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Geology of the Katherine-Darwin Region, Northern Territory

BY

B. P. WALPOLE, P. W. CROHN, P. R. DUNN,
AND M. A. RANDAL

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SUMMARY

The Katherine-Darwin Region occupies about 40,000 square miles in the northern part of the Northern Territory. It is centred on the Lower Proterozoic Pine Creek Geosyncline, but also contains outcrops of other Precambrian and Lower Palaeozoic rocks; Permian, Cretaceous, and Cainozoic cover-rocks occupy a large area of outcrop. Gold and tin mining started in the 1870's, and contributed to a rapid development of the region until the early 1900's, when mining activity declined. The main industry in the region was cattle-raising until after World War II, when uranium and copper were discovered at Rum Jungle and in the South Alligator River area.

Between 1953 and 1958 geologists of the Bureau of Mineral Resources carried out a geological survey of the region; this Bulletin presents a general appraisal of the information obtained during the survey.

The Katherine-Darwin Region is an area of moderate relief. A central area of maturely dissected rounded hills and ridges is flanked to the east and the south-west by sandstone plateaux which have an average height of 1000 feet above sea level. The central hills merge into coastal plains in the north and north-west. The basin of the Daly River forms a broad north-west-trending area of low relief across the centre of the region.

The oldest rocks are the Archaean metamorphics and granites, which crop out on the eastern and western margins of the Pine Creek Geosyncline and in several small inliers within it. The general structural trend in the Archaean rocks appears to be westerly.

The Pine Creek Geosyncline is a shallow composite structure developed during Lower Proterozoic time. Initial sedimentation was from the north and east into a north-west-trending asymmetrical basin (the Primary Basin). The sediments comprise an arkose/quartz greywacke/siltstone/chert/dolomite assemblage (Goodparla and Batchelor Groups) in which the proportion of clastics decreases towards the centre of the basin. The second phase of sedimentation was from the west into a newly developed north-trending Western Fault Zone and the central part of the Primary Basin (the Central Trough). The sediments comprise a turbidite assemblage of greywacke and siltstone (Finniss River Group) and minor volcanics; the coarser-grained sediments lens out to the east. Easterly derived sediments were still being deposited in the Central Trough when the second phase of sedimentation started, but they were cut off when the Eastern Trough was formed on the eastern side of the Primary Basin. The Eastern Trough contains a siltstone-chert-dolomite assemblage (South Alligator Group). The final phase of sedimentation in the Pine Creek Geosyncline was the deposition of sandstone (Chilling Sandstone) on the Chilling Platform in the south-western part of the geosyncline.

The rocks were folded along axes generally trending between 300° and 360°; the trend of the fold axes was apparently controlled by the trend of the margins of the geosyncline, but was locally modified by basement inliers. High-angle reverse and normal faulting accompanied the folding and was mainly parallel to the fold axes. Regional metamorphism of the sediments was generally very low grade. The dolerites intruded both before and after folding were metamorphosed to greenschist and amphibolite.

Early Carpentarian granites were intruded throughout the Katherine-Darwin Region into the geosynclinal sediments and into the basement rocks on the margins of the geosyncline. The main intrusions range from granite to tonalite with subordinate syenitic and gabbroic phases. They have been dated at 1760 m.y.

The granites were associated with acid volcanics (Edith River Volcanics), which formed the basal unit in the McArthur Basin, a large Carpentarian and early Adelaidean structure; the eastern half of the Katherine-Darwin Region was part of the western shelf of the McArthur Basin. The acid volcanics were followed by a sequence of arenites, minor carbonate rocks, and basic volcanics (Katherine River Group) up to 9000 feet thick, which were succeeded by 2000 feet of sandstone and carbonate rock (Mount Rigg Group), all deposited on a stable platform with marginal depressions. Local tectonic activity and erosion caused disconformities within the sequence; faulting was minor and folding was generally due to warping during deposition. The Grace Creek Granite, a large porphyritic granophyric laccolith, was intruded below the base of the Katherine River Group, probably during one of the periods of tectonic activity. In the early Adelaidean, a 6000-foot assemblage of sandstone, shale, and ironstone (Roper Group) was deposited on the partly eroded surface of earlier sediments in the McArthur Basin, and then intruded by dolerite sills. Minor folding and faulting ended the depositional history of the McArthur Basin.

Later Adelaidean sedimentation includes a sandstone-shale sequence in the Victoria River Basin in the south-west of the Katherine-Darwin Region and, after minor warping and erosion, a sandstone-shale-carbonate sequence (Tolmer Group) on the northern margin of the Victoria River Basin and in the centrally situated Daly River Basin. This late Precambrian sedimentation was followed by some erosion before the extrusion of the Lower Cambrian Antrim Plateau Volcanics in the south-western part of the region, including most of the Daly River Basin. About 1000 feet of Middle Cambrian to Ordovician carbonate rocks were then deposited in the Daly River Basin. Transcurrent faults displaced the rocks in the eastern part of the region, including the Tolmer Group, up to 3½ miles.

Permian and Triassic sandstone and shale were laid down in the west, and in Lower Cretaceous time a thin but widespread veneer of sandstone, shale, and conglomerate was deposited over the area. The Cretaceous sediments were both marine and non-marine, the marine conditions encroaching on the non-marine from the east. Final Cretaceous sedimentation was confined to the Darwin area and farther north.

During the Cainozoic, weathering produced three main erosional surfaces, and the eroded material was deposited in the stream valleys and coastal plains. Laterite was formed over most of the earlier erosion surfaces. Some warping and minor faulting has continued until recent times.

Uranium, copper, gold, tin, and iron are the most important minerals mined hitherto; some silver-lead, wolfram, tantalite, and manganese were also produced, and lead will be mined in the near future. None of the mineral deposits are large by world standards. The minerals produced to date are worth about $150,000,000 at present prices; uranium accounts for about $100,000,000.

Uranium, copper, and lead at Rum Jungle occur in Lower Proterozoic shale overlying dolomite adjacent to a basement knoll; the deposits are just below an old land surface. In the South Alligator River Valley, uranium and some gold occur in Lower Proterozoic black shale and Carpentarian volcanics and sandstone. A syngenetic origin has been postulated for the mineral deposits in both localities; in the South Alligator River area the volcanics may be the source beds.

The gold, tin, uranium, and base metal mineralization away from Rum Jungle and the South Alligator River area is generally in shear-zones adjacent to the early Carpentarian granites. The iron deposits include a segregation in syenite and deposits formed by the supergene enrichment of ferruginous sediments.

INTRODUCTION

The Katherine-Darwin Region is an area of about 40,000 square miles situated in the northern part of the Northern Territory of Australia; it was surveyed by the Bureau of Mineral Resources between 1953 and 1958. The survey was generally at reconnaissance detail, and this Bulletin is, therefore, a general appreciation of the geology and mineral resources rather than a detailed account. References to detailed investigations are listed in the Bibliography.

The region is bounded by latitudes 12° and 15°S. and longitudes 130° and 133° 30′E. It was the site of the first permanent white settlement in the Northern Territory (Darwin, in 1869)*. Its northern coastline was reconnoitred by the Dutch in the 17th century, but neither they nor the itinerant Malays from the nearby and far more fertile Indonesian archipelago were encouraged to stay. Despite a certain notoriety brought about by the hardships of early epic explorations, the building of the Overland Telegraph Line, and the lurid promotion and subsequent failure of mining ventures; and although it was the first landfall on the Australian continent for the pioneers of the England-Australia air route, it remained a little-known and isolated part of Australia until the entry of Japan into World War II in 1941. A severe monsoonal climate, poor communications, poor soils, and small orebodies, all combined to discourage the spread of settlement. It was one of the few areas of European settlement in the tropics where the indigenous population did not provide the cheap labour and agricultural support on which so many colonies have been founded: it was an area of many difficulties and frustrated endeavours, few roads, one narrow-gauge railway, and sketchy maps.

Until 1911 the Northern Territory was administered by South Australia, and during this period considerable effort was devoted to exploration attempts to attract settlers to the Katherine-Darwin Region. The first large influx of population was due to the discovery of gold.** The first recorded find of gold was by F. Litchfield on the Blackmore River in 1865, but it was of no economic

* Other settlements, such as those at Port Essington, had been attempted earlier but were abandoned.

** For a more extended account see BLAINEY, G., 1963 — THE RUSH THAT NEVER ENDED. *Melb. Univ. Press*, 90-96.

importance. Strikes in 1872 (Pine Creek) and 1873 (Grove Hill), however, resulted in a rush of prospectors and miners, and because of the numerous and widespread mineral occurrences located, high hopes were held for the future. Unfortunately these were not realized. Although hundreds of orebodies were mined, none were worked to any great depth, and finally most were abandoned or turned over to Chinese tributors, originally brought to the Territory as construction labourers for the Darwin/Pine Creek railway. Lack of natural fuel and poor soils combined against any large-scale change-over from mining to industrial or agricultural pursuits. There were minor resurgences of mining activity — the discovery of rich ore at Maranboy tinfield in 1913 resulted in a small 'rush' — but by and large the outbreak of World War I in 1914 marked a time when any large-scale development of the region looked rather hopeless. The war stripped it of many of its most effective pioneers, few of whom returned.

The history of this early period is to be found in the archives of the Parliament of South Australia; the atmosphere, in three novels in particular — *We of the Never Never* by Mrs Aeneas Gunn, *Capricornia* by Xavier Herbert, and *The Territory* by Ernestine Hill.

Between the two World Wars the region lapsed into somnolence. Low tin and copper prices caused the abandonment of many of the mines still being worked, and the small cattle industry languished. In 1933 the population of the region was only 2000, of whom 1566 were in Darwin. World War II brought about the first major revival of interest in the region, albeit military, since the early gold rushes. Defence measures included the building of nearly 1400 miles of bitumen-sealed highway linking the region with the railheads at Alice Springs in the south and Mount Isa in Queensland, and many airstrips and secondary roads; Army survey maps were compiled, and the aerial photography begun by the Aerial Geological and Geophysical Survey of Northern Australia (AGGSNA) in 1936 was extended. But probably more important to the future development of the region was the postwar disposal of large quantities of military supplies in the form of building materials, tools, and equipment, and four-wheel-drive vehicles; and a growing political awareness of the vulnerability of the region and of its lack of development. This awareness, however, remained largely latent for some years after the war. The isolation from the more populous areas of the continent, the climate, and the inhospitability of the terrain remained to inhibit rapid development. Access to some parts of the region had been improved, but as late as 1953 a Bureau of Mineral Resources field party still found it necessary to employ a guide to find the track from Pine Creek to Goodparla homestead.

The discovery of uranium at Rum Jungle late in 1949, highlighted as it was by the short supply and tremendous strategic importance of this metal at that time, had two important effects: it served to crystallize political awareness of the region, and it eventually resulted in a major inflow of capital, and a valuable income from uranium mining — easily the largest income yet derived from any single industry in the region. It also caused a minor exploration boom, with the usual short life for a number of small companies. The known uranium orebodies, like most other known mineral occurrences of the region, were small: but the search for uranium did result in the first systematic geological mapping of the region as a whole, the introduction of modern prospecting techniques, and the delineation of the first major mineral deposit so far located (Brown's lead deposit at Rum Jungle), which, although low grade, at least proved that not all the mineral deposits of the region are small and shallow. This work is being continued by both Government and industry beyond the reconnaissance stage covered by this Bulletin and coupled with the endeavours of CSIRO, Northern Territory Administration scientists, and private enterprise, in the agricultural and cattle industries, and with marked improvements in communications and services, it is helping to bring about permanent large-scale changes. The region is not one of unlimited potential in any field; but potential it does have, and as our knowledge of it increases so do the chances of establishing economically sound ventures. The 'tall tales' so characteristic of any new development or discovery in the not-too-distant past are finding fewer believers and are being replaced by scientific enquiry.

The population of the region in 1964 was 19,460.

History of Previous Geological Investigations, and Scope and Extent of the Present Survey

The first geological investigations in the Katherine-Darwin Region were carried out in the latter part of the 19th century, and the first reporters were expert advisers to the South Australian Government. They dealt mainly with the mining fields. Tate (1882) and Tenison Woods (1886), although disagreeing on some aspects, both filed reports accompanied by geological sketch maps. Tate in particular recorded some accurate observations on the broad distribution of the mineralized rocks.

H. Y. L. Brown, then Government Geologist of South Australia, produced a number of reports on investigations carried out in the area in the late 19th and early 20th centuries. His observations are supplemented by the routine reports of the Government surveyors, and mining wardens and inspectors of that period.

W. G. Woolnough reconnoitred the area in 1912, after the administration of the Northern Territory was taken over by the Commonwealth Government; this reconnaissance was followed by the setting up of a small geological survey, with H. I. Jensen as Chief Geologist and G. J. Gray and R. J. Winters as assistants. A number of Bulletins were published on the mineral occurrences of the region.

