uppermost strata seen in the McKay Dome are overlain by 63 m (top not exposed) of flaggy to thinly flaggy, brown, ripple-marked, slightly micaceous, fine-grained sandstone, interbedded with brown shaly siltstone. Grooves and faint striae are abundant on bedding planes.

At the base of the formation quartz sandstone (R12008) composed essentially of subrounded to rounded grains of quartz, cemented by quartz overgrowths, is predominant.

Quartzite grains with inclusions of fine opaques, sericite and a kaolinite-group mineral occur in minor amounts, as do grains of tourmaline and aggregates of iron oxide. Beds of ferruginous feldspathic sandstone are less common, but form an important part of the succession: the sandstone (R12009) consists of quartz (60 percent) plagioclase and microcline (5-10 percent) and iron oxides (25-30 percent) - with minor amounts of quartzite and igneous rock fragments.

Table 13. Generalised succession, Cottee Formation, McKay Dome.

Thickness (m)	Unconformably overlain by Shadforth Sandstone.
60	*Quartz sandstone* and *feldspathic sandstone,* white to pink and purple-grey, fine to medium-grained, flaggy, ripple marked, cross-bedded.
60	*Dolomitic siltstone,* purple-green to black, thinly flaggy; interbedded with *dolomitic limestone,* thin-bedded, flaggy; shale, fissile and *dolomitic or calcareous sandstone,* flaggy.
80	Large domal *stromatolitic bioherms* of *silty dolomite* and *silty dolomitic limestone,* irregularly laminated, purple; interfingering with *silty feldspathic dolomite,* flaggy; and *dolomitic siltstone,* thinly flaggy, purple.
50	*Sandy glauconitic feldspathic dolomite,* flaggy, weakly laminated, purple-grey; possibly rare basalt flows(?).
120	*Quartz sandstone* and *ferruginous feldspathic sandstone,* flaggy, orange to white, fine to medium-grained, ripple marked, cross-bedded; interbedded with *dolomitic or calcareous sandstone,* leached, porous, cream and yellow-brown, limonite-stained, fine-grained, abundant clay pellets.
372 total	Conformable on McKay Sandstone.

The basal arenite succession is overlain by about 50 m of sandy dolomite (R12013, R12015, R12016); laminae are produced by fine iron oxide grains and by variations in the content of dolomite, quartz, and feldspar. Dolomite occurs mainly as anhedral grains cemented by coarser-grained dolomite.

Scattered large clastic grains of dolomite are indicated by opaque inclusions which occur along the original grain boundaries. Quartz, microcline, untwinned potash feldspar, and plagioclase constitute up to 40 percent of the rock; muscovite and green biotite are present in minor amounts and are distributed through the rock. Zircon, tourmaline, and sphene are present as accessories. Glauconite occurs in some beds. About 10 km west of the culmination of the McKay Dome a small exposure of basic igneous rock is associated with beds in this part of the formation - its relationships are obscure and although it has been mapped as intrusive dolerite, it may represent an intercalated basalt flow.

The overlying beds, which are about 80 m thick, are largely made up of hemispherical stromatolite mounds up to 12 m in diameter (Plate 00). The mounds are composed of discrete beds of purple laminated silty dolomite and silty dolomitic limestone. Bedding partings are from 5-15 am apart; each bed contains 'wavy' stromatolitic laminations. The laminations are irregular in amplitude and wavelength and are commonly dislocated. In thin section (R12011, R12012) they can be seen to be due to variations in the amount of fine 'reddish' iron oxide included in the carbonate minerals. Silt-sized and occasionally fine sand-sized grains of quartz and feldspar, which form up to 70 percent of the rock, occur in thin laminae and as lenticular bands. Tourmaline and zircon occur as accessories. The lateral relationships between the hemispheres is uncertain, but there is some evidence that they are linked by beds which extend through several of the hemispheres. The hemispheres are spaced from 6 to 30 m or more apart (crest to crest) and probably lie in several distinct beds.

Beds of silty feldspathic dolomite and dolomitic siltstone separate the stromatolitic zones but the contacts are poorly exposed.

Two samples of carbonate rock from the same stromatolite mound have been analysed by AMDEL: one contained 47.6 percent $CaCO_3$ and 35.4 percent $MgCO_3$ and the other 75.5 percent $CaCO_3$ and 5.93 percent $MgCO_3$.

The overlying 60 m of strata consist of closely interbedded purple-green and black, silty, and dolomitic (or calcareous) rocks and provide a contrast to the succeeding 60 m of the section which consists entirely of arenites.

Shadforth Sandstone

Definition

Distribution: Crops out over total area of about 150 km^2 in northwestern part of Mount Marumba Sheet area and southern part of Milingimbi Sheet area.

Reference Area: Vicinity of latitude 13°20'S, longitude 134°20'E, in southwestern part of McKay Dome.

Derivation of Name: From Shadforth Hills.

Stratigraphic Relationships: Rests apparently unconformably on older strata of the Cottee Formation in the McKay Dome; unconformity assumed to be of regional extent. Conformably overlain by McCaw Formation.

Lithology: Predominantly white to buff, medium-grained, blocky quartz sandstone. Rare thin bands fine pebble conglomerate.

Thickness: 40 m northern McKay Dome. Up to 115 m Shadforth Dome.

Distinguishing Features: Distinguished from underlying and overlying strata by lack of carbonate beds. Base marked by unconformity and top marked by change from resistant arenites to less resistant lutites. Formation forms distinctive prominent strike ridge.

Description and comments

Up to 5 percent detrital feldspar occurs in some of the beds. The quartz grains are rounded to subrounded, and are cemented by recrystallisation along the grain boundaries, and in places by optically continuous overgrowths of quartz; the grains contain numerous inclusions. Grains of quartzite, zircon, tourmaline, and opaque minerals occur in minor amounts (R12017).

Towards the base, the formation is coarse in grain and more friable, and contains large-scale cross-beds; the foreset beds in the cross-beds dip almost exclusively to the south or southwest. Towards the top, the formation becomes flaggy and fine-grained and is marked by ironstained laminae.

In the southern part of the McKay Dome glauconite has been observed in the uppermost strata. Ripple marks and cross-beds occur throughout the formation; the cross-beds range from small-scale planar types to large-scale gently dipping types.

McCaw Formation

Definition

Distribution: Exposed only in Mount Marumba Sheet area; crops out over total area of about 400 km^2 in vicinity of McKay Dome and in isolated areas east of Shadforth Dome.

Reference Area: Largest and best exposures south of McKay Dome are faulted, and it was found impossible to reconstruct the sequence. Reference area is in vicinity of latitude 13°22'S, longitude 134°03'E, near southeastern culmination of McKay Dome.

Derivation of Name: From McCaw Creek, a southwesterly flowing tributary of Cottee Creek.

Stratigraphic Relationships: Conformably overlies Shadforth Sandstone and unconformably overlain by Gundi Greywacke.

Lithology: Probably consists essentially of interbedded siltstone, sandstone, dolomite and basalt.

Thickness: Minimum estimate 150 m.

Distinguishing Features: Contact between Shadforth Sandstone and McCaw Formation marked by change in lithology from medium-grained arenite to interbedded fine-grained arenite and lutite.

Description and comments

The order of superposition in the succession cannot be determined due to the effects of faulting.

The siltstone is generally yellow or purple-brown, but grey, green, pink and white beds have also been observed. Some beds are flaggy in outcrop, but most are thinly flaggy and laminated. Rare beds contain scattered grey limestone nodules up to 2.5 cm across, and most of them have a slight porosity which suggests that carbonate minerals may have been leached from them (most of the beds were probably originally dolomitic siltstones). The beds range in thickness from several centimetres to several metres and appear to be interbedded throughout the sequence.

The sandstone is predominantly fine-grained and flaggy and is characteristically red-brown. Quartz greywacke is probably predominant, but quartz sandstone is also well represented. The grains are generally moderately well sorted and subrounded to subangular in shape. Many of the quartz greywacke beds are glauconitic and micaceous; some contain a dolomite cement. The arenaceous beds are from several centimetres to several metres thick and are probably present in most parts of the sequence.

Beds of dolomite are present throughout, but appear to be more common high in the sequence, where they are up to 6 m thick. Terrigenous material is ubiquitous in the dolomite. Silty dolomite is the most common type, and although the original texture has generally been destroyed by recrystallisation, some can be seen in thin section to be silty dololutites. Sandy dolomite is comparatively rare. In outcrop, the dolomite beds are flaggy, blocky or massive, and either yellow, light grey or pink. Vague stromatolitic structures can be seen in some of the beds. Most of the rocks have a cryptocrystalline or microcrystalline texture.

A flow of black vesicular and amygdaloidal basalt has been noted near the base of the formation, and two flows, each about 4.5 m thick, have e noted high in the sequence. Other flows may be present. The basalt (R13546) consists of randomly oriented sericitised laths of albite, measuring 0.3 mm by 0.05 mm, together with chlorite and aggregates of carbonate. The carbonate and some of the chlorite probably pseudomorph pyroxene. Anhedral blade iron oxide and sphene are present. The few phenocrysts present are composed of albite and are up to 2 mm long. The amygdales are filled with chlorite and, in places, by carbonate.

Gundi Greywacke

Definition

Distribution: Broad northeasterly trending zone extending from northeastern part of Katherine Sheet area, through Mount Marumba Sheet area, into southern part of Milingimbi Sheet area; minor exposures in Mount Evelyn and Urapunga Sheet areas.

Reference Area: First mapped by Ruker (1959) as a member of his 'Diljin Hill Formation'. Randal (1963) followed Ruker's usage, but subsequent mapping has led the unit being raised to formation status. Defined by Walpole et al. (1968).

Stratigraphic Relationships: Neither Ruker (1959) nor Randal (1963) recognised an unconformity at the base of the Gundi Greywacke in the Waterhouse River district, but in Arnhem Land abundant evidence of regional unconformity is available, and we consider it likely that the unconformity extends into the Waterhouse River area. In the Waterhouse River area the West Branch Volcanics overlie the Gundi Greywacke unconformably (Ruker, 1959; Randal, 1963); in Arnhem Land the contact with West Branch Volcanics is poorly exposed, but the formations appear to be essentially conformable.

Lithology: Tuffaceous quartz greywacke, feldspathic sandstone, quartz sandstone.

Thickness: About 140 m thick in reference area; about 90 m in Arnhem Land.

Distinguishing Features: In Arnhem Land base marked by unconformity; top marked by change in lithology from arenite to volcanics; actual upper contact nowhere exposed.

Description and comments

About 140 m thick in Waterhouse River area. Consists mainly of purple, medium to coarse-grained tuffaceous quartz greywacke containing scattered pebbles of sandstone, quartz, and pink feldspar; the matrix is composed of pyroclastic materials (Walpole et al. 1968).

In the Mount Marumba and Milingimbi Sheet areas the formation is generally about 90 m thick and consists predominantly of massive and blocky arenites containing varying amounts of feldspar. At the base, red-brown quartz greywacke and feldspathic sandstone are predominant, but upwards white to red quartz sandstone becomes more prominent. No pyroclastic materials have been detected in these areas.

Large-scale cross-beds are characteristic of the unit, and most of the exposures are strongly jointed (Pl. 00).

West Branch Volcanics

Definition

Distribution: Confined mainly to northeastern part of Katherine Sheet area, but isolated poor outcrops occur in southwestern part of Mount Marumba Sheet area.

Reference Area: Between West Branch and Waterhouse River, latitude 14°25'S, longitude 133°05'E (Walpole et al. 1968).

Nomenclature: Ruker (1959) and Randal (1963) described the West Branch Volcanics as a member of the 'Diljin Hill Formation', but as a result of subsequent mapping the unit has been raised to formation status (Walpole et al. 1968).

Stratigraphic Relationships: Unconformable on Gundi Greywacke in Waterhouse River area (Ruker, 1959), but in Arnhem Land, where the contact is not exposed, the formations are probably conformable, or near-conformable. The West Branch Volcanics are unconformably overlain by the Margaret Hill Conglomerate, or, where the conglomerate is absent, by the Bone Creek Formation.

Lithology: Tuffaceous greywacke, arkosic sandstone, amygdaloidal basalt, conglomerate, quartz greywacke (Walpole et al. 1968).

Thickness: 1590 m in reference area (Walpole et al. 1968). Only about 90 m in Arnhem Land.

Distinguishing Features: The base of the formation is marked by an unconformity in the Waterhouse River area and by the appearance of basalt in the Wilton River area. The top is defined by an unconformity.

Description and comments

In the Waterhouse River area the West Branch Volcanics are up to 1590 m thick. Exposures in Arnhem Land are poor; they consist of a few scattered outcrops of dark grey basalt and purple medium-grained quartz greywacke representing a total of about 90 m of section.

DISCUSSION

The Katherine River Group was originally correlated lithostratigraphically with the Tawallah Group of the southern McArthur Basin, on the basis of stratigraphic position and lithological similarity (e.g., Plumb & Derrick, 1975; Plate 1, this report). More recently it has been suggested that it may in fact correlate with the McArthur Group, on the basis of preliminary magnetostratigraphy results and Rb-Sr geochronology (Plumb, 1985; Plumb *et al.*, 1990). New analysis has placed doubt on both these preliminary magnetostratigraphic and geochronological interpretations, and the age of the Katherine River Group remains an open question.

Only preliminary sedimentological interpretation is possible. Ojakangas (1986) has interpreted the Kombolgie Formation to the west of Arnhem Land as a northwest derived fluvial sand. The large scale cross bedding and poorly sorted nature of the Gundi Greywacke, together with its position above a regional erosion break, suggests a fluvial origin for that unit as well. The interbedded carbonates, silts and sands, with stromatolites, glauconite, and abundant shallow-water structures, suggest probable peritidal to perhaps shallow-marine and lacustrine environments for the remaining units; very similar in fact to those interpreted form the Tawallah Group in the south. These palaeoenvironments are all compatible with the frequent erosional breaks and regional unconformities which characterise the group in Arnhem Land.

MCARTHUR GROUP

Introduction

The McArthur Group is defined from the McArthur River district in the southern part of the McArthur Basin, where it is much better exposed than in Arnhem Land. Exposures of the two areas are separated by about 150 km of no outcrop between the Rose and Limmen Bight Rivers. However in both areas the beds are overlain by the Roper Group and they are underlain by thick, predominantly arenaceous, successions (the Parsons Range and Tawallah Groups). Because of the broad lithological and superpositional similarities of the two sequences the use of the name McArthur Group is extended into Arnhem Land.

The formal definition is given in Jackson *et al.* (1987). Only points relevant to Arnhem Land will be discussed here.

Distribution (Arnhem Land): Crops out extensively in Blue Mud Bay Sheet area, east of Parsons Range; small outcrops in southern part of Arnhem Bay Sheet. Much more extensively exposed in southern part of McArthur Basin.

Derivation of Name: From McArthur River.

Crohn (1954) divided rocks of the McArthur Group in Arnhem Land into two units - the Koolatong and Bath Range Formations. His Bath Range Formation corresponds to ours in the Bath Range and Walker River area; the rest of the group was mapped as Koolatong Formation. We have extended the known distribution of Bath Range Formation and subdivided the old Koolatong Formation into several new units of formation rank.

Stratigraphic Relationships (Arnhem Land): Conformably overlies Parsons Range Group and Groote Eylandt Beds. Unconformably overlain by Roper Group. Stratigraphic equivalents in Arnhem Land include the Habgood Group and possibly the Wilberforce Beds.

Components (Arnhem Land): Koolatong Siltstone, Strawbridge Breccia, Vaughton Siltstone, Conway Formation, Zamia Creek Siltstone, Yarrawirrie Formation, Baiguridji Formation, Bath Range Formation, Kookaburra Creek Formation, Blue Mud Bay Beds.

In the McArthur River district the Group includes a further 16 formations, 10 members and 2 sub-groups.

Lithology: Interbedded dolomitic siltstone, dolomite, chert, chert breccia, chert-quartz sandstone, dolarenite, argillaceous siltstone, black shale, minor conglomerate.

Thickness: Variable. 3.9 to 4.2 km exposed in Walker Trough; further 0.6 to 0.9 km probably covered by soil. Only about 1 km exposed to east on Caledon Shelf; further few hundred metres may be present beneath soil. Top eroded in both areas.

Age: Statherian (Palaeoproterozoic)

Description and comments

Stratigraphy is summarised in Table 14 and discussed in detail under various formations.

Koolatong Siltstone

Definition

Distribution: Exposed in three main areas: most extensive exposures in low country east of Parsons and Mitchell Ranges, in headwaters of Koolatong River; second group south of Parsons Range, in headwaters of Walker River; third around southern tip of Parsons Range, in catchment of Rose River. Isolated exposures west of Mitchell Range.

Reference Area: Reference area here designated as area surrounding latitude 13°25'20"S, longitude 135°25'30"E where the most complete section (about 50% of the total) is exposed.

Derivation of Name: Koolatong River, a major stream flowing into Blue Mud Bay. Crohn (1954) informally used the term Koolatong Formation for all the McArthur Group excluding the Bath Range Formation.

Stratigraphic Relationships: Conformably overlies Fleming Sandstone (topmost formation in Parsons Range Group); conformably overlain by Strawbridge Breccia.

Lithology: Interbedded purple to grey-green siltstone and shale; dolomitic siltstone and shale; flaggy and massive dolomite. Minor dolomitic sandstone; quartz sandstone; chert; chert breccia.

Thickness: About 1250 m. Poor thickness control.

Distinguishing Features: The base of the Koolatong Siltstone is marked by a change in lithology from arenites of the Fleming Sandstone to inter-bedded arenites, cherts, and silty strata. The top is marked by the appearance of massive chert-breccia (Strawbridge Breccia).

Description and comments

The Koolatong Siltstone is generally very poorly exposed, and it is only by means of somewhat tenuous correlations that the lithological sequence can be elucidated. The main elements of the sequence are shown diagrammatically on Figure 16; most of the column is based on observations in the Walker River district, but parts of the column are drawn from the Koolatong River district.

In the lowermost 30 m of the formation the lithology appears to be transitional from the arenaceous beads at the top of the Fleming Sandstone to the silty and shaly strata constituting the bulk of the Koolatong Siltstone. The pink, poorly sorted, fine to medium-grained, flaggy, ripple-marked quartz sandstone (R13468) at the base of the formation passes up into a sequence of grey or pink cherty fine-grained sandstone alternating with sandy chert and cherty siltstone. Stromatolites occur in some of the sandy chert beds and, in places, the cherty siltstone beds contain cauliflower cherts after anhydrite (R12647).

Table 14. Summary of stratigraphy, McArthur Group.

ROCK UNIT	THICKNESS (m)	LITHOLOGY	TOPOGRAPHY	DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	REMARKS
Kookaburra Creek Formation	Indeterminate in Arnhem Land	Quartz sandstone, chert breccia, oolitic chert, dolomitic siltstone	Scattered outcrops and ridges amongst soil cover	SW Blue Mud Bay Sheet, extending into Urapunga and Roper R to S.	Overlies Bath R. Fm. Overlain by Limmen Sst; relationship uncertain in Arnhem Land	Limited exposures, not directly in contact with rest of Gp in Arnhem Land. (Now part of Nathan Gp to S)
Bath Range Formation	1000 (max. - top eroded)	Feldspathic (tuffaceous), argillaceous, or dolomitic siltstone; 'pelletal chert'; chert-quartz sandstone; interlaminated siltstone-claystone; chert (oolitic); chert breccia	Scarp cappings and prominent ridges	Between Parsons/ Mitchell Ra. and Blue Mud Bay - Blue Mud Bay & Arnhem Bay Sheets	Conformably overlies Baiguridji Fm. Top mostly eroded. Locally overlain by Kookaburra Fm.	Massive white feldspathic-tuffaceous siltstone at base and abundant 'pelletal chert' distinctive
Baiguridji Formation	120 - 400 190 ref. sect.	Laminated fine-grained feldspathic quartz sandstone; interlaminated siltstone-calystone. Minor chert-quartz sandstone or conglomerate, silicified dolarenite	Crops out poorly in valley between ridges of Bath Ra. and Yarrawirrie Fms		Conformably overlies Yarrawirrie Fm.	Flaggy interbedded fine-grained sandstone and interlaminated siltstone-claystone characterisitic
Yarrawirrie Formation	225 - 345 (ref.area)	Dolomitic siltstone and sandstone; scattered coarse chert-quartz sandstone. Minor stromatolitic chert; local conglomerate	Crops out well in prominent strike ridges		Conformably overlies Zamia Ck Slst.	Distinguished from Zamia Ck Slst. by sandstone component
Zamia Creek Siltstone	100 - 285 120 - 250 ref. area	Uniform flaggy, generally siliceous siltstone. Some chert	Fairly prominent, rubble covered strike ridges; generally lower than Yarrawirrie Fm.	Between Parsons/ Mitchell Ra. and Blue Mud Bay - Blue Mud Bay Sheet	Conformably overlies Conway Fm.	
Conway Formation	30 (ref. area) - 75	Massive chert interstratified with cherty or dolomitic siltstone	Narrow, prominent ridges		Conformably overlies Vaughton Slst.	Chert probably silicified stromatolic dolomite - diagnostic

Table 14 (Continued)

ROCK UNIT	THICKNESS (m)	LITHOLOGY	TOPOGRAPHY	DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	REMARKS
Vaughton Silstone	900	Black shale, dolomitic siltstone, laminated shale, dolomite, silty dolomite	Crops out poorly in wide valley between Conway Fm. and Strawbridge Breccia	Between Parsons/ Mitchell Ra. and Blue Mud Bay - Blue Mud Bay Sheet	Conformably overlies Strawbridge Breccia	Exposed section very incomplete
Strawbridge Breccia	115 (ref area) - 150	Massive chert breccia. Local banded or stromatolitic chert	Persistent prominent strike ridges	Between Parsons & Bath Ra., & W of Mitchell Ra. - Blue Mud Bay & Arnhem Bay Sheets	Conformably overlies Koolatong Slst.	Probably silicified dolomite or limestone
Koolatong Silstone	1250	Purple to grey-green siltstone & shale; dolomitic silstone & shale; dolomite. Minor dolomitic sandstone, quartz sandstone, chert, chert breccia	Crops out poorly. Scattered outcrops amongst soil & in scarps below Lower Cretaceous		Base of McArthur Gp. Conformably overlies Parsons Ra. Gp	Exposed section incomplete; order of superposition based on local correlations
Blue Mud Bay beds	200? Only 75 exposed	Dolomitic siltstone, chert, quartz sandstone, stromatolitic chert, dolomite	Low strike ridge, bounded by valleys	Narrow strip W of Blue Mud Bay; Blue Mud Bay Sheet	Overlies, apparently conformably, Groote Eylandt beds. Apparently overlain by Yarrawirrie Fm.	Most of section not exposed. Apparent stratigraphic equivalent of all or part of McArthur Gp below Yarrawirrie Fm.

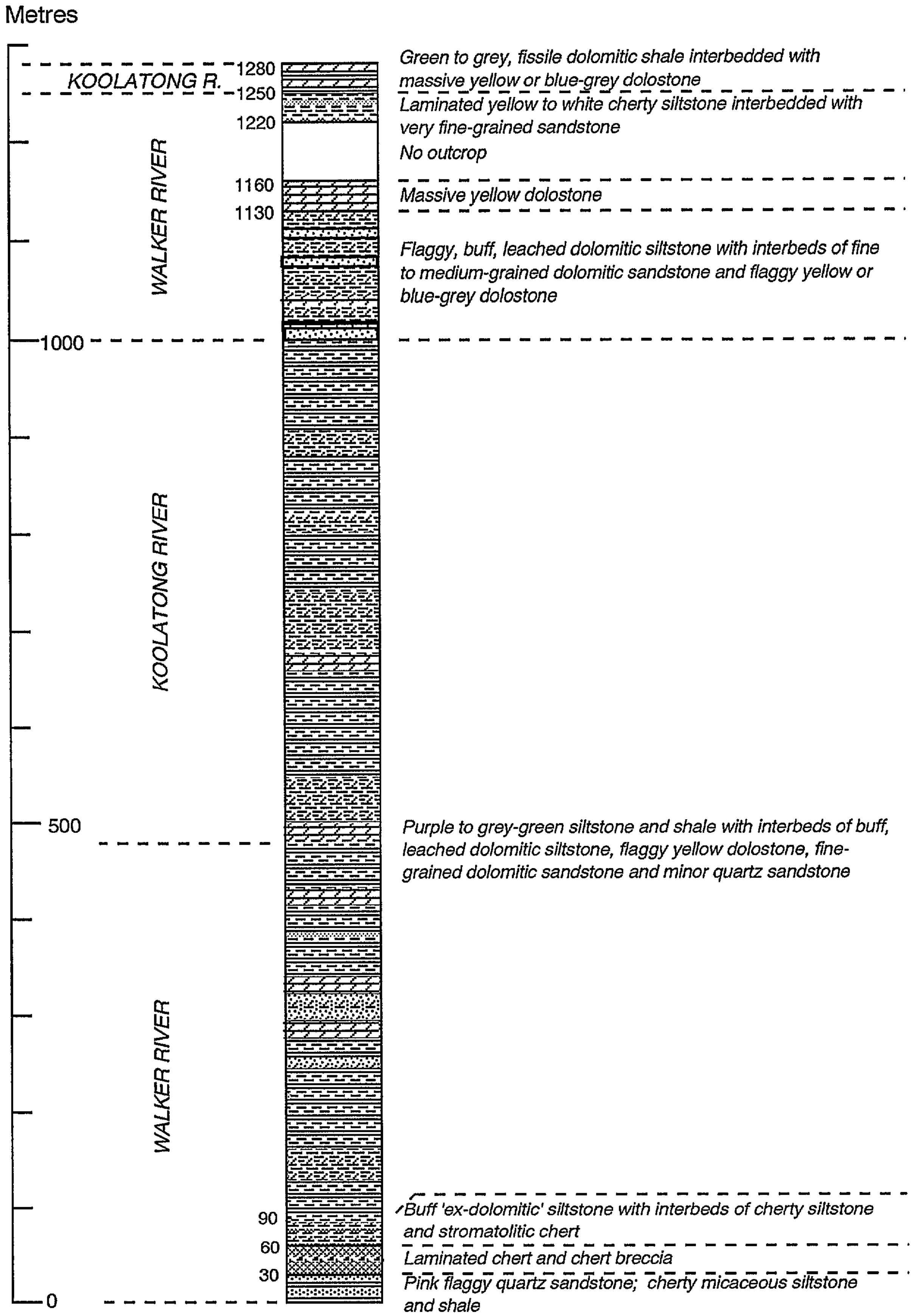

Table 16. Diagrammatic and generalised columnar section, Koolatong Siltstone, compiled from the Walker River and Koolatong River districts.

The overlying 30 m of strata consist of grey laminated chert with interbeds of pelletoid chert conglomerate composed (R12646) of pellets of chert ranging in size from 0.22 to over 6 mm in length, cemented by secondary quartz. The fragments are ellipsoidal in shape and are well rounded.

The succeeding 30 m consists mainly of flaggy, yellow or buff, leached dolomitic siltstone interbedded with flaggy and blocky green-grey cherty siltstone and stromatolitic chert. The stromatolites in the chert are hemispherical bodies up to 60 cm in diameter marked in vertical section by arched concentric 'wavy' laminae - the 'waves' are rarely more than 1 cm long and have an amplitude of about 1 cm.

The overlying sequence, which is about 600 m thick, consists predominantly of purple siltstone (confined mainly to the lower half) and grey-green siltstone and shale which are confined mainly to the upper half.

The purple siltstone is generally lacking in conspicuous bedding lamellae, and bedding partings are rare. The rock (R13594) consists of angular to subrounded poorly sorted silt-sized grains of quartz set in a matrix of clay minerals. Finely dispersed iron oxide dust imparts the purple colouration to the rock.

The grey-green siltstone is closely interlaminated with the grey-green shale or claystone. In thin section (R13464, 65) the boundaries between the silt laminae and clay laminae are sharp. In the clay layers sericite, chlorite, and green biotite have been developed. In the silty layers the grains, mainly quartz and minor feldspar, are separated by a little micaceous material and iron oxide. Tourmaline and rutile are present as accessories.

Interbeds, rarely more than about 3 m thick, of buff leached dolomitic siltstone, flaggy yellow dolomite, grey dolomitic limestone, limestone, fine-grained dolomitic sandstone, and medium-grained quartz sandstone occur in the sequence (particularly in its lower half), but make up probably less than 10 percent of the total thickness.

The dolomite and dolomitic limestone contain varying proportions of terrigenous clastic material. The dolomite (R13466, R134697) is very fine-grained; the terrigenous material appears to be mostly silt-grade quartz, but chemical analyses (Table 15) show that submicroscopic argillaceous terrigenous material or possibly very fine secondary silica may be present in appreciable quantities, and both specimens may in fact be strictly argillaceous dolomites. The silt-sized quartz grains are subangular, and show incipient replacement by the dolomite. Rare flakes of detrital muscovite are present.

The dolomitic limestone (R13460) consists of bands of impure, yellow, ironstained calcite, alternating with dolomite and grey bands of pure calcite. The yellow bands are slightly banded due to the variation in grainsize; the grains are rounded or irregular, but some rhombohedra occur (dolomite?), possibly as a result of recrystallisation. In the grey bands the rhombs are absent, and the grainsize is more even. The chemical analyses suggest that submicroscopic argillaceous material as fine secondary silica may be present.

Table 15. Calculated carbonate content from chemical analysis, of typical carbonate rocks from the Koolatong Siltstone

SPECIMEN NO	DOLOMITE (%)	CALCITE (%)	RESIDUE (%)
R13466	53.4	1.3	45.3
R13497	72.0	3.9	24.1
R13460	33.5	36.7	29.8
R12463	21.0	45.5	33.5
R13459	76.2	6.6	17.2

Limestone is thought to be comparatively rare in the sequence, but one specimen (R13462) has been examined in thin section. It has been recrystallised, but the banded structure, with grains averaging 0.03 and 0.08 mm in diameter, has been preserved. The calcite is clouded due to inclusions and ironstaining. Silt-sized, subangular grains of quartz occur in the finer portion of the rock, but are absent in the coarser. Pods of argillaceous material and patches of pure calcite (rimmed by chlorite and quartz) are present. Very fine-grained opaque minerals are scattered through the rock.

The slightly dolomitic siltstone (R13461) consists of material ranging in size from 0.032 to 0.08 mm (most of which falls in the silt grade), but a few of the grains are slightly coarser. It is finely laminated; the narrow laminae are finer in grain than the rest. The grains are subangular, and are cemented by suturing. Rock fragments and microcline and plagioclase are minor constituents. The interstitial argillaceous material has been recrystallised to chlorite and sericite. Detrital muscovite is rare. Opaque minerals of silt grade are fairly common and scattered evenly through the rock. Tourmaline and zircon are accessory.

The succeeding strata (in the interval 990-1110 m on Fig 16)) consist mainly of flaggy, buff, leached dolomitic siltstone. Interbeds of fine to medium-grained dolomitic or calcareous sandstone, flaggy yellow silty dolomite, and flaggy blue-grey silty dolomitic limestone occur in the sequence. The silty dolomitic limestone (R13463) consists predominantly of fine-grained calcite and dolomite with silt and fine sand-grade quartz, rare detrital flakes of muscovite, and accessory opaque minerals. The quartz grains are subangular to subrounded.

Massive yellow dolomite, possibly up to 30 m thick, overlies this sequence in the Walker River area, but it has not been positively identified in the Koolatong River district. The ensuing 60 m of section is not exposed in the Walker River district and is thought to be obscured in the Koolatong River district.

The uppermost 60 m of the formation are exposed in the Koolatong River district. The lower 30 m consists of laminated yellow to white cherty siltstone interbedded with very fine-grained sandstone; the upper 30 m consists of green to grey fissile dolomitic shale interbedded with massive yellow dolomite and massive blue-grey dolomitic limestone. The dolomite (R13459) consists of fine and very even-grained dolomite. The grainsize rarely exceeds 0.006 mm. Slight variations in the grainsize give rise to one form of lamination while another is due to narrow bands of silt and fine sand-grade quartz. The laminae vary in thickness along their length and from one to the other. Some of the quartz laminae lens out.

Table 16. Generalised stratigraphic succession, Koolatong Siltstone, west of Mitchell Range.

Thickness (m)	Top not exposed
30	Rubble *leached dolomitic sandstone,* grey, flaggy to thinly flaggy, fine-grained; elongate pellets of *leached dolomitic siltstone,* laminated, yellow.
420	No outcrop.
15	*Shale,* fissile, purple, slightly micaceous; interbedded with *silty dolomite,* flaggy, yellow; and *dolomitic sandstone,* flaggy, micaceous, fine-grained; some cross-beds.
15	*Stromatolitic dolomitic limestone,* blocky to massive, thin-bedded, grey and buff; limestone breccia between stromatolite columns. In thin section the rocks (R12649, R12650) consist essentially of fine-grained carbonate with minor amounts of quartz silt and iron oxide. In the breccia the fragments are fine-grained and the matrix medium-grained.
60	No outcrop.
6	*Leached dolomitic sandstone,* thinly flaggy, fine-grained; white clay grains and pellets scattered through rock.
24	No outcrop.
15	*Quartz sandstone,* grey, flaggy to blocky, fine-grained; scattered grains of pyrite. In thin section (R12651) rock is composed mainly of fine angular to sub-angular grains of quartz, with minor K-feldspar; interstitial argillaceous material in some bands; minor rock fragments; accessory zircon, and yellow, green, and blue tourmaline.
150	No outcrop.

15	*Shale and siltstone*, flaggy and laminated, grey; interbedded with *quartz sandstone*, flaggy, fine-grained; scatterd grains of pyrite. In thin section (R12653), identical with R12651 higher in sequence.	
180	No outcrop.	
930 total		Conformably underlain by Fleming Sandstone.

To the west of the Mitchell Range the Koolatong Siltstone is poorly exposed. Although at least 930 m of section is believed to be present, soil and sand are extensive and only isolated exposures are available. The sequence is given in Table 16.

To the west of the Parsons Range Fault zone, towards the southern end of the Parsons Range, a steeply dipping sequence with a thickness of at least 420 m has been mapped as part of the Koolatong Siltstone, but this identification is by no means certain. The sequence consists essentially of interbedded siltstone and flaggy laminated fine-grained sandstone and in the lower part, grey chert. The exposures are poor and it is difficult to assess the relative abundance of the silty rocks, but it is thought that the beds may represent the upper part of the Koolatong Siltstone.

Strawbridge Breccia

Definition

Distribution: Narrow, semi-continuous zones in Koolatong River drainage area (east of Parsons Range); Walker River district (south of Parsons Range), along Vaughton Creek, near southern end of Parsons Range.

Reference Area: Along Strawbridge Creek in vicinity of lat. 13°14'30"S, long. 133°36'E.

Derivation of Name: From Strawbridge Creek, a tributary of Koolatong River.

Stratigraphic Relationships: Conformably overlies Koolatong Siltstone; overlain with apparent conformity by Vaughton Siltstone. Possible, however, that Strawbridge Breccia may have developed as a result of weathering before deposition of Vaughton Siltstone; hence disconformity may be present.

Lithology: Massive chert breccia; banded chert and stromatolitic chert locally important.

Thickness: Fairly uniform, about 115 m in reference area; about 150 m in Vaughton Creek district.

Distinguishing Features: Readily distinguished from underlying and overlying strata by distinctive lithology.

Description and comments

The chert-breccia consists of angular chert fragments ranging from 0.5 to 5 cm or more across, set in a matrix of chalcedony or secondary quartz. The chert fragments are generally laminated; the most common fragments have alternating white and black laminae, but fragments with alternating grey and cream-brown laminae are also common. The matrix is either white, grey, or grey-brown.

The chert-breccia (R13469) consists of brecciated chert cemented by secondary quartz, which in part has the form of chalcedony. The fragments of chert vary greatly in size, and are angular to subangular in shape; they contain fine scattered opaque minerals with occasional scattered coarser euhedral grains. Some fragments show fine laminations. The cementing quartz is mainly in a mosaic of fine grains, but in some areas has the fibrous form of chalcedony; the latter contains dust-like opaque material which outlines a botryoidal form.

In places the breccia displays evidence of a relic bedding, and at several localities beds of massive laminated chert, with the relic textural characteristics of a limestone, occur in intimate association with breccia. Beds of stromatolitic chert occur locally within or at the top of the unit. The presence of these beds suggests that the breccia may have originally been a limestone breccia.

Vaughton Siltstone

Definition

Distribution: Crops out north and west of the Bath Range, and in isolated localities to the east of Vaughton Creek; exposures confined to Blue Mud Bay/Port Langdon Sheet area.

Reference Area: Area surrounding latitude 13°20'S, longitude 135°35'E, in Strawbridge Creek district.

Derivation of Name: From Vaughton Creek, a tributary of Rose River, which rises east of southern tip of Parsons Range.

Stratigraphic Relationships: Conformably or perhaps disconformably overlies Strawbridge Breccia and conformably overlain by Conway Formation.

Lithology: Black shale, leached dolomitic siltstone, white and purple laminated shale, minor chert, dolomite, silty dolomite, dolomitic siltstone.

Thickness: About 900 m. Uniform.

Distinguishing Features: Base marked by change in lithology from chert breccia of Strawbridge Breccia to sandy and silty strata. Top taken at last appearance of black shale; this coincides with base of predominantly cherty sequence (Conway Formation).

Description and comments

The Vaughton Siltstone is estimated to be about 900 m thick in the reference area and is thought to be of the same general order elsewhere.

The lower two-thirds of the formation, although generally poorly exposed, appears to consist predominantly of white to buff leached dolomitic siltstone, interbedded with white to purple laminated shale and very fine-grained sandstone. These rock types are usually closely interlaminated, but in parts of the section sandstone predominates and siltstone or shale occurs as fine lenticular strings; in other parts of the section sandstone is subordinate, and in places is lacking.

In thin section a typical specimen (R13471) is seen to consist of bands of very fine sand-sized quartz set in an almost isotropic matrix alternating with bands of nearly isotropic material containing variable concentrations of quartz silt. Rare bands contain neither silt nor sand. The quartz grains are moderately well sorted and are angular in shape; many are shard-like in outline. Minor amounts of rock fragments, feldspar, and muscovite are present. The colour of the matrix ranges from pale red-brown to dark red-brown or yellow, possibly due to finely divided iron oxide. The material is of doubtful origin, but it may be cherty and of secondary origin. Fragments and rare rounded grains of tourmaline, zircon, and sphene are present in accessory amounts.

Massive medium-grained silica-cemented quartz sandstone occurs as thin lenses and beds up to 1.5 m thick throughout the sequence, but makes up only a small proportion of the total thickness. A bed of flaggy cross-bedded medium-grained ferruginous sandstone about 9 m thick has been noted at the base of the sequence. Beds of pebble conglomerate occur spasmodically throughout the sequence, but like the arenites, make up only a small part of the total thickness. The conglomerate occurs as thin bands and lenses or as beds up to 1.5 m thick and consists of rounded chert pebbles up to three-quarters of an inch in diameter set in a white siltstone matrix.

The upper part of the Vaughton Siltstone is about 300 m thick and consists predominantly of black fissile shale and siltstone. Towards the top thin beds of chert, dolomite, silty dolomite and dolomitic siltstone are interbedded with the black shale and siltstone. In the silty dolomite (R13472) the dolomite is mainly of silt grade with a few grains of fine sand grade. Ironstaining is marked. Quartz, which occurs in almost equal amounts with the dolomite is of the same size grade as the carbonate and occurs as discrete grains scattered through the rock and also in clots of sutured grains. Rock fragments are rare as are flakes of muscovite. Opaque minerals are scattered sporadically through the rock and secondary iron oxide has been introduced along fractures.

The dolomite (R13473) is recrystallised into a mosaic of polygonal ironstained grains of very even size (about 0.03 mm across). Quartz is rare and occurs as angular grains of approximately the same size as the carbonate

Conway Formation

Definition

Distribution: Exposed in long, semi-continuous zones in three main areas; around Strawbridge Creek, west of Bath Range, and south-east of southernmost tip of Parsons Range. Exposures confined to Blue Mud Bay/Port Langdon Sheet area.

Reference Area: Area surrounding latitude 13°22'S, longitude 135°35'E, in the Strawbridge Creek district.

Derivation of Name: From Conway Creek, a tributary of Walker River.

Stratigraphic Relationships: Conformably overlies Vaughton Siltstone; conformably overlain by Zamia Creek Siltstone.

Lithology: Massive chert interstratified with cherty siltstone and leached dolomitic siltstone.

Thickness: About 30 m, reference area. Maximum about 75 m Walker River and southern Parsons Range district.

Distinguishing Features: Base drawn where black shale of Vaughton Siltstone disappears; this coincides with appearance of thick chert beds. Top drawn where beds of stromatolitic chert give way to siltstone of Zamia Creek siltstone. Stromatolitic chert beds are distinctive feature of Conway Formation.

Description and comments

The formation consists of several beds of chert each about 3 m thick, interstratified with beds of cherty siltstone and leached dolomitic siltstone of the same general order of thickness.

The chert is generally blocky, extremely brittle, and either milky white or grey; some beds show traces of regular parallel stratification, but most have indistinct, irregular laminae, in some cases outlining stromatolites. This suggests that the chert may be a silicified carbonate rock.

The cherty siltstone and leached dolomitic siltstone beds are generally flaggy or thinly flaggy and range in colour from buff to brown and grey. These rocks are almost invariably laminated.

Zamia Creek Siltstone

Definition

Distribution: Along line of folded strike ridges extending from Rose River, at southern tip of Parsons Range, along western side of Bath Range, to Koolatong Fault near Strawbridge Creek.

Reference Area: No type section defined; best exposed to southwest of Mount Rankin near lat. 13°39'S, long. 135°36'E.

Derivation of Name: From Zamia Creek, a tributary of Rose River, at about lat. 13°45'S, long. 135°15'E.

Stratigraphic Relationships: Conformably overlies Conway Formation and conformably overlain by Yarrawirrie Formation.