In 1935, the Commonwealth, Queensland, and Western Australian Governments initiated the Aerial, Geological, and Geophysical Survey of Northern Australia (AGGSNA), which carried out geological and geophysical surveys of

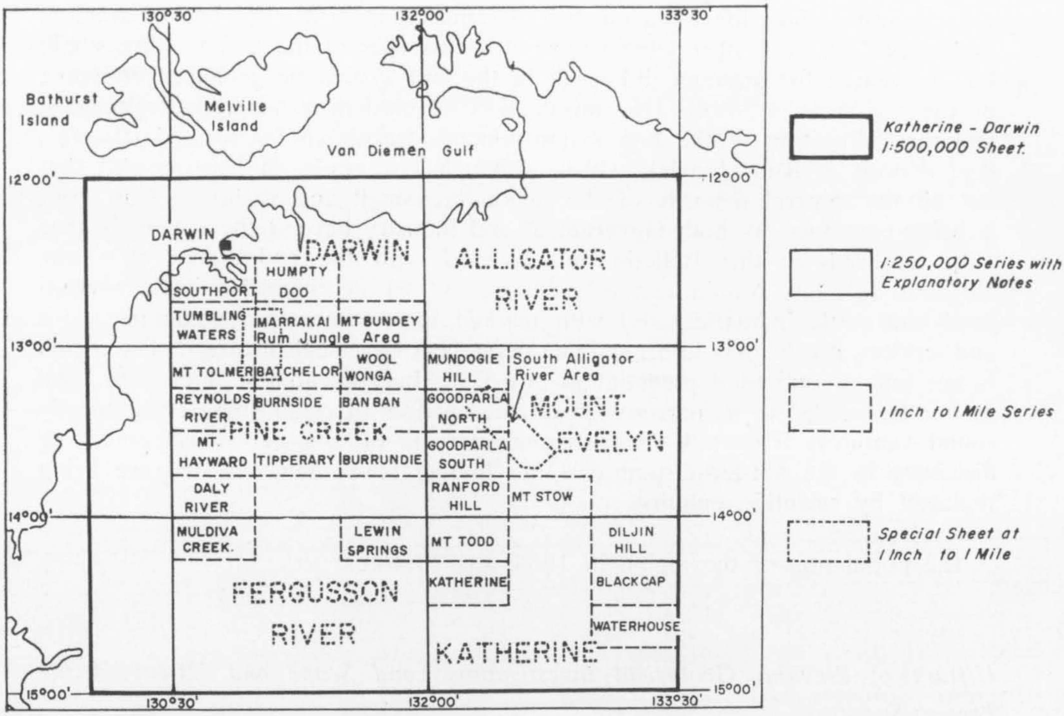

Fig. 1. Index to published geological maps, Katherine-Darwin region

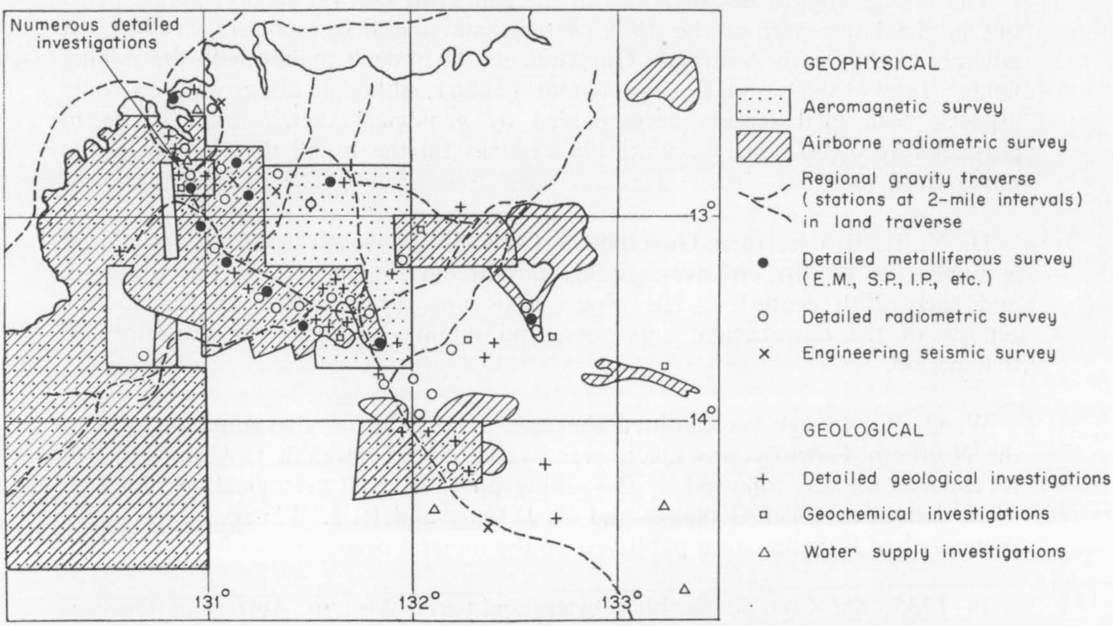

Fig. 2. Geophysical and detailed geological investigations by BMR, 1950-64, Katherine-Darwin region

most of the mineralized areas, and a limited amount of regional mapping, notably in the Brocks Creek, Maranboy-Yeuralba, Pine Creek, and Daly River areas. This work was terminated by the war, and much of it was incomplete or not published. Voisey (1939) and Hossfeld (1954) both produced papers based on their work with AGGSNA.

Apart from a few long reconnaissance traverses (mainly by H. Y. L. Brown), however, most of these investigations were unconnected and repetitive, inasmuch as they covered only parts of the central portion of the region, where most of the known mineral occurrences were located; most of this area is now known to contain only two of the major sedimentary rock units of the region — the Burrell Creek and Golden Dyke Formations. The early work is, therefore, of little value in the interpretation of the geology of the whole region, and very little of it was used during the 1953-58 survey.

Noakes of the Bureau of Mineral Resources accompanied a CSIRO land research survey of the region in 1946. He reviewed the previous work and compiled the first geological map of the region (Noakes, 1949). His map and conclusions have, inevitably, been amended beyond recognition by later more detailed work, but they provided the framework for the survey described in this Bulletin.

Between 1950 and 1953, Bureau field parties carried out a number of separate investigations connected with the uranium deposits, and some regional mapping and reconnaissance surveys. The results of the regional mapping and reconnaissance surveys are included in this Bulletin. Between 1954 and 1958 a concentrated effort was made to complete the regional mapping of the area. Maps produced during these two phases are indexed in Figure 1.

The 1950-58 geological surveys were carried out by the Bureau, and were financed jointly by the Bureau and the Australian Atomic Energy Commission; the work also included airborne and ground magnetometer surveys, scintillation counter surveys, and a regional gravity survey (Fig. 2). The primary objectives were to locate uranium deposits, and to assess the mineral potential of the region, with particular reference to uranium. Attention was mainly directed to the Lower Proterozoic rocks, and, apart from the valley of the South Alligator River, the Carpentarian and Adelaidean sequences were not mapped in detail. Some sequences indicated as 'Upper Proterozoic' on the published maps (Randal, 1963; Walpole, 1962; Dunn, 1962) have since been found to be older. Some major changes in time-rock nomenclature and other minor changes in the published maps have been incorporated in the 1 : 500,000 geological map accompanying this Bulletin (Pl. 28).

The scale of mapping was guided largely by the terrain and exposures. Much of the Lower Proterozoic terrain is poorly exposed; the sediments are commonly deeply weathered and it is difficult to trace the formations on air-photographs. Over a large part of the area scales of 1 : 30,000 and, in places, 1 : 12,000 were used, and the overall geological picture did not become evident until the survey was virtually completed.

Tangible results achieved include the discovery of additional uranium deposits at Rum Jungle, the ABC uranium prospect near Katherine, and the South Alligator uranium field, the latter two directly as a result of the regional investigations.

The surveys occupied about 42 man-years, about half of which were spent on field work; the Bureau geologists who took part in the survey are listed in Appendix 1. Their work, as a whole, is synthesized in this Bulletin. For information on mines and mineral deposits, other than uranium, extensive use has been made of the work of the Resident Geological Section, Darwin, which is staffed by geologists from the Bureau of Mineral Resources seconded to the Northern Territory Administration.

Planimetric base maps were provided by the Division of National Mapping, Department of National Development. They were compiled from air-photographs taken by the Royal Australian Air Force. Control for the base maps was by ground surveys and Shoran, the latter provided by the Bureau. Air-photographs and planimetric maps available in 1964 are indexed in Figures 3 and 4 respectively.

Climate

The climate is monsoonal, with a short summer wet season of 3 to 5 months, and a winter dry season of 7 to 9 months. The mean annual rainfall ranges from 60 inches at Darwin to 35 inches at Katherine 220 miles to the south-south-east. Most of the rain falls between November and April. The intensity of rainfall is high, and Christian & Stewart (1953) give a figure for Darwin of 0.60 inches per wet day, and point out that erosion is very active on all major slopes and bare surfaces. They also note that rainfall is the dominating climatic feature affecting plant growth and, 'apart from specially favoured seepage and flood areas, growth is restricted to a short wet season'.

Flooding of streams rising on the central uplands is common during the wet season, and many parts of the region, particularly the northern plains, are inaccessible by road for several months each year. Summer conditions are unpleasant. At Darwin, for the hottest month (November) the mean maximum temperature is 93.2°F, and the mean minimum temperature is 78.2°F; in the wet season the relative humidity exceeds 70 percent. The humidity decreases away from the coastal regions, but the temperature may rise to 100°F. Most field work is carried out in the winter when the country away from made roads is accessible to vehicles. At Darwin, for the coolest month (July) the mean maximum temperature is 86.6°F and the mean minimum 67.8°F. The mean relative humidity is over 60 percent. Figures are not available for the inland areas, but during the winter months the average temperature and humidity are considerably less than at Darwin.

Vegetation

Christian & Stewart (1953) summarize the vegetation of the region as follows: 'the dominant vegetation in all well drained areas is some form of open forest, or, in some places, palm scrub. Flooded areas carry either grassland or swampy grassland, most commonly fringed by parkland or a mixed community in which *Tristania, Grevillea,* or *Banksia* or *Pandanus* are prominent'.

In the northern part of the area (Koolpinyah Land System — Christian & Stewart, 1953), tall open forests of *Eucalyptus miniata* and *E. tetrodonta* are common. Paperbarks (*Melaleuca* spp.) and *Pandanus* fringe the permanent and semi-permanent lagoons. Palm scrub and mixed open forest characterize the Finniss River area 50 miles south of Darwin. South of Adelaide River and in the Brocks Creek and Cullen River areas the vegetation is mainly of a mixed open forest community with tall annual sorghum grass. The plateaux in the eastern section of the region carry only sparse stunted trees and spinifex grass (commonly *Triodia microstachya*).

There is no tropical jungle. Commercial timbers are present in minor quantities only, and access to them is commonly difficult. The most generally useful wood is obtained from the cypress pine (*Callitris intratropica*), which grows mainly on the Cretaceous tableland country, and on the sandy soils elsewhere. Ironwood (*Erythrophleum chlorostachys*), paperbark (*Melaleuca* spp.), red gum (*Eucalyptus*

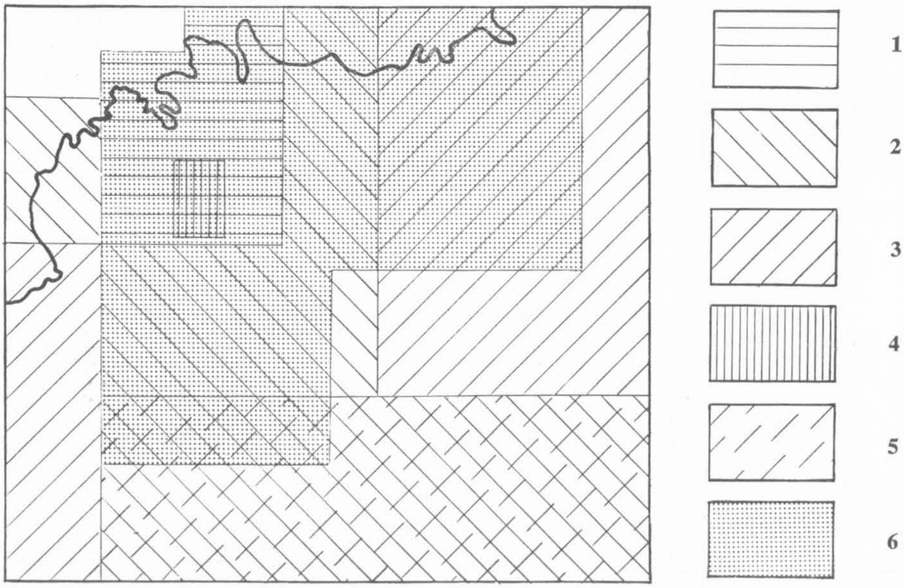

Fig. 3. Index to air-photographs. Katherine-Darwin region
1. 1:14,550, 1941; 2. 1:30,000, 1948-50; 3. 1:50,000, 1950-1; 4. 1:16,000, 1952; 5. 1:72,000, 1962; 6. 1:15,000, 1963-4.

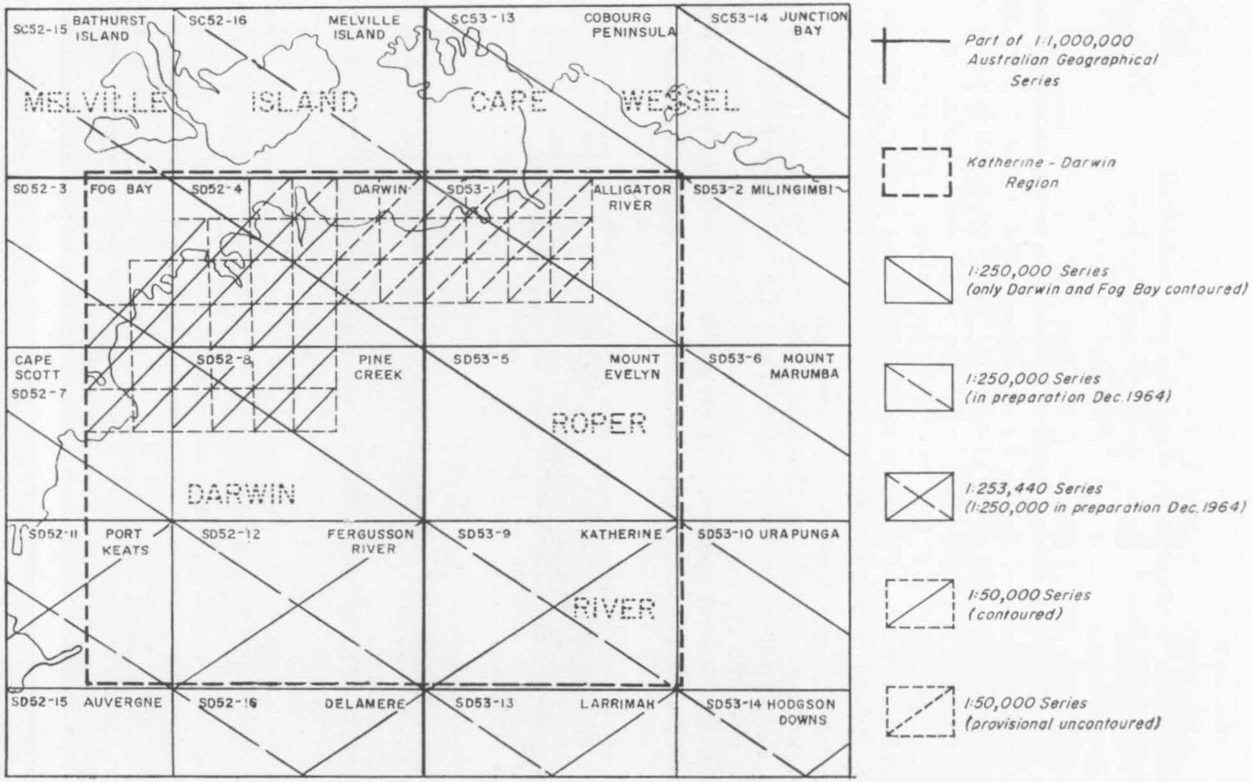

Fig. 4. Index to topographic and planimetric maps, Katherine-Darwin region and adjacent area

camaldulensis) and various savannah eucalypts and lancewood (*Acacia shirleyii*) are also used for various purposes. The cypress pine is in most demand as it is light and resistant to termites. Lancewood is used as a mining timber and for constructional poles.