Lithology: Uniform sequence of flaggy, laminated, white, generally siliceous, siltstone, and some chert.

Thickness: 120 to 150 m, reference area. Maximum 285 m in southwest; 100 m in north.

Distinguishing Features: Distinguished by uniform, thinly bedded, fine-grained siltstone which contrasts with more complex lithology of underlying and overlying units. Base defined by top of uppermost stromatolitic chert of Conway Formation; top defined by first appearance of 'chert-fragment' sandstone interbeds at base of Yarrawirrie Formation.

Does not crop out as prominently as overlying and underlying units; forms slight valley which can be easily traced on air-photographs.

Description and comments

The stratigraphy of the formation is summarised in Figure 17.

The formation is about 120 to 150 m thick in the reference area (Fig. 17). It thickens westwards to about 285 m near the Rose River (section A) and thins northwards to 100 m near Strawbridge Creek (section D).

In outcrop the siltstone ranges from white to grey-pink and is uniformly laminated. Some fine graded-bedding has been observed. The siltstone is very fine-grained and generally appears to be siliceous in hand specimen, although weathered, porous rocks are common. No thin sections have been examined but by analogy with similar rocks in the Yarrawirrie Formation it may be inferred that the rocks were originally dolomitic siltstones and that the carbonate component has been leached out and that they have been silicified during weathering; silt and clay probably made up the bulk of the original sediment.

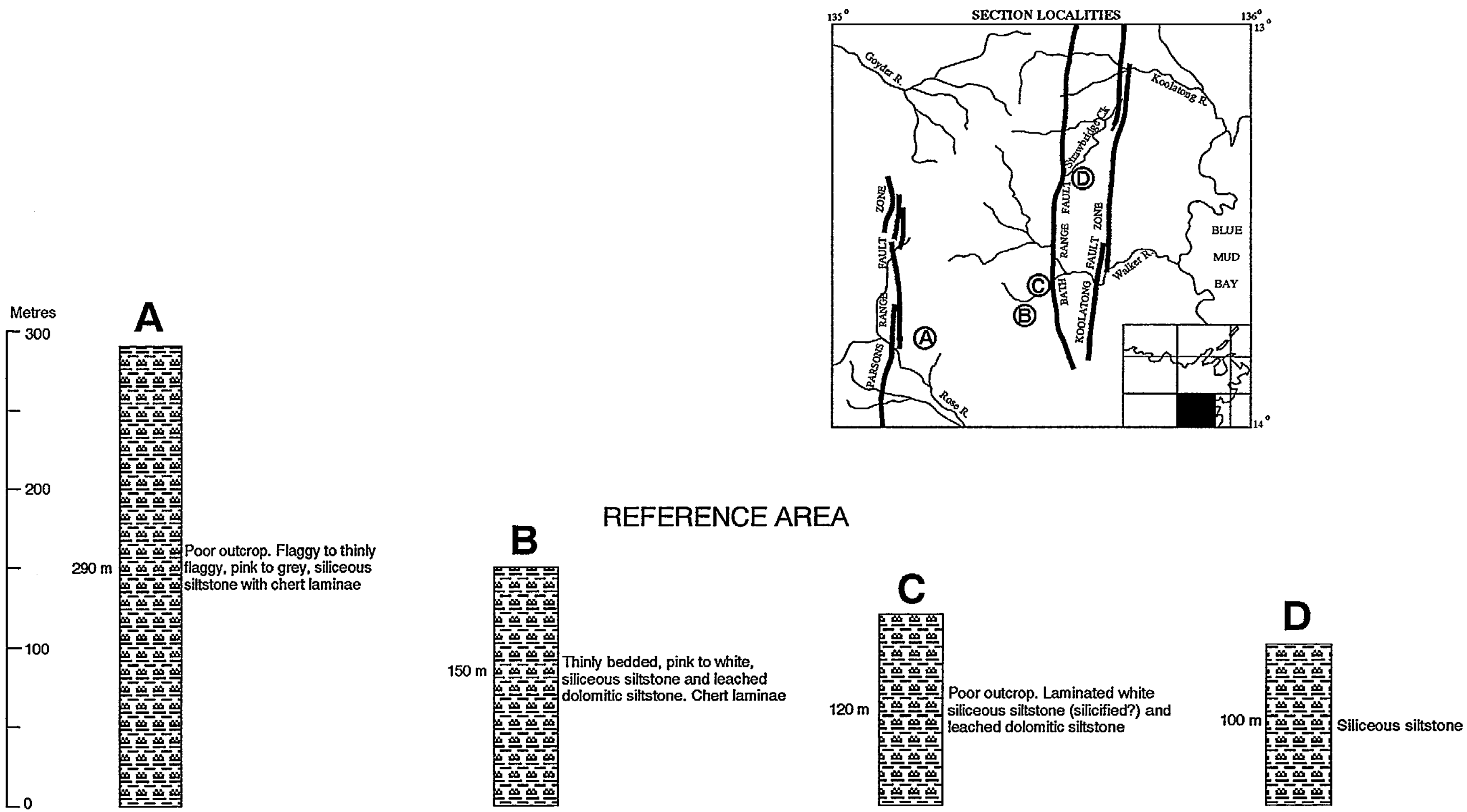

Figure 17. Diagrammatic stratigraphic sections, Zamia Creek Siltstone.

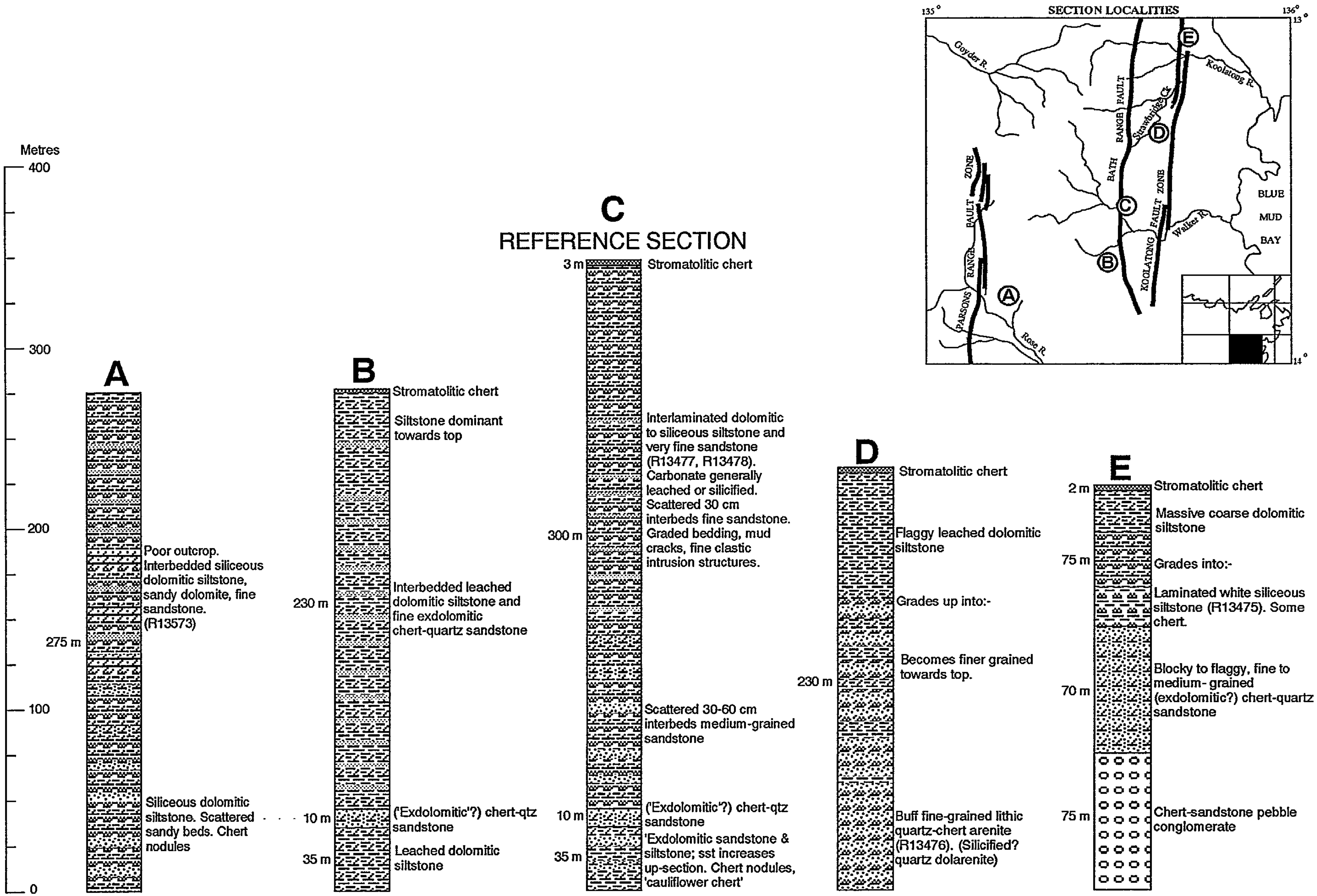

Figure18. Diagrammatic stratigraphic sections, Yarrawirrie Formation

Definition

Distribution: Exposed along folded line of strike ridges extending from Rose River at southern end of Parsons Range, around western and northeastern sides of Bath Range, and then northwards along Koolatong Fault to headwaters of Baiguridji River. Line of exposures continuous except where disrupted by faults.

Reference Area: Best exposed along western side of Bath Range about latitude 13°35'S, longitude 135°32'E, which is here designated as the reference area.

Derivation of Name: From Yarrawirrie Plains, in southern coastal area of Blue Mud Bay Sheet area, around lat. 13°53'S, long. 135°37'E.

Stratigraphic Relationships: Conformably overlies Zamia Creek Siltstone and conformably overlain by Baiguridji Formation.

Lithology: Flaggy dolomitic siltstone; scattered interbeds flaggy to blocky, medium-grained chert-quartz sandstone. Local conglomerate. Stromatolitic chert.

Thickness: About 345 m, reference area. Thins to 270 m southwest and 225 m northeast.

Distinguishing Features: Association of dolomitic siltstone and chert-fragment sandstone, and stratigraphic position diagnostic. Only formation likely to be confused is underlying Zamia Creek Siltstone which lacks sandstone interbeds. Yarrawirrie Formation crops out in prominent strike ridge which can be readily distinguished on air-photographs from less prominent units above and below.

Upper contact defined by stromatolitic chert bed while base defined by appearance of sandstone interbeds above Zamia Creek Siltstone. Both beads generally coincide with topographic breaks in slope.

Description and comments

Stratigraphic sections are given diagrammatically in Figure 18.

Conglomerate is locally developed at the base, while the top of the formation is marked by a persistent bed of stromatolitic chert. In the reference section (C) the thickness of the formation is estimated to be about 345 m; it thins to the northeast to about 225 m (E) and to 270 m in the southwest (A). The sediments show an overall decrease in grainsize from bottom to top.

The formation crops out as a prominent, rubble-covered, rounded, strike ridge which can be traced continuously throughout the area of outcrop. It invariably stands above the more poorly outcropping formations above and below.

The siltstones show flaggy bedding partings and, in general, range from thinly interlaminated siltstone and very fine-grained sandstone in the upper half of the formation to thin-bedded siltstone lower down. The lower half of the formation contains abundant blocky sandstone interbeds ranging from fine to coarse-grained, and, in the northeast, sandstone is predominant in this part of the section. Higher in the section fine-grained sandstone occurs mainly as scattered interbeds about 30 cm thick.

Most outcrops are weathered and the beds range from grey-white siliceous siltstone to white and yellow-brown porous leached siltstone. Scattered chert laminae are ubiquitous. Probable fine graded bedding has been observed in outcrop, but could not be verified in thin section.

In thin section the siliceous siltstones (R13475, R13573) contain abundant scattered quartz grains of coarse silt to fine sand size, and fine opaque minerals and clay or mica set in a cryptocrystalline matrix of silica or chalcedony. Tourmaline and zircon are accessory. Specimen R13475 contains fine wavy laminae similar to replaced stromatolitic laminae, while in specimen R13573 the bedding is highly disrupted due to slumping or alteration. It is unlikely that a primary chert would contain the amount of detrital material found in these rocks, and the chalcedony certainly indicates recrystallisation or cavity filling. Thus it is concluded that the rocks have been silicified, and that they probably originally contained carbonate minerals. The chalcedony matrix of specimen R13573 has ghost detrital grains which are inferred to be replaced dolarenite grains.

Table 17. Carbonate analyses, Yarrawirrie Formation.

SPECIMEN NO	ANALYSIS		CALCULATED		
	$CaCO_3$ (%)	$MgCO_3$ (%)	DOLOMITE (%)	CALCITE (%)	RESIDUE (%)
R13477	15.6	50.4	22.8	3.2	74
R13478	10.4	6.2	13.6	3.0	83.4

The only fresh siltstones observed were in the bed of the Walker River in the reference section (C). They are laminated, buff to dark grey dolomitic siltstones containing possible graded bedding and small auto-intrusion structures due to the injection of very fine sand laminae into the finer silt beds during compaction. Along strike with these beds, in weathered outcrops away from the river, the lithology changes to the typical white leached and siliceous siltstones described above. It is clear that the fresh rocks represent the original sediments prior to leaching and silicification during weathering; this probably also applies to the Zamia Creek Siltstone.

In thin section the rocks (R13477, R13478) are laminated dolomitic siltstones. Chemical analyses (Table 17) show that most of the carbonate is dolomite. The finer-grained laminae are dark grey while the coarse silt to fine sand material is buff. The laminae are completely disrupted by auto-intrusion of fine sand.

Specimen R13477 is estimated to contain about 40 percent of subrounded and well sorted clastic quartz grains lying just within the fine sand field in size. They are suspended in a carbonate matrix. They tend to be concentrated into very thin, light-coloured bands interlaminated with dark-coloured laminae containing less quartz, finer carbonate, and considerable iron oxide, fine mica, and clay. Table 17 shows that clay and iron oxide constitutes about 30 percent of the rock after subtracting 40 percent estimated quartz, but this may include some sub-microscopic silica. Rare grains of plagioclase are present.

The fabric of specimen R13478 is similar, although clastic quartz makes up about 60 percent of the rock; the quartz grains are mostly about 0.05 mm in size, but range up to 0.1 mm. Many of the finer-grained laminae have been partly replaced by chert. The chert content varies along the laminae. In one patch the matrix of a coarser band is partly replaced, leaving quartz grains suspended in a chert cement, producing a rock identical to the siliceous siltstone described earlier. This is considered conclusive evidence that most of the outcrops of the formation have been extensively altered. The analysis in Table 17 suggests that fine silica matrix, and possibly some clay, comprises about 20 percent of the rocks.

The bedding in the chert-fragment sandstone is flaggy to blocky, and ripple marks have been observed. The beds are generally about 30 or 60 cm thick, and are interbedded with siltstone, but about 36 m above the base of the unit in the reference area there is a particularly prominent bed about 9 m thick which contains chert fragments up to half an inch long. The sandstone contains subrounded grains of quartz and angular chert grains ranging from fine to very coarse-grained sand in size, set in a matrix of white to yellow, porous, leached siltstone. In the reference section clusters of botryoidal quartz lie in the bedding of the sandstone while chert nodules are associated with the siltstone.

One specimen of fine-grained sandstone (R13476) from the lower part of the Strawbridge Creek section (section D) can be described as a lithic-quartz-chert arenite; it was probably formed in a similar way to the chert-fragment sandstone. It consists of about 40 percent to 50 percent subrounded quartz of fine sand size and rounded rock fragments up to 0.3 mm in size, cemented by secondary chert. Detrital muscovite is scattered through the matrix and tourmaline is accessory. The rock fragments show a complete gradation between chert and claystone and with the overall evidence of silicification in the rock they were probably originally dolomite or dolomitic silt; the original rock was probably a quartz dolarenite. It is inferred that the coarser chert-fragment sandstone is similar. At the top of the Yarrawirrie Formation a persistent thin bed of stromatolitic chert occurs. This siliceous bed contains typical stromatolite forms. A thin section (R13481) shows thin, wavy, irregular laminae, consistent in form with algae. The rock consists of scattered silt-sized quartz grains in a submicroscopic silica matrix. Fine iron oxide occurs throughout. The detrital quartz and iron oxide content varies in different laminae; the laminae showing stromatolite-like forms are deficient in these materials and are generally composed of chalcedony, with fibres perpendicular to the bedding. The rock probably represents a silicified stromatolitic dolomite in which the voids within the stromatolites have been filled with silt detritus.

To the southwest of the Bath Range the Yarrawirrie Formation shows no significant lateral variations in lithology, but it decreases in thickness (Fig. 18) from about 345 m to 225-270 m. The thickness also decreases to 225 m in the northeast and it is likely that the sudden thickening is a local feature related to the major fault west of the Bath Range.

To the northeast of the Bath Range the lower half of the formation shows an increase in grainsize culminating in a basal conglomerate composed of rounded pebbles and boulders of quartz sandstone and chert, 2.5 to 15.0 cm in diameter, set in a matrix of argillaceous quartz sandstone. This has only been observed adjacent to the Koolatong Fault and is considered to indicate an easterly provenance. The facies changes were probably accentuated by movements on the Koolatong Fault. The quartz sandstone boulders were probably derived from the Groote Eylandt Beds or Parsons Range Group, although no diagnostic features ere observed. The chert may possibly have been derived from older units in the McArthur Group. The presence of the Caledon Shelf in the east supports such an interpretation.

Baiguridji Formation

Definition

Distribution: Crops out poorly in discontinuous folded line of exposures extending from the Rose River at southern end of Parsons Range, along western and northeastern sides of Bath Range, along Koolatong Fault, and as scattered small exposures between Baiguridji River and tidal reaches of Walker River.

Reference Area: No section measured; best exposed along eastern side of Strawbridge Creek half a mile south of Koolatong River (lat. 13°7'S, long. 135°43'E). Upper half of section here cut by strike fault, but correlations with immediately adjacent areas show that very little section is missing.

Derivation of Name: From Baiguridji River, a northerly tributary of Koolatong River which passes nearby around lat. 13°S, long. 135°45'E.

Stratigraphic Relationships: Conformably overlies Yarrawirrie Formation; conformably overlain by Bath Range Formation.

Lithology: Flaggy, pale green, laminated, fine-grained feldspathic quartz sandstone interbedded with pale green interlaminated siltstone and claystone. Minor coarse chert-quartz sandstone or conglomerate; silicified or leached dolarenite.

Thickness: 190 m, reference section. Thins eastwards to 120 m; thickens southwestwards to 400 m.

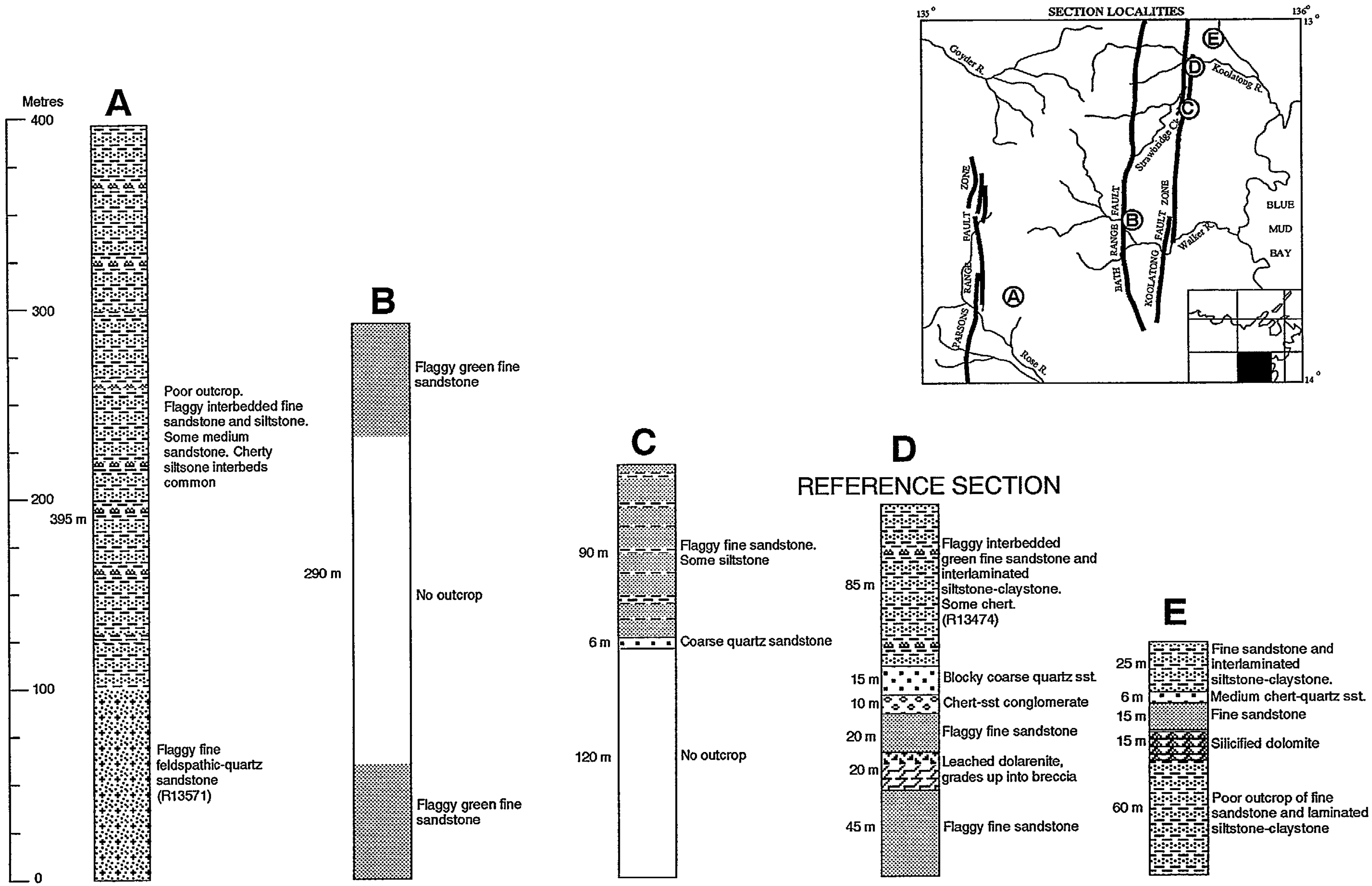

Figure 19. Diagrammatic stratigraphic sections, Baiguridji Formation

Distinguishing Features: Abundant pale green, flaggy, fine-grained quartz sandstones are distinctive, although they are similar to interbeds near base of Bath Range Formation. Top of Baiguridji Formation clearly defined by base of first prominent white siltstone at base of Bath Range Formation; base defined by top of stromatolitic chert at top of Yarrawirrie Formation. Baiguridji Formation forms clearly defined valley between underlying and overlying units in most areas.

Description and comments

The Baiguridji Formation crops out poorly in broad soil-covered valleys. The best exposures are generally found in a low scarp below the base of the Bath Range Formation although locally, well exposed, steeply dipping exposures are found near the Koolatong River.

Stratigraphic sections are shown diagrammatically in Figure 19. The formation consists mainly of flaggy pale green laminated fine-grained feldspathic quartz sandstone interbedded with pale green interlaminated siltstone and claystone. The claystone is frequently silicified. Minor marker beds of coarse chert-quartz sandstone or conglomerate and silicified or leached dolarenite occur near the middle of the formation.

In the reference section (Fig. 19, section D) the formation is estimated to be 190 m thick. It thins eastwards to about 120 m (section E) while to the southwest it thickens gradually to a maximum of 400 m in the Rose River area (section A).

Sedimentary structures within the fine-grained sandstone include small-scale cross-bedding, ripple marks and sand cracks, while wavy bedding is ubiquitous. The waves in the bedding range in amplitude up to 30 cm and have wave-lengths of from 15 to 120 cm. Small waves are frequently superimposed on larger ones. The sandstones show laminar bedding and flaggy partings and regularly alternate with interlaminated siltstone-claystone in beds about 3 to 7 cm thick. In outcrop the finer-grained strata generally weather out leaving flaggy rubble of white or yellow-brown fine-grained sandstone which constitutes only about 50 percent of the unit.

The only thin section of sandstone (R13571) studied consists of subangular, well sorted, fine sand-sized (0.05-0.08 mm) quartz grains, and minor feldspar, cemented by silica. Tourmaline and iron oxide are accessory.

In thin section the fine-grained interbeds (R13479) are composed of laminae of siltstone and claystone. The silt laminae consist principally of subangular well sorted quartz grains about 0.05 to 0.07 mm across and rare feldspar grains, with minor scattered rounded chert fragments about 0.1 mm across and occasional coarse well rounded quartz grains. The matrix consists of fine mica and silica cement, which forms overgrowths on some of the quartz grains.

The claystone bands consist of fine white mica and variable amounts of secondary silica, ranging up to 50 percent in some bands. Some fine opaque minerals and accessory zircon and tourmaline are present. In another specimen of siltstone (R13489) chert fragments are abundant and claystone laminae are lacking; otherwise the rock is the same.

These fine-grained rocks appear to be resulted from a period of continuous clay deposition, and the fine sand or silt-sized quartz were deposited during periodic floods. The chert fragments may have been deposited as chert, but the degrees of rounding suggests they are more likely to have been deposited as carbonate fragments which were subsequently silicified.

In the Koolatong River area two consistent marker beds crop out near the middle of the formation. The first crops out as a prominently cross-bedded, medium to coarse-grained, chert-quartz sandstone and conglomerate from 6 to 24 m thick. The sandstone has a clay matrix. The conglomerate consists of rounded pebbles of sandstone and chert, and angular chert fragments up to 7 cm in diameter, set in a matrix of coarse sand composed of about equal parts of quartz and angular chert.

The second marker bed crops out about 18 m below the conglomerate. It is a highly weathered and leached dolarenite, about 18 m thick, which grades upwards into breccia composed of angular fragments of dolomite and dolomitic siltstone at the top.

The marker beds have not been recognised to the west of the reference area, and as the sandstone and conglomerate generally crop out well they are probably absent or very thin.

The apparent, restricted distribution of conglomerate and sandstone suggests a source area to the east of the Caledon Shelf. The conglomerate has only been observed adjacent to the Koolatong Fault, and its restricted distribution may be due to movements on the fault, but it may have been deposited in a local channel.

Bath Range Formation

Definition

Distribution: Widely distributed in broad belt around headquarters of Rose River, through Bath Range, and coastal area east of Koolatong Fault from south of Walker River to Baiguridji River in north.

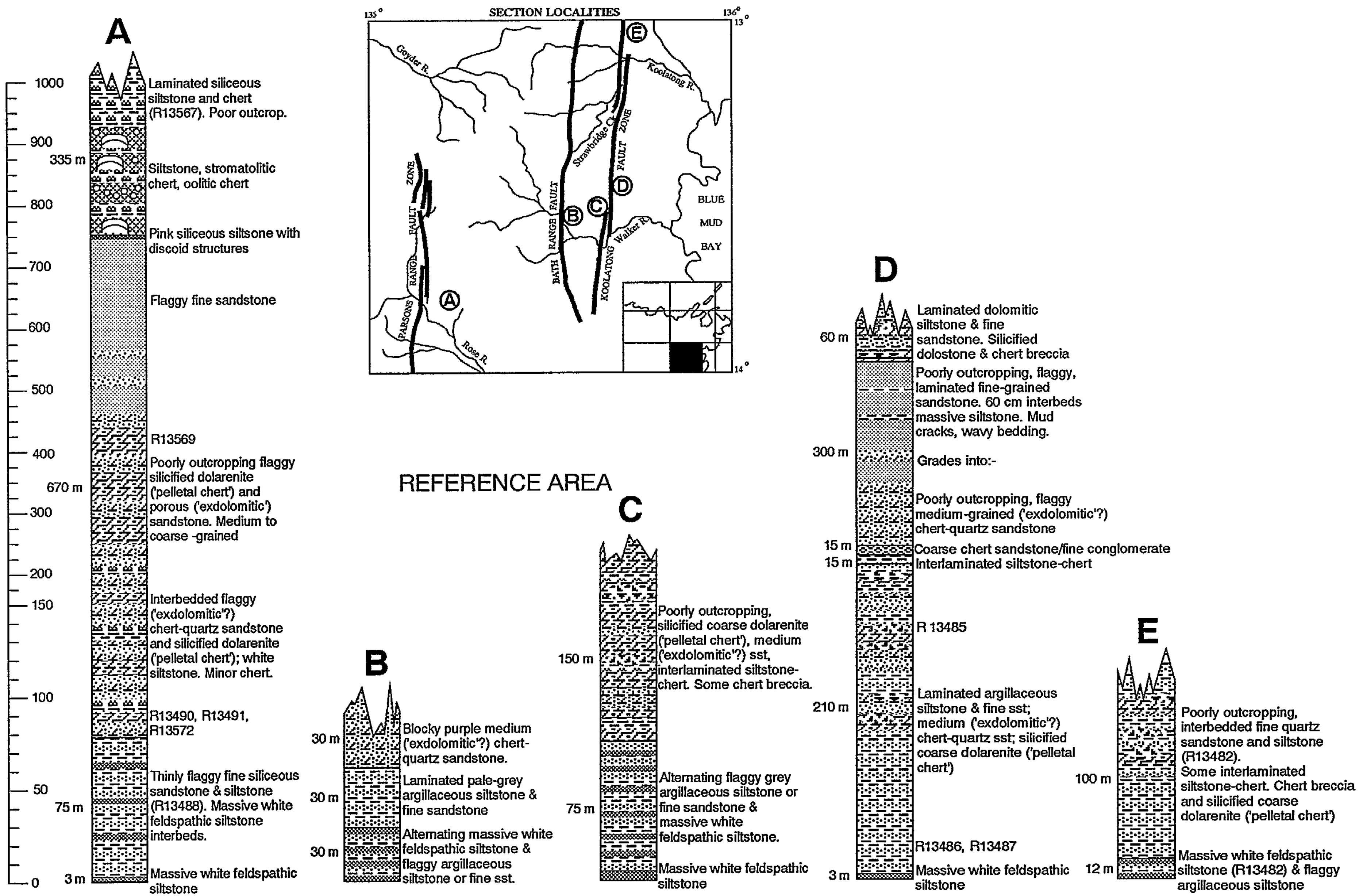

Figure 20. Diagrammatic stratigraphic sections, Bath Range Formation. Note change of vertical scale at 150 m, to accommodate greater detail in lower part of section

Reference Area: Designated as Bath Range north of Walker River around lat. 13°35'S, longitude 135°35'E. Much thicker sections occur elsewhere but the rocks are poorly exposed.

Derivation of Name: From Bath Range, which is capped entirely by the formation. Name used informally by Crohn (1954) for rocks in the reference area.

Stratigraphic Relationships: Conformably overlies Baiguridji Formation; top eroded and unconformably overlain by Lower Cretaceous strata and Cainozoic soils. Inferred that Bath Range Formation is conformably overlain by Kookaburra Creek Formation. They are separated by a wide soil-covered belt; it is possible, but not likely, that they are stratigraphic equivalents.

Lithology: Massive, white feldspathic siltstone; flaggy interbedded pale grey argillaceous siltstone and very fine-grained chert-quartz sandstone; pelletal chert, medium-grained chert-quartz sandstone; leached dolomitic siltstone, interlaminated siltstone-claystone; chert; chert breccia; oolitic chert.

Thickness: Up to 1000 m; top eroded.

Distinguishing Features: Massive white siltstone at base and abundant pelletal chert above diagnostic. Formation crops out boldly as prominent plateau capping; produces strongly banded pattern on air-photographs.

Top of formation eroded; overlain unconformably by Lower Cretaceous rocks or Cainozoic soils. Base defined as base of lowermost, and most consistent, massive white siltstone bed. This bed readily recognised since it caps scarps at edge of Bath Range and similar ridges.

Description and comments

Lithologically the Bath Range Formation is one of the most complex units in the McArthur Group of Arnhem Land and since the rocks are poorly exposed and highly weathered our knowledge is far from complete. Generalised stratigraphic sections are shown in Figure 20, but the two thicker sections (A and D) are based on scattered observation of poorly outcropping, gently dipping strata. The estimated thicknesses are very approximate and lithological descriptions are probably far from complete.

The most characteristic rocks in the Bath Range Formation are well exposed in the reference area (Fig. 20, sections B, C) and elsewhere (sections A, D) are confined to the lower part of the section. The lower couple of hundred metres consist of distinctive massive, white feldspathic siltstone alternating with flaggy interbedded pale grey argillaceous siltstone and very fine-grained chert-quartz sandstone or siltstone. This is overlain by a sequence, about 150 metres thick, which contains characteristic pelletal chert interbedded with medium-grained chert-quartz sandstone, flaggy white siltstone, and interlaminated siltstone-claystone, and some chert and chert breccia.

In the thicker sections this sequence grades up through medium-grained chert-quartz sandstone into a few hundred metres of flaggy, laminated, fine-grained sandstone superficially similar to those at the base of the formation. The upper 300 m or so of exposed section is composed of poorly outcropping, leached and silicified dolomitic siltstone, chert, stromatolitic chert, and oolitic chert.

The top of the Bath Range Formation is eroded, so the total thickness is unknown. In the reference area only about 225 m of section is preserved. East of the Koolatong Fault, in the Walker River area, the preserved section is about 600 m thick, while in the southwest, near the Rose River, about 1000 m of section is exposed, with a probable further 1000 m or more concealed by soil cover.

Figure 20 shows the general similarity between the sections in various areas and that the thickness of the various units are comparable. It is possible however that a slight thickening occurs in the southwest.

The distinctive massive, white to pale grey, feldspathic siltstone or fine-grained sandstone near the base are diagnostic of the Bath Range Formation. The most resistant bed is that which defines the base throughout the area. It is a massive bed about 2 to 3 m thick with very little visible bedding. It crops out prominently to control scarps such as the edge of the Bath Range. The number of massive siltstone beds above this, and the upper limit in the section to which they extend, varies widely from place to place. In the higher beds cross-bedding and ripple marks have been observed.

In thin section the rocks (R13483, R13484) consist essentially of coarse silt to fine sand-sized quartz grains and abundant finer feldspar. The feldspar is mainly potassic although some plagioclase is present. A tuffaceous origin has been suggested to explain the abundance of feldspar.

The interbedded pale grey to buff flaggy siltstone and fine-grained sandstone which alternate with the massive beds are, in outcrop, similar to the underlying Baiguridji Formation. Cross-bedding and wavy bedding are common. In thin section the finer rocks (R13570) consist of argillaceous siltstone composed of about 70 to 75 percent of subangular well sorted quartz grains, 0.03 to 0.06 mm in size, set in a matrix of clay and ironstained sericite. Scattered flakes of muscovite are present and a silica cement forms overgrowths on the quartz grains.

The coarser-grained specimens (R13486, R13488) border on the sand-silt boundary in grainsize and contain very little matrix. They contain about 70 percent quartz and 30 percent ironstained chert fragments with a silica cement and quartz overgrowths. The origin of the chert grains is uncertain - they may be primary grains, but the lithology of the overlying beds suggests they are more likely to be silicified carbonate fragments. Furthermore, some of the fresh outcrops in creeks with the same bedding and textural features contain some carbonate material.

The other particularly diagnostic rock type in the Bath Range Formation is pelletal chert. The chert shows flaggy to blocky bedding partings and is interbedded with flaggy to blocky, medium to coarse, and some fine-grained, chert-quartz sandstone, flaggy, white, apparently originally dolomitic, siltstone, interlaminated siltstone and chert or claystone, and some chert breccia.

The pelletal chert (R13569, R13485, R13487, R13490, R13491) consists essentially of pellets of chert and quartz grains in a silicified silt matrix. The chert pellets are well rounded and ellipsoidal in shape. They are poorly sorted and range in size from 0.1 mm to several millimetres. The matrix consists of silt or fine sand-sized quartz grains in an abundant silica cement. The cement ranges from massive microcrystalline quartz to chalcedony; the chalcedony implies secondary crystallization of silica. Minor feldspar, glauconite, and muscovite are present; tourmaline and zircon are accessory.

The pelletal chert grades into chert-quartz sandstone which is finer-grained and better sorted. Specimen R13572 contains well sorted (0.01 to 0.6 mm) chert and lesser chert in an abundant chalcedony matrix. The sandstone is cross-bedded and ripple marked.

Comparatively fresh pelletal chert was found in only one creek exposure. In thin section (R13482) it consists of coarse-grained quartz dolarenite containing sand-sized elliptical dolomite fragments and scattered rounded quartz grains of the same size, in a matrix of subangular silt-sized quartz and abundant dolomite cement. The texture of the rock is identical to the pelletal chert and in one patch the cement is clearly being replaced by chalcedony. Many fragments are of dolomitic silt although most are pure dolomite. The regular bedding is defined by the variable proportions of quartz and dolomite and the long axes of the pellets are parallel to the bedding. The pelletal chert beds are therefore silicified quartz dolarenites.

The lower two-thirds (section A) of the exposed Bath Range Formation represents a significant interval in the depositional history of the McArthur Group marked by erosion and redeposition of the earlier deposited carbonate rocks of the group. The source of the quartz is less certain. Much of it could have been recycled from the older rocks in the group, but most of it was probably derived from outside the basin.

This period of deposition is also significant in that the thickness of sediment is substantially the same both in the Walker Trough and at least the western parts of the Caledon Shelf while all older units showed marked thinning on the shelf.

The remainder of the exposed section represents a return to conditions of normal carbonate deposition. Outcrop is poor and consists of about 330 m of laminated, leached, and silicified dolomitic siltstone and fine-grained sandstone, chert, oolitic chert, and stromatolitic chert. The chert (R13567) is composed of scattered subangular silt-sized quartz grains in an extremely fine, almost isotropic, silica matrix with fine iron oxide dust throughout. The irregular banding represents relict disrupted bedding. The presence of silt grains and iron oxide suggests that the chert is almost certainly secondary.

At the base of the upper part of the section a distinctive pink to creamy yellow siliceous siltstone bed, 3 to 6 m thick, contains small disc-shaped structures about 2 mm in diameter. The structures may be organic or may be concretionary in origin.

Blue Mud Bay beds

Definition

Distribution: Along thin strip 4 miles inland from west coast of Blue Mud Bay to north of Walker River; exposed at base of dip slope of cuesta of Groote Eylandt Beds. An isolated outcrop occurs 19 km north of Jalma Bay.

Reference Area: Exposures north of Walker River about lat. 13°25'S, long. 135°49'E.

Derivation of Name: From Blue Mud Bay on western side of Gulf of Carpentaria.

Stratigraphic Relationships: Overlies, with structural conformity, Groote Eylandt Beds; overlain, with apparent conformity, by small outcrop mapped as Yarrawirrie Formation, which is in turn overlain by Baiguridji Formation. Yarrawirrie and Baiguridji Formations are separated from Blue Mud Bay Beds by belt of no outcrop; relationships can only be inferred.

Lithology: Interbedded leached dolomitic siltstone, chert, medium-grained quartz sandstone, fine-grained sandstone, stromatolitic chert and dolomite.

Thickness: About 75 m exposed; remainder of section, probably about 200 m, concealed.

Distinguishing Features: Lithologically have nothing to distinguish them from rest of McArthur Group; defined by stratigraphic and geographic position.

Base defined by first appearance of carbonate-bearing rocks above arenites of Groote Eylandt Beds. Top covered by soil; upper limit in relation to recognisable units of McArthur Group unknown.

Description and comments

Only the basal 75 m of the Blue Mud Bay Beds are exposed. The remainder of the section below outcropping Yarrawirrie Formation, and probably totalling some 200 m, is covered by laterite and soil.

The general succession is shown in Table 18. Thicknesses of individual units cannot be estimated.

Table 18. General succession, lower part of Blue Mud Bay beds.

Thickness (m)	Soil cover
	Rubble outcrop of *leached dolomitic siltstone,* laminated; and *quartz sandstone,* blocky, cross-bedded, medium to coarse-grained.
	Stromatolitic chert and *stromatolitic dolomite.*
	Massive chert (probably silicified dolomite).
	Laminated chert, siliceous siltstone, leached siltstone; regularly bedded, uniform sequence (all previously dolomitic?).
	Grades down into:
	Interbedded *quartz sandstone,* flaggy *laminated siltstone, siliceous siltstone, chert.*
	Flaggy fine-grained *sandstone* and leached *dolomitic siltstone.*
70 total	Groote Eylandt beds

In thin section the quartz sandstone (R13494, R13496) contains about 60 to 70 percent of well sorted and well rounded quartz grains with secondary overgrowths, and occasional chert grains, in an abundant chert or chalcedony cement. The detrital grains are rarely in contact with each other, and the chert was probably formed by replacement of the original carbonate matrix.

In the field, the siltstone and chert in the remainder of the section appear to represent altered dolomitic siltstone, and possibly dolomite.

The stratigraphic relationships of the Blue Mud Beds and their overall lithology suggest that they are stratigraphically equivalent to all or part of the McArthur Group below the upper Yarrawirrie Formation. The lithological heterogeneity of the formation makes it impossible to relate it to any one unit in the McArthur Group so it can only be concluded that it is a very much thinner equivalent of the greater part of the McArthur Group (i.e. below the upper Yarrawirrie Formation) deposited on the stable Caledon Shelf.

Geologists of BHP Co Pty Ltd, as a result of work in the area since our mapping, consider it likely that the Blue Mud Bay Beds may unconformably overlie the McArthur Group and Groote Eylandt Beds (W C Smith, pers. comm.). Evidence at this stage is inconclusive, however, because of the poor nature of the outcrop.

DISCUSSION

The McArthur Group succession in Arnhem Land may be broadly compared with the type area to the south, although precise correlations, unit by unit , are not possible; hence the need for a different nomenclature. The poorly exposed Koolatong Siltstone, grading from red and green siltstone with cauliflower chert at the base into buff stromatolitic dolomites higher up, may be compared with the Umbolooga Subgroup at McArthur River. The Koolatong Siltstone does appear to have a much higher component of siltstone, but this is difficult to assess properly with such poor outcrop. In this comparison the overlying Strawbridge Breccia is correlated directly with an extensive silicified dolomite unit which characterises the Emmerugga Dolomite at McArthur River. A peritidal to continental carbonate and sabkha facies deposited on a broad marginal-marine shelf, similar to that interpreted for the Umbolooga Subgroup (Jackson et al., 1987), is inferred. The evaporites which have only relatively recently been identified from the McArthur River area have not been noted from Arnhem Land, except for halite casts, but may be reasonably inferred, from the general nature of the sequence, to be present.