The most common grass is the annual sorghum, which grows in places to a height of about 10 feet during the wet season. The grass is commonly burnt off, by accident or design, during the dry season. The general effect over most of the area is a monotonous landscape with stunted trees and rank grass.

Water Supply

Water for domestic and stock purposes is almost entirely derived from permanent streams, springs, and billabongs. Darwin obtains its supply from Manton Dam on the Manton River, 40 miles south of Darwin. In 1965 two supplementary sources of water supply for Darwin were under investigation: a dam on the Darwin River near the Darwin River Siding, and an underground supply from Lower Proterozoic dolomite near McMinns Lagoon. Because of the shorter pipeline requirements the McMinns Lagoon proposal is currently favoured. Batchelor, the township to the Rum Jungle uranium field, is supplied with water from the Crater Lake, a large sinkhole 4 miles east of Batchelor.

Pine Creek uses water from bores near the township, and Katherine uses water pumped from the nearby Katherine River. A number of bores were put down in the area by the Army during 1939-45, but most of them are no longer operative. Most of the mining camps have adequate water supplies (Maranboy is a major exception). The cattle stations depend mostly on natural supplies of surface water for stock use.

Most creeks and rivers flow only for short periods during the wet season, and dry up completely or become chains of isolated billabongs during the dry season. The major rivers are commonly permanent streams for part of their course. The Katherine, King, Flora, Fergusson, Cullen, and Douglas Rivers are the main tributaries to the Daly River. Of these, the Katherine is a permanent stream below the Katherine Gorge 15 miles north-east of Katherine; the Douglas and Flora Rivers have a spring-fed dry-season flow for part of their courses; the remainder run only during the wet season. The Daly, Adelaide, and East Alligator Rivers are permanent streams with well-defined estuaries, and are navigable to small craft for 30 to 40 miles. The South Alligator and Mary Rivers have a spring-fed dry-season flow in their upper courses only.

Numerous springs and permanent waterholes are present at the base of sandstone escarpments such as those of the Tolmer Plateau and the eastern scarp of the Arnhem Land Plateau, and in places around the residual cappings of flat-lying Mesozoic rocks.

Detailed records of the water resources of the region are compiled by the Water Resources Branch, Northern Territory Administration, which has recently established permanent stream-gauging stations and has a substantial drilling programme throughout the Northern Territory.

Topography

Except for the eastern and south-eastern parts of the area, the region generally has a mature topography. The highest point is about 1400 feet above sea level, and more than half of the area is less than 500 feet above the sea. Noakes (1949, p. 12) has described the present-day topography as developed from an older, peneplaned surface which was warped and uplifted to initiate the present cycle of erosion. Remnants of the older land surface exist as lateritic plains, mesas, and small tablelands in the Katherine-Darwin region, and extensive, although somewhat dissected, tablelands east and south of the region. He recognized four broad physiographic units; they form the basis of subdivisions used in this Bulletin, which are shown in Figure 5 and illustrated by Plates 1, 2, and 3. The main physiographic units are the Arnhem Land Plateau, Daly River Basin, Central Uplands, Northern Plains, and Western Plains. The Central Uplands and Arnhem Land Plateau are major subdivisions of Noakes' 'Uplands', the Central Uplands corresponding roughly to Christian & Stewart's 'elevated backbone country'.

Except for the Northern Plains, the major physiographic units reflect the lithology and structure of the various rock units, as a comparison of Figure 5 with Plate 28 clearly shows.

An arcuate divide separates the streams flowing north into Van Diemen Gulf from those which form part of the Daly River System and others which flow west or north into the Timor Sea. The divide runs south from a point about 25 miles south-east of Darwin to the head of the Adelaide River; from here it bears south-east to Pine Creek and thence east and north-east across the Arnhem Land Plateau to the head of the south-westerly-flowing Katherine River and of Jim Jim Creek, which flows north-west. The Daly River and Roper River Basins are separated by a poorly defined narrow divide, which runs between the King River and the head of the Roper River. These streams both run south-westerly in their upper courses; the King River turns sharply north-west to flow into the Katherine River and finally into the Daly River, but the Roper River turns south-east and eventually runs east into the Gulf of Carpentaria.

Apart from the Fitzmaurice, Finniss, and Adelaide Rivers, and some tributaries of the Daly River, the principal stream systems all originate in the *Arnhem Land Plateau,* which lies in the eastern part of the region. The plateau is made up mainly of resistant Carpentarian sandstone and generally lies at 800 to 1400 feet above sea level. In places, in the south, an older land surface is indicated by remnants of lateritized Mesozoic sediments. The streams in this area head

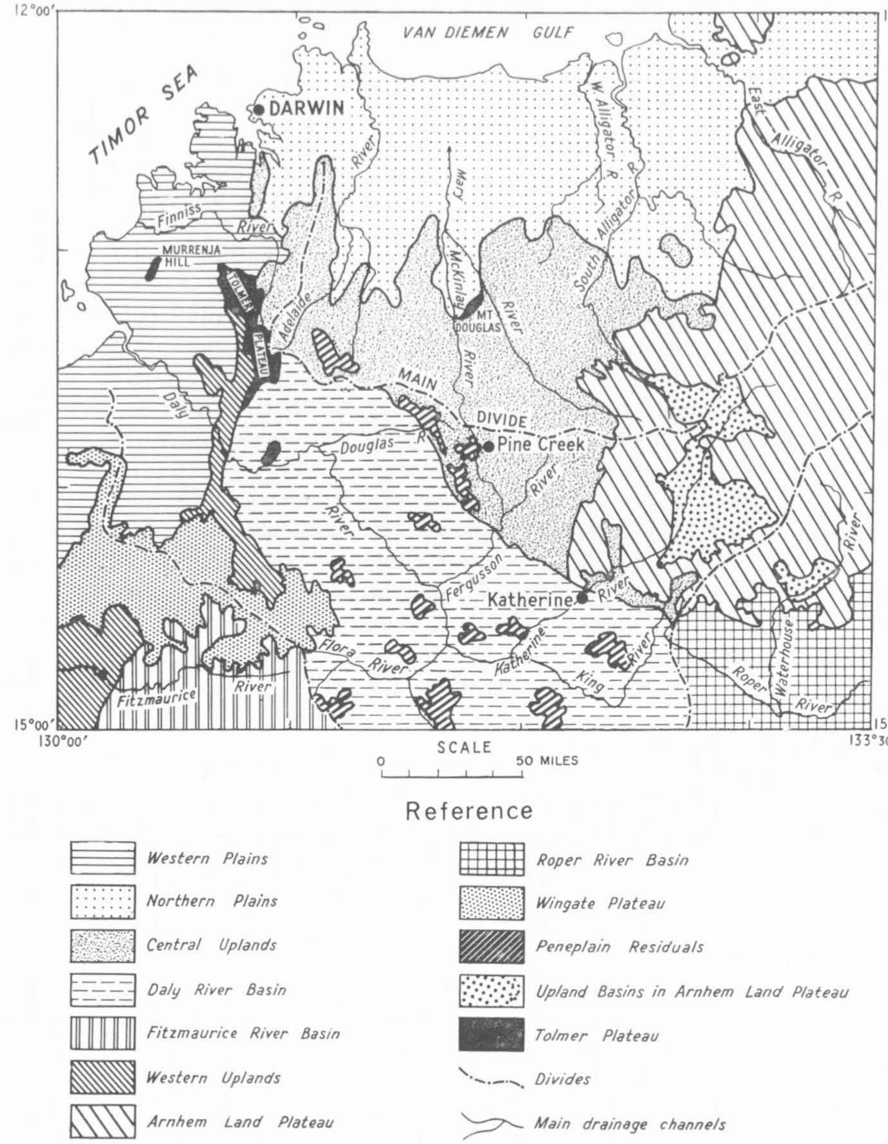

Fig. 5. Physiographic units, Katherine-Darwin region

at the edges of the plateau. In the central and northern sections, the Cretaceous rocks have been stripped off and the streams have eroded deep youthful gorges along the joints in the country rock. This country is exceptionally rugged, and the boundaries of the plateau are commonly marked by escarpments up to 800 feet high.

Erosion by the Waterhouse, Katherine, and South Alligator Rivers and their tributaries resulted in the development of 'upland basin' areas within the Arnhem Land Plateau, which coincide with areas where the plateau rocks formed a thin capping. The stream systems have cut deep gorges through barriers of Carpentarian rocks before entering their main debouchment areas (Pl. 3, fig. 2). The topography in the upland basin areas ranges from youthful to mature.

The *Daly River Basin* is the main debouchment area for the principal tributaries of the Daly River — the Katherine, King, Flora, Fergusson, and Douglas Rivers. The topography is undulating, with numerous mesas capped by lateritized Cretaceous sediments which represent remnants of an older land surface. The Daly River Basin is about 120 miles long and 60 miles wide, and extends south beyond the area mapped.

The outlet from the Daly River Basin is to the west, and is constricted by a narrow belt of uplands — the Western Uplands — through which the Daly River has cut a narrow valley before emerging on to the mature low-lying flats and swamps of the Western Plains.

The *Wingate Plateau* forms the divide between the Daly and Fitzmaurice River systems. Much of it is covered by flat-lying lateritized Cretaceous sediments which are being eroded on all sides.

The *Central Uplands* form part of the morphological unit referred to by Christian & Stewart (1953) as the 'elevated backbone country'. The region consists of ridges, mesas, small tablelands, and numerous isolated rounded hills separated by narrow flat-floored valleys. Most of the mineral occurrences in the Katherine-Darwin Region occur in the Central Uplands, and most of this country can be traversed by vehicle. The uplands are bounded to the east by the Arnhem Land Plateau, and to the south-west by the Daly River Basin. The chief drainage systems north of the main divide are the Adelaide, McKinlay, and Mary Rivers, and tributaries of the South Alligator River.

The Central Uplands merge into the *Northern Plains* at about latitude 13°S. The plains occupy a belt about 70 miles wide south of the coastline of Van Diemen Gulf, and extend for about 100 miles from about longitude 131°E. to the Arnhem Land Plateau. Most of the Northern Plains are flat or gently undulating, with a few small groups of rounded hills or low ridges. There are large swamps, such as the Woolwonga Swamp, and numerous divergences and anabranches of the principal streams draining the Central Uplands and Arnhem Land Plateau. The streams in the plains are mostly aggradational. Some have broad navigable estuaries flanked by mud banks; others, like the Mary River, lose their identity in the plains before reaching the coast. Most of the Northern Plains have an elevation of less than 150 feet. Large sections are flooded during the wet season, and are inaccessible by vehicle for about seven months of each year.

The *Western Plains* occupy a belt of country about 100 miles long and up to 60 miles wide; they are bounded by the Timor Sea to the west and by north-trending ridges of the Western Uplands to the east. Much of the area is covered by swamp. The estuary of the Daly River lies within the Western Plains. Some rivers, like the Reynolds and Finniss, drain into swamps and are not connected to the sea by permanent channels. Like the Northern Plains, most of the area is flooded or inaccessible by vehicle for more than half the year.

The Roper River Basin lies in the extreme south-eastern corner of the Katherine-Darwin Region and the Fitzmaurice River Basin in the south-western corner. The *Fitzmaurice River Basin* is a minor physiographic unit, and drains part of the dissected southern flank of the Wingate Plateau, and the mesas along the divide on the south-western margin of Daly River Basin. The Fitzmaurice River Basin extends south beyond the area mapped. It is still being dissected and is constricted by north-south ridges which cut across the Fitzmaurice River above its estuary.

Only the north-western corner of the *Roper River Basin* lies within the Katherine-Darwin Region. It is separated from the Daly River Basin by a low divide between the upper courses of the King and Roper Rivers. In this area drainage to the Roper is south from the Arnhem Land Plateau, the principal watercourse being the Waterhouse River, which has cut a small upland basin in the Arnhem Land Plateau.

Remnants of old peneplaned land surfaces occur throughout the area. They take the form of residual mesas and small tablelands, which commonly mark the divide between the stream systems. All are being eroded and most owe their survival to a resistant capping of lateritized Lower Cretaceous rocks. They are commonly bounded by escarpments where the capping is thick, or by steep slopes cut in older rocks where the capping is thin. Some of the small tablelands, such as those in the Roper River Basin in the Maranboy area, have an escarpment facing out from the basin and a gentle slope into it.

Fault blocks of resistant Precambrian rocks occur at Murrenji Hill, Mount Douglas, and the Tolmer Plateau. On the *Tolmer Plateau,* a cover of Mesozoic rocks has been removed, but the old land surface is still evident in the levelling of the Adelaidean rocks which constitute the present plateau.