The black shales of the Vaughton Siltstone have been directly correlated with the Barney Creek Formation, and the stromatolitic chert of the Conway Formation suggested as a silicified equivalent of the Reward Dolomite. The Barney Creek Formation was deposited in restricted lakes or lagoons, and is host to the *McArthur* lead-zinc-silver deposits. Black shale is consistent with this interpretation, whilst the shard-like fragments described support the presence of tuff, as in the Barney Creek Formation as well.

The sequence of Zamia Creek Siltstone, Yarrawirrie Formation, Baiguridji Formation, and Bath Range Formation shows a strong parallel with the Caranbirini Member, Hot Spring Member, Yalco Formation-Stretton Sandstone, and Looking Glass Formation of the Batten Subgroup at McArthur River, and contains many almost identical rock types. The Batten Subgroup has been interpreted as a regressive alkaline lake complex, containing abundant felsic tuffs (Plumb, 1986a, b, 1989), and the preliminary knowledge of these equivalent units in Arnhem Land is consistent with such a model at this stage. The K-rich felsic 'siltstones' at the base of the Bath Range Formation indicates the presence of abundant feldspar. The fabric of most siltstones resembles that of the tuffs and tuffaceous siltstones at McArthur: matrix supported silt-sized grains in a cherty (felsic?) matrix. The local conglomerates at the base of the Yarrawirrie Formation, along the Koolatong Fault, indicate local movements at the rift margins of the lake complex, and may correlate with local unconformity at the base of the Batten Subgroup in the south. Local conglomerate in the Baiguridji Formation of the same area further reflect rifting.

In view of the redefinition of the McArthur and Nathan Groups in the south (Jackson *et al.,* 1987), subsequent to the original mapping of Arnhem Land, the identification of the top of the McArthur Group is problematic. The Nathan Group, and the unconformity at its base had not been identified in 1962. The silicified dolarenite-rich lower Bath Range Formation is very similar to the Looking Glass Formation, at the top of the type Batten Subgroup, but the Bath Range Formation as mapped is very much thicker (by an order of magnitude). The stromatolitic and oolitic cherts described from the poorly exposed upper Bath Range Formation are characteristic of the Nathan Group in the south, rather than Looking Glass Formation, and so it has been suggested that the Nathan Group is probably represented within the upper Bath Range Formation, although the unconformity or boundary cannot be identified from the available data (Plumb et al., 1990).

HABGOOD GROUP

Definition

Distribution: Crops out in north-central part of Arnhem Bay Cove Sheet area; exposures cover total of about 235 km^2 within north-northeasterly trending belt, up to 19 km^2 wide, which extends from Flinders Peninsula in the north, to beyond Lake Evella in the south, a distance of about 48 km.

Reference Area: Fairly complete section in vicinity of line from lat. 12°20'S, long. 135°50'E, to lat. 12°27'S, long. 135°53'E, north-central part of Arnhem Bay/Gove Sheet area is here designated as reference area.

Derivation of Name: From Habgood River which flows into southwestern part of Arnhem Bay, Arnhem Bay/Gove Sheet area.

Stratigraphic Relationships: Base not exposed; lithology of upper two-thirds of exposed group is similar to McArthur Group; considered to be, in part, equivalent to McArthur Group; no direct correlation of formations possible. Top of group not exposed; group is probably older than Malay Road Group, and overlain (perhaps unconformably) by it. Habgood Group overlain with angular unconformity by Buckingham Bay Sandstone, the basal unit of Wessel Group.

Components: Consists of six conformable formations (in descending order): Gwakura Formation, Ulunourwi Formation, Darwarunga Sandstone, Yarawoi Formation, Slippery Creek Siltstone, Kurala Sandstone.

Lithology: Quartz sandstone, dolomitic siltstone, dolomite, dolomitic sandstone, micaceous shaly sandstone, cherty siltstone and sandstone, stromatolitic chert, pyritic sandstone, claystone, siltstone, conglomerate.

Thickness: About 3.8 km exposed.

Age: Statherian (Palaeoproterozoic).

Description and comments

The Habgood Group has been folded about north-northeast axes into anticlines and synclines with limbs dipping from 20° to 60° or more; faulting, parallel to the fold axes, has caused strong vertical displacement in some areas.

The stratigraphy of the group is summarised in Table 19. The lithology is discussed under the various formation headings.

Kurala Sandstone

Definition

Distribution: Inliers in Buckingham Bay Sandstone west and southwest of Kurala River in north-central part of Arnhem Bay/Gove Sheet area; total area about 13 km^2.

Reference Area: In vicinity of lat. 12°22'S, long. 135°50'E; north-central part of Arnhem Bay/Gove Sheet area.

Derivation of Name: From Kurala River, which flows into south-eastern part of Buckingham Bay.

Stratigraphic Relationships: Lowermost unit of Habgood Group. Base not exposed; conformably overlain by Slippery Creek Siltstone. Distribution of unconformably overlying Buckingham Bay Sandstone and nature of contact between them suggests arenites comprising Kurala Sandstone may be underlain by less resistant strata.

Lithology: Quartz sandstone; minor green, slightly micaceous quartz sandstone.

Thickness: Maximum exposed, 330 m.

Distinguishing Features: More resistant to erosion than overlying Slippery Creek Siltstone; boundary placed at change from arenite to lutite.

Description and comments

The formation consists of white, medium-grained, cross-bedded, ripple-marked, massive to blocky, thick to thin-bedded quartz sandstone with a 6 m bed of green, fine to medium-grained, flaggy, silicified, slightly micaceous quartz sandstone at the top.

The maximum exposed thickness of 330 m may be close to the total thickness of the Kurala Formation, as the unconformably overlying Buckingham Bay Sandstone appears to be thicker immediately to the west of the Kurala Sandstone exposures, possibly because it was deposited on less resistant rocks.

Table 19. Summary of stratigraphy, Habgood Group.

ROCK UNIT	THICKNESS (m)	LITHOLOGY	TOPOGRAPHY	DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	REMARKS
Gwakura Formation	~ 600	Dolomitic-quartz sandstone, cherty or dolomitic siltstone, oligomictic conglomerate	Moderately resistant - base forms hogsbacks; upper beds low rises	East side of Flinders Peninsula; Probable & Gwakura Is.; Arnhem Bay Sheet	Conformably overlies Ulunourwi Fm. Inferred to be unconformably overlain by Wessel & Malay Rd Gps	Upper unit of Habgood Gp; top not exposed. Section incompletely exposed
Ulunourwi Formation	~ 1000	Dolomitic siltstone; cherty silstone & sandstone; silty dolomite; claystone, siltstone & sandstone. Minor stromatolitic chert	Poorly resistant; mainly low soil-covered rises		Conformably overlies Darwarunga Sst.	Section incompletely exposed. Directly overlain, unconformably, by Buckingham Bay Sst. on Probable Is.
Darwarunga Sandstone	~ 300	Quartz sandstone. Minor chery quartz sandstone	Strongly resistant; prominent strike ridges	East side of Flinders Peninsula, Arnhem Bay Sheet	Conformably overlies Yarawoi Fm.	
Yarawoi Formation	~ 975	Dolomitic siltstone & fine-grained sandstone; dolomite. Minor quartz sandstone, stromatolitic chert, interlaminated siltstone & chert	Poorly resistant; low rises. Occasional good outcrop of quartz sandstone or chert		Conformably overlies Slippery Ck Slst.	Section incompletely exposed
Slippery Creek Siltstone	~ 600	Micaceous shaly siltstone; fine-grained quartz sandstone and pyritic quartz sandstone. Minor coarse-grained quartz sandstone	Moderately resistant; rounded steep-sided hills; local relief up to 120m	Central Flinders Peninsula, Arnhem Bay Sheet	Conformably overlies Kurala Sst	Directly overlain by Buckingham Bay Sst.
Kurala Sandstone	330 exposed	Quartz sandstone; minor micaceous quartz sandstone	Strongly resistant, but topography subdued by unconformably overlying Buckingham Bay Sst.		Lowest exposed unit of Habgood Gp; base not exposed	

The quartz sandstone (R12625) forming the bulk of the formation consists dominantly of quartz with minor rock fragments; the original rounded to well rounded grains have been cemented by overgrowths of optically continuous quartz - strain shadows extend into the overgrowths. Argillaceous material and/or sericite occur in intergranular spaces. Feldspar and chert fragments are very minor constituents and opaque minerals, zircon, and tourmaline are accessory.

The micaceous quartz sandstone in the uppermost 60 m of the formation consists of irregular alternating layers of fine to medium-grained quartz and argillaceous silty bands. The quartzitic layers are only moderately sorted, and have been cemented by overgrowths of quartz, and in part, by recrystallisation; the layers contain scattered feldspar grains partly replaced by sericite, and interstitial argillaceous material. The sericite-rich bands are discontinuous; the quartz tends to be finer in grain and the sericite and clay occur in irregularly shaped pods. Rock fragments and secondary muscovite are scattered sporadically throughout the rock; the former are mainly volcanic or chert fragments. Tourmaline and zircon are accessory. The bed represents a transition between the Kurala Sandstone and the conformably overlying Slippery Creek Siltstone.

Slippery Creek Siltstone

Definition

Distribution: Crops out over area of about 65 km^2 in north-central part of Arnhem Bay/Gove Sheet area; exposures occur mainly along the Kurala River.

Reference Area: In vicinity of latitude 12°21'S, longitude 135°51'E, north-central part of Arnhem Bay/Gove Sheet area.

Derivation of Name: From Slippery Creek, which flows into Ulunourwi Bay, north-central part of Arnhem Bay/Gove Sheet area. Informally named Slippery's Creek Formation by Crohn (1954).

Stratigraphic Relationships: Conformably overlies Kurala Sandstone and conformably overlain by Yarawoi Formation; in places unconformably overlain by Buckingham Bay Sandstone.

Lithology: Purple and green, slightly micaceous, shaly siltstone; fine-grained quartz sandstone; grey, fine-grained, silicified pyritic quartz sandstone; minor coarse-grained quartz sandstone.

Thickness: Probably about 600 m; incompletely exposed.

Distinguishing Features: Less resistant to erosion than underlying Kurala Sandstone; forms steep-sided, but rounded hills with local relief up to 120 m. Base taken at change from arenite to lutite. Boundary with overlying Yarawoi Formation marked by appearance of dolomitic strata.

Description and comments

No complete section of the Siltstone is exposed, but the formation is probably about 600 m thick. The lowermost 390 m consists of finely laminated, purple and green, thinly flaggy and fissile, slightly micaceous shaly siltstone, with thin interbeds of purple, or brown-white, laminated, slightly micaceous, very fine-grained sandstone. Rare 50 cm interbeds of coarse-grained, poorly sorted, quartz sandstone, with an iron oxide matrix, occur in the middle of this succession; the grains are subrounded to angular. Microcross-beds and cone-in-cone structures occur in the very fine-grained sandstone interbeds near the top of the succession.

Finely laminated shaly siltstone predominates in the lower 390 m of the formation: three specimens have been examined in thin section. The laminations in the first (R12612) are due to the alternation of bands composed of sericite, clay, and minor quartz with bands consisting of quartz silt and minor fine sericite; the former bands are thicker and in these, the sericite has developed an incipient foliation at an angle of 45o to the bedding. In the latter bands the sericite, where in juxtaposition with the quartz, has sutured together with it. In the second thin section (R12627) the thicker bands, which comprise the bulk of the rock consist of clay, sericite, and quartz silt and alternate with thin bands of clay, sericite, and iron oxide. The sericite is foliated parallel to the bedding. In the third thin section (R12613) angular to subangular quartz silt and sand grains are scattered randomly through a matrix of sericite and clay. Thin clotted stringers of iron oxide give the rock a banded appearance and impart a reddish purple colour to the rock.

In all three sections minor secondary muscovite has developed parallel to the bedding; biotite, tourmaline, and zircon occur as accessories.

Overlying the shaly siltstone is a 90 m bed of grey, blocky, pyritic, fine-grained silicified quartz sandstone, interbedded with buff, fine-grained, finely banded, silicified quartz sandstone, and purple shaly siltstone. The blocky quartz sandstone (R12614) consists dominantly of a mosaic of fine subangular, sutured quartz grains; strain extinction is common and most of the grains contain minute inclusions. Plagioclase, potash feldspar, and cherty fragments are present in minor amounts, as are carbonate and muscovite. Opaque minerals are interstitial except for rare large euhedral grains of sulphide, partly replaced by iron oxide. Accessories are tourmaline and less abundant zircon.

The topmost 120 m of the Slippery Creek Siltstone consists of fine-grained, finely banded quartz sandstone similar to the interbeds in the section below. The rock (R12617) consists mainly of quartz with minor amounts of feldspar and cherty fragments; the banding is produced by interstitial iron oxide. Zircon and tourmaline are accessory, and small flakes of muscovite are scattered throughout the rock.

Yarawoi Formation

Definition

Distribution: In south-plunging anticline in headwaters of Darwarunga River, and small area 3 km east of mouth of Kurala River in north-central part of Arnhem Bay/Gove Sheet area; exposures cover area of about 13 km^2.

Reference Area: In vicinity of latitude 12°24'S; longitude 135°51'E; north-central part of Arnhem Bay/Gove Sheet area.

Derivation of Name: From Yarawoi district, an Aboriginal tribal area, south of Ulunourwi Bay, Arnhem Bay/Gove Sheet area.

Stratigraphic Relationships: Conformably overlies Slippery Creek Siltstone and conformably overlain by Darwarunga Sandstone.

Lithology: Flaggy dolomitic siltstone, fine-grained dolomitic sandstone, massive dolomite. Minor quartz sandstone, stromatolitic chert, interbanded siltstone and chert.

Thickness: About 975 m.

Distinguishing Features: Less resistant to erosion than overlying Darwarunga Sandstone; top taken at contact between carbonate rocks and overlying quartz sandstone. Base contains dolomitic strata, in contrast to uppermost beds of Slippery Creek Siltstone.

Description and comments

The stratigraphic succession is as shown in Table 20. In thin section the dolomitic siltstone and dolomitic sandstone (R12616, R12615), in the uppermost 345 m of the formation are composed essentially of subangular to subrounded grains of quartz set in a dolomite matrix; in some bands quartz predominates, but in others carbonate is more abundant. Rare grains of feldspar and muscovite and patches of chlorite occur in the dolomitic siltstone and tourmaline is present as an accessory.

Chemical analyses (K Sullivan, AMDEL) of the carbonate fraction of the two samples gave the following results:

	$CaCO_3$ (%)	**$MgCO_3$** (%)	**Ratio**
Siltstone (R12615)	8.2	8.9	0.921
Sandstone (R12616)	18.0	15.9	1.132

In the siltstone the carbonate fraction has the composition of a magnesian dolomite; in the sandstone it has a composition approaching that of a pure dolomite (ideal ratio 1.188).

Table 20. Stratigraphic section, Yarawoi Formation.

Thickness (m)	Conformably overlain by Darwarunga Sandstone.
345	*Dolomite,* purple and grey, blocky and massive, interbedded with flaggy *dolomitic siltstone* and *sandstone,* fine-grained.
105	*Quartz sandstone,* cross-bedded, blocky, medium-grained; quartz veins common.
45	Interbedded ferruginous *stromatolitic chert* and finely banded *siltstone* and *chert.*
420	Not exposed (probably fine-grained dolomite-lutite sequence).
60	Interbedded sequence of *dolomitic shale* and *siltstone,* leached, light buff, with nodules and lenses of *chert,* dark, banded; *clay,* grey, containing travertine nodules; and *dolomitic sandstone,* leached, blocky, buff, calcite stringers.
975 total	Conformably underlain by Slippery Creek Siltstone.

Darwarunga Sandstone

Definition

Distribution: Crops out over about 31 km^2 in north-central part of Arnhem Bay/Gove Sheet area. Exposed on east side of Flinders Peninsula and in ridges trending south-southwest; also in an anticline in headwaters of Darwarunga River.

Reference Area: In vicinity of lat. 12°24'S; long.135°51'E; north-central part of the Arnhem Bay/Gove Sheet area.

Derivation of Name: From Darwarunga River, which flows into Ramungir Bay, a small bay in southwestern part of Arnhem Bay, north-central part of Arnhem Bay/Gove Sheet area.

Stratigraphic Relationships: Conformably overlies Yarawoi Formation and conformably overlain by Ulunourwi Formation.

Lithology: Blocky, medium-grained quartz sandstone; minor cherty quartz sandstone.

Thickness: Usually about 300 m.

Distinguishing Features: More resistant to erosion than underlying and overlying units. Base distinguished by appearance of quartz arenites resting on carbonate rocks of Yarawoi Formation; top marked by change from quartz sandstone to lutite.

Description and comments

The sequence is as shown in Table 21.

Table 21. Stratigraphic succession, Darwarunga Sandstone.

Thickness (m)	Conformably overlain by Ulunourwi Formation.

75	*Quartz sandstone*, white to brown, blocky, medium-bedded, medium to coarse-grained, cavernous, cross-bedded, ripple-marked.
90	*Quartz sandstone*, white, blocky, thin-bedded, medium-grained, ripple-marked; becomes finer in grain towards top.
30	*Cherty quartz sandstone,* white to yellow, massive, fine-grained, silicified.
105	*Quartz sandstone*, white, blocky, medium to thin-bedded, medium-grained, current and oscillation ripple marked, cross-bedded.
300 total	Conformably underlain by Yarawoi Formation.

The basal bed and the 90 m bed higher in the succession are very similar in lithology. In thin section the beds (R12629) consist chiefly of moderately well sorted grains of sutured rounded to subrounded quartz sand with some quartz overgrowths. Most of the grains contain numerous minute inclusions and show slight strain extinction. Rare feldspar and cherty rock fragments occur; zircon and tourmaline are accessory.

The cherty quartz sandstone (30 m thick) (R12628) overlying the basal bed consists of alternating bands of microcrystalline or very fine-grained quartz and slightly coarser quartz. The bands of coarser quartz commonly contain large grains with overgrowths embedded in them. There has probably been some brecciation and re-cementation by secondary quartz which has filled fractures. The primary quartz contains numerous inclusions while the secondary quartz is free of inclusions.

Ulunourwi Formation

Definition

Distribution: Main exposures along east coast of Flinders Peninsula and on Probable Island in Arnhem Bay/Gove Sheet area; scattered outcrops to south; total area of exposure, about 50 km^2.

Reference Area: In vicinity of lat. 12°10'S; long. 135°57'30"E; north-central part of the Arnhem Bay/Gove Sheet area.

Derivation of Name: From Ulunourwi Bay, north-central part of Arnhem Bay/Gove Sheet area.

Stratigraphic Relationship: Conformably overlies Darwarunga Sandstone and conformably overlain by Gwakura Formation.

Lithology: Dolomitic siltstone, commonly leached; cherty siltstone and sandstone; silty dolomite; claystone, siltstone and sandstone. Minor stromatolitic chert.

Thickness: About 1020 m.

Distinguishing Features: Less resistant to erosion than underlying Darwarunga Sandstone and overlying Gwakura Formation. Base marked by appearance of lutite; top taken at base of distinctive resistant bed of quartz-chert sandstone.

Description and comments

The formation is generally poorly exposed in low rises; much of the middle part of the formation is obscured by soil. The succession is as shown in Table 22.

Table 22. Stratigraphic succession, Ulunourwi Formation.

Thickness (m)	Conformably overlain by Gwakura Formation.
180	*Siltstone,* thinly flaggy to flaggy, yellow, orange and red; occasional chert nodules; interbedded with *cherty siltstone; leached dolomitioc siltstone,* yellow; and minor *cherty sandstone,* laminated, very fine-grained.
480	Not exposed (probably fine-grained carbonate-lutite succession).
195	*Leached siltstone,* purple, massive; interbedded with *dolomitic siltstone,* purple to grey-green, laminated to thin-bedded, flaggy to thinly flaggy; and *silty dolomite,* flaggy, purple.
165	*Claystone, siltstoe,* and fine *sandy claystone,* purple, yellow, and red-brown, massive to thinly flaggy; minor interbeds of *sandstone* and *silty sandstone,* fine to medium-grained, ripple marked; occasional thin interbeds of brown *stromatolitic (?) chert.*
1020 total	Conformably underlain by Darwarunga Sandstone.

The rocks comprising the lowermost 165 m of the formation are invariably deeply leached in outcrop but bedding is still recognisable in the finer-grained rocks. Many of the rocks may have originally contained carbonates. Claystone is possibly the most abundant rock type. In thin section (R12642) it consists of alternating bands of limonite-stained kaolin (identified by X-ray diffraction) and quartz laminae. The quartz is from silt to fine sand grade and most of the laminae are free from iron but contain argillaceous material in the pore spaces. The kaolin bands contain scattered grains of very fine quartz, and considerable amounts of clay grade quartz (less than 2 microns) are aligned roughly parallel to the bedding.

The overlying 195 m of strata consists of alternating siltstone and dolomitic siltstone, and subordinate silty dolomite. Even with as little as 25 percent carbonate the dolomitic siltstone has the same weathered appearance as the pure carbonate rocks. In thin section the dolomitic siltstone (R12630, R12641, R12642) consists of varying proportions of subangular to rounded quartz grains of silt size, and occasionally fine or medium sand size, and carbonate. The quartz is distributed either in distinct laminae or randomly throughout the rock. Argillaceous material occurs as clots in the carbonate. Biotite and muscovite are rare; opaque minerals and tourmaline are accessory. At weathered surfaces the carbonate has been leached from the rock and the quartz grains are embedded in clay. This suggests that the claystone present in the basal part of the Ulunourwi Formation may have been formed by leaching of dolomitic rocks.

In places green nodules, up to 2.5 cm across, are present in the dolomitic siltstone. They consist (R12641) of medium to coarse-grained marble composed chiefly of dolomite. The chlorite rims around the nodules are possibly of hydrothermal origin. Clusters of euhedral crystals of barite occur in the marble.

Chemical analyses of the carbonate nodules from two specimens of dolomitic siltstone have been made by K Sullivan (AMDEL):

	$CaCO_3$ (%)	$MgCO_3$ (%)	Ratio
R12630	22.1	16.1	1.373
R12640	12.0	13.6	0.883

The carbonate in the first has the composition of the calcitic dolomite, in the second of magnesian dolomite.

The overlying part of the succession, estimated to be 480 m thick, is not exposed, probably due to the presence of poorly resistant rocks. The topmost beads, 180 m thick, are exposed only on Probable Island.

Gwakura Formation

Definition

Distribution: Main exposures on Probable Island, Gwakura Islands, and in strike ridge trending south-southeast to Darwarunga River, in Arnhem Bay/Gove Sheet area; scattered exposures south of Darwarunga River; total area exposed about 80 km^2.

Reference Area: Southeast coast of Ulunourwi Bay, north-central part of Arnhem Bay/Gove Sheet area.

Derivation of Name: From the Gwakura Islands which are situated between Arnhem Bay and Ulunourwi Bay.

Stratigraphic Relationships: Uppermost exposed unit of Habgood Group; top not exposed; conformably overlies Ulunourwi Formation. Older than Buckingham Bay Sandstone, which, on Probable Island, unconformably overlies Ulunourwi Formation. Probably unconformable below Malay Road Group.

Lithology: Fine-grained leached dolomitic quartz sandstone, cherty siltstone, leached dolomitic siltstone, oligomictic conglomerate.

Thickness: About 600 m exposed.

Distinguishing Features: Base marked by distinctive resistant bed of sandstone composed mainly of quartz and chert grains; top not exposed.

Description and comments

Table 23. Stratigraphic succession, Gwakura Formation.

Thickness (m)	Top not exposed
570	*Leached dolomitic siltstone*, buff to white, laminated, flaggy to very fine-grained; interbedded with *cherty siltstone*, yellow and buff, blocky and flaggy, yelow, porous.
15	*Pebble to cobble conglomerate* composed of subrounded pebbles and cobbles of chert (90%) and fine to medium-grained quartz sandstone (10%) set in cherty sandstone matrix.
15	*Leached dolomitic(?) quartz sandstone*, grey, coarse to fine-grained, cross-bedded, massive to blocky, well laminated.
600 total	Conformably underlain by Ulunourwi Formation.

The stratigraphic succession is given in Table 23. The basal sandstone (R12611) is composed of alternating laminae of fine and coarse-grained subrounded to rounded quartz sand. The coarser-grained laminae are thin and made up of relatively few grains. Orthoclase, microcline, plagioclase and rock fragments are present, mainly in the finer-grained bands. The grains are cemented by overgrowths of quartz. Zircon and tourmaline are accessories.

The leached dolomitic siltstone (R12610, R12543) in the uppermost 570 m of the section consists of alternating bands of silt and clay, and silt. The silt bands are composed of moderately sorted silt to fine sand grade, angular to subangular grains of quartz, cherty rock fragments, minor feldspar and accessory zircon, tourmaline, and opaque minerals. The clay-rich bands contain minor amounts of sub-angular quartz.

The leached dolomitic quartz sandstone (R12619) is composed of fine to very fine quartz sand and occasional grains of feldspar, cemented by interstitial recrystallisation or by overgrowths of quartz. Secondary muscovite is present; zircon, tourmaline, and opaque minerals are accessory. In outcrop the rocks appear to have been leached of carbonate. In some beds (R12618) fragments of chert and chalcedony, and clay pellets are abundant.

DISCUSSION

The Habgood Group is poorly known. The rock types and general succession resemble that of the McArthur Group, but there appears to be sufficient facies change that the same nomenclature cannot be applied, nor direct one-for-one correlation made. The Kurala Sandstone resembles the Fleming Sandstone at the top of the Parsons Range Group. The Slippery Creek Siltstone is immediately comparable with the Koolatong Siltstone. The Darwarunga Sandstone may correlate with local sandstone-conglomerate lenses at the base of the Yarrawirrie Formation. Upper units of the group resemble the upper units to the south, Yarrawirrie - Bath Range Formations. Similar palaeoenvironments may be inferred: peritidal to continental carbonate and sabkha facies, probably passing up into lacustrine conditions with abundant tuff.

STATHERIAN OR CALYMMIAN

MOUNT RIGG GROUP

Introduction

Previous Investigations: Rocks of the Mount Rigg Group in the Beswick homestead district were first reconnoitred during 1951-52 by Walpole (Walpole, 1958). He recognised the unconformity at the base of the group and regarded the rocks as part of the Middle Cambrian Daly River Group.

At about this time rocks now known to belong to the group in the Bulman district were described in unpublished reports by various company geologists (King, 1952, Sturmfels, 1952; Knight, 1952; Patterson, 1954; 1958; Crohn, 1954; Campbell, 1956) and by Opik and Walpole (Opik, 1952). They assigned the rocks to the Upper Proterozoic and did not realise the correlation with the rocks at Beswick; it was not until the 1962 survey that the link between the sequences was established. Opik (1952) first described the unconformity at the top of the group; this unconformity has since been recognised at widely separated localities, as far south as latitude 17°S.

Ruker (1959) systematically mapped the Beswick-Waterhouse River district and established that the succession was not part of the Daly River Group but was, in fact, part of the Precambrian; he referred it to the Upper Proterozoic.

Development of Nomenclature: The rocks of the Mount Rigg Group exposed in the Waterhouse River area were regarded by Walpole (1958) as part of the Daly River Group, which elsewhere contains Middle Cambrian fossils. Walpole recognised and applied tentative names to three rock units within the Waterhouse River succession . In describing the succession Walpole wrote; 'the basal unit is composed of coarse clastic sediments - boulder bed conglomerate and quartz sandstone ..... this is overlain by a limestone (Tipperary Limestone), and by a third formation consisting of interbedded flaggy and ferruginous sandstone with lenses of shale (Beswick Creek Formation). Basaltic flows are intercalated with the arenaceous members of the third unit'.

Subsequent mapping by Ruker (1959) established that the succession was not part of the Daly River Group and was, in fact, part of the Precambrian sequence. Ruker informally revised Walpole's nomenclature. He recognised an additional rock unit (Bore Creek Formation) within the succession which he referred to as the Beswick Group.

Randal (1963) revised Ruker's terminology and had it approved by the Stratigraphic Nomenclature Committee; the units are formally defined by Walpole et al (1968).

Walpole *et al.* (1968) regard the rocks belonging to Ruker's Beswick Creek Formation as possibly being partly equivalent to the Roper Group and partly to the Antrim Plateau Volcanics. They doubt the validity of the unit; we agree with this view.

Only two of the four formations in the Mount Rigg Group have been mapped in Arnhem Land. The Margaret Hill Conglomerate is a local deposit and the problem of the Beswick Creek Formation has been discussed; equivalent beds have not been recognised outside the Beswick Basin. For completeness the definitions of Walpole *et al.,* (1968) are repeated.

Definition

Distribution: Mount Rigg Group exposed in zone trending northeast from near Beswick homestead in Katherine Sheet area through northwestern corner of Urapunga Sheet into Mount Marumba Sheet area. In places rocks are well exposed, but elsewhere largely obscured by Mesozoic and younger deposits. In Wilton River district zone of exposure is up to 50 km wide. Total area of exposure about 4500 km^2.

Reference Area: Beswick homestead - Waterhouse River district. No reference section nominated.

Derivation of Name: See introduction.

Stratigraphic Relationships: Unconformably overlies Katherine River Group. Unconformably overlain by Roper Group. Both unconformities of regional extent; neither noticeably angular - result of transgression of younger strata over slightly disturbed and eroded older strata.

Components: Divided into four formations (in ascending order): Margaret Hill Conglomerate, Bone Creek Formation, Dook Creek Formation, Beswick Creek Formation. Only Bone Creek and Dook Creek Formations crop out in Arnhem Land.

Lithology: Siltstone, dolomitic and cherty; chert, sometimes oolitic; quartz sandstone; dolomite, stromatolitic, oolitic, silty or sandy; chert and dolomite breccia; glauconitic sandstone; conglomerate; quartz greywacke.

Thickness: Up to 400 m, top eroded, in reference area. About 700 m, top eroded, Wilton River district.

Age: Statherian or Calymmian? (Palaeoproterozoic or Mesoproterozoic?).

Table 24. Summary of stratigraphy, Mount Rigg Group

ROCK UNIT	THICKNESS (m)	LITHOLOGY	TOPOGRAPHY	DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	REMARKS
Dook Creek Formation	294 (ref. area) - 530 Arnhem Land	Dolomitic or cherty siltstone, dolomite (stromatolitic), chert (oolitic), quartz sandstone, dolomitic sandstone, chert or dolomitie breccia, siltstone	Moderately resistant - undulating hills	Central Mt Marumba Sheet - extending into Urapunga & Katherine	Conformably overlies Bone Ck Fm. Unconformably overlain by Roper Gp	Stromatolites common. Stratigraphic equivalent of Balbirini Dol. (McArthur area)
Bone Creek Formation	50 (ref. area) - 170 Arnhem Land	Quartz sandstone, conglomerate, glauconitic sandstone	Resistant - cuestas	Western Mt Marumba Sheet - extending into Urapunga & Katherine	Unconformably overlies Katherine R. Gp.	Lowest formation of Mt Rigg Gp in Arnhem Land. Stratigraphic equivalent of Smythe Cgl. Mbr (McArthur area)

Description and comments

Lithologies discussed under the various formations. The stratigraphy is summarised in Table 24.

Bone Creek Formation

Definition

Distribution: Crops out in northeastern part of Katherine Sheet area, northwestern part of Urapunga Sheet area, and extensively in a northeasterly trending zone from southwestern corner of Mount Marumba Sheet area to headwaters of Blyth River in central-northern part of Sheet area.

Reference Area: Reference section: 1.6 km west of Bone Creek lat. 14°25'S; long. 132°58'E.

Derivation of Name: From Bone Creek

Stratigraphic Relationships: In Katherine Sheet area unconformably overlies Katherine River Group and overlies, possibly disconformably, Margaret Hill Conglomerate (Ruker, 1959); in Mount Marumba Sheet area, rests unconformably on Gundi Greywacke, West Branch Volcanics, and McCaw Formation; conformably overlain by Dook Creek Formation.

Lithology: Quartz sandstone, conglomerate, glauconitic sandstone.

Thickness: About 50 m, Beswick homestead area; up to 170 m Arnhem Land.

Description and comments

In the Beswick homestead district, a conglomerate is locally present at the base of the Bone Creek Formation (Ruker, 1959), but elsewhere in the Urapunga and Mount Marumba Sheet areas the base of the formation is generally arenaceous. In the former area the conglomerate is up to 12 m thick and contains in decreasing order of abundance, well rounded boulders and cobbles of white quartz sandstone, rhyolite, green quartzite, and amygdaloidal basalt. The matrix is grey, coarse-grained, poorly sorted quartz sandstone.

The conglomerate is overlain by a much more extensive arenaceous succession consisting predominantly of white, pink or buff, flaggy to blocky, thick-bedded, and less commonly thin-bedded, quartz sandstone. It is about 50 m thick in the Beswick homestead area, but is up to 150 m thick in the upper reaches of Maiwok Creek. It maintains this general order of thickness to the northeast; in Bulman Gorge the formation is about 170 m thick; it is pebbly near the base and contains, towards the top, interbeds of flaggy, ripple-marked, fine-grained glauconitic sandstone. Shaly partings are common in this part of the section. The glauconitic strata may be the fine-grained equivalents of the base of the Dook Creek Formation in the Beswick district, where, according to Ruker (1959), shaly sandstone and glauconitic(?) shaly greywacke are present. In the Bulman Gorge area ripple marks suggest that currents were predominantly from the north and northwest.

The quartz sandstone (R12041) forming the bulk of the formation consists of quartz (95%); quartzite, plagioclase, and microcline (4%); and zircon, tourmaline, muscovite, and glauconite (1%). The quartz grains are cemented by overgrowths of optically continuous quartz.

The glauconitic sandstone (R12040) consists predominantly of quartz, cemented by optically continuous overgrowths, but contains up to 15 percent glauconite in some bands. Some of the glauconite grains have been altered to reddish brown iron oxide. Interstitial aggregates of red-brown opaque minerals are present. The original boundaries of many of the quartz grains are defined by lines of included opaque minerals, apatite and unidentified colourless grains. Accessory minerals are tourmaline and zircon (of similar size to the quartz grains) and apatite.

Dook Creek Formation

Definition

Distribution: Crops out in Mount Marumba, Urapunga, and Katherine Sheet areas; main exposures in central part of Mount Marumba Sheet area, along Wilton River; small exposures occur in Flying Fox Creek district (in northwestern part of Urapunga Sheet area) and around Beswick homestead, in Katherine Sheet area.

Reference Area: Between Waterhouse River and West Branch, lat. 14°27'S, long.133°07'E (Walpole et al. 1968).

Derivation of Name: From Dook Creek.

Stratigraphic Relationships: Rests conformably on Bone Creek Formation; in Beswick homestead district overlain with apparent conformity by 'Beswick Creek Formation', but elsewhere unconformably by Limmen Sandstone (basal unit of Roper Group).

Lithology: Dolomitic siltstone; leached dolomitic siltstone; cherty siltstone; chert; oolitic chert; quartz sandstone; stromatolitic dolomite; dolomite; oolitic dolomite; silty and sandy dolomite; dolomitic sandstone; chert breccia; dolomite breccia; siltstone.

Thickness: 294 m, Beswick homestead district. About 530 m in Wilton River district.

Description and comments

The Dook Creek Formation contains a great variety of rock types, most of which have a carbonate component. Leached dolomitic siltstone or cherty (silicified) dolomitic siltstone make up a large part of the formation, but dolomite, silty dolomite, and other carbonate-bearing strata are abundant in the sequence. The top of the formation has been eroded; the maximum thickness (about 530 m) is found in the Wilton River area, but here, as elsewhere, the top has been eroded.

Wilton River Area : In the Wilton River area the Dook Creek Formation is exposed in a northeasterly trending belt up to 40 km wide, in which the strata are subhorizontal or have a slight regional dip to the southeast. To the northeast and southwest of the Wilton River the beds are obscured by younger rocks and soil; to the north sinkholes and claypans occur in soils covering the formation.

Table 25. Generalised stratigraphic sequence, Dook Creek Formation, Wilton River district.

Thickness (m)	
30	*Dolomite*, silicified, blocky; *leached dolomitic siltstone*, porous, flaggy, cream and pink; *sandstone* (R11961), fine-grained; *oolitic chert*.
20	*Feldspathic sandstone*, flaggy to blocky, fine to medium-grained, slightly dolomitic; *dolomitic siltstone* and *dolomitic shale* (25%), fissile and flaggy.
45	Interbedded sequence of: *Silty dolomite* (R11977, 11998), laminated and flaggy, blue-grey to buff (20%); *Dolomitic sandstone* and *sandy dolomite* (R11997), flaggy, fine-grained (20%); *Stromatolitic silty dolomite* (R11962), massive to blocky, laminated, blue-grey, as lenticular mounds (bioherms) within succession (20%); *Dolomitic limestone* (R11999, R11996, R12000), flaggy, grey to white; and *calcareous dolomite* (10%); *Dolomite breccia*, flaggy (5%).
111	*Dolerite*, slightly trangressive sill.
255	Interbedded sequence of: *Dolomitic siltstone* and *cherty siltstone*, flaggy, porous, more common towards top (20%); *Chert*, flaggy to massive, banded and non-banded, white, blue, and grey (20%); *Oolitic chert*, flaggy, white (15%); *Dolomitic siltstone*, flaggy to fissile, thin-bedded, buff, purple, and grey (15%); *Dolomite* (R11990) and *silty dolomite* (locally 'magnesitic') (R11991, R11992, R11993), flaggy, thin-bedded to laminated, pinkish grey and buff; *oolitic dolomite*, white to buff; *sandy oolitic dolomite; dolomitic sandstone*, fine-grained. Chert bands and nodules common; stromatolites in places (15%); *Calcareous dolomite* and *dolomite* (R11987, R11988, R11989 - near base; R11994, R11995 - near top), massive, thin-bedded, black to grey (5%); *Chert breccia*, massive, yellow-brown, 'slumped'; composed of angular chert fragments in a chalcedonic or cherty siltstone matrix (5%); *Quartz sandstone*, blocky to flaggy, thin-bedded, cross-bedded, friable; chert fragments and scattered chert pebbles up to 1 cm in diameter (5%).

60	*Dolerite*, slightly trangressive sill.
30	Interbedded sequence of: *Leached dolomitic siltstone* (R11979), flaggy, thin-bedded; buff to red; local halite pseudomorphs (50%); *Chert* and *oolitic chert* (R11978), flaggy, laminated, blue-grey (40%); *Dolomite* (R11976), flaggy, thin-bedded, buff; minor shaly partings and nodules and bands of chert; oolitic and sandy in places (10%).
15	*Quartz sandstone*, massive, fine-grained, white; abundant angular chert grains and occasional pebbles.
45	Interbedded sequence of; *Leached dolomitic siltstone* and *cherty siltstone*, flaggy, porous (40%); *Chert*, flaggy, laminated to thick-bedded, white, blue, and grey; *oolitic chert* (40%); *Quartz sandstone*, flaggy and massive, medium-bedded,ripple-marked, fine to medium-grained; scattered angular chert grains (10%); *Silicified stromatolitic dolomite; dolomitic siltstone*, flaggy, laminated; *chert breccia* (10%).
15	*Silty dolomite* (R11985, R11986), flaggy, thin-bedded to laminated; interbeds of *dolomitic siltstone* (R12043), fissile, purple.
30	*Stromatolitic dolomite* and *silty stromatolitic dolomite*, massive to flaggy, laminated, pink, yellow and buff; interbedded with oolitic chert.
45	*Leached dolomitic siltstone*, flaggy, porous; interbedded with *stromatolitic dolomite*, massive, thin-bedded; *silty stromatolitic dolomite* and *oolitic chert;* minor *chert breccia* and *quartz sandstone*, flaggy.
530 total (excluding dolerite sills)	Conformably underlain by Bone Creek Formation.

The piecing together of a composite section of the Dook Creek Formation in the Wilton River area is greatly complicated by the lack of marker beds, by the presence of thick, widespread, and sometimes transgressive, dolerite sills, by the lateral variations arising from the growth of stromatolitic bioherms, and by the effects of leaching and silicification of some of the strata. A broad generalised succession is given in Table 25.

It can be seen from Table 25 that many of the rock types in the Dook Creek Formation occur sporadically almost throughout the entire column -the most common types are dolomitic siltstone, leached dolomitic siltstone, cherty siltstone, chert, oolitic chert, and silty dolomite.

The siliceous rocks - cherty siltstone, chert, and oolitic chert -probably owe their silica content to the post-depositional replacement of carbonate minerals. Much of the replacement may have occurred in the diagenetic stage, but some is almost certainly associated with the recent period of lateritisation. The cherty siltstones were probably originally dolomitic (or calcareous) siltstones, and most, if not all, of the cherts and oolitic cherts were originally limestones or dolomites.

The presence of angular chert pebbles and angular sand-sized grains of chert in the basal beds of the Limmen Sandstone indicates that some of the beds immediately below the unconformable contact with the Limmen Sandstone were originally siliceous or were silicified during the erosional break. The chert fragments appear to have been transported as such rather than in the form of a carbonate rock.

The siliceous rocks tend to form rubble-covered hills and rises, and in places their relationship to the underlying carbonate-bearing strata may be interpreted as due to recent surface silicification involving the replacement of carbonates by silica. In other places, the carbonate minerals have been leached from the rocks, leaving porous siltstone and sandstone.

Finely banded and laminated cherts are possibly the most abundant of the siliceous rocks in the Dook Creek Formation. They consist essentially of chalcedony, but in places scattered clastic grains of sand and silt are present. The cherty siltstone generally consists of bands of chert alternating with leached dolomitic siltstone, but in places chert occurs both as distinct bands and as a cementing agent in the intervening siltstone bands.