STRATIGRAPHY

Regional Setting

The Katherine-Darwin Region is part of the Australian Precambrian Shield, and contains rocks ranging from Archaean to Recent in age. Noakes (1949, p.13) records that it has been a comparatively stable area since Precambrian time. Permian strata of the Bonaparte Gulf Basin crop out along the western margin, but elsewhere the sedimentary record contains only Precambrian, Cambrian, Ordovician, Cretaceous, and Cainozoic rocks.

The central and northern parts of the region contain mainly folded Lower Proterozoic rocks of the Pine Creek Geosyncline; they are commonly unmetamorphosed or metamorphosed only to low greenschist facies, and intruded by granitic bodies and basic to intermediate sills and dykes. Lower Proterozoic rocks also form a rectilinear belt running south-west from Rum Jungle to beyond the south-western corner of the region. Inliers of Archaean rocks crop out in several places.

The Arnhem Land Plateau is the predominant feature on the eastern margin of the region. It is composed of gently folded or flat-lying Carpentarian sediments and volcanics disposed in small basins or on platforms, with inliers of older rocks in places. The Carpentarian rocks form the most westerly outcrops of the McArthur Basin: to the north they rest uncomformably on Lower Proterozoic rocks, and in the south-western corner of the region they are faulted against Adelaidean sediments of the McArthur Basin.

The Daly River Basin runs south-eastwards across the southern half of the region; it is flanked by Lower Proterozoic and Adelaidean sediments, and occupied by Lower Cambrian volcanics and Middle Cambrian and Lower Ordovician sediments. The northern part of the Victoria River Basin, containing probable Adelaidean sediments, occupies a small area in the south-western corner of the region.

Lower Cretaceous sediments crop out as residuals of a veneer which probably originally covered the whole region.

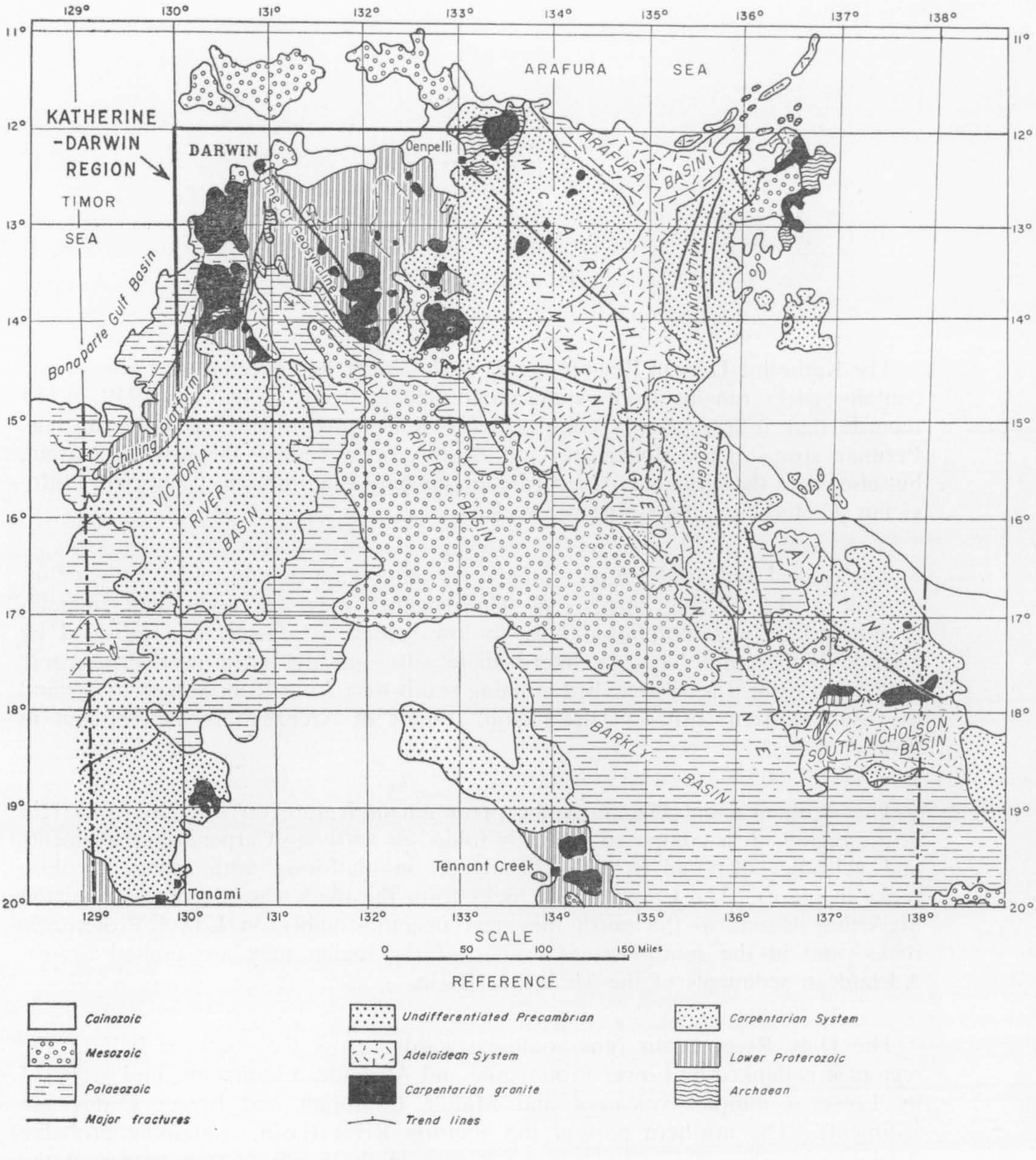

Fig. 6. Major structural and depositional elements, northern part of the Northern Territory

The region contains elements of five major depositional structures, excluding the inliers of Archaean rocks and the veneer of Lower Cretaceous rocks; the distribution of these structures is shown in Figure 6.

Attempts have been made by previous workers to fit the different structures into an overall tectonic framework (Cotton, 1930; Hills, 1946, 1956; Noakes, 1954), but most of the syntheses were based on scanty information and do not satisfactorily explain the latest data. Noakes (1949, p. 13) states that there is no record of major diastrophism since the Proterozoic Era, and this long period of comparative stability and practically uninterrupted erosion has produced a region of low relief which consists, for the greater part, of Precambrian rocks. This summary can now be modified: the structural record shows no severe post-Archaean diastrophism, but rather vertical movements and high-level plutons characteristic of a cratonic area. The last movement of any consequence resulted in the Carpentarian sedimentation. Since then the region has probably remained generally above sea level, and any younger sediments were deposited in very shallow basins, or as thin sheets.

The presence of inliers of Archaean rocks, unknown before the present survey, indicate that the region was part of an Archaean shield area, which helps to explain the shallow character of the Pine Creek Geosyncline and succeeding basins, and the lack of severe regional metamorphism in sedimentary sequences ranging over 2000 million years of geological time. The Pine Creek Geosyncline is an intracratonic basin rather than an orogenic belt. The main axis trends south-east, as recognized by Traves (1955) and earlier by Cotton (1930).

Although the geosynclinal rocks were folded, in places severely, the folding movement apparently did not result in the raising of mountain chains from which the sediments in the younger flanking basins could have been derived. Some sediment must have been contributed from the geosyncline, but the origin of the bulk of the material for the succeeding Carpentarian rocks is obscure. In the Katherine-Darwin Region, the Carpentarian rocks consist of up to 9000 feet of very coarse-grained arenites and rudites with interbeds of volcanic rocks. A westerly or north-westerly source is most probable, but such a thickness of coarse material was unlikely to have been derived from the Pine Creek rocks, most of which are lutites or fine-grained sediments. Moreover, the Mount Douglas outlier shows that the arenite sheet extended at least to near the axis of the geosyncline, thus considerably reducing any possible area of provenance in the Katherine-Darwin Region.

The succeeding Adelaidean and Palaeozoic basins may have been filled by material derived from older sequences within the region.

Most of the granites in the Pine Creek Geosyncline are similar in age to the acid lavas (Edith River Volcanics), which are in sequence with the Carpentarian sediments at the base of the McArthur Basin (P. J. Leggo, BMR, pers. comm.). The intrusion of the granites therefore appears to be related to vertical movements in the basement which initiated the development of the McArthur Basin rather than to the tectonic event which folded the sediments of the Pine Creek Geo syncline.

The thin veneer of Mesozoic sediments extends well beyond the Katherine-Darwin Region, and forms part of the vast area involved in Cretaceous epi-cratonic sedimentation west of the Tasman Geosyncline.

Stratigraphical Nomenclature

Since the Katherine-Darwin survey was completed and the maps published, the adjacent McArthur Basin has been mapped and the geochronology of both areas has been studied; both the time-rock subdivisions and some geological details have been revised (McDougall et al., 1965; Dunn et al., 1966).

The isotopic ages are listed in Appendix 2. The Archaean basement at Rum Jungle is dated at 2550 m.y., and although the Lower Proterozoic boundary may be younger than this, it cannot be older. The upper limit of what we here call Lower Proterozoic is given by the age of the Cullen Granite and of the Edith River Volcanics, about 1800± 50 m.y. The rocks of the interval 1800 to 1400 m.y. are given the name Carpentarian System; and those from about 1400 m.y. to the base of the Cambrian form the Adelaidean System.

Noakes in particular, and other workers have for some years correlated the so-called Upper Proterozoic of the Northern Territory with the Adelaide System of South Australia. The most recent age determinations make such a correlation acceptable — but only for a drastically reduced area of the previously designated 'Upper Proterozoic' in the northern part of the Northern Territory.

Noakes (1949) makes the point that the stratigraphic nomenclature of the Katherine-Darwin Region was confusing until the Code of Stratigraphic Nomenclature was introduced. Thus a large number of names were used for what is now known to be the same unit. This particularly is the case with the Burrell Creek Formation — which received most attention because it contains the majority of the old gold mines; the early workers gave it a different name at each different mine they visited. Also the general relationships were not known, and as late as 1949 Noakes, in defining his Brocks Creek Group, mistakenly suggested that Voisey's 'Golden Dyke Series' was younger than the same writer's 'Pine Creek Series'; our later mapping has shown that the so-called 'Pine Creek Series' is younger.

Before 1950, attention was directed mainly to the central part of the region and the Daly River area, where only three of the formations now recognized occur — the Burrell Creek, Noltenius, and Golden Dyke Formations, of which Burrell Creek and Noltenius can be regarded as one for the purpose of this discussion. Noakes constructed his Brocks Creek Group from the (now) Burrell Creek Formation, possibly part of the Noltenius Formation, and the Golden

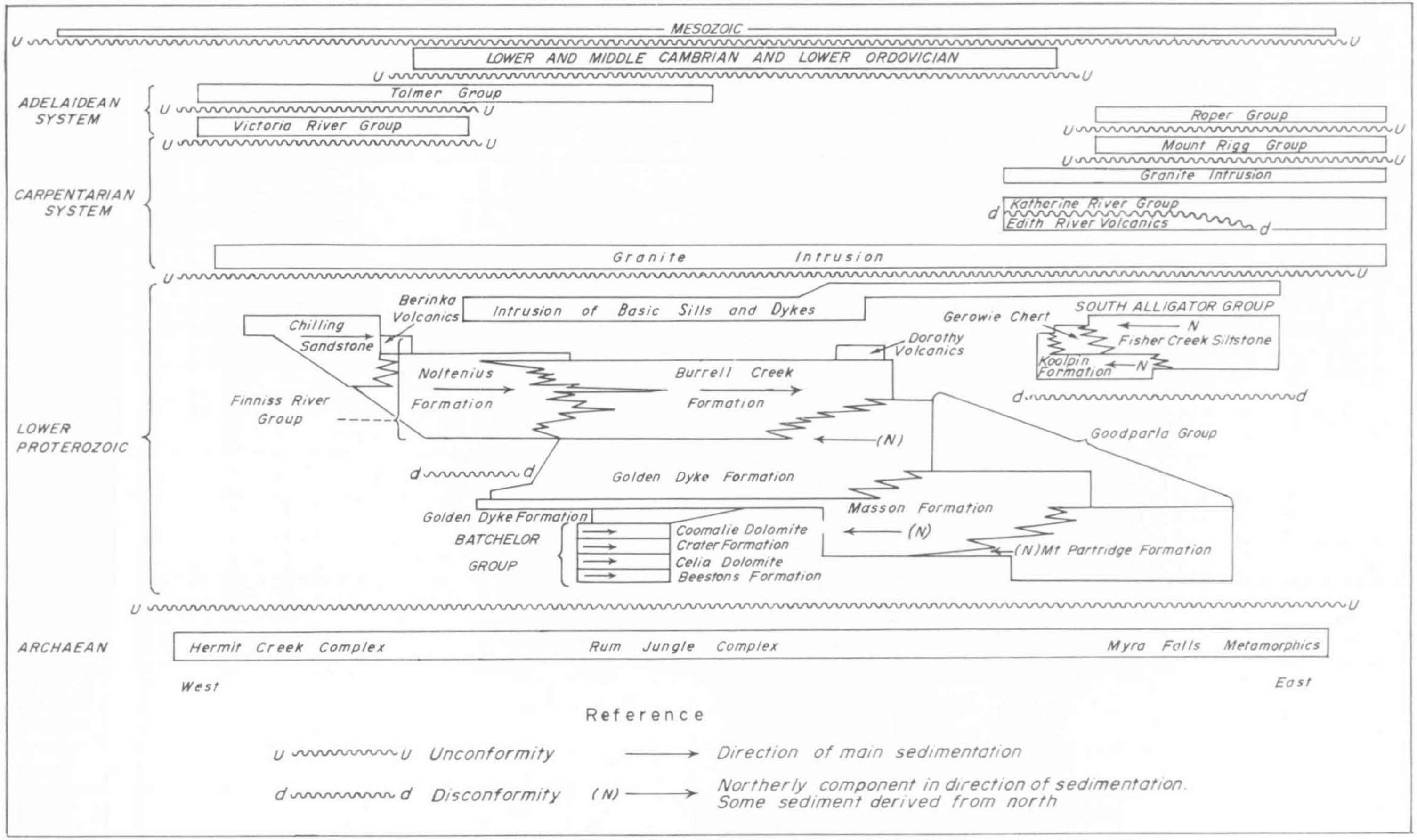

Fig. 7. Relationship of rock units, Katherine-Darwin region

Dyke Formation, but his order of superposition was incorrect. However, he recognized that further subdivision would be necessary and did not define any formations within the group. He extended its usage to cover all Lower Proterozoic rocks in the region, a practice which was continued by later workers until finally abandoned in 1955.

We have not retained Brocks Creek Group because the two main rock units (the Burrell Creek and Golden Dyke Formations) do not form a single natural assemblage, even though they are in contact, and in places interbedded. The Golden Dyke sediments have an easterly and northerly provenance and belong to a suite (Goodparla Group) derived mostly earlier and under different conditions from the Burrell Creek material, which was derived from the west.

Noakes did not accept Voisey's subdivision based on metamorphic grade, and neither do we. Differences in the degree of metamorphism in the geosyncline are of local importance only and are due mainly to shearing stress.

The main changes in previous rock nomenclature (accepting Noakes as the first author to publish on these rocks under the Code of Stratigraphic Nomenclature) affect only two formations and one group. Of the two formations, the name Golden Dyke is retained as a meaningful term and follows Voisey's nomenclature. Burrell Creek is a new name, and in this regard we found it necessary to depart from the rule of nomenclatural priority. There were too many previous names (at least nineteen): 'Dashwood Slate' or 'Dashwood Redwacke' (Jensen & Oliver, 1914), typical of the early names, refers to rock types at a small shaft in the Pine Creek gold field. Burrell Creek was the name adopted as a field term at the start of the survey, and the locality is one of the best and most accessible type areas for this unit. It has been accepted by the Australian Stratigraphic Nomenclature Committee. The term 'Group', as used for Goodparla, Finniss River, and South Alligator Groups, has been used, not for 'two or more Formations deposited one upon the other', but for formations lithogenetically related. The formations in each group are disposed laterally, which is a more natural grouping than superposition in a geosyncline of this type.

Wherever possible, names appearing in previous literature have been retained, although the status of some units has been changed to conform with the new information available, and in accordance with the rules of the Code.

The rock types and distribution of the rock units are summarized in Tables 1, 2, 3, 11, and 13, and their relationships are illustrated in Figure 7.

TABLE 1: STRATIGRAPHIC TABLE, ARCHAEAN ROCK UNITS

Rock Unit	Thickness	Lithology	Distribution (Incl. 1:250,000 Sheets)	Reference Area	Stratigraphic Relationships	Reference
Stag Creek Volcanics	Unknown	Altered basalt and basalt agglomerate	Mundogie Dome and S. Alligator R. valley: Mt Evelyn Sheet	Stag Creek, lat. 13°30′S., long. 132°20′E.	Unconformably overlain by Mundogie Sandstone Mbr and Masson Fm.	Walpole (1962)
Hermit Creek Metamorphics	Unknown	Migmatite, banded granulite, quartzite, and mica schist	Cape Scott, Pine Ck, Fergusson R., and Port Keats Sheets	Hermit Creek, lat. 13°58′S., long. 130°25′E.	Intruded by and grades into Litchfield Complex	Randal (1962), Malone (1962a)
Myra Falls Metamorphics	Unknown	Quartz-mica schist, mica schist, amphibole schist, and quartz sandstone	N.E. corner of Katherine-Darwin Region: Alligator R. Sheet	Myra Falls, lat. 12°27′S., long. 133°20′E.	Boundary with Lower Proterozoic rocks covered by younger sediments	Dunn (1962)

PRECAMBRIAN

ARCHAEAN

Inliers of Archaean rocks crop out in four localities: in the Hermit Hill area, about 15 miles south-west of the Daly River settlement, where rocks of the *Hermit Creek Metamorphics* comprising migmatite, schist, and gneiss are intruded by Carpentarian granite; at Rum Jungle, where the *Rum Jungle Complex* (Rhodes, 1965)* of gneiss, schist, migmatite (Pl. 4, fig. 1), and granite crops out as a core of basement rocks surrounded by sediments of the Lower Proterozoic Batchelor Group; in the valley of the South Alligator River and at Mundogie Hill, where altered basalt and basaltic agglomerate of the *Stag Creek Volcanics* (Pl. 4, fig. 2) form a basement ridge separating different assemblages of the Lower Proterozoic succession, and occupy the core of a small dome in the Lower Proterozoic rocks; and in the Oenpelli area in the far north-western corner of the region, where the *Myra Falls Metamorphics* — mica schist, quartzite, and amphibolite schist — and *Nimbuwah Complex* lie on the eastern margin of the geosyncline; they are, apparently, intruded by granite of the Nimbuwah Complex.

The small outcrops of Nanambu Granite about 20 miles south-west of Oenpelli and part of the Litchfield Complex in the Hermit Hill area may also be part of the Archaean basement. The Archaean unconformity has been observed only in the Rum Jungle area. Elsewhere, the Archaean age is inferred from differences in the degree of metamorphism and structural trends as compared to the adjacent Lower Proterozoic rocks, and because the sedimentary and structural record suggests the presence of basement in or near each area.

Where Archaean structural trends have been observed, they mostly strike west, but the outcrops are too small and widely separated to determine the general structure. The inliers of Archaean rocks help define the limits and explain the structure of the Pine Creek Geosyncline.

LOWER PROTEROZOIC: EVOLUTION OF THE PINE CREEK GEOSYNCLINE

The Lower Proterozoic rocks of the Katherine-Darwin Region are a geosynclinal assemblage deposited in a fairly shallow composite structure — the Pine Creek Geosyncline. Only part of the geosyncline is exposed, but the visible sedimentary record gives a good picture of its evolution, particularly as the sediments

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* The Rum Jungle Complex is shown on existing maps as Proterozoic Granite intruding Archaean, but it is now known to be mostly Archaean. The age of Rhodes' 'leucocratic granite' is uncertain: it could be as young as Carpentarian. We do not regard Rhodes' interpretation of the complex as a type of mantled gneiss dome as proven; there is evidence of differential vertical movement between the sediments and basement, but the lenticularity of the sediments also suggests that it formed a basement knoll during sedimentation.

are practically unmetamorphosed. Metamorphism is confined mainly to contact aureoles around some of the granitic intrusions, and to sheared zones on the margins of the geosyncline; and has nowhere obliterated the original character of the sediments. The original form of part of the basin of deposition is partly preserved. Despite later folding each of the formations mapped still occupies its original position within the geosyncline relative to the units with which it is in contact (compare Fig. 8 and Pl. 28).

The geosyncline contains four rock units of group rank, the Batchelor, Goodparla, Finniss River, and South Alligator Groups. Each group is a particular facies assemblage which can be interpreted as representing an episode in the development of the geosyncline: no single group typifies the geosyncline as a whole; but their interrelationships allow its evolution to be traced. These interrelationships are illustrated by Figure 7.

The episodes of sedimentation represented by the groups largely coincide with, and are controlled by, the main structural units in the composite geosyncline, which are: the Primary Basin (including the Central Trough), the Western Fault Zone, the Eastern Trough, and the Chilling Platform (Fig. 8). The Primary Basin was probably a fairly shallow asymmetrical basin with its long axis trending south-east. The other structures are secondary and partly obscure the primary structure.

SEDIMENTATION IN THE PRIMARY BASIN

The Primary Basin is outlined by the sediments which form the basal units of the geosynclinal pile — the Batchelor and Goodparla Groups.

Batchelor Group

The Batchelor Group lies on the western side of the northern end of the Primary Basin. It is correlated with the Mount Partridge Formation of the Goodparla Group, and consists of four formations which crop out in two domes in the Batchelor area, 50 miles south of Darwin. The cores of these structures are occupied by the Rum Jungle Complex and the Waterhouse Granite (Pl. 30).

The western limit of outcrop is partly determined by the north-trending Mount Fitch Fault*, which is believed to form the eastern margin of the Finniss River Graben. This graben is occupied by the younger Burrell Creek and Noltenius Formations. To the north and east, the Batchelor Group is overlain by the

* The existence of the Mount Fitch Fault is based on interpretation of one or two small outcrops, and it may not be a simple north-trending fracture as shown on Plate 30.

TABLE 2: STRATIGRAPHIC TABLE, LOWER PROTEROZOIC ROCK UNITS

Rock Unit	Thickness (ft)	Lithology	Distribution (Incl. 1:250,000 Sheets)	Reference Area	Stratigraphic Relationships	References
Chilling Sandstone	1500	Coarse to medium-grained quartz sandstone	Mainly developed in S.W. part of Katherine-Darwin Region: Darwin, Cape Scott, Pine Ck, Ferguson R., and Port Keats Sheets	Chilling Ck, N. of Wingate Plateau, lat. 14°15′S., long. 130°36′E.	Overlies Noltenius Fm. near Fletchers Gully	Randal (1962)
SOUTH ALLIGATOR GROUP			S. Alligator R. valley and eastwards: Alligator R. and Mt Evelyn Sheets			
Fisher Creek Siltstone	17,000	Siltstone, minor greywacke siltstone, and micaceous siltstone	S. Alligator R. valley: Mt Evelyn Sheet	Upper reaches of Fisher Ck, lat. 13°36′S., long. 132°50′E.	Overlies and interfingers with Gerowie Chert and Koolpin Fm.	Walpole (1962)
Gerowie Chert	3000	Chert and impure chert; siliceous siltstone	S. Alligator R. valley: Mt Evelyn Sheet	4 miles due S. of Shovel Billabong near S. Alligator R., lat. 13°21′S., long. 132°20′E.	Facies variant of underlying Koolpin Fm.; may be diagenetic alteration product of dolomitic rocks	Walpole (1962)
Koolpin Formation	5000	Algal dolomite, as discontinuous bioherms in places at base; pyritic carbonaceous siltstone, with lenses, nodules, and bands of chert; carbonaceous siltstone; pyritic siltstone, in places capped by gossanous hematite	Along S. Alligator R. valley: Mt Evelyn and Alligator R. Sheets	Reference section for biohermal structures: between Pul Pul Hill and Coronation Hill, lat. 13°34′S., long. 132°35′E. For other rocks: Koolpin Ck, lat. 13°31′S., long. 132°33′E.	Basal unit of S. Alligator Gp. Essentially a reef facies on old basement ridge along W. margin of Eastern Trough. Disconformably overlies Goodparla Gp	Walpole (1962) Dunn (1962)
FINNISS RIVER GROUP						
Burrell Creek Formation	5000	Greywacke, siltstone, and greywacke siltstone; locally metamorphosed to andalusite-mica schist and mica schist	Central Trough of Pine Ck Geosyncline in central and N.W. part of Katherine-Darwin Region: Darwin, Pine Ck, Mt Evelyn, Fergusson R., and Katherine Sheets	Reference section: Burrell Ck, near Stuart Highway, lat. 13° 20′S., long. 131°08′E.	Conformably overlies Golden Dyke Fm. with some interfingering W. of Brocks Ck. Overlaps Golden Dyke Fm. S. of Waterhouse Granite	Walpole (1962), Malone (1962a, b)
Noltenius Formation	5000	Quartz greywacke, siltstone, quartz pebble and cobble conglomerate; locally metamorphosed to andalusite mica schist and mica schist	Mainly on W. margin of Pine Ck Geosyncline: Darwin, Pine Ck, and Fergusson R. Sheets	Hills near Noltenius Billabong N. of Daly R. police post, lat. 13°35′S., long. 130°47′E.	Lateral facies variant of Burrell Ck. Fm. Contains unidentified organisms	Malone (1962a)
Berinka Volcanics	(?)	Spherulitic rhyolite, ashstone, intermediate amygdaloidal volcanics, and granophyre	W. of Muldiva Ck: Fergusson R. Sheet	Berinka pastoral lease, lat. 14°5′S., long. 130°33′E.	Interbedded with Noltenius Fm.	Randal (1962)
Dorothy Volcanics	1000	Basic volcanics, tuff, and tuffaceous sediments	Small area E. of Katherine: Katherine Sheet	Dorothy Ck, lat. 14°27′S., long. 132°29′E.	Overlies Burrell Ck Fm. and folded with it	Rattigan & Clark (1955, unpubl.), Randal (1963)
GOODPARLA GROUP						
Golden Dyke Formation	9000	Carbonaceous dolomitic shale, in places pyritic; pyritic carbonaceous siltstone, with lenses, bands, and nodules of chert; chert, quartz siltstone, dolomite, and slump breccia	E., central, and N. parts of Central Trough: Darwin, Mt Evelyn, and Pine Ck Sheets	Golden Dyke mine, lat. 13°34′S., long. 131°31′E.	Deposited in Central Trough, interfingers with overlying Burrell Ck Fm.	Walpole (1962) Malone (1962a, b)
Craig Creek Member	2000	Pyritic carbonaceous dolomitic siltstone; slump breccia; pyritic carbonaceous siltstone with chert nodules	Near lower reaches of Mary R.: Darwin and Pine Ck Sheets	Craig Ck., lat. 13°09′S., long. 131°55′E.	Basal part of Golden Dyke Fm. on Woolwonga and Mt Bundey 1 mile Sheets	Dow & Pritchard (1958, unpubl.)
Masson Formation	10,000	Quartz greywacke, siltstone, conglomerate, quartz sandstone, pyritic and carbonaceous siltstone, and dolomitic sediments	E. and N. parts of Pine Ck Geosyncline: Darwin, Mt Evelyn, Alligator R., and Pine Ck Sheets	Near Mt Masson mine, lat. 13°20′S., long. 131°50′E.	Transitional facies of Goodparla Gp. Conformably overlies Mt Partridge Fm. and underlies Golden Dyke Fm.	Malone (1962)
Acacia Gap Tongue	4000	Interbedded pyritic carbonaceous siltstone and siliceous quartz greywacke, in places pyritic	Locally N. and E. of Rum Jungle: Darwin and Pine Ck Sheets	Acacia Gap, lat. 12°48′S., long. 131°12′E.	Tongue of Masson Fm. underlying and interfingered with Golden Dyke Fm.	Malone (1962b)
Coirwong Greywacke Member	1000	Medium to coarse quartz greywacke and minor conglomerate	S. Alligator R. valley: Mt Evelyn Sheet	Coirwong Gorge, lat. 13°13′S., long. 132°09′E.	Prominent marker in Masson Fm. in S. Alligator R.	Walpole (1962)
Mount Partridge Formation	10,000	Arkose, arkose conglomerate, siltstone, and medium quartz sandstone, in places ripple-marked and cross-bedded: conglomerate, and minor quartz greywacke, silicified dolomite lenses, and ferruginous siltstone; locally metamorphosed.	N.E. part of Pine Ck Geosyncline: Darwin, Alligator R., and Mt Evelyn Sheets	Mt Partridge, lat. 13°05′S., long. 132°31′E.	Marginal facies assemblage; conformably overlain by Masson Fm.	Walpole (1962) Dunn (1962)
Mundogie Sandstone Member	5000 (?)	Coarse to medium quartz sandstone, conglomerate, and sandy siltstone; minor quartz siltstone and quartz greywacke	Mundogie Hill area only: Mt Evelyn Sheet	Reference section: Mundogie Hill, lat. 13°10′S., long. 132°20′E.		Walpole (1962)
BATCHELOR GROUP			Batchelor area only: Darwin and Pine Ck Sheets		Conformable repeated succession of clastic sediments followed by dolomitic sediments	Malone (1962a, b), Raggatt (1958)
Coomalie Dolomite	1000	Silicified and metamorphosed algal dolomite, calcilutite, siltstone, and tremolite schist	Around Rum Jungle and Waterhouse Domes and northwards: Darwin and Pine Ck Sheets	Headwaters of Coomalie Ck. lat. 13°03′S., long. 131° 03′E.	Mainly reef dolomite; algal bioherms	Malone (1962a, b), Raggatt (1958)
Crater Formation.	2000	Quartz greywacke, greywacke arkose, fine pebble conglomerate, and siltstone; pyritic carbonaceous dolomitic marl	Around Rum Jungle and Waterhouse Domes: Darwin and Pine Ck Sheets	Crater Hill, ¾ mile E. of Batchelor, lat. 13°03′S., long. 131°02′E.	Mainly coarse clastic sediments; thickest and most widespread unit of Batchelor Gp.	Malone (1962a, b), Raggatt (1958)
Celia Dolomite	1000	Algal dolomite, in places silicified and metamorphosed; silicified dolomite breccia	Around Rum Jungle and Water house Domes: Darwin and Pine Ck Sheets	Celia Ck area, lat. 12°52′S., long. 130°58′E.	Mainly reef dolomite	Malone (1962a, b)
Beestons Formation	1000	Arkose, greywacke, siltstone, conglomerate, and arkosic conglomerate	Lenses out N. and S. of Rum Jungle: Pine Ck and Darwin Sheets	Beestons Ck lat. 12°55′S., long. 130°58′E.	Oldest known sediments deposited in the Pine Ck Geosyncline	Malone (1962a, b)