The oolitic chert consists predominantly of zoned siliceous oolites set in a chalcedony matrix. In places carbonate minerals occur in the matrix and occasionally in the oolites (R11978). Detrital quartz and chlorite are common in the matrix. Spherical oolites predominate, but smaller, elongate oolites are common.

Among the carbonate-bearing rocks dolomitic siltstone is the most common type. Leaching of the carbonate component in surface exposures is common, particularly in the more permeable, coarser-grained siltstones. Quartz is the dominant clastic constituent, and potash feldspar and muscovite occur in lesser amounts; the matrix consists of dolomite and varying amounts of amorphous clay minerals (R11979), and probably, in some, magnesite.

Silty (or argillaceous) dolomite, although not as common as the dolomitic siltstone, constitutes an important part of the formation. The silty dolomite (R11985-7, R11991-3) consists of anhedral or subhedral interlocking grains of carbonate with varying amounts of amorphous clay minerals and minor amounts of quartz, muscovite, chlorite, and zeolite. Irregular patches of recrystallised carbonate grains are common. Banding is produced by variations in the clay content. One specimen of silty dolomite containing microscopic algal laminae (R11962) differs from most of the silty dolomites in containing almost no amorphous clay; it consists of carbonates (80%) as subhedral grains from 0.01 to 0.06 mm with occasional coarser patches and quartz (20%) as subangular grains scattered throughout the carbonates, but tending to be concentrated along particular laminae.

The sandy dolomite (R11997, R11976) consists of sand-sized grains of quartz (30-40%), quartzite (5%), and feldspar (mainly potash feldspar) (5%) set in a groundmass of dolomite (50%) containing amorphous clay minerals, and minor amounts of muscovite. Dolomite and cherty oolites occur in some of the rocks. Some of the larger quartz grains show strain lamellae and may be of volcanic origin.

Many of the dolomites, dolomitic limestones, and calcareous dolomites contain algal laminae, but others show little or no evidence of organic origin. They (R11987-90, R11995, R11999-00) consist of crystalline carbonate minerals with minor amounts of chlorite, amorphous clay, muscovite, and quartz. Some contain patches of coarse-grained (recrystallised?) carbonates.

Chemical analysis of the carbonate-bearing rocks (Table 26 and Fig. 21) show that those containing less than 10 percent of 'impurities' range in composition from dolomitic limestone to dolomite. Where the 'impurities' are greater than 10 percent the carbonate fraction is predominantly dolomitic. The two examples containing 'modal' magnesite as well as dolomite (Nos. 10, 4) are among the most 'impure' rocks. The lack of impurities in the more calcareous rocks (Nos. 5, 12, 2, 6) suggests that they may be partly biogenic.

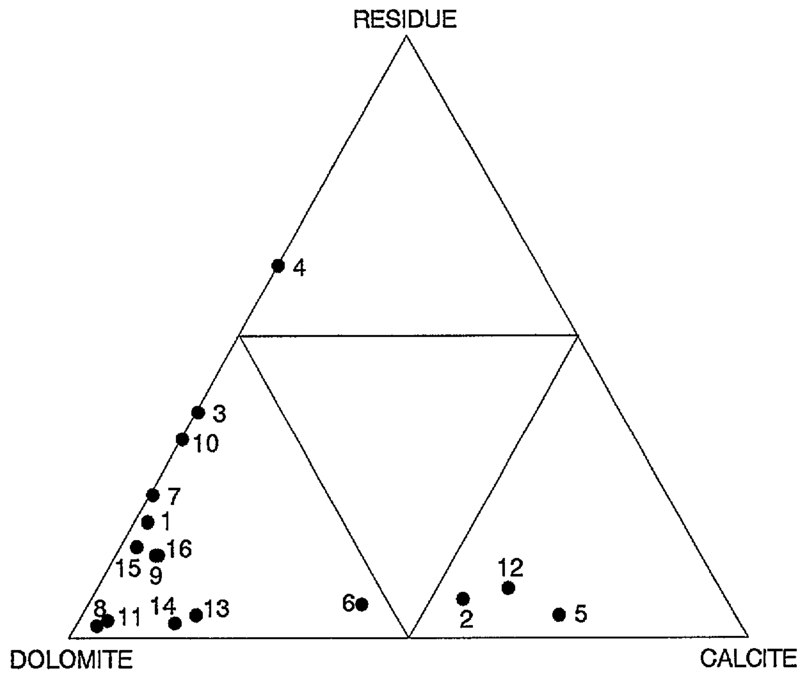

Figure 21. Calculated compositions of 16 randomly selected carbonate-bearing samples from the Dook Creek Formation. In samples 4 and 10 "magnesite" (Table **) is included with residue.

Table 26. Calculated carbonate content from chemical analysis, of randomly selected carbonate-bearing rocks from the Dook Creek Formation, Wilton River district

	SPECIMEN NO	DOLOMITE (%)	CALCITE (%)	MAGNESITE (%)	RESIDUE (%)
1	R11962	78.9	1.4	-	19.7
2	R11996	38.9	54.5	-	6.6
3	R11997	62.4	-	-	37.6
4	R11998	30.6	-	1.0	48.4
5	R11999	25.8	70.1	-	4.1
6	R12000	54.2	40.1	-	5.7
7	R11993	75.6	0.3	-	24.1
8	R11995	94.8	3.0	-	2.2
9	R11991	80.4	5.3	-	14.3
10	R11992	66.9	-	8.8	24.3
11	R11990	93.1	3.8	-	3.1
12	R11987	31.2	60.2	-	8.6
13	R11988	79.6	16.4	-	4.0
14	R11989	83.4	13.8	-	2.8
15	R11985	82.6	2.1	-	15.3

16	R11986	80.0	5.7	-	14.3

DISCUSSION

After the 1962 mapping the Mount Rig Group, a carbonate sequence between the Katherine River and Roper Groups, was traditionally correlated with the McArthur Group (e.g., Plumb & Derrick, 1975; Plate 1, this report). However, although most of the group is very poorly exposed and highly silicified, it is characterised by features diagnostic of the more recently defined Nathan Group, abundant oolitic chert and a characteristic stromatolite form, *Kussiella kussiensis* , and so the group is now correlated with the Nathan Group (Plumb, 1985; Jackson *et al.,* 1987) A similar sedimentological setting may be provisionally inferred - a basal alluvial fan facies (Bone Creek Formation), passing up into cyclic carbonate complexes deposited in broad hypersaline playas and lakes or peritidal settings (Dook Creek Formation).

"Kookaburra Creek Formation "(informal term)

Description and comments

Only isolated exposures have been examined in Arnhem Land in the bed of a tributary of the Rose River around latitude 13°54'S, longitude 135°06'E; they are too small to be shown on accompanying map.

In this area there are several exposures of grey-yellow and white, massive fine and medium-grained quartz sandstone containing scattered chert grains and silt pellets. Current ripple marks occur on some of the bedding planes. Massive chert-breccia consisting of chalcedonic chert fragments set in a matrix of yellow siltstone crops out at one locality and massive white oolitic chert and yellow porous thinly flaggy leached dolomitic siltstone crop out in other localities. The scattered nature of the exposures precludes determination of the order of superposition of the various beds, and no estimate of their thickness can be given.

In the 'type area' of the formation, around the Roper River, the 'Kookaburra Creek Formation' is now known to be part of the Nathan Group, and the name has been abandoned. The 'Kookaburra Creek Formation' is therefore equivalent to the Mount Rigg Group, and not the McArthur Group as shown on Plate 1.

Table 27. Summary of stratigraphy, units of uncertain correlation.

ROCK UNIT	THICKNESS (m)	LITHOLOGY	TOPOGRAPHY	DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	REMARKS
Wilberforce beds	~ 1500 Only top 60 exposed	Micaceous-dolomitic-quartz siltstone & shale; fine-grained sandstone. Unexposed section inferred to be probably dolomite-lutite succession	Very poor outcrop; mainly exposed only in scarp beneath Mallison Sst. Mostly sand & alluvium covered plains	Narrow line of exposures between Mallison & Bromby Is; scattered exposures between Cape Newbold & Cape Wilberforce; Arnhem Bay/Gove & Wessel Is/Truant Is. Sheets	Overlain with erosional contact by Malay Rd Gp (Mallison Sst). Overlies, apparently conformably, Mt Bonner Sst	Had been correlated with McArthur & Habgood Gps; alternative is new Nathan Gp in southern McArthur Basin; exposed shales at top resemble new Mantungula Fm., at base of Roper Gp
Mount Bonner Sandstone	~ 150	Quartz sandstone; cobble conglomerate	Resistant; forms cuestas	Between Arnhem and Melville Bays; Arnhem Bay/Gove Sheet	Unconformably overlies Spencer Ck Volcs. Overlain, apparently conformably, by Wilberforce beds	Basal conglomerate. Had been correlated with Parsons Ra. Gp. More likely equivalent to basal sandstone of McArthur or Nathan Gps
Baralminar beds	>200	Alternating quartz sandstone & micaceous shale	Discontinuous outcrop in creeks. Occasional sandstone ridges	Isolated outcrops south of Arnhem Bay, Arnhem Bay Sheet	Unconformably overlain by Lower Cretaceous rocks. No exposed top or base; no exposed relationship to any Proterozoic unit	Has been tentatively correlated with all or part of Parsons Ra. Gp, or with Mt Bonner Sst, on broad lithological grounds
Groote Eylandt beds	9 - ~600 (ref. sect.) Top eroded	Quartz sandstone, argillaceous sandstone, lithic quartz greywacke, red shale, conglomerate	Prominent hills & dissected plateaux	Shoreline of, & islands within & around, Blue Mud Bay; Blue Mud Bay/Port Langdon Sheet	Unconformably overlies Grindall Mets, Caledon Gran., Bickerton Volcs. Overlain, apparently conformably, by Blue Mud Bay beds. Top eroded most areas	Sits everywhere on basement, but marked differences in facies & thickness between different areas means not neccessarily all same unit. Had been correlated with Parsons Ra. or Katherine R. Gps, before sandstones identified at base of McArthur & Nathan Gps in southern McArthur Basin

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Groote Eylandt beds

Definition

Distribution : On islands within, and along the coastline bordering, Blue Mud Bay in the Blue Mud Bay/Port Langdon Sheet area; exposures on Groote Eylandt extend southwards into the Roper River/Cape Beatrice Sheet area.

The most extensive exposures are found on Groote Eylandt and Bickerton Island. Good sections are also found on Woodah Island, Morgan and Nicol Island, and on the mainland between the Walker and Koolatong Rivers. Small exposures occur in the Grindall Point and Cape Shield areas and on most of the smaller islands in Blue Mud Bay.

Reference Area : Whole of Groote Eylandt (about latitude 14°00'S, longitude 136°35'E) and the adjoining islands to the north.

Derivation of Name : From Groote Eylandt

Stratigraphic Relationships: Rest on Grindall Metamorphics and Caledon Granite with pronounced angular unconformity; overlie Bickerton Volcanics with an erosional unconformity but no evidence of angular discordance; overlain apparently conformably by Blue Mud Bay Beds.

Lithology : Three facies can be recognised in the Groote Eylandt Beds. The Walker River facies, as seen between the Walker and Koolatong Rivers and on Grindall Point (section A; fig. 22) is typified by a thin red and white sandstone sequence with some thin sales and lenses of conglomerate. The Morgan Island facies (section B) is typified by a red shale between a basal conglomerate and overlying sandstone succession. The Groote Eylandt facies (section D) has a thick sequence of lithic quartz greywacke and argillaceous sandstone, grading up into quartz sandstone. The distribution of these facies is shown on Figure 22.

Thickness : Increase in thickness from north to south accompanied by lateral change in lithology (see Fig. 22). Preserved thickness on Grindall Point (section, loc.A; fig. 22) about 9 m; about 42 m preserved on Morgan Island (loc. B) and northern tip of Bickerton Island (loc. C). Top of each section eroded, but section underlying Blue Mud Bay Beds near Walker and Koolatong Rivers has similar order of thickness. On Bickerton Island proper and Groote Eylandt thickens suddenly to about 600 m; cannot be estimated accurately because of prevailing low dips and eroded top.

Distinguishing Features : The lithology and succession of both the Groote Eylandt facies and the Morgan Island facies are distinctive; similarities do exist with some rocks of the Parsons Range Group and the Tawallah Group (Dunn et al., in prep.), but their geographical position is diagnostic.

The base of the Groote Eylandt Beds is marked by an unconformity; the upper contact is marked by a change in lithology from purple ferruginous sandstone to chert, dolomitic siltstone, and chert sandstone of the Blue Mud Bay Beds.

Age : Statherian? (Palaeoproterozoic?)

Description and comments

In the *Groote Eylandt facies* the lower part of the section consists of massive, medium to coarse-grained, pale grey, lithic, argillaceous quartz greywacke with scattered interbeds of blocky white quartz sandstone. The quartz greywacke grades upwards into massive coarse-grained argillaceous quartz sandstone followed by white blocky medium-grained quartz sandstone at the top of the section. Scattered lenses of boulder conglomerate are common in the lower part of the formation on Bickerton Island; thin beds of purple shale have also been observed, but they are rarely exposed.

In the lower part of the section the quartz sandstone tends to occur in beds about 15 m thick capping small cliffs, with the softer quartz greywacke and argillaceous quartz sandstone below; the contacts are gradational. The quartz greywacke and argillaceous quartz sandstone are generally poorly to moderately sorted and contain scattered pebbles of quartz and, in places, acid volcanics. Outcrops are massive, and irregularly oriented cross-beds with sets about 3 m thick, are ubiquitous.

In thin section the lithic quartz greywacke (R13647) contains about 75 percent of moderately sorted subangular grains of quartz mostly about 0.5 to 1.0 mm across, but ranging from 0.1 to 1.5 mm, and scattered grains of fine-grained volcanic rock set in a matrix of clay or sericite and a little very fine-grained quartz. In hand specimen some of the rocks are very coarse-grained and contain up to 40 percent of clay matrix.

The argillaceous quartz sandstone is generally somewhat friable although similar to the quartz greywacke in bedding features and grainsize. In thin section (R13648) the rock contains about 90 to 95 percent of well sorted (0.25 - 2.0 mm but mostly 0.5 - 1.0 mm) and rounded quartz grains of metamorphic and granitic origin. Some fine volcanic fragments are present and the matrix consists of a very fine aggregate of quartz, sericite, and clay.

A specimen of blocky cross-bedded quartz sandstone (R13649) from near the top of the unit consists of well sorted and rounded quartz grains, 0.1 to 1.0 mm in size but mostly about 0.5 mm and scattered chert fragments, in a silica cement. The cement forms secondary overgrowths in optical continuity with the enclosed grains and the original detrital grains make up only about 60 percent of the total rock.

On *Bickerton Island* the basal strata, which rest on the Bickerton Volcanics or Grindall Metamorphics, are exposed in a number of places; the strata are composed of massive lithic-argillaceous quartz greywacke with scattered pebbles of sandstone and acid volcanics. On the eastern shoreline of South Bay a massive conglomerate crops out; it contains boulders up to 1.5 m in diameter of slate and greywacke (Grindall Metamorphics), acid volcanics (Bickerton Volcanics), and argillaceous quartz greywacke, set in a matrix of coarse-grained argillaceous sandstone. The basement is Bickerton Volcanics. The boulders of argillaceous quartz greywacke are lithologically identical to the distinctive host rock and were apparently derived from the Groote Eylandt Beds in adjacent areas. Occasional lenses of a similar conglomerate are found higher in the section in the northern part of the island.

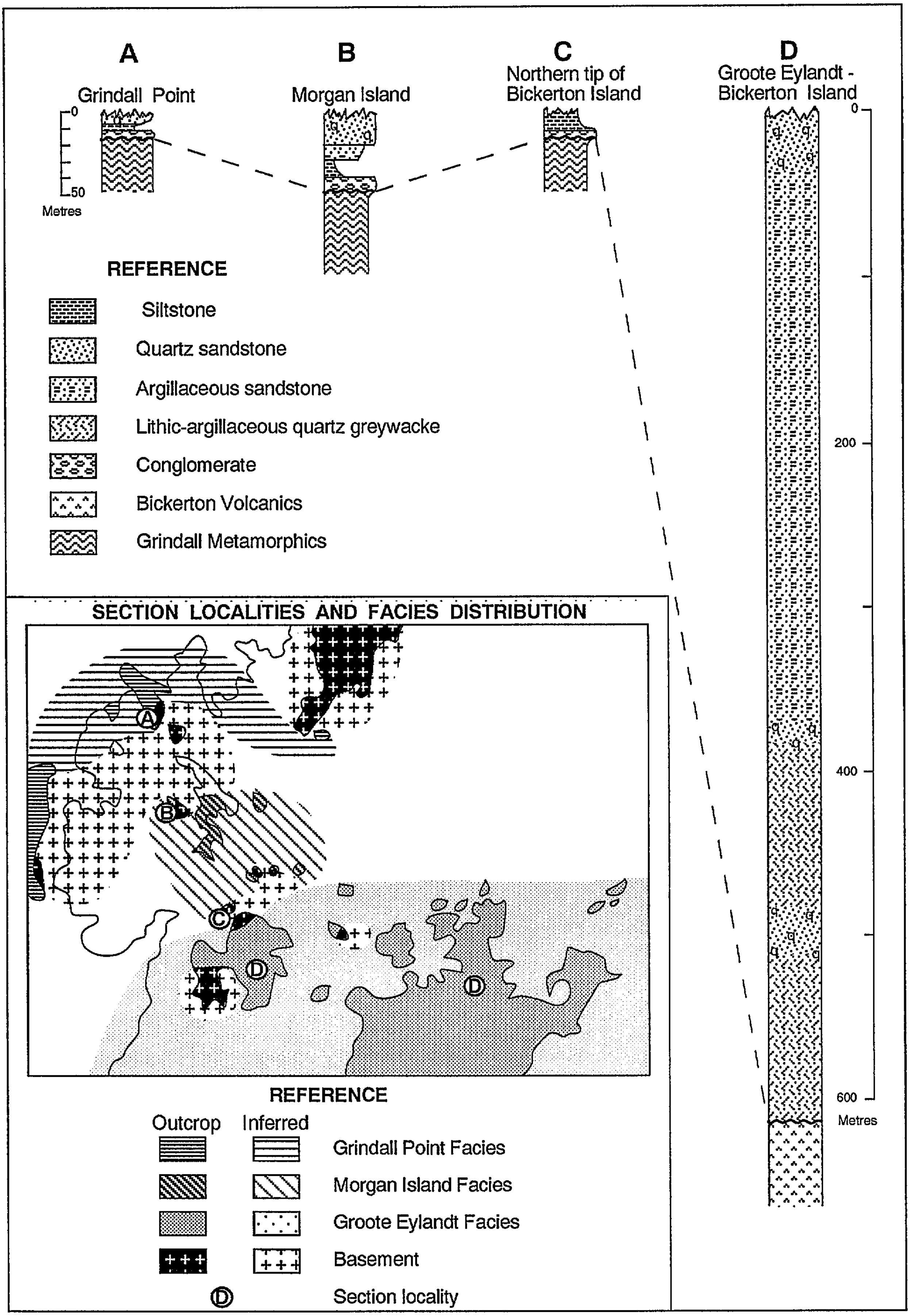

Figure 22. Diagrammatic stratigraphic sections, Groote Eylandt beds.

The contact between the Groote Eylandt Beds and underlying Bickerton Volcanics is well exposed on the southern tip of *Bustard Island* where erosion has stripped off the sediments and exposed the irregular upper surface of the volcanics. The hollows in the upper surface of the volcanics are filled with a distinctive red coarse-grained lithic-feldspathic greywacke (R13646) composed of about 60 poorly sorted quartz grains, 0.25 to 4 mm in size, and 10 percent altered feldspar and devitrified acid volcanics. Most of the quartz is fractured and shows strain extinction; rounded, clear quartz grains show relict embayments. The abundant groundmass consists of very fine quartz, and sericite or clay; these are similar to the alteration products of the feldspar and rock fragments. An outstanding feature is the presence of abundant subhedral authigenic apatite within the groundmass associated with a colourless fibrous mineral which is probably wavellite; the same mineral also occurs in thin veinlets.

As shown on figure 22 the Groote Eylandt Beds thin suddenly at the northern end of Bickerton Island and change in character as shown by the section on *Morgan Island* (Table 28).

Table 28. Stratigraphic section, lower part of Groote Eylandt beds, Morgan Island.

Thickness (m)	Soil cover
15+	*Quartz sandstone* (R13644), blocky, cross-bedded, white, medium-grained; some shale pellets.
9	*Argillaceous quartz sandstone* (R13645), cross-bedded, red,medium to coarse-grained.
12	Poor outcrop (rubble of *micaceous shale*, fissile, purple, and *quartz greywacke*.)
3-6	*Pebble conglomerate;* rounded pebbles up to 7.5 cm across of slate, quartz, and quartz sandstone in a coarse red matrix of sand.
42 Total	Unconformity Grindall Metamorphics and Caledon Granite.

The upper sandstone (R13644) is a quartz sandstone composed of about 99 percent well sorted (0.1 - 0.8 mm) and well rounded quartz grains cemented by silica and secondary overgrowths. Trains of minute inclusions are common in the cement and many of the grains. A little muscovite, zircon, and tourmaline are present.

The underlying red argillaceous sandstone (R13645) contains about 90 to 95 percent of well sorted (0.2 - 0.7 mm) and well rounded quartz grains, with rare grains of chert and feldspar, set in a matrix of clay and minor fine quartz, mica, and iron oxide. In places clay pseudomorphs the feldspar. Zircon is accessory.

Farther north near *Grindall Point* and *Cape Shield* only about 9 m of the sequence is preserved, and the shale bed is represented by a few very thin beds of shale within the quartz sandstone.

In the section on the mainland between the *Walker* and *Koolatong Rivers* definition of the base of the Beds is problematical. The top of Groote Eylandt Beds, beneath the Blue Mud Bay Beds, is a purple ferruginous sandstone which is underlain by white quartz sandstone containing ripple marks, cross-bedding, and clay pellet impressions. Underlying this in the scarp is a red quartz sandstone with irregular conglomerate bands. Below this the rocks crop out very poorly; the rubble of purple micaceous greywacke and siltstone shows a marked foliation approaching schistosity, and although they may be equivalent to the shales on Morgan Island the degree of deformation suggests that they belong to the Grindall Metamorphics.

DISCUSSION

In cannot be established that the three spatially-separate facies of the Groote Eylandt beds belong, in fact, to the same formation, although all occupy the same stratigraphic position, sitting immediately on 'basement'. On the basis of stratigraphic position the Groote Eylandt beds have been correlated with the other lower sandstone sequences of the region, the Katherine River Group or the Parsons Range Group. However, only the 'Grindall Point Facies', between the Walker and Koolatong Rivers, has any upper constraint: it is overlain by Blue Mud Bay beds.

Figure 22 indicates a marked thickening of the Groote Eylandt beds, southwards from the northern tips of Bickerton Island and Groote Eylandt. This thickening trends into a deep trough or rift, identified from magnetics beneath the Gulf of Carpentaria, to the south of Groote Eylandt, by Plumb and Wellman (1987). The large-scale cross-bedding, poor sorting, lithic fragments and argillaceous matrix in the 'Groote Eylandt Facies' indicates a probable fluvial origin for this facies. The basal conglomeratic sands of the other facies are consistent with this interpretation, whilst the associated red shales might represent alluvial overbank or flood-plain deposits. This overall distribution of facies, offlapping from a basement high, are consistent with this tectonic setting.

Baralminar beds

Definition

Distribution : Exposed in area between the Gobalpa and Habgood Rivers, immediately south of Arnhem Bay.

Reference Area : Baralminar River district around latitude 12°33"S, longitude 136°00'E.

Derivation of Name : From the Baralminar River.

Stratigraphic Relationships : Not definitely established; overlain unconformably by Lower Cretaceous rocks. Provisionally correlated with Parsons Range Group on lithology; regional trend of outcrops suggest correlation with Mount Bonner Sandstone.

Lithology : Massive quartz sandstone alternating with flaggy purple-brown micaceous shale.

Thickness : About 200 m exposed but top and bottom not exposed.

Distinguishing Features : Although distinguished mainly because of their geographical position and indefinite stratigraphic position, the sequence of alternating massive quartz sandstone and purple shale is distinctive.

Age : Statherian or Calymmian (Palaeoproterozoic or Mesoproterozoic)

Description and comments

Table 29. Stratigraphic section, part of Baralminar beds, Baralminar Creek area.

Thickness (m)	Soil cover
9	*Quartz sandstone,* blocky to massive, cross-bedded, fine-grained; white with scattered red-brown iron-rich spots (R13651).
90	No outcrop (rubble of micaceous ferruginous shale, flaggy, deep purple-brown, laminated).
6	*Quartz sandstone,* flaggy to blocky, pink, subfriable, scattered fine-grained hematite (R13652, 13653).
3	*Shale*
4.5	*Quartz sandstone,* flaggy to masssive, fine-grained, clean, white.
6	*Micaceous shale.*
45	*Quartz sandstone,* massive, cross-bedded, medium to coarse-grained, well-sorted, friable.
45	Poor outcrop. *Ferruginous micaceous shale,* flaggy purple, with interbeds of *micaceous sandstone,* flaggy, purple to grey, fine-grained (rubble of R13654, R13655).
210 total	Soil cover

A very generalised stratigraphic section is given in Table 29.

The quartz sandstones (R13651, R13652, R13653) consist almost entirely of well sorted quartz grains tightly cemented by silica overgrowths. Tourmaline, muscovite, and zircon are accessory. Specimens R13651 and R13652 contain very fine iron oxide scattered throughout.

The micaceous sandstones (R13654, R13655) contain mostly fine-grained quartz (0.05-0.1 mm) cemented by silica overgrowths. Scattered muscovite flakes lie parallel to the bedding, but only constitute about 2 percent of the rock. Fine iron oxide is scattered through the rocks; in specimen R13654 variations in iron oxide content (2-10 percent) emphasises the bedding laminations. Tourmaline and zircon are accessory.

DISCUSSION

Little is known about the Baralminar beds, and their stratigraphic position and correlation is virtually unconstrained.

Mount Bonner Sandstone

Definition

Distribution : Crops out in a northeasterly trending zone covering an area of 25 km^2 on peninsula between Arnhem and Melville Bays, in the northeastern part of Arnhem Bay/Gove Sheet area.

Reference Area : Vicinity of Mount Bonner designated as reference area.

Derivation of Name : From Mount Bonner, a prominent landmark on northeastern coast of peninsula between Arnhem and Melville Bays.

Stratigraphic Relationships : Unconformable on Spencer Creek Volcanics and, at one locality on east coast of peninsula, rests directly on weathered garnetiferous granite (probably Bradshaw Granite); overlain, probably conformably, by Wilberforce Beds. Although they rarely crop out, the Wilberforce Beds probably underlie much of the peninsula north of the exposures of the Mount Bonner Sandstone; no contacts between the two units have been observed.

Lithology : White, massive, thin-bedded, coarse-grained quartz sandstone; massive cobble conglomerate.

Thickness : About 150 m.

Distinguishing Features : The base of the Mount Bonner Sandstone is generally marked by rudites, but in places arenites occur at the base. Both rock types are readily distinguished from the underlying volcanic or granitic rocks. The top of the unit is assumed to lie along a line marked by a sharp physiographic break produced by a change in lithology from arenites to less resistant strata. The less resistant strata are not exposed near the contact.

Age : Statherian or Calymmian (Palaeoproterozoic or Mesoproterozoic)

Description and comments

In most places a bed of conglomerate, up to 30 m thick, occurs at the base of the formation. The conglomerate contains boulders, cobbles, and pebbles of white and pink quartz sandstone, quartz, quartzite, and rarely, granite. Cobbles of quartz sandstone make up most of the rock. The matrix consists of coarse-grained quartz sandstone.

The conglomerate is overlain by about 120 m of white cross-bedded quartz sandstone. It is dominantly coarse-grained, massive, and thin-bedded, although medium-grained zones and zones of feldspathic sandstone occur in parts of the sequence. The grains are subrounded to angular. Ripple marks are present, but are not abundant. Bedding laminations are commonly accentuated by concentrations of black minerals. Jointing of the sandstone tends to produce karst topography.

In thin section (R12656) the rock is seen to contain minor rock fragments as well as poorly sorted quartz sand. The rock fragments include quartzite, chert, and volcanic rocks. Suturing is the main form of cementation, but overgrowths are more abundant in the finer-grained zones. Sericite occurs interstitially and a small amount of barite cement is present in some bands.

DISCUSSION

As a basal sandstone and conglomerate unit, the Mount Bonner Sandstone has traditionally been correlated with the Parsons Range or Katherine River Groups (Plate1; Plumb & Derrick, 1975). However, basal sandstones now characterise each of the principal carbonate-rich groups to the south - the McArthur or the Nathan Groups (Jackson *et al.,* 1987). The upper limit of the Mount Bonner Sandstone - Wilberforce beds pair is constrained only by the Roper Group equivalent, the Malay Road Group, and so the Mount Bonner Sandstone may be correlated with the basal sandstone of either the McArthur or Nathan Groups (Plumb *et al.*, 1990).

Wilberforce beds

Definition

Distribution: Exposed in small cliffs beneath resistant Mallison Sandstone along southern coasts of Mallison Island, Cape Wilberforce Peninsula, and Bromby Islands in northeastern part of Arnhem Land; minor exposures on mainland between Cape Newbold and Cape Wilberforce.

Reference Area: Peninsula leading to Cape Wilberforce, about latitude 11°57'S; longitude 136°31'E. No section measured.

Derivation of Name: From Cape Wilberforce.

Stratigraphic Relationships: Overlain unconformably by Mallison Sandstone; probably overlie Mount Bonner Sandstone conformably, but contact not exposed; considered stratigraphically equivalent to parts of Habgood and McArthur Groups.

Lithology: Flaggy, black, micaceous-dolomitic-quartz siltstone and shale; interbeds flaggy, pink fine-grained sandstone.

Thickness: Probably about 1500 m; only top 60 m exposed.

Distinguishing Features: Stratigraphic position diagnostic; sequence of black micaceous shale and lenticular fine sandy interbeds distinctive. Top readily recognised at contact with unconformably overlying Mallison Sandstone; base not exposed; defined as top of Bonner Sandstone.

Age: Statherian or Calymmian (Palaeoproterozoic or Mesoproterozoic)

Description and comments

Only about 60 m of the Wilberforce Beds, immediately below the Mallison Sandstone, is exposed; between these exposures and the Mount Bonner Sandstone, in the Peter John River area, a wide zone is covered by Lower Cretaceous rocks and Cainozoic soils. This area must contain easily eroded beds, probably similar to the exposed Wilberforce Beds; these subsurface rocks are defined as belonging to the Wilberforce Beds. On this basis the Wilberforce Beds are probably about 1500 m thick.

The exposed Wilberforce Beds consist of flaggy to fissile, black to deep purple-brown, micaceous, dolomitic quartz siltstone and shale, with lenticular interbeds, 7.5 to 15 cm thick, of flaggy, pink to pale green, fine-grained sandstone. The bedding is generally irregular and rolling. In the reference area the section shows a gradation from mainly shale at the base to siltstone or fine-grained sandstone higher up.

In thin section the siltstone (R13657) consists of about 40 percent quartz, 40 percent carbonate, 15 percent matrix, and 5 percent muscovite. The quartz ranges from about 0.03 to 0.07 mm in size, while the carbonate occurs as very fine crystals concentrated in microlenses about 0.5 mm long. The carbonate encloses detrital quartz and mica grains, but the pods are characterised by a lack of other groundmass material. The mica lies on the bedding planes, and the groundmass consists of clay and very fine quartz. Tourmaline, zircon, and fine iron oxides are accessory. The carbonate is assumed to be dolomite.

In the cliffs near Cape Wilberforce an erosional unconformity can be seen at the contact of the Wilberforce Beds and overlying Mallison Sandstone. Erosional channels, up to 10 m deep, in the Wilberforce Beds, are filled with Mallison Sandstone. No angular discordance is visible and the total amount of erosion is unknown.

DISCUSSION

Table 30. Summary of stratigraphy, Roper Group.

ROCK UNIT	THICKNESS (m)	LITHOLOGY	TOPOGRAPHY	DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	REMARKS
Bessie Creek Sandstone	15 - 30	Fine to medium-grained quartz sandstone	Moderately resistant - low cuestas		Conformably overlies Corcoran Formation	Top unit of Roper Gp exposed in Arnhem Land. Highly jointed; weathers into characteristic sandstone karst. *High-energy tidal shelf - tidal flat sands*
Corcoran Formation	120	Flaggy micaceous sandstone, shale, & siltstone	Poorly resistant - soil-covered valleys		Conformably overlies Abner Sst	Very poorly exposed. *Low-energy tidal shelf - tidal flat muds and silts*
Abner Sandstone	180 - 240	Alternating sandstone and siltstone; divided into four members				
Munyi Member	30 - 45	Ferruginous sandstone & siltstone; minor quartz sandstone & micaceous shale	Crops out poorly as low undulating cappings on Hodgson Sst Mbr	E Mt Marumba Sheet, extending into Blue Mud Bay Sheet to W of Parsons Range	Conformably overlies Hodgson Sst Mbr	Strongly ferruginous in SW, with quartz sandstone and siltstone dominating in NE. *Rapid transition to low-energy shelf muds*
Hodgson Sandstone Member	30 - 45	Medium-grained quartz sandstone	Resistant - low cuestas & plateau cappings		Conformably overlies Jalboi Fm	Top unit of Roper Gp exposed in Arnhem Land. Highly jointed; weathers into characteristic sandstone karst. *High-energy tidal shelf - tidal flat sands*
Jalboi Member	120	Blocky quartz sandstone alternates with interbedded green, white and purple micaceous sandstone and siltstone	Alternating low ridges and soil-covered valleys		Conformably overlies Arnold Sst Mbr	Principal member of Abner Sst in Arnhem Land. Becomes more silty to NE. Abundant & varied sedimentary structures. *Shoreface sands & silts*

Almost none of the stratigraphic interval assigned to the Wilberforce beds is exposed.From their stratigraphic position, recessive nature, and nature of the uppermost, exposed beds they are presumed to comprise a carbonate sequence which has been, traditionally, correlated with the McArthur Group (Plate 1; Plumb & Derrick. 1975). However, with the revised stratigraphy of the southern McArthur Basin (Jackson *et al*, 1987) the possibility now arises that they may correlate with either the McArthur or the Nathan/Mount Rigg Groups (Plumb *et al.*, 1990). In addition, the uppermost exposed beds of flaggy micaceous siltstone and shale are immediately reminiscent of the recently discovered, shallow-marine Mantangula Formation at the base of the Roper Group (Powell *et al.*, 1987; Jackson, Sweet, and Powell, 1988); the described "erosional unconformity" beneath the Mallison Sandstone may be nothing more than sandstone channels, and the regional unconformity concealed beneath the area of no outcrop. The likely thickness of unexposed section seems to be too thick for the Mantungula Formation alone, and so a thick, unexposed carbonate equivalent of either the McArthur or Nathan Group is still inferred to lie beneath..

CALYMMIAN

ROPER GROUP

DISCUSSION

The Roper Group is widely exposed throughout the McArthur Basin to the south of Arnhem Land. A very much thinned and poorly exposed section, at the northern margin of its distribution, extends into Arnhem Land to the west of the Parsons Range. Locally, the Roper Group laps directly onto the Parsons Range Group at the edge of the range.

The Roper Group is noted for the remarkably continuity and consistency of its units over vast distances. Little work has been carried out on the Roper Group in Arnhem Land. The units have all been defined from areas to the south (Jackson *et al.,* 1987), where they have been studied in some detail and interpreted sedimentologically by Powell *et al.* (1987) and Jackson *et al.* (1988). Briefly, they interpret a cyclic marine-shelf sequence, related to fluctuations in sea level. The Roper Group is simply summarised herein in Table 30, including the environmental interpretations of Powell *et al.* and Jackson *et al.* .

Definition

Distribution: Eastern end of north coast of Arnhem Land; exposures confined to small northeasterly trending belt bounded by line from Mallison Island to the Bromby Islands in south, and The English Companys Islands in the north.

Reference Area: The English Companys Islands/Cape Wilberforce area. No sections measured.

Derivation of Name: From Malay Road, a strait between Cape Wilberforce and The English Companys Islands. Strait bounded on both sides by the group; inferred that group is continuous beneath strait.

Stratigraphic Relationships: Overlies Wilberforce Beds with erosional unconformity; overlain with angular unconformity by Wessel Group. Correlated, on basis of lithology and stratigraphic position, with Roper Group.

Components: Made up of Mallison Sandstone, Wigram Formation, Pobassoo Formation and Astell Sandstone.

Lithology: Massive quartz sandstone alternates with interbedded argillaceous siltstone and fine-grained quartz greywacke; micaceous quartz greywacke and siltstone; black shale; glauconitic fine-grained sandstone.

Thickness: About 1.5 km estimated. Only about 0.6 km actually exposed.

Distinguishing Features: Stratigraphic position diagnostic; succession as a whole distinct from Wessel Group, with which it is most likely to be confused. Mallison Sandstone more quartzose than Buckingham Bay Sandstone; Wigram Formation/Pobassoo Formation sequence distinguished by black shale, overlain by grey to black fine-grained quartz greywacke with distinctive sandstone marker beds, and, finally, purple to red, highly micaceous quartz greywacke and siltstone.

Base of group is unconformity between Wilberforce Beds and overlying Mallison Sandstone; top is unconformity at base of Buckingham Bay Sandstone.

Age: Calymmian (Mesoproterozoic).

Description and comments

Although only about two-fifths of the group is exposed, the available sections generally occur in coastal cliffs and are therefore fresh and very well exposed.

The stratigraphy is summarised in Table 31. The lithology is discussed under individual formation headings.

The quartz sandstone is generally cross-bedded and in places ripple marked. The finer-grained sediments consist mainly of fine quartz and very fine-grained clay or sericite. Some rocks are rich in iron oxides while others are rich in muscovite and glauconite. These "impure" sediments generally consist of thinly and regularly interbedded lutite and fine-grained arenite. Fine cross-bedding and well developed slumping is present.

No direct evidence of age of the Group is available; it is considered Calymmian on the basis of its correlation with the Roper Group, which, on overall lithology and stratigraphic position seems quite sound.

Table 31. Summary of stratigraphy, Malay Road Group.

<table>
<tr><th>ROCK UNIT</th><th>THICKNESS (m)</th><th>LITHOLOGY</th><th>TOPOGRAPHY</th><th>DISTRIBUTION</th><th>STRATIGRAPHIC RELATIONSHIPS</th><th>REMARKS</th></tr>
<tr><td>Astell Sandstone</td><td>180+</td><td>Quartz sandstone</td><td>Resistant unit; forms cuesta</td><td>Astell Is.; Wessel Is Sheet</td><td>Conformably overlies Pobassoo Fm. No exposed top; inferred to be unconformably overlain by Wessel Gp (Buckingham Bay Sst.)</td><td>Upper unit of Malay Rd Gp; top eroded</td></tr>
<tr><td>Pobassoo Formation</td><td>~ 480. Only ~ 75 exposed</td><td>Purple to green, micaceous siltstone and quartz greywacke; micaceous sandstone; micaceous glauconitic sandstone</td><td>Moderately resistant where exposed; capping to back slopes of large ridges</td><td rowspan="2">The English Company's Islands; Wessel Is/ Truant Is., Arnhem Bay/Gove Sheets</td><td>Conformably overlies Wigram Formation</td><td rowspan="2">Only upper and lower parts of each formation exposed. Rest of section concealed benath sea. Dolerite sill intrudes Wigram Fm</td></tr>
<tr><td>Wigram Formation</td><td>~ 600 Only ~ 120 exposed</td><td>Quartz greywacke; micaceous quartz greywacke, sandstone & siltstone; quartz sandstone; black shale; argillaceous ferruginous siltstone</td><td>Only exposed in coastal cliffs beneath more resistant rocks</td><td>Conformably overlies Mallison Sandstone</td></tr>
<tr><td>Mallison Sandstone</td><td>~ 270</td><td>Quartz sandstone. Minor flaggy sandstone, laminated shale</td><td>Resistant unit; forms prominent cuesta</td><td>Line of ridges between Mallison & Bromby Is.; Arnhem Bay/Gove, Wessel Is./Truant Is. Sheets</td><td>Overlies with erosional contact Wilberforce beds</td><td>Lower unit of Malay Rd Gp</td></tr>
</table>

Mallison Sandstone

Definition

Distribution: Exposed in small northeasterly trending belt from Mallison Island in southwest, along southern side of Nalwarung Strait, to Bromby Islands in northeast.

Reference Area: Reference section exposed on Mallison Island at about lat. 12°12'S, long. 136°07'E; no section measured.

Derivation of Name: From Mallison Island.

Stratigraphic Relationships: Unconformably overlies Wilberforce Beds; conformably overlain by Wigram Formation. Erosional unconformity exposed at contact with Wilberforce Beds in cliff sections along Cape Wilberforce.

Lithology: Blocky to massive, quartz sandstone; minor flaggy sandstone and laminated, purple shale.

Thickness: About 270 m.

Distinguishing Features: Distinguished from other sandstone units mainly by stratigraphic position; abundance of tourmaline, readily visible to naked eye, is distinctive.

Lower contact taken at sudden change from black siltstone and shale of Wilberforce Beds to clean sandstone of Mallison Sandstone; an erosional unconformity is present. Top taken where massive sandstone gives way to flaggy green to grey siltstone and fine sandstone of Wigram Formation.

Description and comments

The Mallison Sandstone consists almost entirely of blocky to massive, white, pink, and pale brown, fine to medium-grained quartz sandstone. Black specks of tourmaline can be seen throughout hand specimen. The rocks are invariably cross-bedded and characteristically weather into large rounded boulders. Flaggy ripple-marked sandstone is present in places. Some laminated purple shale occurs near the top of the formation.