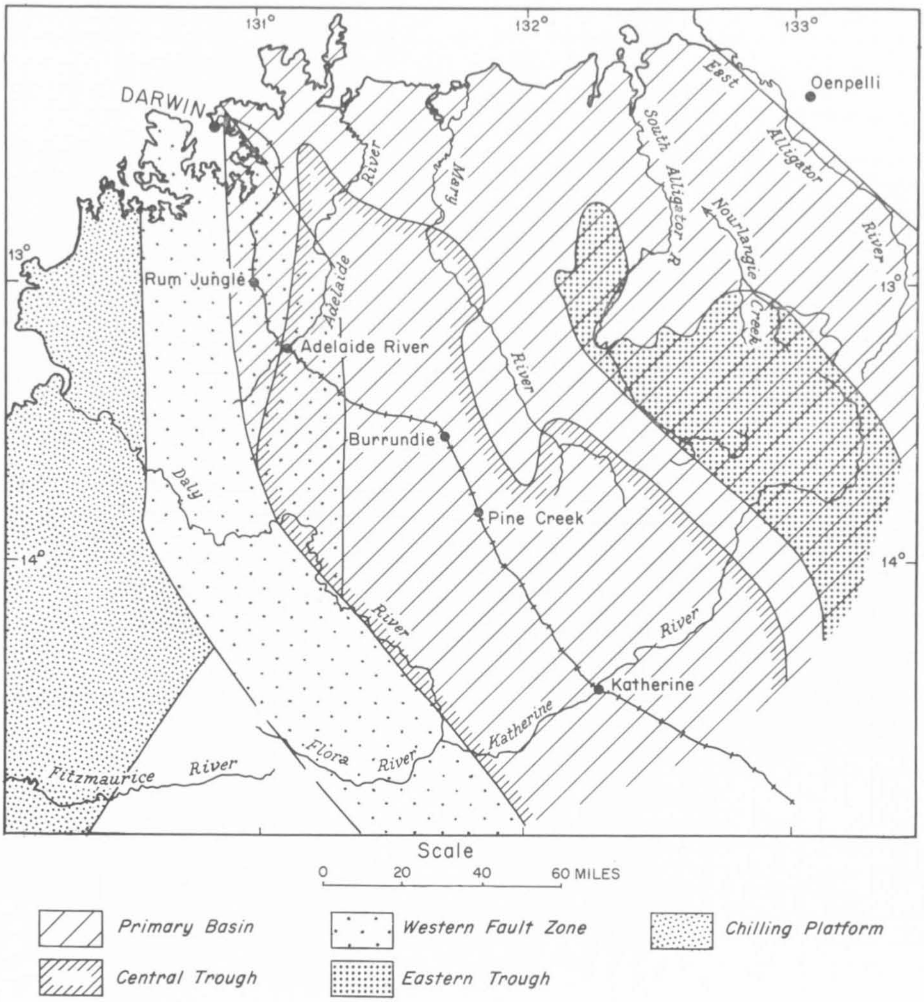

Fig. 8. Major structural elements, Pine Creek Geosyncline

Golden Dyke Formation, and to the south it is disconformably overlain by the Burrell Creek and Noltenius Formations. Between Humpty Doo and Rum Jungle part of the Batchelor Group (Crater Formation and Coomalie Dolomite) crops out in the core of an anticline.

The group consists of alternating clastic and dolomitic rocks. The formations are markedly lenticular, thickening eastwards and lensing out to the south. The lithology and lenticularity of the formations in the group, and the exposure of the basement Archaean Rum Jungle Complex, strongly suggest that the Rum Jungle area is on or near the original north-western margin of the Primary Basin.

Beestons Formation

The Beestons Formation is the basal unit of the Batchelor Group. It crops out in the Rum Jungle Dome and on the eastern flank of the Waterhouse Dome; it lenses out to the north, and is not present around the northern margin of the complex. The contact with the underlying Rum Jungle Complex is exposed between Batchelor and Rum Jungle.

The formation consists of arkose, arkosic and breccia conglomerate, quartz greywacke, quartz sandstone, greywacke, and siltstone. Only arkose and siltstone are present in the Beestons Creek area. The thickness has not been measured because of the paucity of outcrop, but is estimated at about 1000 feet. Arkose is the most abundant rock type, and constitutes more than half the succession in the Beestons Creek area. The arkose is commonly composed of coarse angular grains of feldspar and quartz in a kaolinitic matrix. An arkosic conglomerate, which crops out 6 miles north-east of Batchelor, contains rounded pebbles of jaspilite, quartz, and quartzite, up to 2 inches in diameter. The matrix is silicified and contains coarse angular fragments of feldspar and quartz. Siltstone is common, particularly in the Beestons Creek area, but outcrop is poor. In places, the siltstone has been metamorphosed to mica schist.

A partly silicified heavy-mineral sandstone forms a prominent outcrop near the south-eastern margin of the Rum Jungle Dome, but was not seen elsewhere in the formation.

Medium to coarse-grained quartz greywacke and greywacke are common near the top of the formation. The highest member is a bed of brown micaceous greywacke, cross-bedded in places, which crops out 3¼ miles east of Rum Jungle. The bed is directly overlain by the Celia Dolomite.

A white friable superficially silicified quartz sandstone crops out east of the Waterhouse Granite. The bed is correlated with the Beestons Formation, and is overlain by silicified dolomite and dolomitic breccia of the Celia Dolomite.

Celia Dolomite

The Celia Dolomite also crops out in the Rum Jungle Dome and on the eastern margin of the Waterhouse Dome. It is markedly lenticular, and is well exposed 1 mile north-west of the Batchelor road at a point 2 miles from the Stuart Highway. The estimated maximum thickness is about 1000 feet.

The formation consists of silicified dolomite, algal dolomite, and dolomitic breccia, and is believed to be, at least in part, biohermal. In places, the dolomite has been converted into coarsely crystalline silicified marble or tremolite schist and calc-silicate hornfels. Sheared and silicified *Collenia* sp. and indeterminate algal structures occur at several places.

Crater Formation

The Crater Formation conformably overlies the Celia Dolomite. It is the most extensive unit in the Batchelor Group, and crops out around the Rum Jungle and Waterhouse Domes, and in the core of a closed anticline east of the Stuart Highway near Manton Dam; it lenses out north of Mount Fitch on the western flank of the Rum Jungle Dome, and on the northern flank a few miles west of Manton Dam. It is about 2000 feet thick, and consists of quartz greywacke, feldspathic greywacke, arkose, quartz pebble and fine conglomerate, quartz sandstone, and siltstone.

Around the Waterhouse Dome, where it is not well exposed, it is probably less than 1000 feet thick. A silicified pyritic, carbonaceous, dolomitic marl with chert lenses and nodules, in places slumped and brecciated, and interbedded with pyritic carbonaceous siltstone, forms a distinctive marker horizon in the formation. This rock, which was referred to as the 'hematite boulder conglomerate' by Dodd (1953, unpubl.) (the hematite has been formed by the oxidation of pyrite), is about 80 feet thick, and consists in places of slump breccia conglomerate containing rounded pebbles and cobbles of quartz. A quartz pebble conglomerate overlying the marl was apparently involved in the slumping and was partly included in the resultant rock; this type of slump breccia conglomerate (Pl. 7, fig. 1) is common in the Katherine-Darwin Region.

Quartz greywacke is the most abundant rock type. A typical specimen contains 10 to 20 percent feldspar, and has a chloritic or sericitic matrix; it ranges from medium to coarse-grained, and grades into fine-grained quartz conglomerate and quartz pebble conglomerate. Greywacke, arkose, and quartz sandstone crop out in many places and constitute possibly 15 percent of the succession. Siltstone, in places rich in hematite, is fairly abundant in the top 400 feet of the formation in the type area.

The coarse-grained sediments are sheared and sericitized in places. Sericite schist is present near Manton Dam, and metamorphosed greywacke and 'hematite boulder conglomerate' overlie the Rum Jungle Complex south of Mount Fitch. Quartz-tourmaline veins and replacement of minerals by tourmaline are common around the southern and eastern flanks of the Waterhouse Granite.

The weak radioactivity of the lenses of quartz pebble conglomerate in the Crater Formation is due to detrital thorite and monazite.

Coomalie Dolomite

The Coomalie Dolomite is the uppermost unit of the Batchelor Group. It is about 1000 feet thick and conformably overlies the Crater Formation. It crops out in a syncline between the Rum Jungle and Waterhouse Domes, around most of the Rum Jungle Dome, on the east flank of the Waterhouse Dome, and in an anticline north-east of Manton Dam, where exposures are isolated and commonly silicified or lateritized. It lenses out to the south and is not present over the Crater Formation around the south-western margin of the Waterhouse Dome.

The formation consists of algal dolomite (Pl. 5, fig. 1), silicified dolomite, in places coarsely crystalline, silicified dolomitic marl and slump breccia, black calcilutite and siltstone, tremolite schist, and coarse marble. The lenses of algal dolomite in the formation are interpreted as bioherms.

Black calcilutite and siltstone crop out at the top of the formation; the boundary between them and the overlying rocks of the Golden Dyke Formation is indefinite.

Goodparla Group

The Goodparla Group is a facies assemblage comprising the Mount Partridge, Masson, and Golden Dyke Formations. The relationships between the formation are essentially lateral and, ignoring minor variations in rock type within each unit, are as shown in Figure 9.

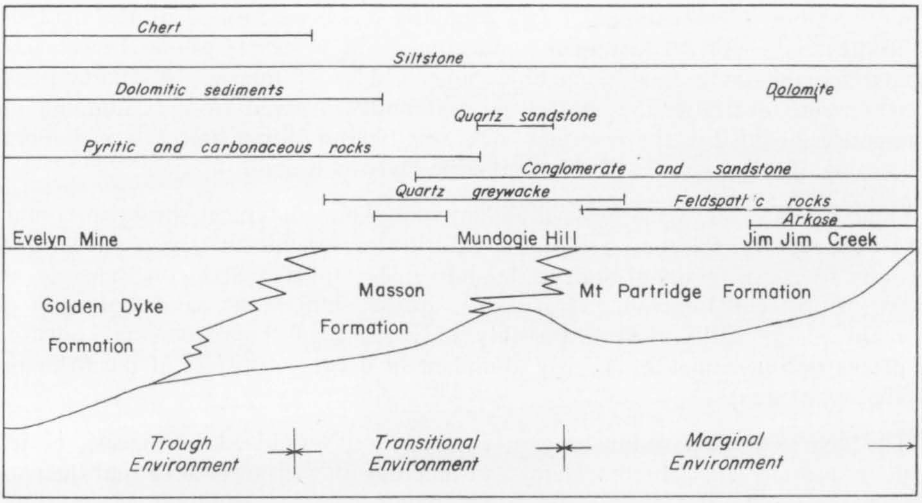

Fig. 9. Relationship between Mount Partridge, Masson, and Golden Dyke Formations, Goodparla Group, showing distribution of main rock types

The near-source environment is typified by the arkose and arkose conglomerate of the most easterly exposures of the Mount Partridge Formation. To the west, the arkose gives way to sandstone, sandy siltstone, and siltstone, with conglomerate and minor quartz greywacke. The Masson Formation represents a transitional environment and contains similar rock types to those found in both the Mount Partridge and the Golden Dyke Formations. The Golden Dyke Formation was deposited in a trough environment, and is typified by dolomitic and carbonaceous siltstone.

Mount Partridge Formation

The Mount Partridge Formation crops out around the northern and north-eastern margins of the geosyncline. It is a complex unit with, in places, very marked and irregular lensing and interbedding of arenite, rudite, and lutite, and irregular lateral gradations and interfingering of the different rock types present. It contains a wide range of sediments, but because of the lack of exposures in many areas and the scale at which the mapping was carried out it was not subdivided. Two main assemblages of rock types were recognized; but it was not possible to draw a boundary between them.

In the Jim Jim Creek/Mount Partridge area, the formation consists of coarse arkose containing fragments of feldspar and quartz up to half an inch in diameter (Pl. 5, fig. 2); arkose conglomerate consisting of polymictic boulders in a matrix of coarse feldspar and fine quartz fragments (Pl. 6, fig. 1); siltstone, coarse greywacke conglomerate, quartz-pebble conglomerate, quartz greywacke, and fine friable white quartz sandstone. In places, the arkose crops out as tors and has been mistaken for porphyry (Gray, 1915). In places the conglomerate contains angular and rounded fragments and pebbles of altered basic volcanics and banded amphibolite, both of which have been recognized in the underlying basement. Strong shearing in certain zones has resulted locally in metamorphism to mica schist, schistose conglomerate, and phyllite. In places, shearing of the coarse arkose has re-aligned the feldspars and the rocks resemble a gneiss. At Mount Basedow, a bed of shale about 2 feet thick has been almost entirely transformed into coarse biotite. An ilmenite-rich siltstone, composed of fine angular to subangular grains of ilmenite in a matrix of fine quartz, crops out between the estuaries of the South and West Alligator Rivers. Like the quartz-pebble conglomerate in the Crater Formation, some lenses of arkose and feldspathic conglomerate are radioactive owing to the presence of thorium minerals.

Lenses of silicified dolomite crop out between Mudginbarry homestead and the South Alligator River, but the lenses are particularly poorly exposed and their size is unknown.

The intensity of shearing and dynamic metamorphism decreases to the west, and in the Mundogie Hill area the rocks are not metamorphosed. Here they consist mainly of sandstone and siltstone with some conglomerate; there is little arkose. The conglomerate contains little or no feldspathic material, and no fragments of amphibolite and volcanic rocks such as those found in the conglomerates at Mount Partridge. In places, the sandstone is blocky, coarse-grained, ripple-marked (Pl. 6, fig. 2), and cross-bedded, and grades laterally through sandy siltstone to siltstone. These rocks have been separated from the main part of the formation and named the Mundogie Sandstone Member.

West and north in the Wildman, Mary, and Adelaide River areas, the Mount Partridge Formation crops out mainly as sandstone or pebble conglomerate. The most westerly outcrops are silicified (probably a surface effect) white medium-grained well sorted and bedded sandstone. In the Mary River area (Dow & Pritchard, 1958, unpubl.), the formation consists of purple and red quartz sandstone and interbedded siltstone, orthoquartzite, and conglomerate. The sandstone is medium to thick-bedded, commonly cross-bedded, and is medium to coarse-grained, grading into pebble conglomerate. It is composed of rounded and well sorted quartz grains set in an ironstained siliceous and sericitic matrix which imparts a dark red or purple colour to the rock. Detrital grains of muscovite and chert are common. One specimen of sandstone was found to consist of rounded and well sorted scattered quartz grains in a matrix of opaline silica which forms about one-third of the rock. The rock may have been originally a calcareous sandstone which has been silicified. The quartzite consists of an interlocking mosaic of quartz with a few interstitial flakes of muscovite; in places relics of rounded quartz grains can still be seen. The siltstone is commonly a dark red massive sericitic quartz siltstone which forms about 40 percent of the sequence. The conglomerate is composed of angular and subrounded pebbles of quartzite and chert up to 1 inch in diameter set in a matrix of red quartz sandstone.

The rocks of the Mount Partridge Formation in the Adelaide, Mary, and Wildman River areas may correspond to the Mundogie Sandstone Member, and the arkosic terrain may be either farther north, and therefore concealed, or absent; but the rocks have not been subdivided.

The Mount Partridge Formation crops out west of the main outcrop area of the Archaean Myra Falls Metamorphics. No contact between the two units has been found; but there is a strong metamorphic unconformity between the two units, and rare pebbles in the conglomerate of the Mount Partridge Formation can be matched with Myra Falls Metamorphics.

The thickness of the Mount Partridge Formation cannot be accurately estimated: the maximum may be 10,000 feet. It probably lies on an irregular basement, and the thickness may vary considerably from place to place. The formation crops out over an area about 40 miles wide: a width markedly different from the Batchelor Group, and probably controlled by the profile of the basement on which the rocks were deposited.

The *Mundogie Sandstone Member* crops out between the South Alligator River and Barramundie Creek.

Poorly sorted basal conglomerate is exposed at Mundogie Hill, where the member directly overlies the Archaean Stag Creek Volcanics; the conglomerate is overlain by white quartz sandstone, silicified in places, quartz greywacke, and rare reddish sandy siltstone. Ripple marks and cross-bedding are common.

Quartz sandstone is the most abundant rock within the member. It is typically white, blocky, and ripple-marked, and consists of rounded quartz grains in a siliceous matrix. Thick-bedded white orthoquartzite is present in places.

The quartz greywacke is generally darker in colour, and the bedding is better developed than in the quartz sandstone. Beds vary in thickness, but are commonly about 1 foot thick; cross-bedding is common. Shearing of the beds is shown by minute flexures, faults, and undulations.

Conglomerate also occurs in lenses and beds throughout the member. Pebbles range up to a maximum diameter of 2 inches, but are commonly much smaller, and are contained in a quartz greywacke matrix.

Red sandy siltstone is present in the member near Mundogie Hill, but is much more abundant farther north. Interbedded red siltstone, fine-grained red quartz greywacke, and white quartz sandstone crop out south-west of Mundogie Hill, and these three rocks grade laterally into one another. Interbedded quartz sandstone and alternating white and red quartz siltstone crop out in a few places.

White, grey, red or dark-coloured siliceous arkosic fine conglomerate, arkosic greywacke, and arkose crop out east of Mundogie Hill. The sediments are not ripple-marked, but are commonly cross-bedded; they are more thinly bedded, with alternating fine and coarse layers, and better graded than the quartz sandstone.

The bedding of the Mundogie Sandstone Member dips gently and undulates near the Archaean rocks. Away from them, folding is more complex; bedding planes are commonly slickensided because of bedding-plane shears. The ripple marks and cross-bedding indicate supply of sediment from the north and east, with sharp local changes of direction of supply.

Mundogie Hill is a dome with an Archaean core. The abrupt facies change from arkose and siltstone to sandstone in this area suggests that the dome may have been a basement hill. This is supported by the disposition of the Eastern Trough sediments and the presence of a thrust fault on the eastern flank, which could have been localized by sediments being thrust against the suggested basement knoll during folding. On the other hand, the facies change to sandy rocks continues still farther west.

Masson Formation

The Masson Formation crops out around the northern and eastern sections of the geosyncline. The western limit is a tongue (Acacia Gap Tongue), ranging up to 2500 feet thick, which interfingers with the Golden Dyke Formation in the Rum Jungle area (Pl. 30). From here the Masson Formation crops out as far north as the 18-mile peg on the Stuart Highway south-east of Darwin, and extends in a broad sweep eastwards to the Mary River. In the Mount Masson area the plan of the outcrop of the formation shows a large anticlinal bulge which transgresses the otherwise fairly regular, south-east-trending line of outcrop of the formation. The western flank of the anticline is marked by a zone of shearing and the presence of basic dykes. The most southerly outcrop of the formation is on the divide at the head of the South Alligator River.

Dolomitic rocks, with minor exceptions, are concentrated towards the eastern boundary of the formation; a few lenses of silicified calcareous greywacke crop out in the Goodparla area.

The siltstone commonly crops out as a reddish rock similar in appearance to the siltstone of the Burrell Creek Formation. In places, however, diamond-drilling or deep creek sections have shown the unweathered rock to be carbonaceous and pyritic. Its surface expression is a result of weathering: the carbonaceous content has been bleached and the rock impregnated with iron oxides derived from pyrite. The pyrite is commonly very fine-grained, and is presumably syngenetic. Surface oxidation is a common feature of this type of rock in northern Australia, but the effects differ with the locality, and it is not always possible to determine macroscopically whether or not the sediment is carbonaceous and pyritic. The siltstones of the Burrell Creek Formation are neither pyritic nor carbonaceous. In places, the siltstone of the Masson Formation is distinctively colour-banded in red and green bands, up to an inch thick; it is commonly laminated, and small-scale cross-bedding and ripple marks occur.

The large north-plunging anticlinorium in the Mount Masson area was mapped in some detail by Hays (1960, unpubl.) and the formation subdivided into three arenite and two lutite members. The arenite units contain between 30 and 50 percent of arenite and rudite interbedded with lutite; the lutite units contain 80 to 90 percent lutite with thin arenite bands, and individual beds range from 1 to 300 feet thick.

The base of the formation is not exposed in this area. Estimates of the thicknesses of Hays' subdivisions are:

Unit	Thickness (ft)
Upper arenite unit	2000
Upper lutite unit	1500
Middle arenite unit	2000
Lower lutite unit	1500
Lower arenite unit	+5000

The indicated total thickness of the formation is over 12,000 feet, but all the members are affected by drag folding on the flanks of the major structure, and the thicknesses are probably exaggerated by the folding.

The arenites consist mainly of buff, medium-grained quartz greywacke with a thin dark grey siliceous skin on exposed surfaces. The quartz greywacke contains rounded to angular quartz grains and some angular feldspar fragments in a siliceous and slightly ferruginous matrix. In places, the feldspar fragments are large and the rock grades into arkosic coarse greywacke or fine conglomerate. Greywacke with a sericitic or chloritic matrix is present in places.

Conglomerate lenses are common; for instance, near Mount Masson mine well rounded quartz pebbles occur in a matrix of siliceous greywacke.

The lutites crop out as buff or red and buff banded siltstone. The spoil from the water shaft at the Mount Masson mine contains material representing every stage of the transition from the weathered siltstone at the surface to the parent black pyritic carbonaceous siltstone at depth. Cleavage is well developed in the siltstone and commonly obscures the bedding.

Graded bedding was observed in the arenites in a few places; cross-bedding is more common, but only a few observations could be made of the direction of the sedimentary structures, which indicate an easterly provenance.

To the north-west, the Masson Formation changes gradually along the strike, and in the Mount Bundey area (Dow & Pritchard, 1958, unpubl.) it consists mainly of red siltstone with lenses of regularly bedded fine-grained quartz sandstone, quartz greywacke, and orthoquartzite. The arenites are confined to the upper half of the formation. The lenses of quartz sandstone and orthoquartzite range up to 20 feet thick, but are mostly less than 6 feet. Cross-bedding is rare, and the rocks are generally thin-bedded or laminated. The quartz sandstone consists of rounded and well sorted quartz grains with a little ironstained finely granular siliceous matrix. Most of the quartz grains are partly recrystallized, and in places the rock grades into quartzite.

Fine-grained quartz greywacke is common as massive beds up to 5 feet thick. It consists of subangular to angular quartz grains in a matrix of fine-grained quartz and sericite with a little muscovite, biotite, iron oxides, and ferro-magnesian minerals.

Scours and cross-bedding are present in the Coirwong Gorge and Goodparla areas, but are not common in the formation as a whole. Some of the rocks in the Coirwong Gorge area could conceivably be placed in the Mount Partridge Formation; but the boundary between the two formations is gradational, and in this case has been arbitrarily chosen. It has commonly been determined by the proportion of large lenses of arenite in the carbonaceous siltstone which is characteristic of the Masson Formation.

The Masson Formation grades laterally in part into the Mount Partridge Formation, and is regarded as derived by reworking and redistribution of material initially deposited with the Mount Partridge sediments. In part, it overlies the Mount Partridge Formation, but extends farther into the basin of deposition. The small inliers of Archaean Stag Creek Volcanics west of Coirwong Gorge and the ridge of Stag Creek Volcanics in the South Alligator River valley show that the Masson Formation lies directly on basement in places.

Much the same relationship exists between the Masson Formation and the Golden Dyke Formation — the Masson Formation partly underlies, partly grades into, and partly interfingers with the Golden Dyke Formation. In the Rum Jungle area the Acacia Gap Tongue of the Masson Formation lies above the base of the Golden Dyke Formation (Pl. 30). In the Mount Bundey area the boundary is gradational and represents a transition from carbonaceous siltstone,

siltstone, arenite (Masson Formation) to an assemblage of carbonacous siltstone, siltstone, dolomite (Golden Dyke Formation). South of Mount Douglas the boundary between the two formations is much sharper, and the contact is commonly faulted and intruded by dolerite dykes.

The *Acacia Gap Tongue* is the most westerly extension of the Masson Formation. It overlies the Batchelor Group and part of the Golden Dyke Formation. It is approximately 4000 feet thick near Manton Dam, about 2500 feet thick near the junction of the Batchelor road and the Stuart Highway, and lenses out about 3 miles south-east of Batchelor and to the west over the Rum Jungle Complex. It is represented by only a few small outcrops at Mount Fitch and Mount Burton, south-west of the Rum Jungle Dome. The lensing-out to the south-west and west indicates that the sediments were derived from a source to the north-east.