In thin section a single specimen (R13658) consists of about 98 percent of well sorted quartz (0.07-0.2 mm, with a norm of about 0.09-0.1 mm). Overgrowths of quartz have produced a close interlocking network of grains. The remainder of the rock is composed of accessory blue-grey tourmaline, zircon, muscovite, and very fine iron oxide.

Wigram Formation

Definition

Distribution: Upper part well exposed in cliffs and scarps along south-eastern side of The English Companys Islands; lower part lies below the sea in Nalwarung Strait and Malay Road; small exposures of base can be seen along mainland shore of Nalwarung Strait.

Reference Area: Composite section on Bosanquet (lat. 11°57'S, long. 136°28'E) and Cotton Islands (lat. 11°51'S, long. 136°28'E).

Derivation of Name: From Wigram Island at northeastern end of The English Companys Islands chain.

Stratigraphic Relationships: Conformably overlies Mallison Sandstone and conformably overlain by Pobassoo Formation; in places directly overlain with marked angular unconformity by Buckingham Bay Sandstone.

Lithology: Fine-grained quartz greywacke, micaceous quartz greywacke and sandstone; blocky quartz sandstone; black shale; micaceous siltstone and argillaceous ferruginous siltstone.

Thickness: About 600 m; only top 90 m and basal 30 m exposed above sea.

Distinguishing Features: Distinguished by stratigraphic position, and distinctive sequence of mainly thinly bedded, grey to green, fine-grained sandstone and siltstone, with some blocky sandstone interbeds; black shale forms a characteristic marker bed.

Base of formation taken at top of massive white quartz sandstone of Mallison Sandstone; top taken where dominantly grey fine-grained sediments change to purple and deep red micaceous sediments characteristic of Pobassoo Formation. This contact is readily recognised on air-photographs.

Description and comments

The basal part of the section, exposed on the mainland, consists of flaggy to fissile, green to grey, ferruginous quartz greywacke, which weathers to a flaggy, white to pale purple, laminated, fine-grained sandstone. In thin section the rock (R13660) contains about 70 percent quartz; 20 percent matrix; 10 percent iron oxide; less than 5 percent glauconite (?); minor mica, chlorite, and feldspar, and accessory tourmaline. The quartz grains are well sorted and range from 0.03 to 0.07 mm. The matrix is greenish yellow and very fine-grained; it is probably an iron-stained clay. The mica is partly altered to chlorite, and irregular patches of chlorite and iron oxide are present. Iron stained glauconite (?) is present.

The upper parts of the formation are best seen on Cotton Island (Table 32).

The two sandstone beds (Table 32) crop out boldly to form small cliffs in the scarp along the eastern side of Cotton Island. The upper 30 m of the formation is characterised by the abundance of mica, and is transitional into the overlying Pobassoo Formation.

In thin section the argillaceous and ferruginous siltstone (R13659) consists of about 25 percent quartz, 35 percent clay and sericite matrix, and 40 percent leucoxene. The quartz is scattered uniformly through the rock as subangular grains with a uniform grainsize of about 0.05 mm. Leucoxene occurs as scattered grains about 0.05 mm across and as very fine interstitial material, which is commonly concentrated in fine lenses parallel to the bedding. The matrix is fine-grained clay and ironstained sericite.

The black shale (R13515) consists mainly of clay and subordinate sericite with 20 to 30 percent of silt sized quartz, sericite, and carbonaceous opaque material scattered randomly through the rock. The flakes of clay and mica all show a marked planar orientation parallel to bedding. This type of shale is characteristic of the Wigram Formation.

Table 32. Stratigraphic section, upper part of Wigram Formation, Cotton Island.

Thickness (m)	Overlain by Pobassoo Formation
30	*Quartz greywacke*, blocky, pale grey to mauve, fine-grained; interbedded with *micaceous siltstone* and *quartz greywacke*, fine-grained, fissile, buff to brown.
3	*Micaceous quartz greywacke*, blocky, pale yellow, fine-grained.
9	Por outcrop. (From Wigram Island section inferred to be *argillaceous, ferruginous siltstone* (R13659), flaggy, dark green to grey, fissile; 15 cm interbeds of *sandstone*, fine-grained. Grades up into fine-grained *sandstone*).
4.5	Prominent outcrop. *Quartz sandstone,* blocky to flaggy, thinly bedded, pale grey, medium-grained; and *quartz greywacke*, pink to mauve.
4.5	*Quartz sandstone*, interbedded dark grey, thinly bedded, fine-grained, and blocky, buff.
3.6	Prominent outcrop. *Quartz sandstone*, blocky, buff, medium-grained.
18	*Quartz sandstone* and *micaceous sandstone*, thinly bedded, fine-grained, white, grey, and black.
	Dolerite sill
9+	*Black shale* (R13515), flaggy.
82 Total	Sea

Detailed correlation of sections from island to island is difficult owing to the apparent lensing of various marker beds, but no significant lateral variations have been noted.

Throughout its length of exposure the Wigram Formation has been intruded by a dolerite sill. Although it generally occurs near the black shale it does show a slight stratigraphic discordance. The black shale and dolerite crop out only at the edge of the water at the base of prominent cliffs. They have probably controlled the formation of the cliffs as they are easily eroded.

No sedimentary structures have been noted from the Wigram Formation.

Pobassoo Formation

Definition

Distribution: Lower part exposed in dip slopes and small scarps along western and northern sides of The English Companys Islands; top exposed only on Astell Island; bulk of formation concealed beneath the sea.

Reference Area: Cotton Island at about lat. 11°51'S, long. 136°28'E.

Derivation of Name: From Pobassoo Island.

Stratigraphic Relationships: Conformably overlies Wigram Formation; conformably overlain by Astell Sandstone. In places directly overlain unconformably by Buckingham Bay Sandstone.

Lithology: Flaggy, pink, purple, deep red, and green, interbedded micaceous siltstone and fine-grained quartz greywacke; interbeds of flaggy, medium-grained, buff to white, micaceous sandstone; some blocky, purple, micaceous quartz greywacke; laminated, fine-grained, micaceous glauconitic sandstone.

Thickness: About 480 m; maximum exposed about 60 m at base on Cotton and Pobassoo Islands and top 15 m on Astell Island; remainder covered by sea.

Distinguishing Features: Abundance of mica and dominant deep red to purple colour characteristic; laminated green sandstone and siltstone at top with abundant glauconite also distinctive.

Lower contact with Wigram Formation gradational; taken where the dominantly grey sediments of Wigram Formation change into dominantly red, highly micaceous, sediments of Pobassoo Formation; top defined at base of massive white quartz sandstone of Astell Sandstone.

Description and comments

The lower part of the formation consists of a sequence of pink to purple and deep red, flaggy micaceous siltstone interbedded with fine-grained quartz greywacke, with interbeds of flaggy, medium-grained, buff to white, micaceous sandstone, and some blocky, purple, micaceous quartz greywacke. In places the flaggy quartz greywacke is cross-bedded and contains abundant, well developed slump structures. The purple to red colour and the abundance of mica are prominent features of the formation.

The upper part of the formation, which is exposed only on Astell Island, consists of a sequence of interbedded flaggy to fissile, green to purple, micaceous siltstone or fine-grained quartz greywacke (R13662); flaggy dark green fine-grained quartz greywacke; and laminated, green and buff, fine-grained, micaceous glauconitic sandstone (R13661).

The micaceous, glauconitic sandstone (R13661) has a well developed lamination of buff-coloured bands and green glauconite-rich bands; the glauconite pellets are readily visible to the naked eye. In thin section the rock consists of about 60 percent quartz, 15 percent glauconite, 15 percent mica, 5 percent feldspar, and 5 percent iron oxide. The quartz is well sorted (0.07-0.1 mm) and shows secondary overgrowths. Small grains of potash feldspar are scattered through the rock. The glauconite is almost colourless and the pellets are about the

same size as the quartz grains. The muscovite generally lies in the bedding planes. The abundant olive-green material is thought to be ironstained mica, but could be a chloritic clay. Fine iron oxide is scattered through the rock and tourmaline is a common accessory.

The micaceous siltstone (R13662) contains about 50 percent quartz, 5 to 10 percent muscovite, 40 percent matrix, 5 percent feldspar, and less than 5 percent glauconite. The quartz is moderately well rounded and well sorted (0.05-0.1 mm, with a norm of 0.06-0.07 mm). Feldspar (probably potash feldspar) is scattered through the rock. The glauconite is ironstained and identification is difficult. The mica lies in the bedding planes, which tends to give a false impression of mica content in hand specimen. The matrix is composed of an olive-green-brown iron-stained limonitic or chloritic clay.

Astell Sandstone

Definition

Distribution: Exposed only on Astell Island in The English Companys Islands; forms bedrock of the island.

Reference Area: Astell Island (lat. 11°53'S, long.136°25'E).

Derivation of Name: From Astell Island.

Stratigraphic Relationships: Conformably overlies Pobassoo Formation; inferred to be overlain with angular unconformity by Buckingham Bay Sandstone.

Lithology: Massively outcropping, medium-grained, white quartz sandstone; well developed large cross-beds.

Thickness: About 180 m exposed; top eroded.

Distinguishing Features: Distinguished mainly by stratigraphic position. Base is contact between flaggy glauconitic sediments of Pobassoo Formation and overlying clean quartz sandstone of Astell Sandstone. No beds overlie Astell Sandstone on Astell Island; formation presumed to be overlain unconformably by Buckingham Bay Sandstone.

Description and comments

The Astell Sandstone is similar in lithology and has a similar air-photo pattern to the lower Buckingham Bay Sandstone, but throughout The English Companys Islands the Buckingham Bay Sandstone overlies the Malay Road Group with a marked angular unconformity. There is no sign of an unconformity between the Astell Sandstone and Pobassoo Formation, so the Astell Sandstone is considered to be a conformable unit of the Malay Road Group.

DISCUSSION

No detailed sedimentological data is available for the Malay Road Group, but it may be compared directly with the lower Roper Group, with which it has long been correlated; cycles I-J of Powell *et al* (1987) and Jackson *et al.* (1988). The Mallison Sandstone is identical in outcrop and stratigraphic position to wide areas of the Limmen Sandstone. The reddish-coloured micaceous and glauconitic siltstone and quartz greywacke of the Pobassoo Formation, passing up into the quartzitic Astell Sandstone, immediately resembles the Crawford Formation and Abner Sandstone respectively. Most of the Wigram Formation lies beneath the sea in the Malay Road and and is presumed to comprise the black shale and the dolerite which intrudes it, at the base of the Cotton Island section. This and the gradation into both the Mallison Sandstone and the Pobassoo Formation, below and above, resembles the ubiquitously regressive Mainoru Formation.

Jackson *et al* (1988) interpret the equivalent Roper Group cycle as sheetlike fluvial sands (Limmen Sandstone), passing through low-energy marine shelf silt and mud (upper Mainoru Formation) and higher energy inner shelf or shoreface (Crawford Formation) environments, to tidal flat and tidal shelf sands (Abner Sandstone).

STRUCTURE, McARTHUR BASIN

The structure of the McArthur Basin in Arnhem Land is dominated by the 50 km-wide, meridional Walker Fault Zone, flanked by the very mildly deformed Caledon and Arnhem Shelves to the east and west (Fig. 3). The Walker Fault Zone is defined as lying between the Parsons Range and Koolatong Fault Zones. It corresponds spatially with, and is the product of the syndepositional and later deformation of, the Walker Trough. In general terms the Walker Trough is now uplifted relative to the shelves either side, but it is uncertain how much of this apparent uplift is the product of post-depositional inversion of the trough or how much of it is the product of synrift central uplift and tilt blocks.

WALKER FAULT ZONE

As the name implies, deformation of the Walker Fault Zone is dominated by faulting (Fig. 23). Folding is relatively broad and open, and largely related to the faulting. Largely by analogy with the McArthur River region to the south, the major faults are considered to be syndepositional structures which controlled deposition in the Walker Trough, but evidence for this syndepositional movement in Arnhem Land is somewhat circumstantial.

Faulting : The *Parsons Range Fault Zone* lies along the western edge of the Walker Fault Zone and separates it from the Caledon Shelf to the west. Although it separates distinct, major

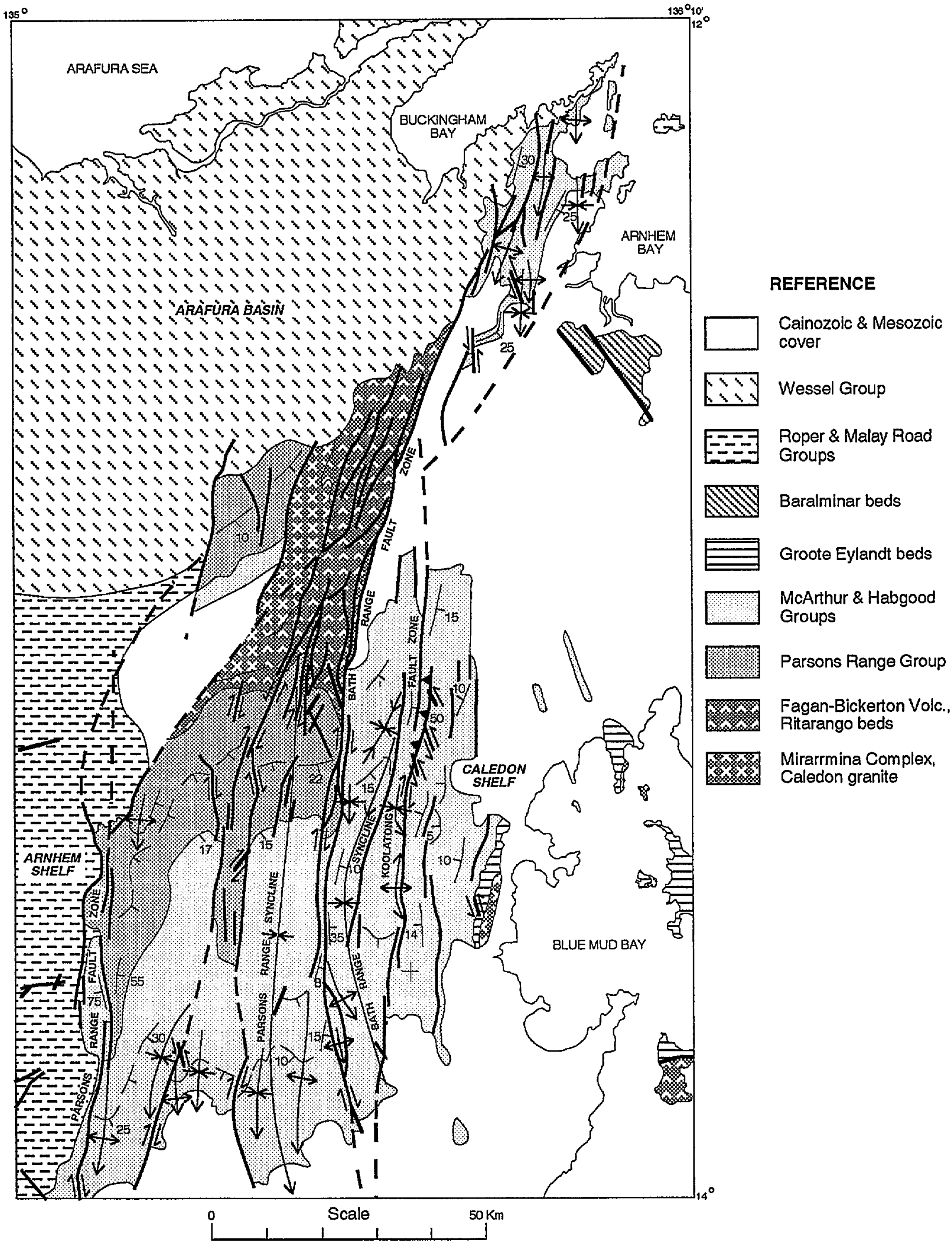

Figure 23. Structural sketch map, showing principal structures, Walker Fault Zone.

tectonic elements and is thus considered to be one of the fundamental faults of the region, there is little direct expression of the fault itself at the surface. No major shear zone is visible; only a zone of apparently minor, discontinuous faults. However, even quite short, apparently minor looking fractures display stratigraphic separations of 7 km or more, between lower Parsons Range Group to the east and Roper Group to the west. Locally the zone as whole shows stratigraphic separations of up to 10km, and perhaps more; precise estimates are not possible, because the thickness of the McArthur Group or equivalents is unknown at depth. The zone undoubtedly marks the line of a major structure at depth, and is considered to mark the sudden boundary between the very thick McArthur and Parsons Range Groups and their very much thinner equivalents only exposed again many tens of kilometres west on the Arnhem Shelf.

Stratigraphic separations vary rapidly along strike. At the southwestern tip of the Parsons Range the stratigraphic separation across the fault is about 1.7 km, west block down, and decreases rapidly southwards. Bedding dips change from easterly, east of the fault, to westerly, west of the fault. 24 kms to the north there is no visible fault, yet Parsons Range Group is in contact with Roper Group; a stratigraphic separation of in excess of 3 km. The western margin of the central Parsons Range is marked by either small faults of no visible faults at all, and yet there is some 7 km or more of stratigraphic displacement between severely down-dragged lower Parsons Range Group, and virtually undisturbed Roper Group, onlapping onto the Parsons Range Group. Clearly, the major displacements of the Parsons Range Fault Zone must predate the Roper Group, and probably include significant syndepositional components.

Northwards in the Sheridan Creek district the soil-covered extension of the fault is inferred to bifurcate into two arms. The eastern splay has a stratigraphic separation of about 10km, west-block-down, and the western splay up to 2.5 km. The point of maximum stratigraphic separation lies adjacent to the culmination of the Parsons Range Syncline. The isolated block of Parsons Range Group north of Sheridan Creek might be interpreted as having been displaced 100 km dextrally from the southwestern tip of the Parsons Range, but no unequivocal markers exist.

Physiographically, the *Bath Range Fault* is the most striking structure in Arnhem Land. It is continuously exposed for 200 km down the middle of the Walker Trough. It forms a fault-line scarp along the Parsons and Mitchell Ranges. It controls the Bath Range Range Syncline and truncates the eastern limb of the Parsons Range Syncline. There is no outcropping Parsons Range Group east of the fault. The dip of the fault is unknown but is assumed, from its trace and surface expression, to be very steep or subvertical.The shear zone is narrow and sharply defined. The fault bifurcates into anastomosing splays up to 2 km apart.

Stratigraphic displacement ranges from zero at the fault's extremities, to around 10 km, east block down, adjacent to the Mitchell Range and, once again, to the culmination of the

Parsons Range Syncline. Southwards from the Parsons Range the direct fault displacement grades into a largely monoclinal flexure, but still with large structural elevation across the feature as a whole. The overall drag and form of the eastern Parsons Range Syncline suggests a large component of dextral displacement along the Bath Range Fault. This is supported by several small to moderate dextral faults between the Bath Range and Parsons Range Faults (Fig. 23), the plethora of subparallel dextral faults in the younger system described earlier from the Mitchell Range, and steep anastomosing geometry of the fault zone. However, as is typical for large, fundamental faults, no markers for direct measurement of displacement are available.

The *Koolatong Fault Zone* is defined as marking the eastern edge of the Walker Fault Zone. Although only exposed for about 100 km, it is inferred to link up with a fault along the eastern side of Probable Island, east of Flinders Peninsula, 100 kms to the north. Both deformation and stratigraphic thickness decrease rapidly onto the Caledon Shelf to the east. East of the Koolatong Fault all of the McArthur Group below the Yarrawirrie Formation appears to be absent. The thinning of Parsons Range Group (6 km to 0), which may or may not be present at depth between the Parsons Range and Koolatong Faults, is too great for normal depositional slopes; syndepositional faulting seems inevitable.

Surface expression of the Koolatong Fault Zone is not marked (the actual fault trace is largely concealed beneath a narrow soil-filled valley), and present-day direct displacements are small. Maximum stratigraphic displacement is only about 300 m, east block down, but is the Koolatong River area a steep monoclinal flexure associated with the fault shows structural elevation of 3km, west block up. This contrasts with the large syndepositional, west block down displacement inferred by the stratigraphic differences described above, supported by local conglomerate in the Yarrawirrie Formation along the fault. NNW-trending cross faults show small sinistral offset of the Koolatong Fault (Fig. 23), and these cross faults are in turn displaced by a small dextral movement of the Koolatong Fault. A small easterly splay of the Koolatong Fault, near the Koolatong River, shows reverse movement and dips 50^{o} west.

Folding : Folds are generally broad and open. Dips only exceed 10-20^{o} near faults, where they locally range up to vertical. Synclines predominate, separated by faults, and have box fold outlines. Smaller folds may be chevron in form. Major anticlines are absent. Folds tend to be discontinuous along strike, except the major Parsons Range and Bath Range Synclines, and are closely relate to faults.

The *Parsons Range Syncline* lies between the Parsons Range and Bath Range Fault Zones, plunges up to about 20^{o} to the south, and marks the most uplifted part of the Walker Fault Zone. The western limb lies along the Parsons Range Fault, where dips range up to 55^{o}, while the eastern limb is truncated by the Bath Range Fault. The Parsons Range itself outlines a large, simple box fold with with flat trough, of thick Parsons Range Group sandstones, but farther south a more complex pattern of smaller synclines and anticlines, offset by mostly dextral faults, mark the more appressed core of McArthur Group rocks.

The trough and western limb of the shallowly south-plunging *Bath Range Syncline* is continuous for 65 km along the eastern side of the Bath Range Fault Zone. The syncline has a simple asymmetric box fold profile with a steep western limb, and a flat eastern limb, greatly modified by small cross faults and subsidiary folds, extending right across to the Koolatong Fault. Local doubly-plunging folds indicate refolded axes, but the relative chronology is uncertain. Northeast from the tip of the Bath Range, a distinctive, more-complex set of chevron folds with faulted anticlinal crests fan out from the Bath Range Syncline, in a zone correlating directly with the most structurally-elevated block between the Bath Range and Koolatong Faults.

In the *Flinders Peninsula area* folding is apparently much more significant relative to faulting than farther south. Ridge-fold anticlines with tightly appressed crests, and broad irregular synclinal troughs predominate. Limbs dip between 50-70^{o}, and folds plunge to north and south. Tight synclines occur adjacent to the Koolatong Fault extension on Gwakura and Probable Islands. Maximum uplift, south of the Kurala River, is associated with the termination of the Bath Range Fault.Young NNW-trending sinistral cross-faults offset the earlier folds.

ARNHEM SHELF

Folding : Most of the Arnhem Shelf is unfolded. Major rock units show a younging and general dip of less than 5^{o} to the southeast . The Roper Group in the southeast is mildly folded in association with faulting, with intensity increasing adjacent to the Walker Fault Zone. Box fold profiles comprise broad shallow basins, separated by narrow anticlines or small faults. Folds are elongated in a northerly direction, parallel to the main fault trends and Walker Fault Zone.

Three sharp, well-defined domes are developed within otherwise flat-lying units in the McKay and Shadforth Hills, of southwest Arnhem. The McKay Dome is 19 km long by 10 km wide, with a faulted long axis subparallel to the nearby Bulman Fault. The Shadforth Domes are circular, and about 6 and 10 km wide. Limbs dip at between 15^{o} and 25^{o}. Basement is exposed in the core of two domes, and several abutment unconformities occur through the overlying units of the Katherine River Group. The domes and associated fault are clearly synsedimentary growth features, and the assymmetry of the McKay Dome relative to the Bulman Fault indicates a sinistral displacement along the fault. Most doming appears to predate the Gundi Greywacke, but there is subsequent tectonic jointing within the Greywacke also.

Faulting : Faults on the Arnhem Shelf are clearly mapped for considerable considerable distances on air photographs but displacements are small, rarely more than 100 m of stratigraphic separation can be identified. Faults with identified displacements are most abundant in the Roper Group in the southeast, increasing in number towards the Walker Fault Zone. The minor faults form three groups striking about NW, NE, and N-NNE, parallel to those of the fracture analysis below.

The *Bulman Fault* is the major structure of the Arnhem Shelf in Arnhem Land. It trends about 130°, and is exposed as a clearly defined fracture with a very straight trace for about 100 km (plus 50 km of inferred non-exposure) across Mount Marumba. It continues for a further 130 km into the Alligator Rivers area to the northwest, while discontinuous structures continue for 100 km into the Roper River region, to the southeast. However, it shows little, if any, stratigraphic separation. It may show a few metres of vertical displacement, north block down, in the upper Wilton River area. Roberts and Plumb (1965) suggested some dextral displacement, but this is difficult to substantiate. More likely is a sinistral displacement of about 2.5 km of the Showell Creek Fault, in the east, although this displacement is not apparent in the adjacent flat-lying formations. This is consistent with fracture analysis, below, and with the apparent growth of the McKay Dome above an active sinistral fault (above).

Southeast is one of the primary trends of repeated structural reactivation in northern Australia (Plumb, 1979). Faults of this trend were reactivated several times and had a major influence on tectonic development of the Orosirian basement in the South Alligator region, to the southwest of the Bulman Fault (Needham and Stuart-Smith, 1985; Needham and de Ross, 1990). Similar major Orosirian movements on the Bulman Fault are likely, but are difficult to demonstrate in the East Alligator River area, because of the lack of outcrop of the fault's extension into the basement and of the immediately adjacent country rock. It is considered that the Bulman Fault in the Arnhem Shelf represents a reactivation of an older basement fault, in response probably to a variety of Statherian to Calymmian stresses.

The *Showell Creek Fault* trends northerly and is exposed for about 55 km across the Roper Group in the southeast of Mount Marumba Sheet, before disappearing beneath soil cover. It extends a further 150 km or more to the south, beyond the Roper River. Again, the fault shows up as a very clear fracture zone with very straight trace, but with little movement in Arnhem Land. Stratigraphic separations are very small. There may be some lateral displacement at the intersection with the Bulman Fault , but identification of the precise trace of the Bulman Fault to the southeast is difficult.The complex fracture pattern at the intersection suggests repeated reactivation and displacements of each other, and resultant development of new extensions. To the south of Arnhem Land the Showell Creek fault Zone shows a dextral offset of perhaps up to 20 km or more across the Urapunga Tectonic Ridge, but this dies out rapidly northwards. Displacements seem much greater in pre-Roper Group units, and may have been growth-fault in nature.

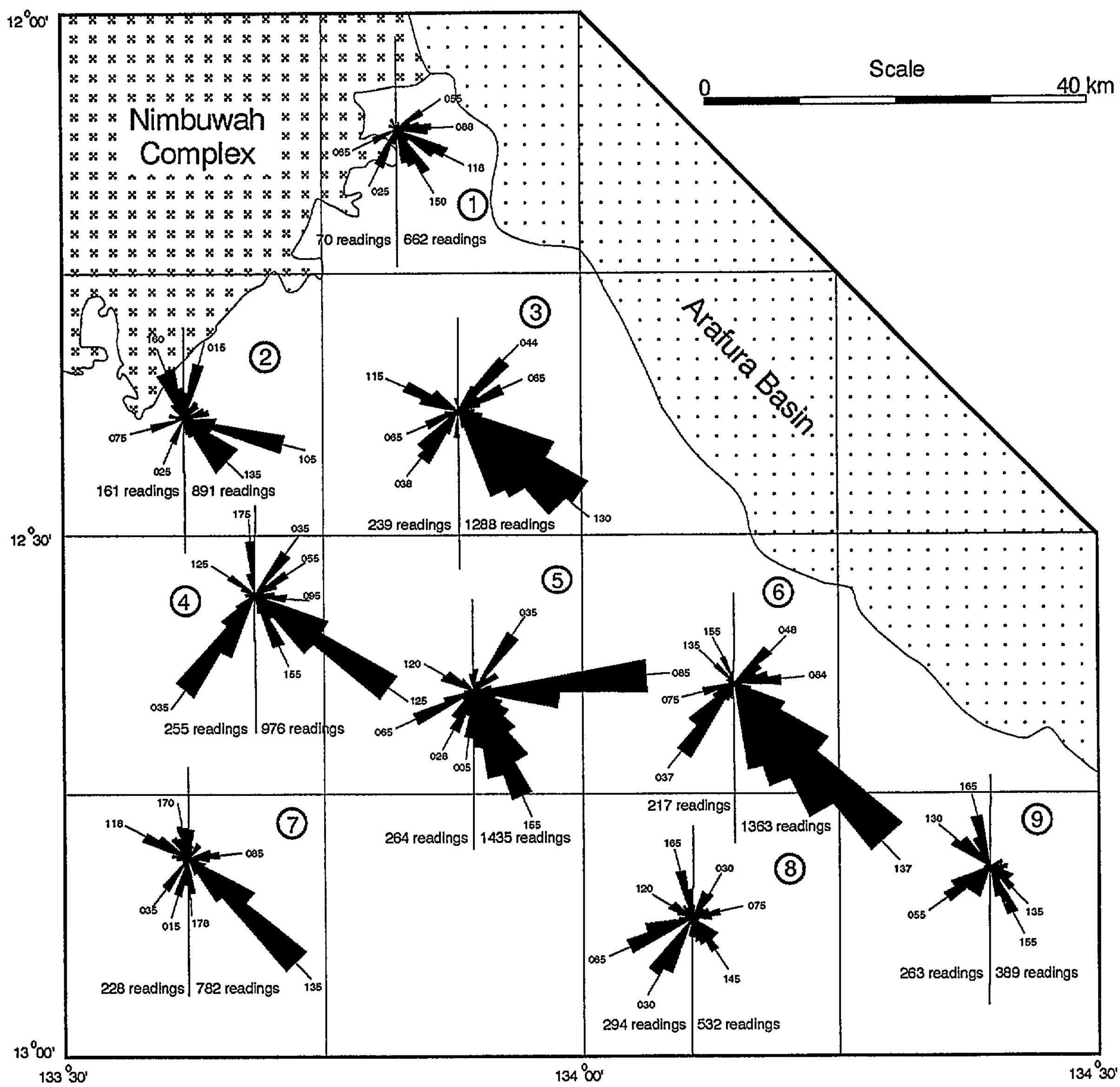

Figure 24. Strike-frequencies of joints and fractures from air photographs, Kombolgie Formation, Milingimbi Sheet area. Each diagram represents one photograph, selected as representative of 15' square. Western hemispheres show major joints (strike-length > 1.6 km, or 1 mile), plotted proportionate to length. Eastern hemispheres show minor joints plotted proportionate to number.

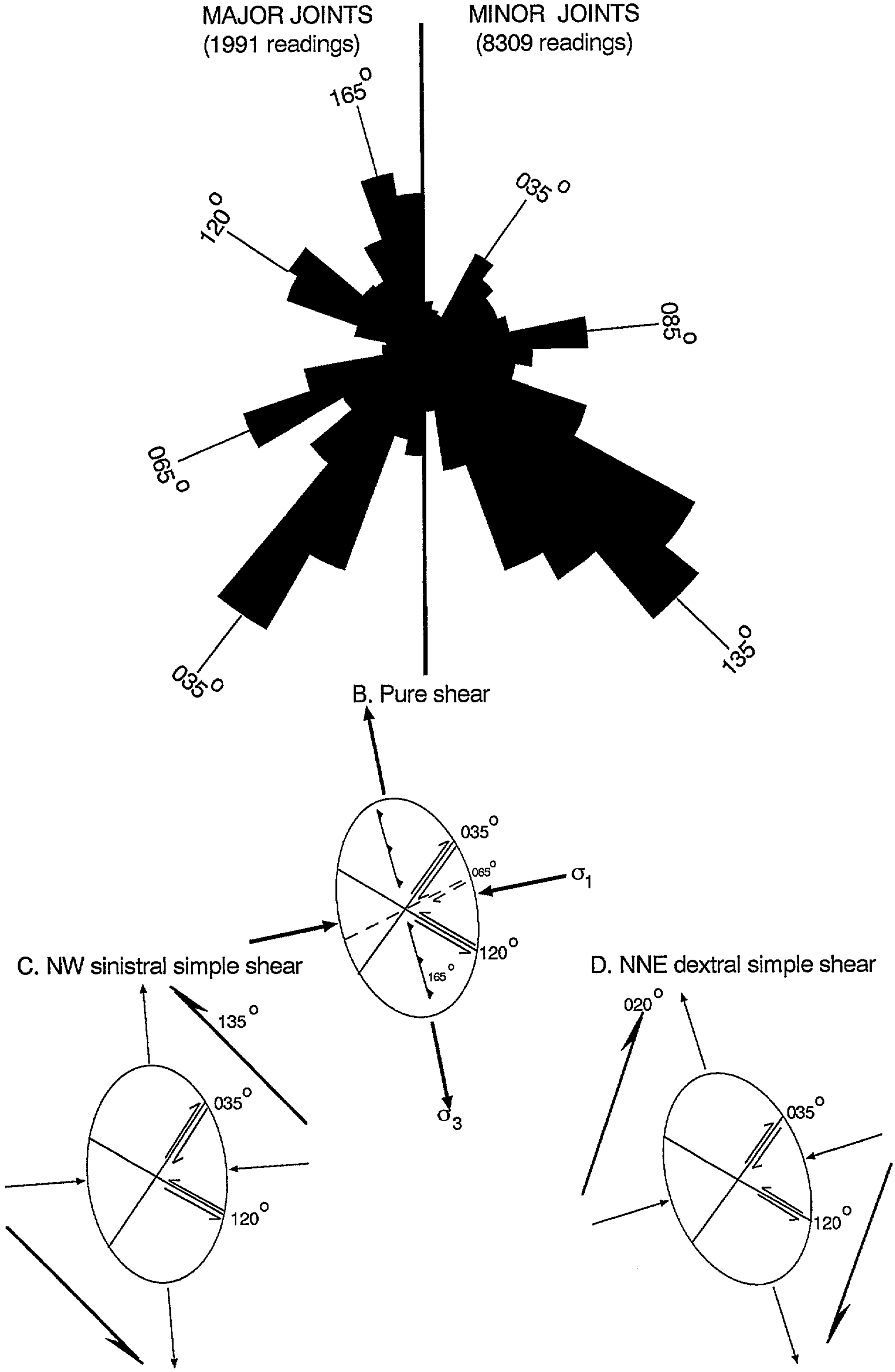

Figure 25. Composite strike-frequency of all joints and fractures measured in Figure 24. Scale of major joints 4x that of minor joints. Diagrams B, C, & D show possible theoretical strain ellipses.

Jointing : The Arnhem Land Plateau has long been famous for the very strong jointing and deep gorges in the flat-lying sandstones of the Kombolgie Formation. Large master joints can be traced for many miles and extend through several beds (gorges are up to 100 m deep), indicating a tectonic origin. They are probably small faults, but no displacement can be detected at photo scale on most of them. No dips have been measured but they are assumed, from their straight traces, to be very steep to subvertical. A statistical analysis has been carried out from air photographs from the Milingimbi Sheet area (Figs 24, 25).

The area was divided into a 15' grid and one air photo selected from each square, as representative, on the basis of (a) outcrop and intensity of jointing, and (b) proximity to the centre of the square (Fig. 24). Joints were classified as major or minor on the basis of length. Major joints are arbitrarily defined as those with a strike length of one mile (1.6 km) or greater, and their strike frequencies plotted proportionate to their length. Minor joints are shorter than one mile, and have simply been plotted in proportion to number of joints. More than 10 000 readings have been made, and grouped together in Figure 25.

The major sets, striking about 035° ("NE") and 120° ("SE"), tend to have straight traces and generally form a well defined rectangular grid; this interrelationship is apparent from the local plots on Figure 24. The "SE" fractures tend to be the longer, straighter, more through-going structures. The "NE" fractures form the shorter sides of the grid, are commonly truncated by the "SE" set, and commonly bend into more northeasterly trends. The "NE" and "SE" fractures may be considered as comprising a single conjugate set.

The other major fractures generally occur as more isolated structures, and without clear interrelationships. The 065° ("ENE") fractures commonly form long through-going structures which truncate most others. The 165° ("SSE") set tends to have short, curved, irregular traces. The "ENE" and "SSE" fractures sometimes appear to form a conjugate set but, just as commonly, "ENE" fractures form an apparent conjugate relationship with "SE" fractures.

Major fractures sometimes show small strike-slip offsets of other sets, consistent in sense of displacement, but overlapping in age. The "SE" set shows sinistral displacement of all other sets. The "NE" set shows rare dextral displacement of the "ENE" and "SSE" sets. The "ENE" set in turn shows common dextral displacement of the "NE" set, and rare sinistral displacement of the "SE" and "NE" set; extensions of the "ENE" faults in the Alligator Rivers area to the west show apparent sinistral displacement of the SE-trending Bulman Fault. The "SSE" set shows common sinistral displacement of the "NE" set and, rarely, dextral displacement of both the "NE" and "ENE" sets; in the Alligator Rivers area this same set shows consistent dextral displacement of the "ENE" set, the same sense of displacement as the subparallel Showell Creek Fault in the east.

There has clearly been multiple reactivations, with reversals in sense in some cases, and probably synchronous overlapping movements on all sets, at times. Overall, the "NE" set and, by corollary, its conjugate "SE partner", seems to have been the earliest, but the "SE" set has been associated with all movements.

The minor joints occur in consistent conjugate sets, arranged along the major joints or within blocks framed by major conjugate sets. Angular relationships observed directly on photos, both within the conjugate minor sets and between them and their controlling major joints, agree extremely well with patterns obtained by rotation or simple shear of underlying basement in the classic clay experiments of Cloos (1955; Plate 2, Fig.3). The secondary shears predicted from Cloos's results (Table 33), for the major fractures in Figure 25, agree well with the patterns of Minor Joints generated in Figure 25 .

Table 33. Theoretical orientation of secondary joints generated from observed shear on the major fractures from Figure 25, from mechanism used in calculations of Figure 25C and D after Cloos (1955).

MAJOR SHEARS	SECONDARY JOINTS	
	SYNTHETIC	ANTITHETIC
020° - 040° ("NE") DEXTRAL	035° - 055°	110° - 130°
110° - 130° ("SE") SINISTRAL	095° - 115°	020° - 040°
060° - 080° ("ENE") DEXTRAL	075° - 095°	150° - 170°
160° - 180° ("SSE") SINISTRAL	145° - 165°	070° - 090°
160° - 180° ("SSE") DEXTRAL	175° - 195°	070° - 090°

These combined data are interpreted to be clear evidence that the joint pattern of Arnhem Land is the product of strike-slip shear. Plumb *et al.* (1980), in a summary analysis, interpreted the data of Figure 25 in terms of the ordered wrench-fault tectonics model of Moody and Hill (1956), to propose deformation of the Arnhem Shelf by shearing along major shears parallel to either the Bulman Fault or the 'Batten' (Walker) Fault Zone. A new analysis is presented below.

The models used by Cloos (1955) for shear deformation of clay are assumed, in which either stretching/compression (pure shear) or rotational shear (simple shear) within the basement is transmitted into the overlying cover (Kombolgie Formation). In the experiments of Cloos, and many others, symmetrical conjugate shears are initially propagated at angles of 30° either side of the principal stress (σ_1) and, as deformation proceeds, the angle between the shears (2θ)

progressively opens. For pure shear, the deformation obviously proceeds symmetrically relative to σ_1 and σ_2 throughout. For simple shear, σ_1 is first propogated in the cover at 45° to the direction of shear, but will become assymetric relative to shears as rotation proceeds.

In Figure 25 symmetrical conjugate shears with $2\theta = 60°$ are 'deformed' graphically, by stretching an initial unstrained circle into strain ellipses in which 2θ has increased to 85°, the angle between 035° and 120° in Figure 25. All three possible strains are tested; pure shear (Fig 25B), sinistral simple shear (Fig. 25C), and dextral simple shear (Fig. 25D). The resultant ellipses are then rotated so that the secondary shears are parallel to 035° and 120°. Two features are immediately apparent:

1. The ellipses are not significantly different in orientation;

2. The directions of primary simple shear precisely parallel major strike-slip structures in the region; the sinistral Bulman Fault (130°), and the dextral Walker Fault Zone (020°) along the Mitchell Range.

The subparallel orientation of the alternative ellipses is, to some degree fortuitous, because the angles between the various structures are not far different from 90° or 45°. However, the parallelism between the theoretical simple shear directions and major regional structures is unique. The Kombolgie Formation has been deformed in response to shear deformation in the underlying basement.

It is not possible from the data in Figure 25 alone to unequivocally eliminate any of the three mechanisms, B, C, or D. However, in the absence of any major shear or fault zones nearby (the Walker Fault Zone, for example, is 200 km to the east), pure shear in the underlying basement (Fig. 25B), related to either regional extension or compression, is the preferred model.

The actual shear planes developed in the basement are most likely controlled by reactivation of preexisting structures. NW (130°) and NNE (020°) structures are fundamental trends in Arnhem Land and throughout northern Australia. They were initiated before the McArthur Basin, and are probably widespread beneath the Arnhem Shelf. In the Alligator Rivers area ENE faults have definitely been reactivated from earlier faults in the basement. Major controlling structures of the Batten Trough (e.g. Emu Fault) and southern Walker Trough, the Showell Creek Fault (above), and pre-McArthur Basin faults in the Fagan Volcanics and Ritarango beds (above) parallel the SSE group.

Any stress field oriented approximately like that of Fig. 25B will reactivate NW (130°) and NNE (020°) basement shears to generate, in turn, secondary shears in the cover as in Fig. 25C or D. The shears actually propagated into the cover will, of course, vary from parallel to the primary shears, to fully-rotated synthetic shears, so the final spread of major fractures will be 130°-110° and 020°-040°, the range actually observed. In view of the distance from the Walker Fault Zone, the principal direction of reactivation on the Arnhem Shelf is probably NW, parallel to the Bulman Fault and principal structures in the nearby Alligator Rivers region. This is supported by the through-going nature of these structures and the predominance of minor joints in this direction.

The ENE and SSE fracture sets are more obscure. As noted, the four major sets have probably all operated concurrently, by reactivation, for much of their history. The long, through-going traces of the ENE fractures are consistent with reactivation of old structures. Their trend (060°-080°) is subparallel to σ_1 (Fig. 25B). Small variations in direction of σ_1 during successive reactivations can produce either the dextral or sinistral offsets observed, or the faults may be tensional. In the Katherine area, to the southwest of Arnhem Land, the ENE and NW sets form a clear conjugate pair.

The SSE fractures are subperpendicular to σ_1 in Fig. 25B, and may therefore have a reverse or thrust component of movement; a feature in agreement with their short irregular curved traces. Similarly to the ENE set, small variations in σ_1 can produce either small dextral or sinistral offset; e.g., σ_1 for a conjugate ENE-NW pair will produce a sinistral component of offset on ENE fractures, as observed. The SSE-trending major structures of the Batten and Walker Troughs and the Showell Creek Fault, have all had major dextral displacements at times, both syndepositional with rifting and post-Roper Group (Plumb *et al.*, 1980).

In summary, the Arnhem Shelf has been deformed principally by strike-slip shear on a network of mostly small faults and fractures, developed in response to reactivations of pre-existing structures in the underlying basement, and during several periods of regional compressive or extensional stress. The overall mild deformation and lack of folding suggests extension as the more important. Tension has been in a generally northerly direction, and compression generally easterly, during all events.

CALEDON SHELF

The McArthur Basin sediments on the poorly-exposed Caledon Shelf are essentially undeformed. The Groote Eylandt beds, Baralminar beds, Mount Bonner Sandstone, Wilberforce beds, and Malay Road Group dip at less than 10° in uniform patterns away from their respective basement highs, essentially reflecting primary basinal dips. There is an indication of a set of small northwesterly-trending faults in the Baralminar beds, but outcrop is insufficient to determine any pattern of movements.

DISCUSSION

Several consistent patterns emerge from the descriptions above, both of the Walker Fault Zone and Arnhem Shelf, and of the Ritarango beds and Fagan Volcanics. The deformation is always controlled by regional faulting. There are several periods of syndepositional and post-depositional fault reactivation. Major faults are inherited from older basement features: those of the Walker Fault Zone are continuous with faults which seem to have been active before the McArthur Basin, in the Ritarango beds; faults on the Arnhem Shelf are continuous with older basement faults of the Pine Creek Inlier. Although markers are not available to assess actual displacements on the major faults, there is abundant evidence for large strike-slip displacements. Strike-slip shear patterns clearly dominate the fracture system of the Arnhem Shelf. Strike slip displacements may be demonstrated on many of the minor faults of the Walker Fault Zone, while the steep dips and anastomosing form of the major faults and associated drag structures support their strike-slip nature.

The latest structural event apparent in the Walker Trough is clearly a roughly E-W to perhaps NE-SW compressional component which has caused inversion of the earlier rift structures and most of the deformation now apparent. It is most immediately apparent as a conjugate st of minor NW and NE faults which offset major faults such as the Koolatong Fault, the development of reverse faulting on the Koolatong Fault, and probably on other faults such as the Bath Range Fault, and probably much of the folding observed. This stress field would also be consistent with observed major dextral movements on major NNE-trending faults, such as the Bath Range Fault. This pattern is also precisely consistent with the youngest movements described from the Ritarango beds and Fagan Volcanics, and the fracture pattern of the Arnhem Shelf.

Earlier movements, syndepositional with the McArthur and Parsons Range Groups are more equivocal. The only direct evidence of faulting at this time is local conglomerate at the base of the Yarrawirrie Formation along the Koolatong Fault, and the clear evidence that the major movements on the Parsons Range Fault are pre-Roper Group. Circumstantial evidence involves the fault-bounded nature of the major depositional units of the McArthur and Parsons Range Groups, and analogy with equivalent sequences in the Batten Trough, of the southern McArthur Basin, where syndepositional faulting can be clearly demonstrated (e.g., Plumb *et al.*, 1990). In the southern McArthur Basin there is clear evidence of a strong dextral component of syndepositional movement along the NNW-trending Batten Trough (Plumb *et al.*, 1980; Dashlooty & Davidson, 1986). This has been interpreted in terms of extension in a general NW-SE direction, oblique to the trend of the Batten and Walker Troughs (Plumb *et al.*, 1990), an interpretation wholly in agreement with the pure shear model for the Arnhem Shelf (Fig 25), and the predominantly dextral component of movement along faults of the Walker Trough. Reconstructing the shape of the resultant rift(s) within the Walker Trough from palaeogeography reveals a dichotomy between the Parsons Range and McArthur Groups. Thickness variations from the stratigraphy described above reveals a clear half-graben thickening to the east or northeast for the Parsons Range Group, while the McArthur Group half-graben clearly thickens in the reverse direction, to the west or southwest. The present uplift of the Parsons Range Group and underlying basement of Fagan Volcanics, Ritarango beds, and Mirarrmina Complex is not necessarily entirely due to post-depositional deformation or reversal. Much of the uplift may well be due to the development of syndepositional tilt blocks, although no evidence is yet available from the stratigraphy for such uplift. In this context, it is likely that much of the NNE dextral faulting within the Ritarango beds, which dies out at the base of the McArthur Basin sequence, could also be related to this McArthur Basin extension and tilt block development..

ARAFURA BASIN SUCCESSION

CAMBRIAN

WESSEL GROUP

Definition

Distribution: Arafura Basin in northern part of Arnhem Land. Outcrops bounded in south by arcuate line from The English Companys Islands and Flinders Peninsula in northeast, southwards along east side of Buckingham River, westwards around headwaters of Woolen and Goyder Rivers, and then north-westwards across Milingimbi Sheet area to the coast near Junction Bay. In the north, exposures are concealed by the sea.

Reference Area: From Woolen River, in the south, to Wessel and The English Companys Islands in north.

Derivation of Name: From Wessel Islands.

Stratigraphic Relationships: Rests with marked angular unconformity on Malay Road, Habgood, Parsons Range, Roper and Katherine River Groups, Ritarango Beds, Fagan Volcanics, and Nimbuwah Complex; unconformably overlain by Lower Cretaceous Mullaman Beds and younger deposits.

Components: Comprises Buckingham Bay Sandstone, Raiwalla Shale, Marchinbar Sandstone, and Elcho Island Formation.

Lithology: Alternating arenite (quartz sandstone, quartz greywacke) and lutite (rich in clay and carbonate).

Thickness: About 1.4 km exposed; several thousand metres of additional section probably obscured by sea.

Distinguishing Features: Mainly stratigraphic relationship to older units. Base defined by angular unconformity; top lies beneath sea.

Age: Early(?) to Middle Cambrian

Description and comments

Table 34. Summary of stratigraphy, Wessel Group.

ROCK UNIT	THICKNESS (m)	LITHOLOGY	TOPOGRAPHY	DISTRIBUTION	STRATIGRAPHIC RELATIONSHIPS	REMARKS
Elcho Island Formation	150+	Ferruginous or feldspathic, micaceous glauconitic siltstone & sandstone; dolomitic siltstone; chert; chert breccia	Crops out poorly in coastal cliffs and wave-cut platforms	Scattered exposures along shoreline, from near mouth of Woolen R. to Drysdale Is.; Wessel Is/Truant Is., Arnhem Bay/Gove Sheets	Conformably overlies Marchinbar Sst.; unconformably overlain by Lower Cretaceous rocks	Upper part of unit extends beneath sea; thickness unknown
Marchinbar Sandstone	~ 240	Quartz sandstone	Resistant unit; forms line of cuestas	Arcuate belt of outcrops from Wessel Is., in Wessel Is Sheet, across Arnhem Bay and Milingimbi Sheets, to the coast in Junction Bay Sheet	Conformably overlies Raiwalla Shale	
Raiwalla Shale	~ 550 - 600	Shale & siltstone (dolomitic); interbeds fine-grained sandstone, argillaceous quartz greywacke, micaceous ferruginous quartz greywacke; minor quartz sandstone	Very poorly resistant. Scattered outcrops in creeks or in scarps beneath resistant overlying units		Conformably overlies Buckingham Bay Sst.	Little known. Very sparse outcrop
Buckingham Bay Sandstone	150 - 450 (ref. area.)	Brown quartz greywacke; quartz sandstone	Resistant unit; forms scarps and rugged rocky outcrops, or caps backslopes of islands	Arcuate belt of outcrops from The English Company's Is, in Wessel Is/Truant Is Sheet, across Arnhem Bay and Milingimbi Sheets, to the coast in Junction Bay Sheet	Basal unit of Wessel Gp. Unconformably overlies a wide variety of older units	Contains *Scolithus*

Outcrops of the Group are poor; most of the Arafura Basin is covered by Lower Cretaceous Mullaman Beds, Cainozoic soils and laterite, or sea.

The group consists of alternating arenite and lutite. The arenites are generally quartz sandstone containing cross-beds and ripple marks. The lower part of the Buckingham Bay Sandstone at the base of the group consists predominantly of quartz greywacke containing volcanic rock fragments, mica, sericite, and in places glauconite. These rocks probably reflect relative tectonic instability during the initial deposition within the basin. The arenites grade downwards into flaggy fine-grained sandstone and quartz greywacke, with varying amounts of volcanic fragments, clay, feldspar and, almost invariably, glauconite. Fine ripple marks and lenticular bedding are common. The lutite sequences are generally thinly bedded and rich in clay and carbonates.

The lithology is discussed under the formations. The stratigraphy is summarised in Table 34.

Buckingham Bay Sandstone

Definition

Distribution: Crops out around Arafura Basin in arcuate line from northern edge of The English Companys Islands and Flinders Peninsula in northeast, southwards along east side of Buckingham River, westwards around headwaters of Woolen and Goyder Rivers, and then northwestwards across Milingimbi Sheet area to coast on western side of Junction Bay. Outcrops reasonably consistent in east, but very scattered to west in Milingimbi Sheet area.

Reference Area: Northwestern side of Flinders Peninsula around mouth of Kurala River (about lat. 12°15'S, long. 135°53'E).

Derivation of Name: From Buckingham Bay. Informally named Buckingham Bay Formation (Crohn, 1954).

Stratigraphic Relationships: Conformably overlain by Raiwalla Shale; overlies Malay Road, Habgood, Parsons Range, Roper, and Katherine River Groups, Ritarango Beds, Fagan Volcanics, and Nimbuwah Complex with marked angular unconformity.

Lithology: Massive purple-brown quartz greywacke; white quartz sandstone.

Thickness: About 450 m, reference area; thins to less than 150 m westwards. Distinguishing Features: Massive purple-brown ferruginous quartz greywacke with large cross-beds has a characteristic tendency to weather into large rounded boulders; occurrence of *Scolithus* diagnostic. Arenites strongly jointed and generally crop out boldly; results in a very distinctive 'jointed' pattern on air-photographs.

Base defined by marked angular unconformity; upper boundary taken where shale becomes predominant.

Description and comments

Because of the prevailing low dips throughout most of the area of outcrop it is extremely difficult to determine the complete sequence. Outcrops are scattered and access is poor; most of the observations were made at scattered localities during a rapid helicopter reconnaissance.

From the air-photographs and the limited dip information the Buckingham Bay Sandstone is estimated to be about 450 m thick in the Arnhem Bay/Gove and Wessel Islands/Truant Island Sheet areas. Farther west in the Milingimbi Sheet area, it is to be estimated to be about 150 m thick and thinning westwards.

Throughout the area two broad divisions can be recognised within the formation: an upper zone about 150 m thick, consisting of white quartz sandstone, and a lower zone, about 300 m thick, consisting mainly of massive purple quartz greywacke and minor quartz sandstone. No significant lateral variations are apparent.

The best sections of the lower part of the formation are found in the coastal exposures to the west of the mouth of the Kurala River. The sequence consists of irregularly alternating massive purple-brown fine-grained ferruginous quartz greywacke, massive purple spotted quartz greywacke, distinctive flaggy reddish purple fine-grained micaceous, ferruginous, and argillaceous quartz greywacke, and blocky white quartz sandstone.

The white quartz sandstone beds commonly contain vertical tubes formed by burrowing organisms and identified by Opik (pers. comm.) as *Scolithus*.

The massive quartz greywacke beds are up to 3 m thick; intense intraformational folding (apparently due to slumping) is a common feature.

The massive purple-brown, fine to medium-grained ferruginous quartz greywacke is the most characteristic rock type of the Buckingham Bay Sandstone. Bedding units range from about 2.5 to 3 m thick, and are commonly cross-bedded. The quartz greywacke is regularly jointed and characteristically weathers into large rounded boulders. In thin section the rock (R13458) consists dominantly of quartz (85-90%) which is subrounded and moderately well sorted. Fine-grained igneous rock fragments, clay pellets, and rare feldspar, constitute up to 5 to 10 percent of the rock, while small discrete grains of iron oxide, less than 0.006 mm in size, along the intergranular boundaries forms up to 5 percent of the rock. The rock is cemented by quartz.

The spotted quartz greywacke (R13456) contains abundant dark spherical patches about 0.5 cm in diameter marked by concentrations of hematite and, locally, mica; the iron oxide forms only about 2 to 3 percent of the rock. The rock contains from 80 to 85 percent of rounded quartz grains which show secondary overgrowths. The grainsize falls in the fine sand range. Igneous rock fragments, subordinate feldspar, and pods of sericite after feldspar, make up the rest of the rock. Sphene is accessory and detrital muscovite is rare.

The micaceous ferruginous, argillaceous quartz greywacke (R13457) is distinguished by flaggy bedding partings with abundant mica lying in the bedding, and by its distinctive reddish purple colour. The rock is fine-grained and contains about 70 percent subrounded quartz grains. Interstitial clay, and pods of clay, probably after feldspar, form about 30 percent of the rock. Iron oxide coats grains, and feldspar and rock fragments, both igneous and chert, are minor. Tourmaline, zircon, muscovite and sphene are accessory.

The base of the lower unit consists of massive cross-bedded white quartz sandstone, with Scolithus(?), or a thin massive sandstone conglomerate. The conglomerate is poorly sorted and contains boulders up to 1 foot across derived directly from the underlying basement.

The upper unit consists invariably of massive, cross-bedded, white, medium-grained quartz sandstone with minor coarse-grained zones. In places the exposed surfaces of the sandstone weathers purple-brown. In the upper Buckingham River, large-scale steep cross-beds have been recorded, while farther north near the Warawuruwo River the foresets dip at a very low angle.

In thin section the rocks (R1354, R13663, R13664) consist almost entirely of quartz grains set in silica cement; secondary enlargement of grains is common. The original grains are well sorted and rounded. Grains of cloudy feldspar, rock fragments and chert generally make up about 1 to 2 percent of the rocks, and one specimen (R13663), from south of the Muckaninnie Plains, contains scattered grains of pale green glauconite.

In this southern area the top of the unit, (overlying the quartz sandstone), consists of flaggy purple medium-grained quartz greywacke with interbeds of laminated shale increasing towards the top

Definition

Distribution: Generally exposed only in scarps beneath more resistant overlying units or in creeks. In north-east upper 30 to 60 m well exposed in scattered cliff sections beneath resistant Marchinbar Sandstone along eastern side of Wessel Islands and Napier Peninsula; rest of sequence lies beneath sea. On mainland formation is exposed in arcuate belt of scattered exposures from Buckingham Bay, southwestwards across Woolen and Goyder Rivers, then northwestwards across the Milingimbi Sheet area to near Maningrida Settlement.

Reference Area: Scattered outcrops around Woolen River (about lat. 12°20'S, long. 135°25'E), between Napier Peninsula and Muckaninnie Plains.

Derivation of Name: From Raiwalla River on southwestern side of Buckingham Bay.

Stratigraphic Relationships: Conformably overlies Buckingham Bay Sandstone; conformably overlain by Marchinbar Sandstone.

Lithology: Green to grey shale and siltstone (dolomitic); interbeds of flaggy fine-grained sandstone, argillaceous quartz greywacke, micaceous ferruginous quartz greywacke; minor quartz sandstone.

Thickness: About 550 to 600 m.

Distinguishing Features: Distinguished by stratigraphic position and predominance of flaggy green and grey shale.

Both top and bottom contacts gradational; top taken where thick shale units disappear and quartz sandstone becomes predominant; base drawn where dominantly arenaceous succession of Buckingham Bay Sandstone gives way to finer-grained rocks.

Description and comments

The thickness is difficult to estimate because of poor exposure and the prevailing low dips. In Arnhem Bay/Gove and Wessel Islands/Truant Island Sheet areas the thickness has been estimated from maps to be about 550 to 600 m. Farther west in the Milingimbi Sheet area Rix (1963) gives 900 m (3000 feet) as the thickness, but in view of the very poor outcrop this figure must be regarded as only a rough approximation.

From isolated well exposed sections in creek beds it is apparent that most of the formation is composed of fissile, green to grey shale and siltstone with scattered 2 cm interbeds of grey to white fine-grained sandstone; the shale only crops out rarely. Most of the exposures in the area consist of low rubble-covered rises with scattered outcrops of thinly flaggy, ripple-marked, pale green to white, fine-grained sandstone (micaceous in places); fissile, argillaceous fine-grained quartz greywacke and siltstone; and fissile, grey to purple, micaceous, ferruginous quartz greywacke and siltstone. It is apparent from the relationship to known outcrops of shale that these rubble-covered rises are simply erosional remnants within a dominantly grey shale succession. Beds about 15 m thick of white, cross-bedded and ripple-marked, sugary quartz sandstone are scattered through the section.

The available outcrop suggests that the flaggy sandstone interbeds are most prominent in the upper 150 m and lower 150 m or so of the unit while the central 270 m is shale with only about 5 percent of fine-grained sandstone; this interpretation could be misleading however as outcrop is very sparse in this central portion.

In thin section the rock (R13669) is an argillaceous dololutite composed of very fine-grained (less than 0.01 mm) carbonate (70%) and clay (30%); the carbonate is probably dolomite. It is laminated and the clay tends to be concentrated into microlenses rimmed by relatively coarse (0.03 mm) carbonate crystals. The clay grains are oriented parallel to the bedding. In outcrop the shale lacks any sedimentary structures except thin, regular, bedding.

The most common sandy interbeds are pale green to white, thinly flaggy, ripple-marked, fine-grained sandstone which weathers purple. In thin section, the sandstone (R13665) contains about 90 percent quartz and about 1 to 2 percent each of feldspar (plagioclase and potash feldspar), rock fragments, fine iron oxide, glauconite, and accessory muscovite, zircon, tourmaline, and apatite. The sandstone is well sorted, and the grainsize is mainly about 0.1 to 0.06 mm. The silica cement forms overgrowths on the quartz grains.

The fissile, fine to medium-grained argillaceous quartz greywacke contains about 15 to 20 percent of interstitial clay (probably kaolin) matrix in an open framework of well sorted quartz grains. Small amounts of rock fragments, glauconite, and feldspar are present.

Fine-grained micaceous, ferruginous quartz greywacke (R13668) is common; muscovite tends to lie in the bedding, but constitutes only about 2 to 4 percent of the rock. Ragged interstitial hematite grains (in excess of 5%) are scattered throughout the rock. The rock contains about 85 percent of well sorted quartz grains (average 0.06 mm) recrystallised into a tightly packed mosaic. It contains some feldspar and rock fragments and accessory tourmaline and zircon.

The best exposures of the formation are found in small cliffs along the east coast of Napier Peninsula and the Wessel Islands where the top 45 m is preserved beneath the resistant Marchinbar Sandstone.

A section has been measured by Owen (1954) on Marchinbar Island; his unit 8 is the base of our Marchinbar Sandstone. He notes that unit 5 is important in being the host rock for some of the bauxite deposits in the area and records that an analysis shows it to contain about 55 percent sericite, 42 percent quartz, and the balance, hydrous titania and limonite. Most of the quartz grains are less than 0.03 mm although some range up to 0.15 mm. Farther south, on

Napier Peninsula the siltstone of units 5 to 7 is laminated with fissile bedding partings and mudcracks. Scattered flaggy interbeds of ripple-marked white quartz sandstone occur with occasional interbeds, 3 feet thick, of a distinctive fissile purple-brown siltstone.

In the sandstone bed (unit 2) Owen records persistent thin shaly bedding partings and notes large symmetrical ripple marks with an amplitude of 2 to 3 inches (-5-7.5 cm) and wave length of 12 inches (30 cm).

The lowest member consists of fissile interlaminated and white siltstone with some mica and 2-inch (5 cm) lenticular beds of white quartz sandstone. Owen notes that the interbeds have convex lower surfaces and planar upper surfaces which indicates that they are infillings of gutters in offshore silts. In thin section the laminated siltstone (R13671) consists of alternating beds of iron-rich silt and clay-rich silt. The dark banks contain about 40 percent quartz, 55 percent leucoxene, and 3 to 4 percent mica. Both the quartz and leucoxene has a uniform grainsize of about 0.03 mm.

Marchinbar Sandstone

Definition

Distribution: Forms bedrock of most of Wessel Islands; scattered exposures also found in narrow arcuate belt from Napier Peninsula and eastern side of Elcho and Drysdale Islands in northeast, southwest part Woolen River, then west-northwest across Milingimbi Sheet area to coast at Hawkesbury Point, near Junction Bay.

Reference Section: Marchinbar Island at about lat. 11°15'S, long. 136°39'E.

Derivation of Name: From Marchinbar Island.

Stratigraphic Relationships: Conformably overlies Raiwalla Shale and conformably overlain by Elcho Island Formation.

Lithology: Uniform white quartz sandstone.

Thickness: About 240 m.

Distinguishing Features: Uniform quartz sandstone, regular thin bedding in lower parts, banded and strongly jointed sandstone pattern on air photographs, distinctive.

Base defined as point where dominantly shaly beds of Raiwalla Shale change into thick sandstone unit; at top, Marchinbar Sandstone in contact with flaggy ferruginous sandstone, grading up into flaggy fine sandstone and siltstone of Elcho Island Formation.

Description and comments

In outcrop the Marchinbar Sandstone consists entirely of white quartz sandstone.

On air-photographs it has a distinctive pattern due to the development of the prominent closely spaced jointing; the two joint directions generally intersect at angles about 60o to 70o. A marked light and dark banding is present near the middle of the unit, apparently due to non-outcropping shale interbeds.

In the Napier Peninsula/Elcho Island area the lower part of the formation is more thinly bedded than the top. The base consists of regularly thin-bedded, pink to white, fine to medium-grained quartz sandstone. Ripple marks are common, cross-bedding is minor, and very thin shale bedding partings are common; the massive outcrops of thin-bedded sandstone are very distinctive. In thin section the rock (R13672) is composed of more than 90 percent well sorted and rounded quartz grains, 0.1 to 0.3 mm in size, forming an open framework within a matrix of very fine leucoxene.

The upper part of the formation on Elcho Island consists of massive, pink to white quartz sandstone with well developed cross-bedding. In thin section the rock (R13673) consists of over 95 percent well sorted quartz grains, 0.06 to 0.3 mm in size, set in a silica cement. Quartz overgrowths are common. Very fine specks of leucoxene (1-2%), with occasional larger grains of ilmenite, are scattered throughout the rock, as is minor muscovite (1-2%). Rare sericitised feldspar occurs and tourmaline and zircon are accessory.

Farther south near the Woolen River, and to the north on Drysdale Island, the Marchinbar Sandstone is thinly bedded throughout the section and contains both cross-beds and ripple marks.

Elcho Island Formation

Definition

Distribution: Exposed along shores of Elcho and Howard Islands; minor exposures to northeast on Drysdale Island, and near mouth of Woolen River, in southwest.

Reference Area: Cliffs at Elcho Island Mission and, along northwest coast of island.

Derivation of Name: From Elcho Island.

Stratigraphic Relationships: Conformably overlies Marchinbar Sandstone; unconformably overlain by Lower Cretaceous rocks and Cainozoic soils.

Lithology: Flaggy, green to purple-brown, ferruginous or feldspathic, micaceous glauconitic siltstone and sandstone; flaggy leached dolomitic siltstone, chert, chert breccia.

Thickness: Only lower 150 m crop out; probable that further several thousand metres of younger sediments lie beneath sea.

Distinguishing Features: Green to purple glauconitic sediments at base, grading upwards into carbonate succession, characteristic. Base defined at change from quartz sandstone of Marchinbar Sandstone to glauconitic sediments of Elcho Island Formation; top not exposed.

Description and comments

The base of the formation is best exposed in the low cliffs adjacent to the Elcho Island Mission Station. The section is shown in Table 35.

Table 35. Stratigraphic section, lower part of Elcho Island Formation, Elcho Island.

Thickness (m)	
3	Laterite profile
21	*Ferruginous, micaceous, glauconitic siltstone* and *fine sandstone,* flaggy, green-grey to purple (R13676); interbedded with *feldspathic, micaceous, glauconitic sandstone* and *shale* (R13675), flaggy to fissile, green to brown.
~15	Forms wave-cut platform - difficult to estimate thickness. *Feldspathic, glauconitic, ferruginous sandstone* (R13674), deep purple to chocolate-brown, flaggy (with some blocky beds), slightly micaceous, fine-grained; irregular 'wavy' bedding, some ripple marks.
	Conformably underlain by Marchinbar Sandstone.

Farther north along the western coastline of Elcho Island this section is overlain by a distinctive succession of flaggy white leached dolomitic siltstone, chert, and chert breccia. The bedding is irregular and complex intraformational folding, probably due to slumping, is common. Many of the chert breccias are clearly slump breccias related to the folds. These outcrops are discontinuous and no contact is visible with the underlying glauconitic sediments.

Scattered outcrops of these rocks continue southwards along the coast of Howard Island and the mainland near the Woolen River. Away from the immediate shoreline, however, the rocks become highly lateritised and silicified and are barely recognisable; lateritisation of the basal beds of the formation has given rise to most of the bauxite deposits on Elcho and Marchinbar Islands.

In thin section, the ferruginous, micaceous, glauconitic siltstone (R13676), contains about 75 percent quartz with a grainsize of 0.03 to 0.07 mm. It is cemented by silica with secondary overgrowths of quartz. Small pellets of glauconite, about 5 to 10 percent of the rock, are scattered throughout the rock while mica, about 10 percent of the rock, lies in the bedding.

Both muscovite and subordinate biotite occur, but the biotite is frequently altered to iron oxide. Scattered fine (0.02 mm) grains of black iron oxide constitute about 5 percent of the rock and feldspar is less than 5 percent. Apatite, zircon, and tourmaline are accessory.

In specimen R13675, a feldspathic, micaceous, glauconitic sandstone, quartz (about 80%) and feldspar (less than 5%) are well sorted (0.06-0.08 mm) and cemented by silica. Glauconite and mica both form about 5 to 10 percent of the rock as in specimen R13676, but iron oxide is very minor (1-2%) and appears to be an alteration product of biotite. Minor rock fragments are present and tourmaline, zircon, apatite, and biotite are accessory.

The basal fine-grained feldspathic, glauconitic, ferruginous sandstone (R13674) contains well sorted and rounded grains of quartz (75-80%), feldspar (5%), and rock fragments (2-3%) about 0.07 to 0.08 mm. The feldspar includes both plagioclase and microcline while the rock fragments appear to be volcanic. Interstitial hematite (10%) forms a matrix with fine silica, which probably acts as a cement. Olive-green glauconite forms well developed pellets up to 0.5 mm, but is frequently weathered out of the rock. Minor mica lies in the bedding and tourmaline, apatite, and coarse iron oxide are accessory.

DISCUSSION

The Wessel Group has previously been considered to be of latest Proterozoic age on the basis of a K-Ar age determination of glauconite (e.g., Dunnet, 1965; Plumb, 1965; Plumb & Derrick, 1975), but the discovery of trilobites in the Elcho Island Formation has clearly confirmed an Early to Middle Cambrian age (Plumb, Shergold & Stefanski, 1976). The Elcho Island fauna belongs to the Templetonian stage, while *Skolithus* is common in the lower Cambrian of northern Australia. The Buckingham Bay Sandstone and Raiwalla Shale may be correlated with the Bukulara Sandstone and Cox Formation of McArthur River region (Plumb and Paine, 1964), where Dunn (1963) has shown that the Bukalara Sandstone interfingers with the Lower Cambrian Antrim Plateau Volcanics.

No detailed sedimentological studies have been carrried out. The presence of trilobites, Skolithus, and glauconite all indicate shallow marine to probably intertidal conditions. This and the general setting of the basin is provisionally interpreted as indicating a broad shallow, intertidal to subtidal marine shelf setting.

STRUCTURE, ARAFURA BASIN

The onshore part of the Arafura Basin is undeformed. Primary depositional dips of just a couple of degrees towards the north (NW - NNE), follow the southern margin of the off-shore basin.

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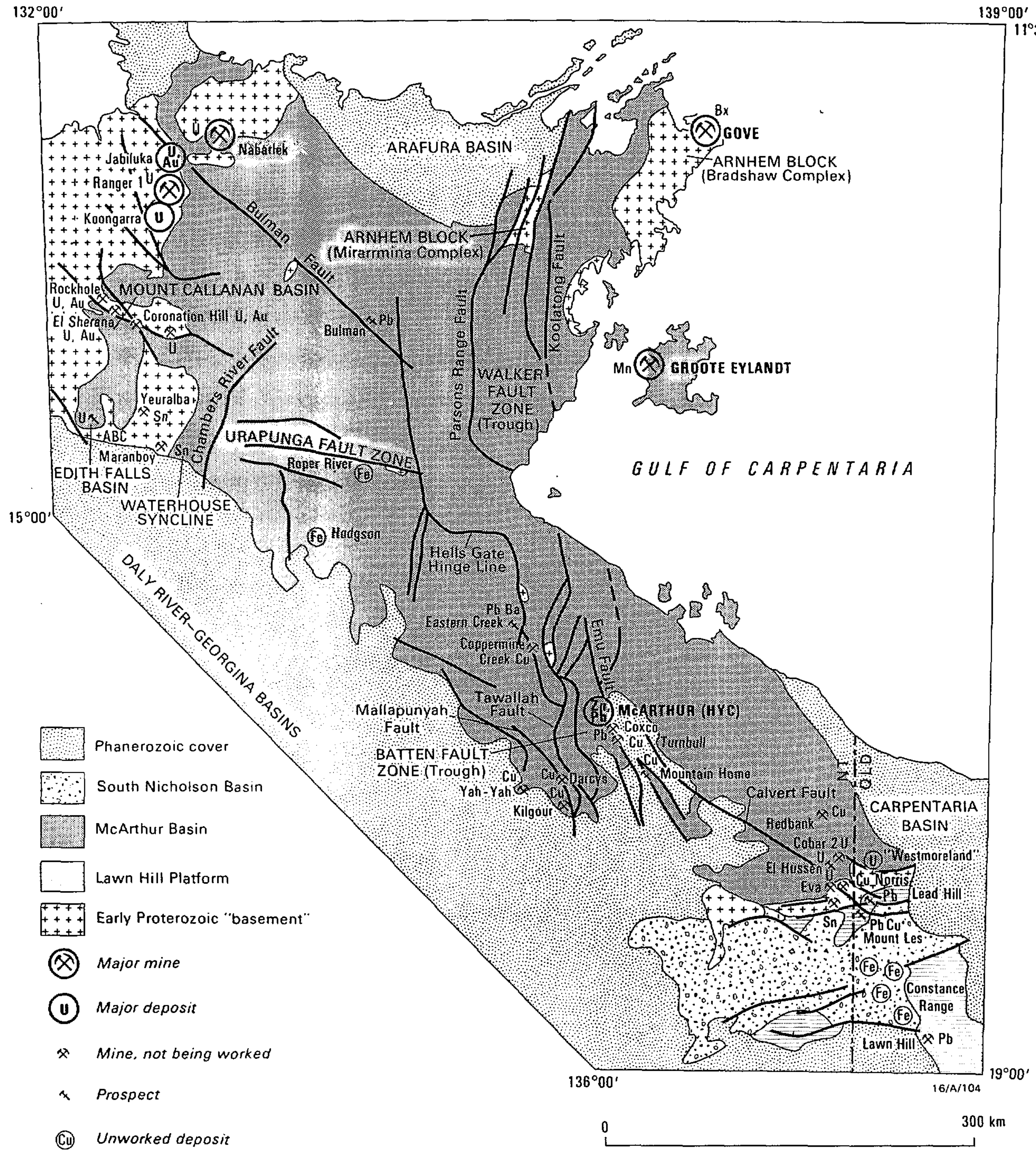


Figure 2. Principal structures and mineral deposits of the McArthur Basin and adjoining tectonic units surrounding Arnhem Land (from Plumb *et al.*, 1990)

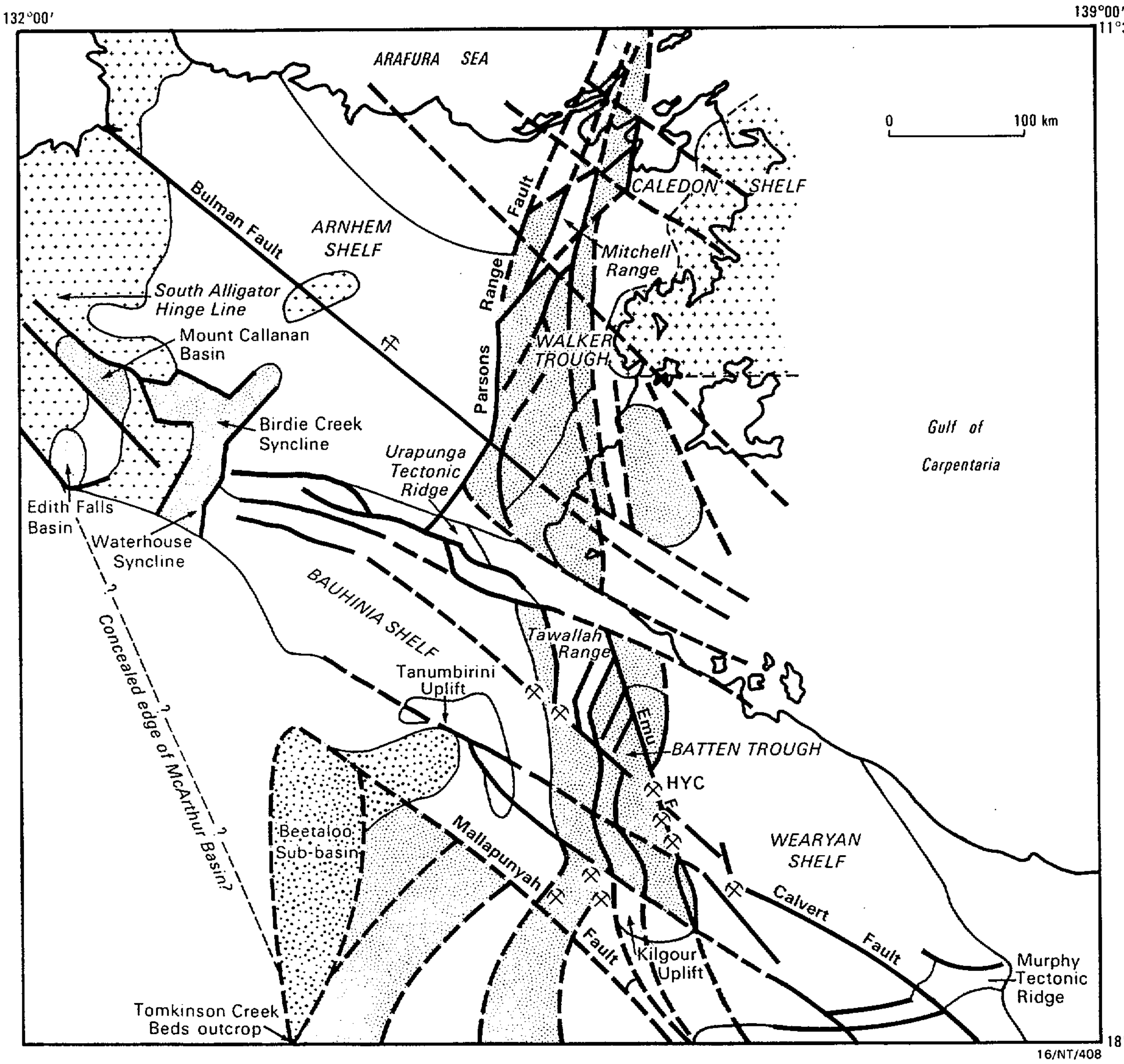
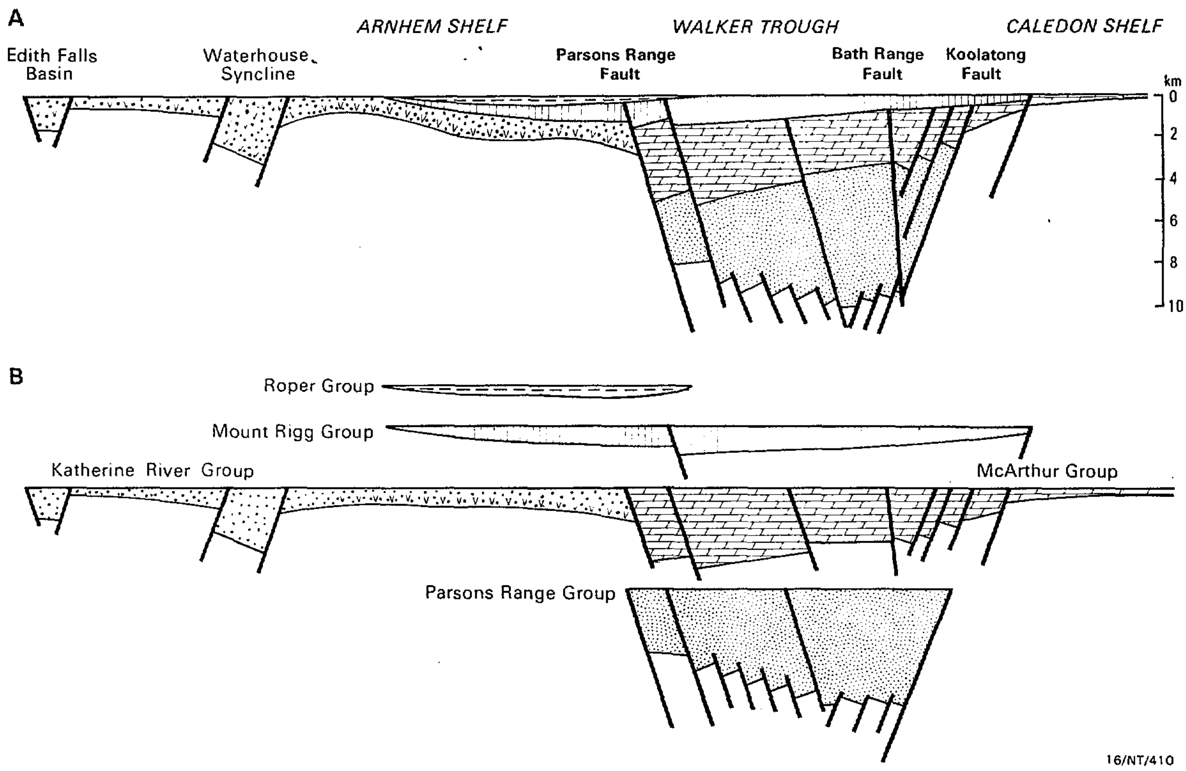


Figure 3. Tectonic setting of Arnhem Land, in terms of the principal tectonic elements of the McArthur Basin (after Plumb, 1987). Patterned areas outline major rifts (stipples), tectonic highs (diagonal lines) and basement inliers (crosses).



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B. Schematic development of the principal depositional units.

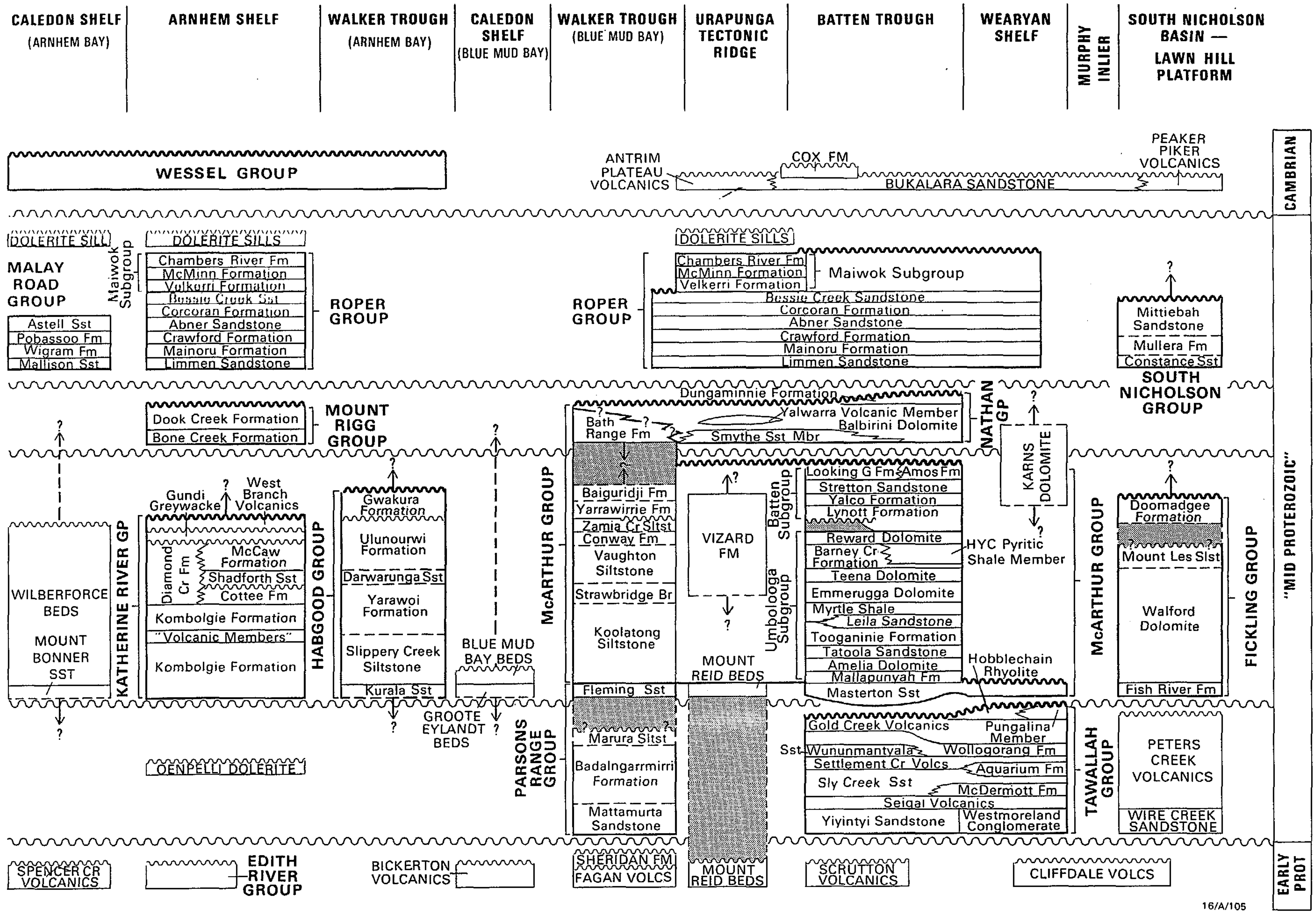


Figure 6. Stratigraphic correlation chart of the McArthur Basin-South Nicholson Region (after Plumb *et al.*, 1990).Patterned areas refer to postulated time gaps within units previously defined as continuous.

PRESENT INVESTIGATIONS

The investigations on which this Bulletin is based were conducted between May and October 1962 by a BMR field party; geologists in the party were P Rix, D Dunnet, P R Dunn, and the authors. The project was under the supervision of D A White and B P Walpole, R A Ruker assisted in the field work for five weeks, and S K Skwarko spent several weeks in the area collecting Mesozoic fossils. Prior to the field mapping the area was photo-interpreted by the Institut Francais du Petrole in association with the BMR; R A Ruker (BMR) prepared photogeological maps of the Milingimbi, Mount Marumba, and Blue Mud Bay/Port Langdon 1:250 000 Sheet areas, and W J Perry (BMR) prepared a photogeological map of the Arnhem Bay/Gove and Wessel Island/Truant Island Sheet areas. These maps were utilised in the field and contributed much to the planning of the field survey.

Survey Methods

Field mapping was conducted from two main base camps; the first, near Bulman waterhole, was used for the mapping of the Mount Marumba Sheet area and the second, on the western side of the Mitchell Range, was used in the mapping of the remainder of the area. A primitive vehicle track between the two camps was established by the repeated use of the same route. The party was equipped with six short-wheel-base Land Rovers, two long-wheel-base Land Rovers, and a Bedford 5-ton 4-wheel drive truck. Vehicle traverses covered most of the Mount Marumba Sheet area, most of the mainland part of the Blue Mud Bay/Port Langdon Sheet area, and the most critical parts of the Arnhem Bay/Gove Sheet area. Traverses were spaced in accordance with the complexity of the geology. A helicopter was used to visit the more inaccessible areas, and landings were made at several hundred points throughout Arnhem Land; Milingimbi, Junction Bay, islands of the Arnhem Bay/Gove and Blue Mud Bay/Port Langdon Sheet areas, were covered almost exclusively in this manner. Over 8000 miles (140 flying hours) were flown during the survey.

Compilation

Mapping was carried out with the aid of air-photographs at a scale of approximately 1:50 000, flown by the Royal Australian Air Force in 1950. The geology was photo-interpreted onto transparent photo overlays and this information was then transferred, in most cases, onto photo-scale slotted template assemblies prepared by the Royal Australian Army Survey Corps, which were subsequently reduced to a scale of 1:250 000. Most of the 1:250 000 Geological Sheets were compiled in this way, but the Milingimbi and Mount Marumba Sheets were compiled directly from reduced photo-overlays.

Definition

Distribution: Poorly exposed along east coast of Arnhem Land between Melville and Caledon Bays. Main exposures in two areas: a narrow belt south-westwards from Port Bradshaw and along the eastern shoreline of Melville Bay. The two belts total about 500 km but actual outcrop sparse. True extent obscured by widespread cover of Lower Cretaceous sediments and Cainozoic soil and laterites.

Type Locality: The belt of exposures southwest of Port Bradshaw.

Derivation of Name: From Port Bradshaw. Previously named Bradshaw Granite (Dunnet, 1965) because granitoid rocks are the most abundant in outcrop. Complex now considered more appropriate because of metamorphic-anatectic origin of rocks.

Stratigraphic Relationships: Part of the basement complex of Arnhem Land. Intruded by post-tectonic Caledon and Giddy Granites. Unconformably overlain by Spencer Creek Volcanics. Lower Proterozoic isotopic age. Correlated with Myaoola Granite, Nimbuwah and Gunbatgari Complexes, and 'granite gneisses' of Mirarrmina Complex.

Lithology: Cordierite adamellite and granodiorite; massive leucocratic garnetiferous adamellite; (garnetiferous) biotite adamellite and granite; garnetiferous-biotite-plagioclase-quartz and cordierite-biotite-microcline-plagioclase-quartz paragneisses; cordierite rich, banded granulites; leucocratic granulite; quartzite, migmatite.

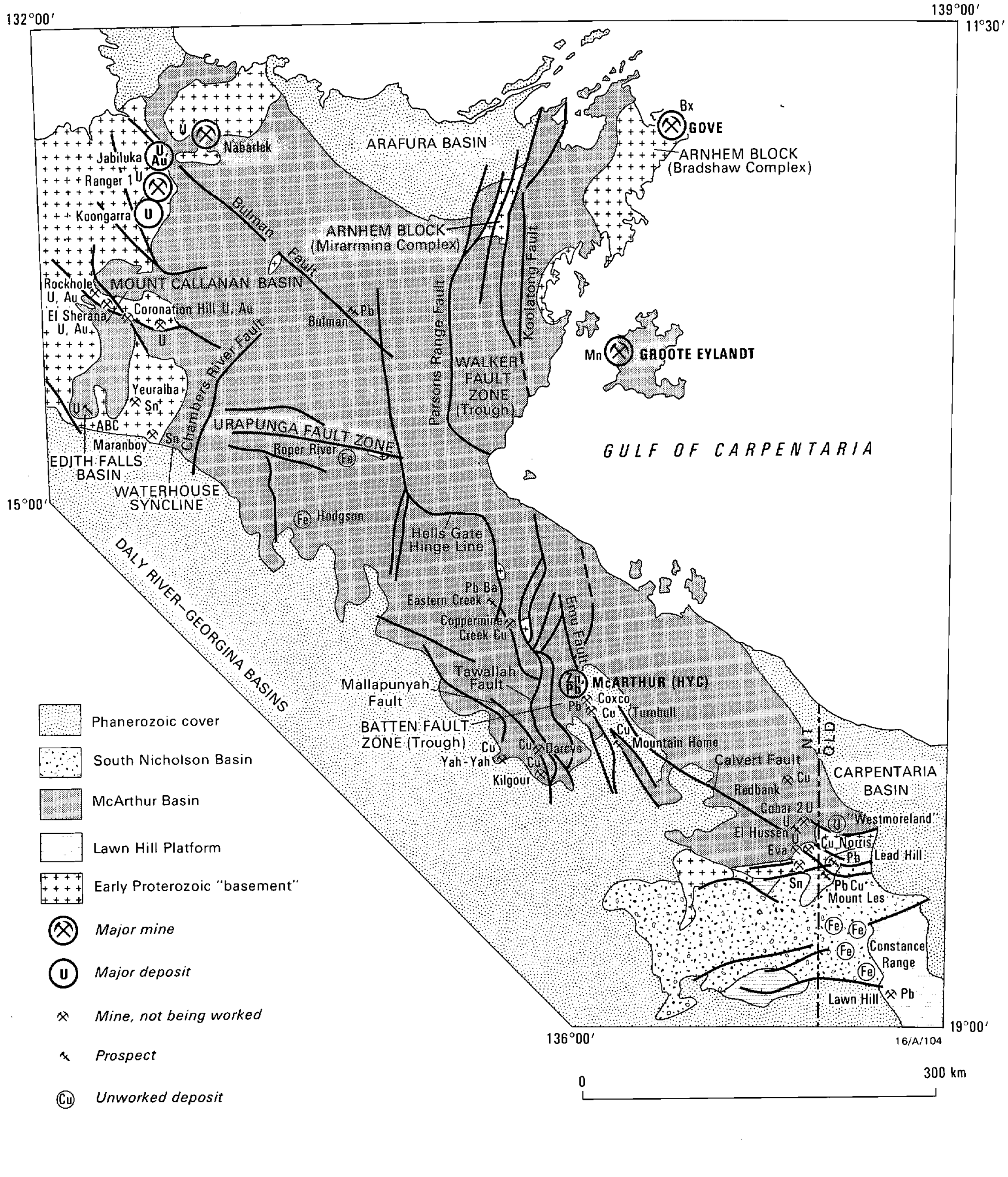
Age: Orosirian (Palaeoproterozoic)

Description and comments

The Bradshaw Complex is a mixture of granitic, migmatitic, and high-grade metamorphic rocks, with similar pelitic compositions and gradational contacts. The granites formed by anatexis of the metasediments. Many of the rocks are foliated and folded about shallowly plunging west to north-westerly trending axes; the structural history is complex. Only one major metamorphism of low-pressure granulite to upper amphibolite facies can be recognised; retrogressive effects are slight.

The two main areas of outcrop are best treated separately (Fig.7), and in each area two informally named groups of rocks are recognised. The metamorphic grade in the *Port Bradshaw area* is lower (upper amphibolite facies) than the *Melville Bay area* (low-pressure granulite facies).

At Port Bradshaw, the *Mount Alexander Type* is a complex of paragneiss and granitic rocks. Garnetiferous-biotite-plagioclase-quartz and cordierite-biotite-microcline-plagioclase-quartz paragneisses grade through garnetiferous biotite or biotite-cordierite gneissic adamellites and granites (migmatites) into massive biotite adamellites and granites, both with and without garnet. Megacrysts of K-feldspar are common in the latter; the rocks are intimately intermixed in the field; and paragneiss inclusions are common within the granitic rocks. The *Holly Inlet Type* consists of massive cordierite rich adamellite and granodiorite, exposed in a large body to the west of Holly Inlet and surrounded by 'Mount Alexander Type'; hypersthene-cordierite



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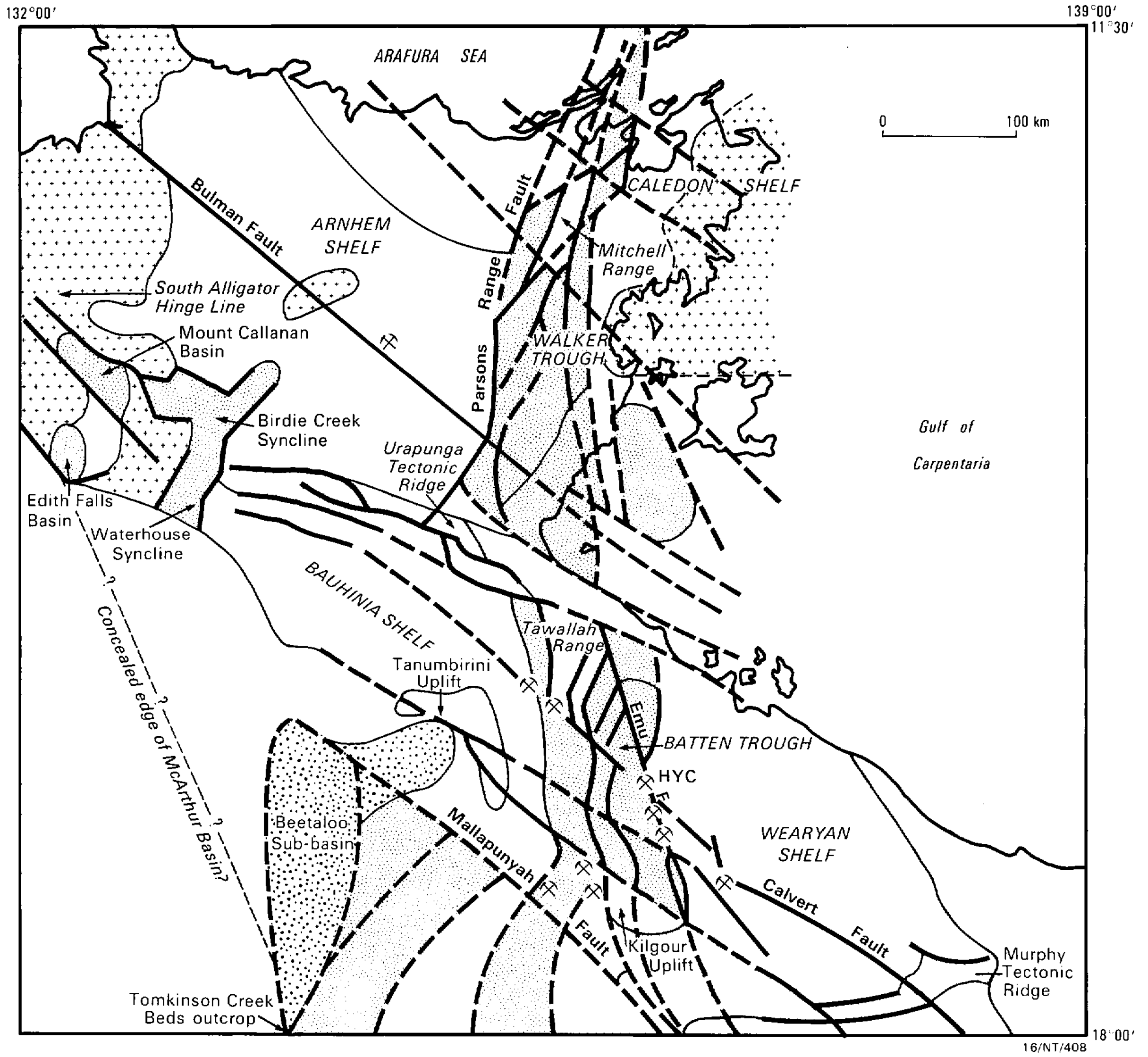

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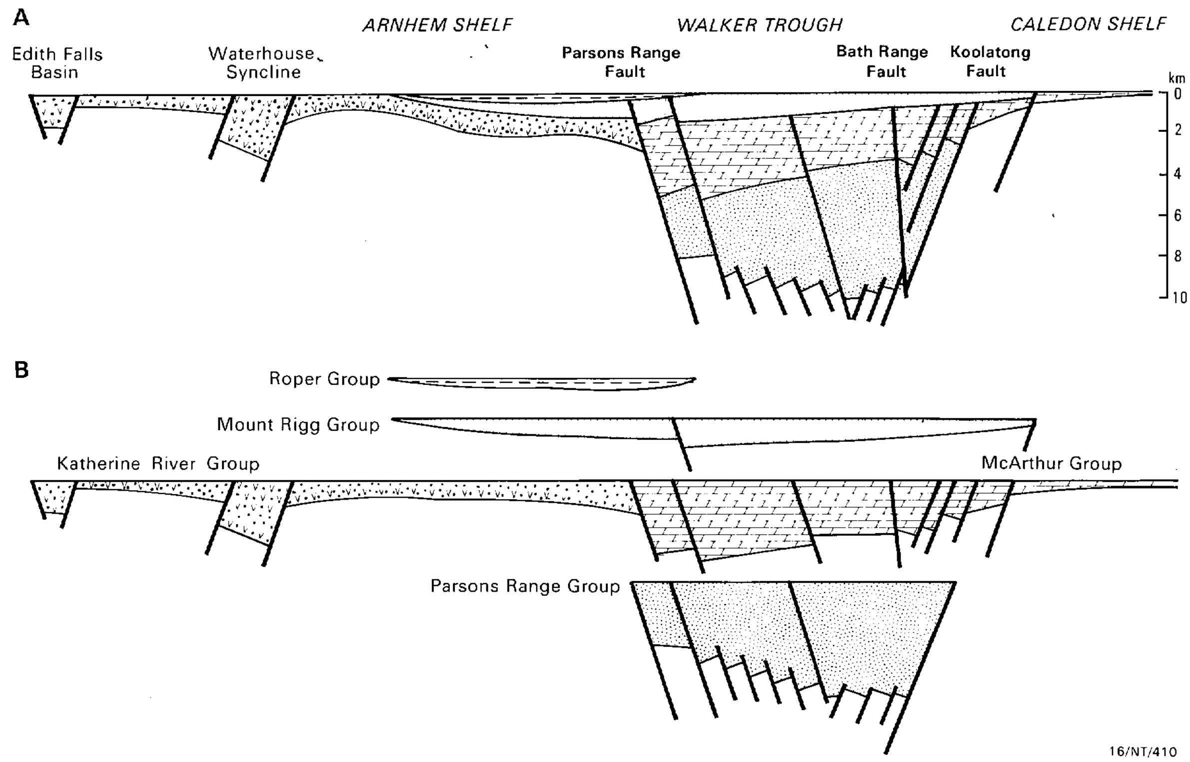

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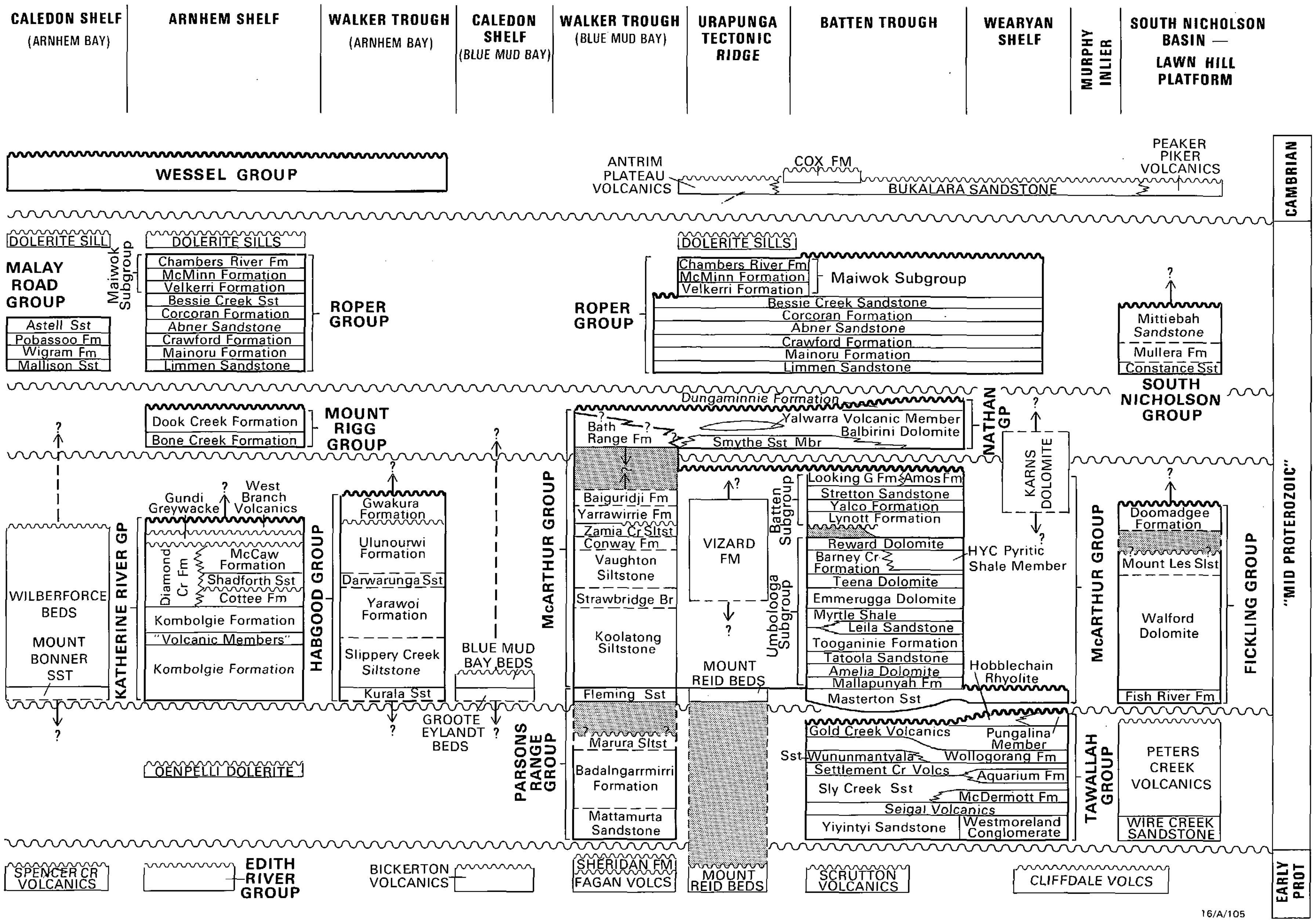

Figure 6. Stratigraphic correlation chart of the McArthur Basin-South Nicholson Region (after Plumb *et al.*, 1990).Patterned areas refer to postulated time gaps within units previously defined as continuous.

Definition

Distribution: Crop out as scattered inliers amongst Mesozoic and Cainozoic cover along north-east trending belt about 130 km^2 in area, between Spencer Creek and Mount Bonner on peninsula separating Arnhem Bay and Melville Bay in north-eastern corner of Arnhem Bay-Gove Sheet area.

Reference Area: No complete section exposed in any one place. Taken as being exposures immediately north of Spencer Creek at about lat. 12°18'S, long. 136°26'E.

Derivation of Name: From Spencer Creek (Lat. 12°20'S, Long. 136°25'30"E).

Stratigraphic Relationships: Unconformably overlie Bradshaw Granite and in turn overlain with angular unconformity by Mount Bonner Sandstone. Considered to be comagmatic with Giddy Granite but cannot be demonstrated whether they overlie or are intruded by the Granite. Correlated with Fagan and Bickerton Volcanics and considered to be Orosirian? in age.

Lithology: Massive, red-brown, porphyritic rhyolitic volcanics; blocky, cross-bedded, medium to coarse-grained quartz sandstone.

Thickness: Very poor control. Assuming uniform dip indicated by sandstone member in middle of unit some 1.7 km indicated.

Distinguishing Features: Presence of volcanic rocks readily distinguishes unit from units above and below. Both upper and lower contacts defined by unconformities.

Age: Orosirian (Late Palaeoproterozoic)?

Description and comments

The Spencer Creek Volcanics consist of two volcanic bands, each about 600 m thick, separated by a sandstone member about 450 m thick.

Phenocrysts in the volcanics are predominantly feldspar and range up to about 1 cm in size; smaller quartz and chlorite pseudomorphs after ferromagnesian minerals also occur. Feldspar phenocrysts are generally altered to a pale green colour. The microcrystalline groundmass is coloured red by disseminated iron oxide dust.

Feldspar phenocrysts are kaolinised sanidine and minor sericitised plagioclase. They are generally euhedral or subhedral in form with slight magmatic corrosion of corners. Quartz phenocrysts are highly corroded and embayed. Fracturing of phenocrysts is rare.

The groundmass is composed of fine quartz and alkali feldspar and scattered iron oxide dust. Specimens from the lower volcanic member are notable for the development of spherulitic and micrographic intergrowths; they could in fact be called granophyres. In one specimen the micrographic fabric is quite coarse.

Another distinctive feature of the lower volcanic member is the presence of a flow foliation, revealed in outcrops by subparallel alignment of phenocrysts. In thin section thin

Introduction

The Katherine River Group crops out widely in both the Katherine-Darwin region and Arnhem Land. Some of the constituent units are known only from Arnhem Land, some from the Katherine-Darwin region, and some are common to both.

The following units, first recognised in Arnhem Land, are defined here: Goomadeer and Nungbalgarri Volcanic Members (of the Kombolgie Formation); McKay Sandstone; Cottee Formation; Shadforth Sandstone; McCaw Formation.

Definitions of units defined by Walpole et al. (1968) and common to both areas are repeated here. The units are: Kombolgie Formation; Gundi Greywacke; and West Branch Volcanics.

Development of Nomenclature: Since rocks of the Katherine River Group were first described, the nomenclature of the constituent units has undergone several revisions, both in published and unpublished work.

Table 11. Comparison of nomenclature, Katherine River Group.

<table>
<tr><th>Walpole (1958)</th><th colspan="2">Ruker (1959), Randal (1963)</th><th colspan="2">This work, and Walpole and others (1968)</th></tr>
<tr><td rowspan="3">West Branch Volcanics</td><td rowspan="8">Diljin Hill Formation</td><td>West Branch Volcanic Member</td><td colspan="2">West Branch Volcanics</td></tr>
<tr><td>Unconformity</td><td colspan="2">Unconformity</td></tr>
<tr><td>Gundi Greywacke Member</td><td colspan="2">Gundi Greywacke</td></tr>
<tr><td rowspan="7">Kombolgie Formation</td><td rowspan="5">Diamond Creek Member</td><td colspan="2">Unconformity</td></tr>
<tr><td rowspan="4">Diamond Creek Formation</td><td>McCaw Formation</td></tr>
<tr><td>Shadforth Sandstone</td></tr>
<tr><td>Unconformity</td></tr>
<tr><td>Cottee Formation</td></tr>
<tr><td colspan="2" rowspan="2">Kombolgie Formation</td><td></td><td>McKay Sandstone</td></tr>
<tr><td colspan="2">Kombolgie Formation</td></tr>
</table>

Noakes (1949, p.18) described an 'Upper Proterozoic' succession in the eastern part of the Katherine-Darwin region, and considered it to be an extension of the Buldiva Quartzite described by Hossfeld (1937) in the western part of the region. This correlation was

Definition

Distribution: Crops out over about 5 km^2 in northwestern part of Mount Marumba Sheet area and over about 260 km^2 in western part of Milingimbi Sheet area; extends into adjoining Mount Evelyn and Alligator River sheets area, but although mapped (Walpole, 1962; Dunn, 1962) they have not been named. The revised edition of the Katherine-Darwin 1:500 000 Geological Sheet indicates the probable westward extent of the unit.

Reference Area: Here designated as area surrounding latitude 12°16'S, longitude 133°47'E (between Goomadeer River and Nungbalgarri Creek in northwestern part of Milingimbi Sheet area).

Derivation of Name: From Nungbalgarri Creek, which flows northeast from northwestern part of Milingimbi Sheet area into Rolling Bay (Junction Bay Sheet area).

Stratigraphic Relationships: Conformably overlain and underlain by arenites of Kombolgie Formation; in places in Wilton River area, the underlying strata lens out and the Nungbalgarri Volcanic Member rests directly on Jimbu Granite. The member is possibly stratigraphically equivalent to the Birdie Creek and Plum Tree Creek Volcanic Members and to un-named volcanic sequences exposed in isolated areas of the Mount Evelyn and Alligator River Sheet area.

Lithology: Basalt, partly amygdaloidal or vesicular. Minor quartz sandstone interbeds locally.

Thickness: About 60 m.

Description and comments

The volcanics are partly amygdaloidal or vesicular. Red, flaggy, fine-grained quartz sandstone interbeds occur in the exposures in the Shadforth Dome; and in the Milingimbi Sheet area an interbed of white medium-grained blocky quartz sandstone up to 50 feet thick occurs in places.

Dykes and sills of dolerite possibly associated with the extrusive activity, intrude the volcanics in places.

W R Morgan (pers. comm.) has described several thin sections of albite basalt from the Nungbalgarri Volcanic Member.

Albite basalt (spilite?) (R13626): Consists of randomly oriented albite laths about 0.3 mm long with a few completely chloritised pyroxene crystals and some magnetite, set in a mass of fine flakes of sericite and chlorite. The sericite and chlorite together form 60 to 70 percent of the rock and probably represent altered basaltic glass.

Albite basalt (spilite?) (R13624): A sparsely porphyritic rock with a basaltic texture. The phenocrysts are mostly rhomb-shaped crystals of slightly sericitised albite and range up to 2 mm in diameter; a few phenocrysts of augite are present. The groundmass contains laths of slightly sericitised albite averaging 0.25 mm long and 0.03 mm wide, together with prismatic to granular, colourless, slightly chloritised augite. Octohedral magnetite is also present in the

Gundi Greywacke

Definition

Distribution: Broad northeasterly trending zone extending from northeastern part of Katherine Sheet area, through Mount Marumba Sheet area, into southern part of Milingimbi Sheet area; minor exposures in Mount Evelyn and Urapunga Sheet areas.

Reference Area: First mapped by Ruker (1959) as a member of his 'Diljin Hill Formation'. Randal (1963) followed Ruker's usage, but subsequent mapping has led the unit being raised to formation status. Defined by Walpole et al. (1968).

Stratigraphic Relationships: Neither Ruker (1959) nor Randal (1963) recognised an unconformity at the base of the Gundi Greywacke in the Waterhouse River district, but in Arnhem Land abundant evidence of regional unconformity is available, and we consider it likely that the unconformity extends into the Waterhouse River area. In the Waterhouse River area the West Branch Volcanics overlie the Gundi Greywacke unconformably (Ruker, 1959; Randal, 1963); in Arnhem Land the contact with West Branch Volcanics is poorly exposed, but the formations appear to be essentially conformable.

Lithology: Tuffaceous quartz greywacke, feldspathic sandstone, quartz sandstone.

Thickness: About 140 m thick in reference area; about 90 m in Arnhem Land.

Distinguishing Features: In Arnhem Land base marked by unconformity; top marked by change in lithology from arenite to volcanics; actual upper contact nowhere exposed.

Description and comments

About 140 m thick in Waterhouse River area. Consists mainly of purple, medium to coarse-grained tuffaceous quartz greywacke containing scattered pebbles of sandstone, quartz, and pink feldspar; the matrix is composed of pyroclastic materials (Walpole et al. 1968).

In the Mount Marumba and Milingimbi Sheet areas the formation is generally about 90 m thick and consists predominantly of massive and blocky arenites containing varying amounts of feldspar. At the base, red-brown quartz greywacke and feldspathic sandstone are predominant, but upwards white to red quartz sandstone becomes more prominent. No pyroclastic materials have been detected in these areas.

Large-scale cross-beds are characteristic of the unit, and most of the exposures are strongly jointed (Pl. 00).

West Branch Volcanics

Definition

Distribution: Confined mainly to northeastern part of Katherine Sheet area, but isolated poor outcrops occur in southwestern part of Mount Marumba Sheet area.

Reference Area: Between West Branch and Waterhouse River, latitude 14°25'S, longitude 133°05'E (Walpole et al. 1968).

Definition

Distribution: Exposed along folded line of strike ridges extending from Rose River at southern end of Parsons Range, around western and northeastern sides of Bath Range, and then northwards along Koolatong Fault to headwaters of Baiguridji River. Line of exposures continuous except where disrupted by faults.

Reference Area: Best exposed along western side of Bath Range about latitude 13°35'S, longitude 135°32'E, which is here designated as the reference area.

Derivation of Name: From Yarrawirrie Plains, in southern coastal area of Blue Mud Bay Sheet area, around lat. 13°53'S, long. 135°37'E.

Stratigraphic Relationships: Conformably overlies Zamia Creek Siltstone and conformably overlain by Baiguridji Formation.

Lithology: Flaggy dolomitic siltstone; scattered interbeds flaggy to blocky, medium-grained chert-quartz sandstone. Local conglomerate. Stromatolitic chert.

Thickness: About 345 m, reference area. Thins to 270 m southwest and 225 m northeast.

Distinguishing Features: Association of dolomitic siltstone and chert-fragment sandstone, and stratigraphic position diagnostic. Only formation likely to be confused is underlying Zamia Creek Siltstone which lacks sandstone interbeds. Yarrawirrie Formation crops out in prominent strike ridge which can be readily distinguished on air-photographs from less prominent units above and below.

Upper contact defined by stromatolitic chert bed while base defined by appearance of sandstone interbeds above Zamia Creek Siltstone. Both beads generally coincide with topographic breaks in slope.

Description and comments

Stratigraphic sections are given diagrammatically in Figure 18.

Conglomerate is locally developed at the base, while the top of the formation is marked by a persistent bed of stromatolitic chert. In the reference section (C) the thickness of the formation is estimated to be about 345 m; it thins to the northeast to about 225 m (E) and to 270 m in the southwest (A). The sediments show an overall decrease in grainsize from bottom to top.

The formation crops out as a prominent, rubble-covered, rounded, strike ridge which can be traced continuously throughout the area of outcrop. It invariably stands above the more poorly outcropping formations above and below.

The siltstones show flaggy bedding partings and, in general, range from thinly interlaminated siltstone and very fine-grained sandstone in the upper half of the formation to thin-bedded siltstone lower down. The lower half of the formation contains abundant blocky sandstone interbeds ranging from fine to coarse-grained, and, in the northeast, sandstone is predominant in this part of the section. Higher in the section fine-grained sandstone occurs mainly as scattered interbeds about 30 cm thick.

CORRELATION UNCERTAIN

Groote Eylandt beds

Definition

Distribution : On islands within, and along the coastline bordering, Blue Mud Bay in the Blue Mud Bay/Port Langdon Sheet area; exposures on Groote Eylandt extend southwards into the Roper River/Cape Beatrice Sheet area.

The most extensive exposures are found on Groote Eylandt and Bickerton Island. Good sections are also found on Woodah Island, Morgan and Nicol Island, and on the mainland between the Walker and Koolatong Rivers. Small exposures occur in the Grindall Point and Cape Shield areas and on most of the smaller islands in Blue Mud Bay.

Reference Area : Whole of Groote Eylandt (about latitude 14°00'S, longitude 136°35'E) and the adjoining islands to the north.

Derivation of Name : From Groote Eylandt

Stratigraphic Relationships: Rest on Grindall Metamorphics and Caledon Granite with pronounced angular unconformity; overlie Bickerton Volcanics with an erosional unconformity but no evidence of angular discordance; overlain apparently conformably by Blue Mud Bay Beds.

Lithology : Three facies can be recognised in the Groote Eylandt Beds. The Walker River facies, as seen between the Walker and Koolatong Rivers and on Grindall Point (section A; fig. 22) is typified by a thin red and white sandstone sequence with some thin sales and lenses of conglomerate. The Morgan Island facies (section B) is typified by a red shale between a basal conglomerate and overlying sandstone succession. The Groote Eylandt facies (section D) has a thick sequence of lithic quartz greywacke and argillaceous sandstone, grading up into quartz sandstone. The distribution of these facies is shown on Figure 22.

Thickness : Increase in thickness from north to south accompanied by lateral change in lithology (see Fig. 22). Preserved thickness on Grindall Point (section, loc.A; fig. 22) about 9 m; about 42 m preserved on Morgan Island (loc. B) and northern tip of Bickerton Island (loc. C). Top of each section eroded, but section underlying Blue Mud Bay Beds near Walker and Koolatong Rivers has similar order of thickness. On Bickerton Island proper and Groote Eylandt thickens suddenly to about 600 m; cannot be estimated accurately because of prevailing low dips and eroded top.

Distinguishing Features : The lithology and succession of both the Groote Eylandt facies and the Morgan Island facies are distinctive; similarities do exist with some rocks of the Parsons Range Group and the Tawallah Group (Dunn et al., in prep.), but their geographical position is diagnostic.

The base of the Groote Eylandt Beds is marked by an unconformity; the upper contact is marked by a change in lithology from purple ferruginous sandstone to chert, dolomitic siltstone, and chert sandstone of the Blue Mud Bay Beds.

Age : Statherian? (Palaeoproterozoic?)

Description and comments

In the *Groote Eylandt facies* the lower part of the section consists of massive, medium to coarse-grained, pale grey, lithic, argillaceous quartz greywacke with scattered interbeds of blocky white quartz sandstone. The quartz greywacke grades upwards into massive coarse-grained argillaceous quartz sandstone followed by white blocky medium-grained quartz sandstone at the top of the section. Scattered lenses of boulder conglomerate are common in the lower part of the formation on Bickerton Island; thin beds of purple shale have also been observed, but they are rarely exposed.

Definition

Distribution: Eastern end of north coast of Arnhem Land; exposures confined to small northeasterly trending belt bounded by line from Mallison Island to the Bromby Islands in south, and The English Companys Islands in the north.

Reference Area: The English Companys Islands/Cape Wilberforce area. No sections measured.

Derivation of Name: From Malay Road, a strait between Cape Wilberforce and The English Companys Islands. Strait bounded on both sides by the group; inferred that group is continuous beneath strait.

Stratigraphic Relationships: Overlies Wilberforce Beds with erosional unconformity; overlain with angular unconformity by Wessel Group. Correlated, on basis of lithology and stratigraphic position, with Roper Group.

Components: Made up of Mallison Sandstone, Wigram Formation, Pobassoo Formation and Astell Sandstone.

Lithology: Massive quartz sandstone alternates with interbedded argillaceous siltstone and fine-grained quartz greywacke; micaceous quartz greywacke and siltstone; black shale; glauconitic fine-grained sandstone.

Thickness: About 1.5 km estimated. Only about 0.6 km actually exposed.

Distinguishing Features: Stratigraphic position diagnostic; succession as a whole distinct from Wessel Group, with which it is most likely to be confused. Mallison Sandstone more quartzose than Buckingham Bay Sandstone; Wigram Formation/Pobassoo Formation sequence distinguished by black shale, overlain by grey to black fine-grained quartz greywacke with distinctive sandstone marker beds, and, finally, purple to red, highly micaceous quartz greywacke and siltstone.

Base of group is unconformity between Wilberforce Beds and overlying Mallison Sandstone; top is unconformity at base of Buckingham Bay Sandstone.

Age: Calymmian (Mesoproterozoic).

Description and comments

Although only about two-fifths of the group is exposed, the available sections generally occur in coastal cliffs and are therefore fresh and very well exposed.

The stratigraphy is summarised in Table 31. The lithology is discussed under individual formation headings.

The quartz sandstone is generally cross-bedded and in places ripple marked. The finer-grained sediments consist mainly of fine quartz and very fine-grained clay or sericite. Some rocks are rich in iron oxides while others are rich in muscovite and glauconite. These "impure" sediments generally consist of thinly and regularly interbedded lutite and fine-grained arenite. Fine cross-bedding and well developed slumping is present.

No direct evidence of age of the Group is available; it is considered Calymmian on the basis of its correlation with the Roper Group, which, on overall lithology and stratigraphic position seems quite sound.

Pobassoo Formation

Definition

Distribution: Lower part exposed in dip slopes and small scarps along western and northern sides of The English Companys Islands; top exposed only on Astell Island; bulk of formation concealed beneath the sea.

Reference Area: Cotton Island at about lat. 11°51'S, long. 136°28'E.

Derivation of Name: From Pobassoo Island.

Stratigraphic Relationships: Conformably overlies Wigram Formation; conformably overlain by Astell Sandstone. In places directly overlain unconformably by Buckingham Bay Sandstone.

Lithology: Flaggy, pink, purple, deep red, and green, interbedded micaceous siltstone and fine-grained quartz greywacke; interbeds of flaggy, medium-grained, buff to white, micaceous sandstone; some blocky, purple, micaceous quartz greywacke; laminated, fine-grained, micaceous glauconitic sandstone.

Thickness: About 480 m; maximum exposed about 60 m at base on Cotton and Pobassoo Islands and top 15 m on Astell Island; remainder covered by sea.

Distinguishing Features: Abundance of mica and dominant deep red to purple colour characteristic; laminated green sandstone and siltstone at top with abundant glauconite also distinctive.

Lower contact with Wigram Formation gradational; taken where the dominantly grey sediments of Wigram Formation change into dominantly red, highly micaceous, sediments of Pobassoo Formation; top defined at base of massive white quartz sandstone of Astell Sandstone.

Description and comments

The lower part of the formation consists of a sequence of pink to purple and deep red, flaggy micaceous siltstone interbedded with fine-grained quartz greywacke, with interbeds of flaggy, medium-grained, buff to white, micaceous sandstone, and some blocky, purple, micaceous quartz greywacke. In places the flaggy quartz greywacke is cross-bedded and contains abundant, well developed slump structures. The purple to red colour and the abundance of mica are prominent features of the formation.

The upper part of the formation, which is exposed only on Astell Island, consists of a sequence of interbedded flaggy to fissile, green to purple, micaceous siltstone or fine-grained quartz greywacke (R13662); flaggy dark green fine-grained quartz greywacke; and laminated, green and buff, fine-grained, micaceous glauconitic sandstone (R13661).

The micaceous, glauconitic sandstone (R13661) has a well developed lamination of buff-coloured bands and green glauconite-rich bands; the glauconite pellets are readily visible to the naked eye. In thin section the rock consists of about 60 percent quartz, 15 percent glauconite, 15 percent mica, 5 percent feldspar, and 5 percent iron oxide. The quartz is well sorted (0.07-0.1 mm) and shows secondary overgrowths. Small grains of potash feldspar are scattered through the rock. The glauconite is almost colourless and the pellets are about the

Definition

Distribution: Generally exposed only in scarps beneath more resistant overlying units or in creeks. In north-east upper 30 to 60 m well exposed in scattered cliff sections beneath resistant Marchinbar Sandstone along eastern side of Wessel Islands and Napier Peninsula; rest of sequence lies beneath sea. On mainland formation is exposed in arcuate belt of scattered exposures from Buckingham Bay, southwestwards across Woolen and Goyder Rivers, then northwestwards across the Milingimbi Sheet area to near Maningrida Settlement.

Reference Area: Scattered outcrops around Woolen River (about lat. 12°20'S, long. 135°25'E), between Napier Peninsula and Muckaninnie Plains.

Derivation of Name: From Raiwalla River on southwestern side of Buckingham Bay.

Stratigraphic Relationships: Conformably overlies Buckingham Bay Sandstone; conformably overlain by Marchinbar Sandstone.

Lithology: Green to grey shale and siltstone (dolomitic); interbeds of flaggy fine-grained sandstone, argillaceous quartz greywacke, micaceous ferruginous quartz greywacke; minor quartz sandstone.

Thickness: About 550 to 600 m.

Distinguishing Features: Distinguished by stratigraphic position and predominance of flaggy green and grey shale.

Both top and bottom contacts gradational; top taken where thick shale units disappear and quartz sandstone becomes predominant; base drawn where dominantly arenaceous succession of Buckingham Bay Sandstone gives way to finer-grained rocks.

Description and comments

The thickness is difficult to estimate because of poor exposure and the prevailing low dips. In Arnhem Bay/Gove and Wessel Islands/Truant Island Sheet areas the thickness has been estimated from maps to be about 550 to 600 m. Farther west in the Milingimbi Sheet area Rix (1963) gives 900 m (3000 feet) as the thickness, but in view of the very poor outcrop this figure must be regarded as only a rough approximation.

From isolated well exposed sections in creek beds it is apparent that most of the formation is composed of fissile, green to grey shale and siltstone with scattered 2 cm interbeds of grey to white fine-grained sandstone; the shale only crops out rarely. Most of the exposures in the area consist of low rubble-covered rises with scattered outcrops of thinly flaggy, ripple-marked, pale green to white, fine-grained sandstone (micaceous in places); fissile, argillaceous fine-grained quartz greywacke and siltstone; and fissile, grey to purple, micaceous, ferruginous quartz greywacke and siltstone. It is apparent from the relationship to known outcrops of shale that these rubble-covered rises are simply erosional remnants within a dominantly grey shale succession. Beds about 15 m thick of white, cross-bedded and ripple-marked, sugary quartz sandstone are scattered through the section.

STRUCTURE, ARAFURA BASIN

The onshore part of the Arafura Basin is undeformed. Primary depositional dips of just a couple of degrees towards the north (NW - NNE), follow the southern margin of the off-shore basin.

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Definition

Distribution: Crop out as scattered inliers amongst Mesozoic and Cainozoic cover along north-east trending belt about 130 km^2 in area, between Spencer Creek and Mount Bonner on peninsula separating Arnhem Bay and Melville Bay in north-eastern corner of Arnhem Bay-Gove Sheet area.

Reference Area: No complete section exposed in any one place. Taken as being exposures immediately north of Spencer Creek at about lat. 12°18'S, long. 136°26'E.

Derivation of Name: From Spencer Creek (Lat. 12°20'S, Long. 136°25'30"E).

Stratigraphic Relationships: Unconformably overlie Bradshaw Granite and in turn overlain with angular unconformity by Mount Bonner Sandstone. Considered to be comagmatic with Giddy Granite but cannot be demonstrated whether they overlie or are intruded by the Granite. Correlated with Fagan and Bickerton Volcanics and considered to be Orosirian? in age.

Lithology: Massive, red-brown, porphyritic rhyolitic volcanics; blocky, cross-bedded, medium to coarse-grained quartz sandstone.

Thickness: Very poor control. Assuming uniform dip indicated by sandstone member in middle of unit some 1.7 km indicated.

Distinguishing Features: Presence of volcanic rocks readily distinguishes unit from units above and below. Both upper and lower contacts defined by unconformities.

Age: Orosirian (Late Palaeoproterozoic)?

Description and comments

The Spencer Creek Volcanics consist of two volcanic bands, each about 600 m thick, separated by a sandstone member about 450 m thick.

Phenocrysts in the volcanics are predominantly feldspar and range up to about 1 cm in size; smaller quartz and chlorite pseudomorphs after ferromagnesian minerals also occur. Feldspar phenocrysts are generally altered to a pale green colour. The microcrystalline groundmass is coloured red by disseminated iron oxide dust.

Feldspar phenocrysts are kaolinised sanidine and minor sericitised plagioclase. They are generally euhedral or subhedral in form with slight magmatic corrosion of corners. Quartz phenocrysts are highly corroded and embayed. Fracturing of phenocrysts is rare.

The groundmass is composed of fine quartz and alkali feldspar and scattered iron oxide dust. Specimens from the lower volcanic member are notable for the development of spherulitic and micrographic intergrowths; they could in fact be called granophyres. In one specimen the micrographic fabric is quite coarse.

Another distinctive feature of the lower volcanic member is the presence of a flow foliation, revealed in outcrops by subparallel alignment of phenocrysts. In thin section thin

Introduction

The Katherine River Group crops out widely in both the Katherine-Darwin region and Arnhem Land. Some of the constituent units are known only from Arnhem Land, some from the Katherine-Darwin region, and some are common to both.

The following units, first recognised in Arnhem Land, are defined here: Goomadeer and Nungbalgarri Volcanic Members (of the Kombolgie Formation); McKay Sandstone; Cottee Formation; Shadforth Sandstone; McCaw Formation.

Definitions of units defined by Walpole et al. (1968) and common to both areas are repeated here. The units are: Kombolgie Formation; Gundi Greywacke; and West Branch Volcanics.

Development of Nomenclature: Since rocks of the Katherine River Group were first described, the nomenclature of the constituent units has undergone several revisions, both in published and unpublished work.

Table 11. Comparison of nomenclature, Katherine River Group.

<table>
<tr><th>Walpole (1958)</th><th colspan="2">Ruker (1959), Randal (1963)</th><th colspan="2">This work, and Walpole and others (1968)</th></tr>
<tr><td rowspan="3">West Branch Volcanics</td><td rowspan="8">Diljin Hill Formation</td><td>West Branch Volcanic Member</td><td colspan="2">West Branch Volcanics</td></tr>
<tr><td>Unconformity</td><td colspan="2">Unconformity</td></tr>
<tr><td>Gundi Greywacke Member</td><td colspan="2">Gundi Greywacke</td></tr>
<tr><td rowspan="7">Kombolgie Formation</td><td rowspan="5">Diamond Creek Member</td><td colspan="2">Unconformity</td></tr>
<tr><td rowspan="4">Diamond Creek Formation</td><td>McCaw Formation</td></tr>
<tr><td>Shadforth Sandstone</td></tr>
<tr><td>Unconformity</td></tr>
<tr><td>Cottee Formation</td></tr>
<tr><td colspan="2" rowspan="2">Kombolgie Formation</td><td></td><td>McKay Sandstone</td></tr>
<tr><td colspan="2">Kombolgie Formation</td></tr>
</table>

Noakes (1949, p.18) described an 'Upper Proterozoic' succession in the eastern part of the Katherine-Darwin region, and considered it to be an extension of the Buldiva Quartzite described by Hossfeld (1937) in the western part of the region. This correlation was

Definition

Distribution: Crops out over about 5 km^2 in northwestern part of Mount Marumba Sheet area and over about 260 km^2 in western part of Milingimbi Sheet area; extends into adjoining Mount Evelyn and Alligator River sheets area, but although mapped (Walpole, 1962; Dunn, 1962) they have not been named. The revised edition of the Katherine-Darwin 1:500 000 Geological Sheet indicates the probable westward extent of the unit.

Reference Area: Here designated as area surrounding latitude 12°16'S, longitude 133°47'E (between Goomadeer River and Nungbalgarri Creek in northwestern part of Milingimbi Sheet area).

Derivation of Name: From Nungbalgarri Creek, which flows northeast from northwestern part of Milingimbi Sheet area into Rolling Bay (Junction Bay Sheet area).

Stratigraphic Relationships: Conformably overlain and underlain by arenites of Kombolgie Formation; in places in Wilton River area, the underlying strata lens out and the Nungbalgarri Volcanic Member rests directly on Jimbu Granite. The member is possibly stratigraphically equivalent to the Birdie Creek and Plum Tree Creek Volcanic Members and to un-named volcanic sequences exposed in isolated areas of the Mount Evelyn and Alligator River Sheet area.

Lithology: Basalt, partly amygdaloidal or vesicular. Minor quartz sandstone interbeds locally.

Thickness: About 60 m.

Description and comments

The volcanics are partly amygdaloidal or vesicular. Red, flaggy, fine-grained quartz sandstone interbeds occur in the exposures in the Shadforth Dome; and in the Milingimbi Sheet area an interbed of white medium-grained blocky quartz sandstone up to 50 feet thick occurs in places.

Dykes and sills of dolerite possibly associated with the extrusive activity, intrude the volcanics in places.

W R Morgan (pers. comm.) has described several thin sections of albite basalt from the Nungbalgarri Volcanic Member.

Albite basalt (spilite?) (R13626): Consists of randomly oriented albite laths about 0.3 mm long with a few completely chloritised pyroxene crystals and some magnetite, set in a mass of fine flakes of sericite and chlorite. The sericite and chlorite together form 60 to 70 percent of the rock and probably represent altered basaltic glass.

Albite basalt (spilite?) (R13624): A sparsely porphyritic rock with a basaltic texture. The phenocrysts are mostly rhomb-shaped crystals of slightly sericitised albite and range up to 2 mm in diameter; a few phenocrysts of augite are present. The groundmass contains laths of slightly sericitised albite averaging 0.25 mm long and 0.03 mm wide, together with prismatic to granular, colourless, slightly chloritised augite. Octohedral magnetite is also present in the

Gundi Greywacke

Definition

Distribution: Broad northeasterly trending zone extending from northeastern part of Katherine Sheet area, through Mount Marumba Sheet area, into southern part of Milingimbi Sheet area; minor exposures in Mount Evelyn and Urapunga Sheet areas.

Reference Area: First mapped by Ruker (1959) as a member of his 'Diljin Hill Formation'. Randal (1963) followed Ruker's usage, but subsequent mapping has led the unit being raised to formation status. Defined by Walpole et al. (1968).

Stratigraphic Relationships: Neither Ruker (1959) nor Randal (1963) recognised an unconformity at the base of the Gundi Greywacke in the Waterhouse River district, but in Arnhem Land abundant evidence of regional unconformity is available, and we consider it likely that the unconformity extends into the Waterhouse River area. In the Waterhouse River area the West Branch Volcanics overlie the Gundi Greywacke unconformably (Ruker, 1959; Randal, 1963); in Arnhem Land the contact with West Branch Volcanics is poorly exposed, but the formations appear to be essentially conformable.

Lithology: Tuffaceous quartz greywacke, feldspathic sandstone, quartz sandstone.

Thickness: About 140 m thick in reference area; about 90 m in Arnhem Land.

Distinguishing Features: In Arnhem Land base marked by unconformity; top marked by change in lithology from arenite to volcanics; actual upper contact nowhere exposed.

Description and comments

About 140 m thick in Waterhouse River area. Consists mainly of purple, medium to coarse-grained tuffaceous quartz greywacke containing scattered pebbles of sandstone, quartz, and pink feldspar; the matrix is composed of pyroclastic materials (Walpole et al. 1968).

In the Mount Marumba and Milingimbi Sheet areas the formation is generally about 90 m thick and consists predominantly of massive and blocky arenites containing varying amounts of feldspar. At the base, red-brown quartz greywacke and feldspathic sandstone are predominant, but upwards white to red quartz sandstone becomes more prominent. No pyroclastic materials have been detected in these areas.

Large-scale cross-beds are characteristic of the unit, and most of the exposures are strongly jointed (Pl. 00).

West Branch Volcanics

Definition

Distribution: Confined mainly to northeastern part of Katherine Sheet area, but isolated poor outcrops occur in southwestern part of Mount Marumba Sheet area.

Reference Area: Between West Branch and Waterhouse River, latitude 14°25'S, longitude 133°05'E (Walpole et al. 1968).

Definition

Distribution: Exposed along folded line of strike ridges extending from Rose River at southern end of Parsons Range, around western and northeastern sides of Bath Range, and then northwards along Koolatong Fault to headwaters of Baiguridji River. Line of exposures continuous except where disrupted by faults.

Reference Area: Best exposed along western side of Bafh Range about latitude 13°35'S, longitude 135°32'E, which is here designated as the reference area.

Derivation of Name: From Yarrawirrie Plains, in southern coastal area of Blue Mud Bay Sheet area, around lat. 13°53'S, long. 135°37'E.

Stratigraphic Relationships: Conformably overlies Zamia Creek Siltstone and conformably overlain by Baiguridji Formation.

Lithology: Flaggy dolomitic siltstone; scattered interbeds flaggy to blocky, medium-grained chert-quartz sandstone. Local conglomerate. Stromatolitic chert.

Thickness: About 345 m, reference area. Thins to 270 m southwest and 225 m northeast.

Distinguishing Features: Association of dolomitic siltstone and chert-fragment sandstone, and stratigraphic position diagnostic. Only formation likely to be confused is underlying Zamia Creek Siltstone which lacks sandstone interbeds. Yarrawirrie Formation crops out in prominent strike ridge which can be readily distinguished on air-photographs from less prominent units above and below.

Upper contact defined by stromatolitic chert bed while base defined by appearance of sandstone interbeds above Zamia Creek Siltstone. Both beads generally coincide with topographic breaks in slope.

Description and comments

Stratigraphic sections are given diagrammatically in Figure 18.

Conglomerate is locally developed at the base, while the top of the formation is marked by a persistent bed of stromatolitic chert. In the reference section (C) the thickness of the formation is estimated to be about 345 m; it thins to the northeast to about 225 m (E) and to 270 m in the southwest (A). The sediments show an overall decrease in grainsize from bottom to top.

The formation crops out as a prominent, rubble-covered, rounded, strike ridge which can be traced continuously throughout the area of outcrop. It invariably stands above the more poorly outcropping formations above and below.

The siltstones show flaggy bedding partings and, in general, range from thinly interlaminated siltstone and very fine-grained sandstone in the upper half of the formation to thin-bedded siltstone lower down. The lower half of the formation contains abundant blocky sandstone interbeds ranging from fine to coarse-grained, and, in the northeast, sandstone is predominant in this part of the section. Higher in the section fine-grained sandstone occurs mainly as scattered interbeds about 30 cm thick.

Groote Eylandt beds

Definition

Distribution : On islands within, and along the coastline bordering, Blue Mud Bay in the Blue Mud Bay/Port Langdon Sheet area; exposures on Groote Eylandt extend southwards into the Roper River/Cape Beatrice Sheet area.

The most extensive exposures are found on Groote Eylandt and Bickerton Island. Good sections are also found on Woodah Island, Morgan and Nicol Island, and on the mainland between the Walker and Koolatong Rivers. Small exposures occur in the Grindall Point and Cape Shield areas and on most of the smaller islands in Blue Mud Bay.

Reference Area : Whole of Groote Eylandt (about latitude 14°00'S, longitude 136°35'E) and the adjoining islands to the north.

Derivation of Name : From Groote Eylandt

Stratigraphic Relationships: Rest on Grindall Metamorphics and Caledon Granite with pronounced angular unconformity; overlie Bickerton Volcanics with an erosional unconformity but no evidence of angular discordance; overlain apparently conformably by Blue Mud Bay Beds.

Lithology : Three facies can be recognised in the Groote Eylandt Beds. The Walker River facies, as seen between the Walker and Koolatong Rivers and on Grindall Point (section A; fig. 22) is typified by a thin red and white sandstone sequence with some thin sales and lenses of conglomerate. The Morgan Island facies (section B) is typified by a red shale between a basal conglomerate and overlying sandstone succession. The Groote Eylandt facies (section D) has a thick sequence of lithic quartz greywacke and argillaceous sandstone, grading up into quartz sandstone. The distribution of these facies is shown on Figure 22.

Thickness : Increase in thickness from north to south accompanied by lateral change in lithology (see Fig. 22). Preserved thickness on Grindall Point (section, loc.A; fig. 22) about 9 m; about 42 m preserved on Morgan Island (loc. B) and northern tip of Bickerton Island (loc. C). Top of each section eroded, but section underlying Blue Mud Bay Beds near Walker and Koolatong Rivers has similar order of thickness. On Bickerton Island proper and Groote Eylandt thickens suddenly to about 600 m; cannot be estimated accurately because of prevailing low dips and eroded top.

Distinguishing Features : The lithology and succession of both the Groote Eylandt facies and the Morgan Island facies are distinctive; similarities do exist with some rocks of the Parsons Range Group and the Tawallah Group (Dunn et al., in prep.), but their geographical position is diagnostic.

The base of the Groote Eylandt Beds is marked by an unconformity; the upper contact is marked by a change in lithology from purple ferruginous sandstone to chert, dolomitic siltstone, and chert sandstone of the Blue Mud Bay Beds.

Age : Statherian? (Palaeoproterozoic?)

Description and comments

In the *Groote Eylandt facies* the lower part of the section consists of massive, medium to coarse-grained, pale grey, lithic, argillaceous quartz greywacke with scattered interbeds of blocky white quartz sandstone. The quartz greywacke grades upwards into massive coarse-grained argillaceous quartz sandstone followed by white blocky medium-grained quartz sandstone at the top of the section. Scattered lenses of boulder conglomerate are common in the lower part of the formation on Bickerton Island; thin beds of purple shale have also been observed, but they are rarely exposed.

Definition

Distribution: Eastern end of north coast of Arnhem Land; exposures confined to small northeasterly trending belt bounded by line from Mallison Island to the Bromby Islands in south, and The English Companys Islands in the north.

Reference Area: The English Companys Islands/Cape Wilberforce area. No sections measured.

Derivation of Name: From Malay Road, a strait between Cape Wilberforce and The English Companys Islands. Strait bounded on both sides by the group; inferred that group is continuous beneath strait.

Stratigraphic Relationships: Overlies Wilberforce Beds with erosional unconformity; overlain with angular unconformity by Wessel Group. Correlated, on basis of lithology and stratigraphic position, with Roper Group.

Components: Made up of Mallison Sandstone, Wigram Formation, Pobassoo Formation and Astell Sandstone.

Lithology: Massive quartz sandstone alternates with interbedded argillaceous siltstone and fine-grained quartz greywacke; micaceous quartz greywacke and siltstone; black shale; glauconitic fine-grained sandstone.

Thickness: About 1.5 km estimated. Only about 0.6 km actually exposed.

Distinguishing Features: Stratigraphic position diagnostic; succession as a whole distinct from Wessel Group, with which it is most likely to be confused. Mallison Sandstone more quartzose than Buckingham Bay Sandstone; Wigram Formation/Pobassoo Formation sequence distinguished by black shale, overlain by grey to black fine-grained quartz greywacke with distinctive sandstone marker beds, and, finally, purple to red, highly micaceous quartz greywacke and siltstone.

Base of group is unconformity between Wilberforce Beds and overlying Mallison Sandstone; top is unconformity at base of Buckingham Bay Sandstone.

Age: Calymmian (Mesoproterozoic).

Description and comments

Although only about two-fifths of the group is exposed, the available sections generally occur in coastal cliffs and are therefore fresh and very well exposed.

The stratigraphy is summarised in Table 31. The lithology is discussed under individual formation headings.

The quartz sandstone is generally cross-bedded and in places ripple marked. The finer-grained sediments consist mainly of fine quartz and very fine-grained clay or sericite. Some rocks are rich in iron oxides while others are rich in muscovite and glauconite. These "impure" sediments generally consist of thinly and regularly interbedded lutite and fine-grained arenite. Fine cross-bedding and well developed slumping is present.

No direct evidence of age of the Group is available; it is considered Calymmian on the basis of its correlation with the Roper Group, which, on overall lithology and stratigraphic position seems quite sound.

Pobassoo Formation

Definition

Distribution: Lower part exposed in dip slopes and small scarps along western and northern sides of The English Companys Islands; top exposed only on Astell Island; bulk of formation concealed beneath the sea.

Reference Area: Cotton Island at about lat. 11°51'S, long. 136°28'E.

Derivation of Name: From Pobassoo Island.

Stratigraphic Relationships: Conformably overlies Wigram Formation; conformably overlain by Astell Sandstone. In places directly overlain unconformably by Buckingham Bay Sandstone.

Lithology: Flaggy, pink, purple, deep red, and green, interbedded micaceous siltstone and fine-grained quartz greywacke; interbeds of flaggy, medium-grained, buff to white, micaceous sandstone; some blocky, purple, micaceous quartz greywacke; laminated, fine-grained, micaceous glauconitic sandstone.

Thickness: About 480 m; maximum exposed about 60 m at base on Cotton and Pobassoo Islands and top 15 m on Astell Island; remainder covered by sea.

Distinguishing Features: Abundance of mica and dominant deep red to purple colour characteristic; laminated green sandstone and siltstone at top with abundant glauconite also distinctive.

Lower contact with Wigram Formation gradational; taken where the dominantly grey sediments of Wigram Formation change into dominantly red, highly micaceous, sediments of Pobassoo Formation; top defined at base of massive white quartz sandstone of Astell Sandstone.

Description and comments

The lower part of the formation consists of a sequence of pink to purple and deep red, flaggy micaceous siltstone interbedded with fine-grained quartz greywacke, with interbeds of flaggy, medium-grained, buff to white, micaceous sandstone, and some blocky, purple, micaceous quartz greywacke. In places the flaggy quartz greywacke is cross-bedded and contains abundant, well developed slump structures. The purple to red colour and the abundance of mica are prominent features of the formation.

The upper part of the formation, which is exposed only on Astell Island, consists of a sequence of interbedded flaggy to fissile, green to purple, micaceous siltstone or fine-grained quartz greywacke (R13662); flaggy dark green fine-grained quartz greywacke; and laminated, green and buff, fine-grained, micaceous glauconitic sandstone (R13661).

The micaceous, glauconitic sandstone (R13661) has a well developed lamination of buff-coloured bands and green glauconite-rich bands; the glauconite pellets are readily visible to the naked eye. In thin section the rock consists of about 60 percent quartz, 15 percent glauconite, 15 percent mica, 5 percent feldspar, and 5 percent iron oxide. The quartz is well sorted (0.07-0.1 mm) and shows secondary overgrowths. Small grains of potash feldspar are scattered through the rock. The glauconite is almost colourless and the pellets are about the

Definition

Distribution: Generally exposed only in scarps beneath more resistant overlying units or in creeks. In north-east upper 30 to 60 m well exposed in scattered cliff sections beneath resistant Marchinbar Sandstone along eastern side of Wessel Islands and Napier Peninsula; rest of sequence lies beneath sea. On mainland formation is exposed in arcuate belt of scattered exposures from Buckingham Bay, southwestwards across Woolen and Goyder Rivers, then northwestwards across the Milingimbi Sheet area to near Maningrida Settlement.

Reference Area: Scattered outcrops around Woolen River (about lat. 12°20'S, long. 135°25'E), between Napier Peninsula and Muckaninnie Plains.

Derivation of Name: From Raiwalla River on southwestern side of Buckingham Bay.

Stratigraphic Relationships: Conformably overlies Buckingham Bay Sandstone; conformably overlain by Marchinbar Sandstone.

Lithology: Green to grey shale and siltstone (dolomitic); interbeds of flaggy fine-grained sandstone, argillaceous quartz greywacke, micaceous ferruginous quartz greywacke; minor quartz sandstone.

Thickness: About 550 to 600 m.

Distinguishing Features: Distinguished by stratigraphic position and predominance of flaggy green and grey shale.

Both top and bottom contacts gradational; top taken where thick shale units disappear and quartz sandstone becomes predominant; base drawn where dominantly arenaceous succession of Buckingham Bay Sandstone gives way to finer-grained rocks.

Description and comments

The thickness is difficult to estimate because of poor exposure and the prevailing low dips. In Arnhem Bay/Gove and Wessel Islands/Truant Island Sheet areas the thickness has been estimated from maps to be about 550 to 600 m. Farther west in the Milingimbi Sheet area Rix (1963) gives 900 m (3000 feet) as the thickness, but in view of the very poor outcrop this figure must be regarded as only a rough approximation.

From isolated well exposed sections in creek beds it is apparent that most of the formation is composed of fissile, green to grey shale and siltstone with scattered 2 cm interbeds of grey to white fine-grained sandstone; the shale only crops out rarely. Most of the exposures in the area consist of low rubble-covered rises with scattered outcrops of thinly flaggy, ripple-marked, pale green to white, fine-grained sandstone (micaceous in places); fissile, argillaceous fine-grained quartz greywacke and siltstone; and fissile, grey to purple, micaceous, ferruginous quartz greywacke and siltstone. It is apparent from the relationship to known outcrops of shale that these rubble-covered rises are simply erosional remnants within a dominantly grey shale succession. Beds about 15 m thick of white, cross-bedded and ripple-marked, sugary quartz sandstone are scattered through the section.

STRUCTURE, ARAFURA BASIN

The onshore part of the Arafura Basin is undeformed. Primary depositional dips of just a couple of degrees towards the north (NW - NNE), follow the southern margin of the off-shore basin.

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GEOLOGICAL MAP
ARNHEM LAND
NORTHERN TERRITORY – AUSTRALIA

1967

Scale 1:500,000

10 0 10 20 30 MILES

10 0 10 20 30 40 50 KILOMETRES

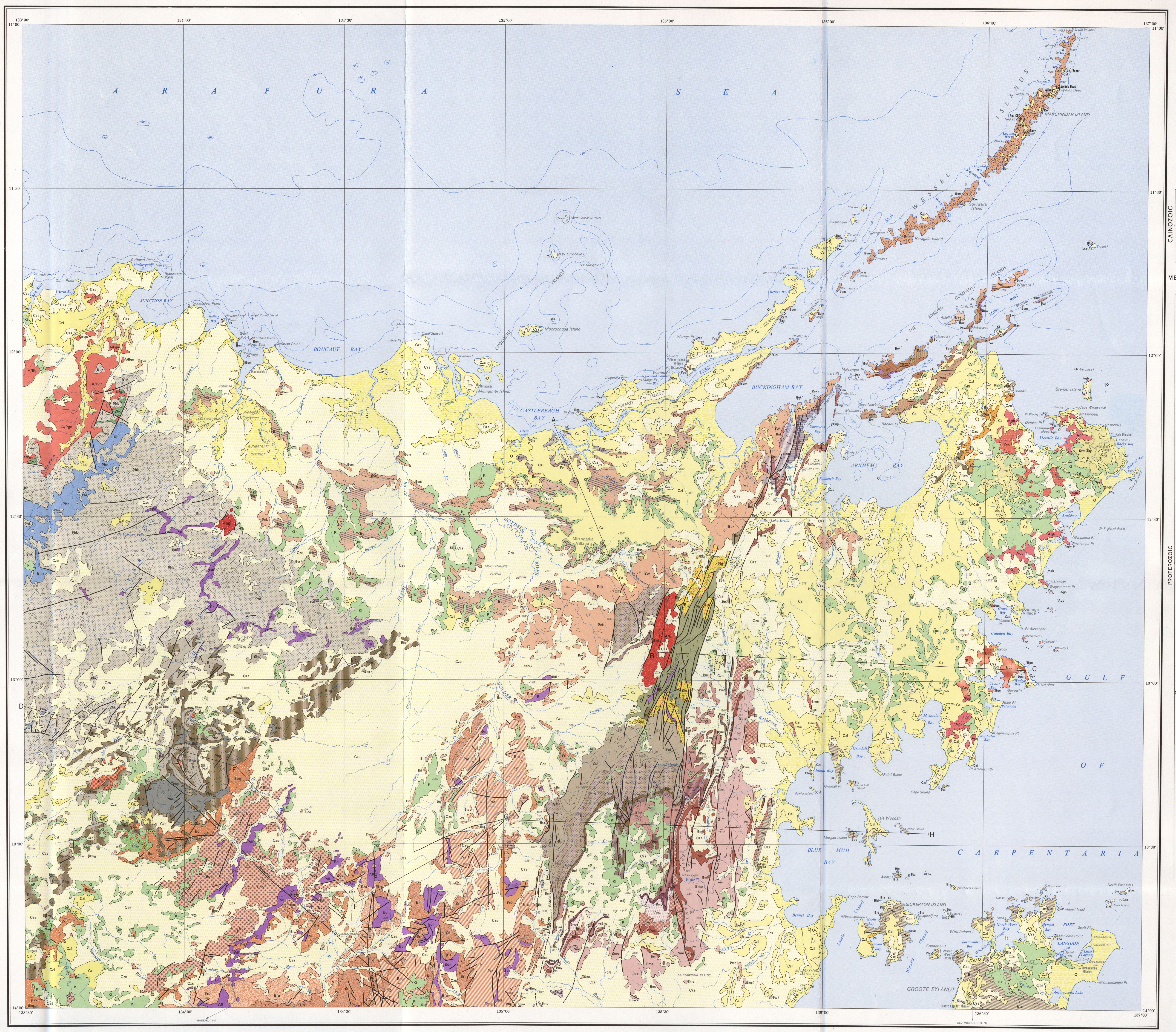
Geology, 1962, by: K. A. Plumb, H. G. Roberts, D. Dunnet, P. Rix, P. R. Dunn, R. A. Ruker

Compiled, 1965, by: H. G. Roberts

Cartography by: Geological Branch B.M.R.

Drawn by: Austral Cartographic Service, Canberra, A.C.T.

Compiled and issued by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Aerial photography: complete coverage by the Royal Australian Air Force. Transverse Mercator Projection



Reference

Era	Period	Group	Unit	Symbol	Description
CAINOZOIC	QUATERNARY			Q	Coastal silt, sand, evaporite deposits
				Czs	Sand, residual soil, alluvium
				Czb	Aluminous laterite, bauxite
				Czl	Laterite, lateritic soil, ferricrete
	TERTIARY		Annie Creek Limestone	Ta	Massive buff to grey limestone
MESOZOIC			Mullaman Beds	Kl	Siltstone, claystone, sandstone
PROTEROZOIC	ADELAIDEAN	Wessel Group	Elcho Island Formation	Ᵽee	Flaggy micaceous siltstone, micaceous glauconitic quartz greywacke, ferruginous sandstone, quartz sandstone, dolomitic siltstone, chert breccia
		Wessel Group	Marchinbar Sandstone	Ᵽem	Flaggy to massive thin-bedded quartz sandstone
		Wessel Group	Raiwalla Shale	Ᵽer	Fissile, interlaminated grey, green, and purple shale; fine-grained quartz greywacke; siltstone
		Wessel Group	Buckingham Bay Sandstone	Ᵽek	Massive to blocky quartz sandstone and quartz greywacke, minor pebble conglomerate, ferruginous siltstone
				Ᵽdl	Dolerite (intrusive)
		Malay Road Group	Astell Sandstone	Ᵽaa	Medium-grained quartz sandstone
		Malay Road Group	Pobassoo Formation	Ᵽap	Flaggy, purple, green, and white micaceous siltstone, quartz greywacke, quartz sandstone, glauconitic sandstone
		Malay Road Group	Wigram Formation	Ᵽaw	Black, green, and purple shale, grey fine-grained quartz greywacke, micaceous siltstone, glauconitic sandstone
		Malay Road Group	Mallison Sandstone	Ᵽam	Massive pink and pale brown quartz sandstone
		Roper Group	Undifferentiated	Ᵽo	Section only
		Roper Group	Bessie Creek Sandstone	Ᵽre	Massive fine to medium-grained quartz sandstone
		Roper Group	Corcoran Formation	Ᵽro	Flaggy micaceous quartz sandstone, micaceous quartz greywacke, shale, siltstone
		Roper Group	Abner Sandstone	Ᵽra	Medium-grained quartz sandstone, micaceous sandstone, siltstone, ferruginous sandstone, ferruginous siltstone
		Roper Group	Crawford Formation	Ᵽrr	Blocky to massive pink micaceous quartz greywacke; flaggy, purple micaceous sandstone and siltstone, micaceous glauconitic sandstone
		Roper Group	Mainoru Formation	Ᵽru	Flaggy, laminated cherty siltstone and dolomitic siltstone; purple micaceous shale, siltstone, and sandstone, glauconitic sandstone
		Roper Group	Limmen Sandstone	Ᵽri	Massive to flaggy fine to medium-grained quartz sandstone, minor pebble conglomerate
	CARPENTARIAN	Habgood Group	Undifferentiated	Ᵽn	Diagram only
		Habgood Group	Gwakura Formation	Ᵽng	Quartz sandstone, cherty siltstone, dolomitic siltstone, conglomerate
		Habgood Group	Ulunourwi Formation	Ᵽnu	Dolomitic siltstone, claystone, silty dolomite, cherty siltstone, cherty sandstone
		Habgood Group	Darwarunga Formation	Ᵽnd	Quartz sandstone, cherty quartz sandstone
		Habgood Group	Yarawoi Formation	Ᵽny	Dolomitic siltstone, shale and sandstone, dolomite, quartz sandstone, chert, siltstone
		Habgood Group	Slippery Creek Siltstone	Ᵽns	Purple and green to white laminated shaly siltstone, minor fine-grained quartz sandstone
		Habgood Group	Kurala Sandstone	Ᵽnk	Flaggy to blocky medium-grained quartz sandstone
			Wilberforce Beds	Ᵽwi	Black dolomitic shale, micaceous shale and siltstone, fine-grained sandstone
			Baralminar Beds	Ᵽr	Quartz sandstone, micaceous sandstone, micaceous siltstone
		McArthur Group	Undifferentiated	Ᵽm	Section and diagram only
		McArthur Group	Kookaburra Creek Formation	Ᵽmu	Oolitic chert, cherty siltstone, chert, chert breccia
		McArthur Group	Bath Range Formation	Ᵽme	Pelletal chert, siltstone, dolomitic siltstone, sandstone, chert breccia, laminated siltstone-chert, pelletal dolomite
		McArthur Group	Baiguridji Formation	Ᵽmi	Dolomitic and cherty sandstone, dolomitic siltstone, micaceous sandstone and siltstone
		McArthur Group	Yarrawirrie Formation	Ᵽmy	Chert sandstone, quartz sandstone, chert, dolomitic siltstone, cherty siltstone
		McArthur Group	Zamia Creek Siltstone	Ᵽmz	Chert, cherty siltstone, dolomitic siltstone
		McArthur Group	Conway Formation	Ᵽmc	Chert, cherty siltstone, dolomitic siltstone
		McArthur Group	Vaughton Siltstone	Ᵽmv	Dolomitic siltstone, black shale, minor chert, dolomite, and dolomitic sandstone
		McArthur Group	Strawbridge Breccia	Ᵽms	Massive chert breccia
		McArthur Group	Koolatong Siltstone	Ᵽmk	Siltstone, dolomitic siltstone, dolomite, sandstone, minor chert, chert breccia, and cherty siltstone
		McArthur Group	Blue Mud Bay Beds	Ᵽmm	Dolomitic siltstone and sandstone, chert, quartz sandstone, chert sandstone, dolomite
		Mount Rigg Group	Dook Creek Formation	Ᵽoo	Dolomitic siltstone, dolomite, chert, cherty siltstone, quartz sandstone, chert breccia
		Mount Rigg Group	Bone Creek Formation	Ᵽon	Quartz sandstone, glauconitic sandstone
		Parsons Range Group	Undifferentiated	Ᵽp	
		Parsons Range Group	Fleming Sandstone	Ᵽpf	Flaggy to massive quartz sandstone
		Parsons Range Group	Marura Siltstone	Ᵽpm	Siltstone, shale, dolomitic siltstone, sandstone, dolomite
		Parsons Range Group	Badalngarrmirri Formation	Ᵽpb	Quartz sandstone, ferruginous sandstone, feldspathic sandstone, siltstone, minor chert, dolomite, and dolomitic siltstone
		Parsons Range Group	Mattamurta Sandstone	Ᵽpt	Quartz sandstone, feldspathic sandstone, minor pebble conglomerate
PROTEROZOIC	CARPENTARIAN		Mount Bonner Sandstone	Ᵽb	Medium to coarse-grained quartz sandstone, pebble conglomerate
			Groote Eylandt Beds	Ᵽta	Pebbly quartz sandstone, lithic quartz greywacke, boulder conglomerate, micaceous siltstone
		Katherine River Group	Undifferentiated	Ᵽh	Diagram only
		Katherine River Group	West Branch Volcanics	Ᵽhw	Basalt, quartz greywacke
		Katherine River Group	Gundi Greywacke	Ᵽhg	Quartz greywacke, quartz sandstone, feldspathic sandstone
		Katherine River Group	McCaw Formation	Ᵽha	Dolomitic siltstone, sandstone, and quartz greywacke, dolomite, dolutite, quartz sandstone, siltstone, basalt
		Katherine River Group	Shadforth Sandstone	Ᵽhs	Quartz sandstone, feldspathic sandstone, glauconitic sandstone
		Katherine River Group	Cottee Formation	Ᵽhc	Quartz sandstone, ferruginous sandstone, feldspathic sandstone, dolomite; dolomitic siltstone, sandstone, limestone, and quartz greywacke; shale
		Katherine River Group	McKay Sandstone	Ᵽhm	Ferruginous sandstone, quartz sandstone, feldspathic sandstone
		Katherine River Group	Kombolgie Formation	Ᵽhk	Quartz sandstone, quartz greywacke
		Katherine River Group	Nungbalgarri Volcanic Member	Ᵽhn	Albite basalt, minor quartz sandstone
		Katherine River Group	Goomadeer Volcanic Member	Ᵽho	Basalt (?)
			Sheridan Formation	Ᵽs	Feldspathic and lithic greywacke, pebbly greywacke feldspathic sandstone, siltstone, pebble conglomerate
			Spencer Creek Volcanics	Ᵽls	Pink porphyritic rhyolitic and rhyodacitic volcanics, quartz sandstone
			Bickerton Volcanics	Ᵽli	Pink porphyritic rhyodacitic volcanics, fragmental tuff
			Fagan Volcanics	Ᵽlg	Red to grey porphyritic rhyolitic volcanics, purple ashstone, tuffaceous greywacke and siltstone, feldspathic sandstone, argillaceous quartz greywacke, minor rhyodacitic volcanics
			Ritarango Beds	Ᵽlr	Quartz sandstone, feldspathic sandstone, lithic quartz greywacke, minor lithic greywacke and siltstone
	LOWER (?) PROTEROZOIC		Giddy Granite	Ᵽgg	Massive pink granophyric granite, porphyritic hornblende-biotite and biotite granite
			Caledon Granite	Ᵽgc	Massive pink leucocratic granophyric granite and chlorite-biotite granite, minor sheared granodiorite, fayalite granite
			Jimbu Granite	Ᵽgi	Massive pink porphyritic microgranite
			Grindall Metamorphics	Ᵽld	Quartz-biotite and quartz-sericite slates and phyllites, purple sheared greywacke and quartz greywacke
	LOWER (?) PROTEROZOIC & ARCHAEAN (?)		Nimbuwah Complex	A/Ᵽgn	Massive and gneissic hornblende-biotite, biotite, and muscovite-biotite granodiorite, minor foliated granite
			Mirarrmina Complex	A/Ᵽn	Schist, massive and foliated garnetiferous granite and adamellite, gabbro, porphyritic microgranite, dolerite dykes
ARCHAEAN (?)			Gunbatgari Granite	Agg	Foliated porphyritic hornblende-biotite adamellite
			Myaoola Granite	Agy	Leucocratic foliated granite
			Bradshaw Granite	Agb	Quartz-feldspar-garnet-biotite-cordierite-sillimanite gneiss, massive porphyritic adamellite and cordierite granodiorite

Geological boundary

Fault

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

53 Strike and dip of strata

Horizontal strata

Horizontal strata, Dip < 15°, Dip 15°-45°, Trend line, Joint pattern } air-photo interpretation

Dyke

Mine

(Bx) Unexploited mineral deposit

Bx Bauxite

Fe Iron

Pb Lead

Mn Manganese

Zn Zinc

Spring

Road

Vehicle track

Settlement or mission

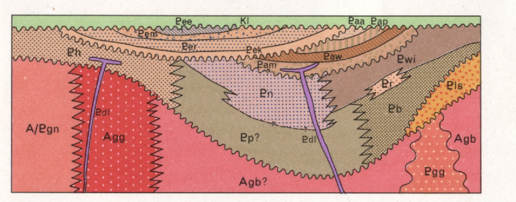
Landing ground

.506′ Height in feet, barometric; datum: mean sea level

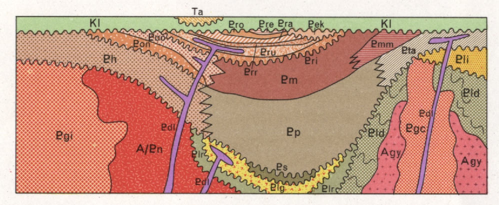
6 Fathom line

DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS

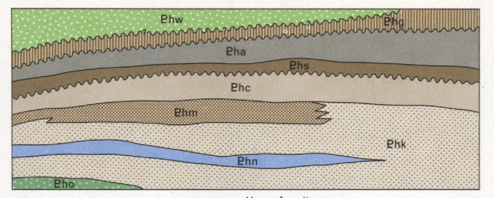
North



South



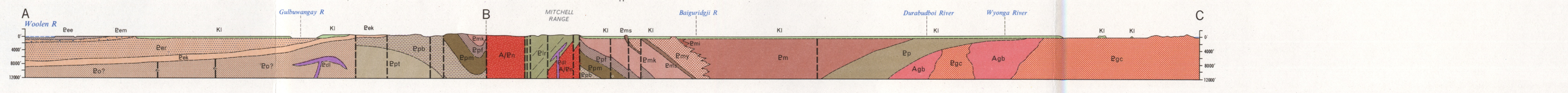
Katherine River Group Detail



Unconformity

Sections

Scale $\frac{V}{H} = 2$



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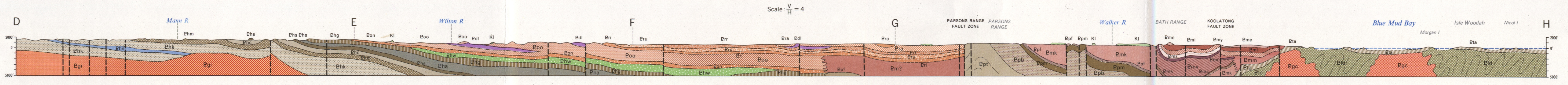
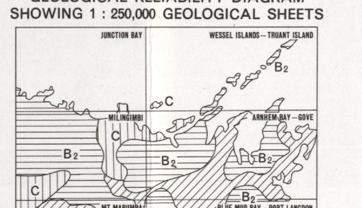


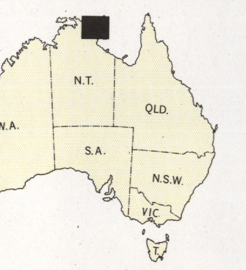
GEOLOGICAL RELIABILITY DIAGRAM SHOWING 1 : 250,000 GEOLOGICAL SHEETS



B_1 Reconnaissance — ground traverses and air-photo interprepation

B_2 Reconnaissance — helicopter traverses and air-photo interpretation

C Air-photo interpretation



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