The Acacia Gap Tongue consists of silicified quartz greywacke and quartz sandstone interbedded with pyritic carbonaceous siltstone and quartz siltstone. Pyrite casts and some crystals, up to a quarter of an inch in diameter, are common in both greywacke and siltstone. The arenites are typically massive, with beds 5 to 20 feet thick, and contain poorly sorted subrounded quartz grains. A few beds of white thin-bedded fine-grained quartz sandstone are also present. The siltstone is not well exposed. In places, it crops out as thinly interbedded black quartz siltstone and white bleached carbonaceous siltstone.

The *Coirwong Greywacke Member* consists mainly of coarse greenish grey to white quartz greywacke containing subangular grains of quartz with some grains of pink feldspar and grey chert in places. Lenses of quartz pebble conglomerate are common near the middle of the unit, but become less common along the strike to the north-west and south-east. The quartz greywacke is commonly cross-bedded; the cross-bedding indicates that the south-western margin of the unit is the bottom.

The Coirwong Greywacke forms a prominent ridge along the South Alligator River Valley, where it rests on or is faulted against Archaean Stag Creek Volcanics and is overlain by or faulted against the Koolpin Formation.

Golden Dyke Formation

The Golden Dyke Formation occupies the Central Trough of the geosyncline. It crops out west and south of the Masson Formation in the eastern and northern sections of the geosyncline and in the Rum Jungle area. Near Stapleton Siding, the unit thins out and locally interfingers with the Noltenius Formation. South of Stapleton Siding it is disconformably overlain by the Burrell Creek and Noltenius Formations. There is no evidence to suggest that the Golden Dyke Formation originally extended more than a few miles west of the Rum Jungle area.

The formation has a maximum thickness of about 9000 feet, and consists mainly of dolomitic and carbonaceous siltstone, quartz siltstone, chert, and dolomite. The chert may be a diagenetic alteration product of dolomite*. A coarsely bedded 'shale' consisting of bands of silicified dolomite or chert in a carbonaceous siltstone matrix is common in some areas. Pyrite is common in the matrix. In places the dolomite bands lens out into nodules (see Crater Formation); the bands range from very thin up to 6 inches thick; slumping is common, and is also a feature of the chert.

In the Rum Jungle and Mount Bundey areas the formation consists of carbonaceous siltstone, silicified dolomite and marl, and silicified dolomitic slump breccia. The dolomite bands range from ½ to 3 inches thick. Pyrite is a common constituent of the carbonaceous rocks in this and other areas. Some siltstone and quartz siltstone are present, but are subordinate to the carbonaceous and dolomitic rocks. Silicified dolomitic slump breccias are prominent near Stapleton Siding and, to the north of the siding, a slump breccia can be traced for about 4 miles from Mount Minza.

Pyritic carbonaceous siltstone, with dolomite bands and nodules, and slump breccia developed from these rocks (Pl. 7, figs 1 and 2) are prominent at the base of the Golden Dyke Formation in the Mount Bundey area; they have been mapped as the Craig Creek Member by Dow & Pritchard (op. cit.). West of the Adelaide River, carbonaceous dolomitic siltstone is common throughout the formation, and the Craig Creek Member loses its identity. Rocks of similar lithology to the Craig Creek Member are known at the base of the Golden Dyke Formation west of Mount Masson, but they have not been mapped separately in this area.

The upper part of the Golden Dyke Formation in the Mount Bundey/Mount Douglas area consists of interbedded grey and white silicified dolomitic marl and chert. Chert is the main outcrop, partly because of its greater resistance to weathering. It is mostly thin-bedded but the beds range up to 3 feet thick in a few places; it is grey or white, with minor red, black, and green bands in places.

South of Mount Douglas, the formation consists mainly of carbonaceous siltstone. Pyritic carbonaceous siltstone with chert lenses and nodules is present at the base of the formation, together with slump breccias. The chert constitutes only about 10 percent of the interbedded chert and siltstone at the top of the formation.

Farther south along the strike, slumped and contorted chert constitutes almost the whole of the formation.

In the Brocks Creek and Burrundie areas, which include the type area, the rock types include quartz siltstone, dolomite, some prominent bands of nodular pyritic,

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* All gradations from dolomite to silicified 'saccharoidal' dolomite to chert can be found in the dolomitic shales. In places a 'quartzite' is developed on these rocks as a surface effect, but the alteration is generally believed to be diagenetic.

carbonaceous, and dolomitic siltstone, and minor thin-bedded dolomitic siltstone. Chert crops out extensively in the eastern part of this area, but is not common west of the Margaret River. The quartz siltstone occurs near the top of the formation. The rocks are markedly lenticular, and the lithological boundaries in many places transgress the trends of the folds. Intense slumping is also a feature of the chert in the Burrundie area.

In the Moline area lenses and tongues of the Golden Dyke Formation crop out, and are interfingered with the Burrell Creek Formation. Here, the formation consists mainly of chert and carbonaceous siltstone with lenses of dolomite and thin-bedded silicified dolomite (Pl. 8, fig. 1). Nodular pyritic and carbonaceous beds occur in places.

The Golden Dyke Formation is in contact with two overlying formations, the Noltenius and Burrell Creek Formations. The contact with the Noltenius Formation is interfingered and gradational in the Stapleton area, but elsewhere there is a regional disconformity; with the Burrell Creek Formation, the Golden Dyke is partly interfingered, partly gradational, and partly disconformable. Sediments of the two are intermixed in the area about 8 miles due south of Burrundie siding on the Darwin-Birdum railway.

The *Craig Creek Member* is not shown on Plate 28, but crops out from Marrakai homestead to Mount Bundey, and south-east along the Mary River as far as Mount Douglas (see Mount Bundey and Woolwonga 1-mile geological Sheets). It occurs at the base of the Golden Dyke Formation, directly overlying the Masson Formation. The lower contact is marked by an abrupt lithological change from silicified quartz greywacke of the Masson Formation to ferruginous dolomitic siltstone of the Craig Creek Member.

The member consists of pyritic carbonaceous siltstone with dolomite bands (mostly silicified), which weathers to a hematite-rich, gossan-like outcrop, and in places contains lenses, nodules, and bands of chert; slump breccia composed mainly of angular fragments of chert, but in places also containing angular fragments, up to 1 foot across, of siltstone, quartz greywacke, and sandstone apparently derived from the underlying Masson Formation; and lenses of grey to white, massive silicified dolomitic marl.

Both composition and thickness change along the strike. The thickness generally ranges from 20 to 600 feet, but the member lenses out completely in places, where the upper part of the Golden Dyke Formation directly overlies the Masson Formation.

Sedimentary Environment of the Batchelor and Goodparla Groups

The Goodparla and Batchelor Groups represent the initial stages of sedimentation in the Pine Creek Geosyncline. The character of the sediments, their distribution, provenance, and relationship to basement and to succeeding units, distinguish their deposition as a primary episode in the evolution of the geosyncline.

The Batchelor and Goodparla Groups are confined to the Primary Basin, including the Central Trough; but the Central Trough continued to receive sediments after the deposition of the two groups.

The Batchelor Group and the Mount Partridge Formation are very similar in that both are basal units*; both contain abundant arkose intercalated with siltstone and lenses of pebble conglomerate and quartz greywacke. The Mount Partridge Formation also contains a few small lenses of silicified dolomite in the Yemelba and Woolwonga Swamp areas, but these do not crop out well enough to warrant definition as separate units.

The formations in the Batchelor Group are markedly lenticular, and in some places the lateral limits can be seen (Pl. 30).

The restricted marginal environment on the western side of the northern end of the Primary Basin is more a matter of lateral extent than thickness of the rock units present in each area. The Mount Partridge and Masson Formations on the eastern side of the Primary Basin spread over an area with a maximum exposed width of about 80 miles. The Batchelor Group is exposed over an area with a width of about 10 miles, and the mixed arenaceous and biohermal character of the rocks and their known distribution suggest that they did not extend much farther west beyond the present outcrop limits. The presence of bioherms also suggests that the fall-away into the Central Trough in this area was much more abrupt than on the eastern (Mount Partridge) side of the Primary Basin.

Two features of importance in this first phase of sedimentation in the geosyncline in the Batchelor area are:

(i) The Batchelor Group is directly overlain by the Golden Dyke Formation — i.e., the Masson Formation or its equivalent does not occur between the Batchelor Group and Golden Dyke Formation as it does between the Mount Partridge and Golden Dyke Formations.

(ii) A large, west-facing tongue of the Masson Formation (Acacia Gap Tongue) crops out above the base of the Golden Dyke Formation and thins out from about 4000 feet near Manton Dam to less than 100 feet on the western side of the Rum Jungle Dome.

These features are interpreted as follows:

The absence of Masson Formation or similar rocks in conjunction with the Batchelor Group is a reflection of the slope of the Primary Basin in this area — the reef formation takes its place and the broad slope into the Central Trough,

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* In the sense that they are nearest to source. Other units also rest on basement (e.g. Masson Formation).

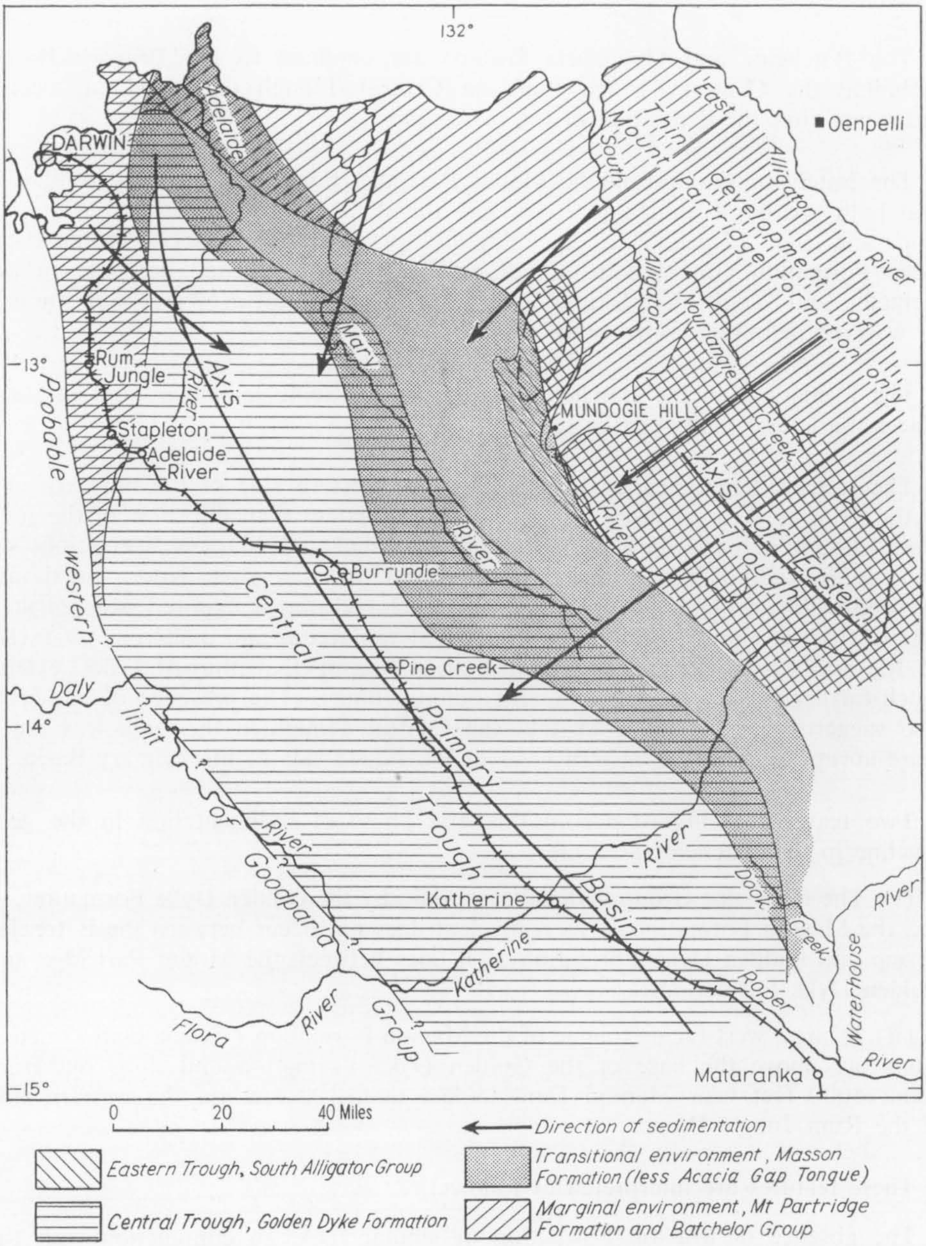

Fig. 10. Distribution of sediments of Goodparla, Batchelor, and South Alligator Groups in the Primary Basin, Pine Creek Geosyncline

which was present on the eastern side of the geosyncline, is missing. Instead the fall-away was sharp. The very prominent west-facing Acacia Gap Tongue is clear evidence of a northerly to easterly provenance for the Masson Formation and, by inference, for most of the Golden Dyke Formation. This direction of provenance is, of course, also indicated by the gradation of rock types illustrated in Figure 9; and is also supported by the few sedimentary structures which are measured. The type of sediment in the Batchelor Group, and the thinning out of the group to the west, suggest that the western margin of the Primary Basin was a fairly short distance west of Rum Jungle.

The Central Trough is part of the Primary Basin and is outlined by the extent of the Golden Dyke Formation. It continued to receive sedimentary material after the deposition of the Golden Dyke Formation, and its outline in plan probably remained largely unchanged by succeeding events in the development of the geosyncline.

The distribution of the Mount Partridge, Masson, and Golden Dyke Formations and of the Batchelor Group suggests that the outline of the Primary Basin was approximately as shown in Figure 10. There was a broad marginal and transitional environment in the east and north; the marginal zone is more restricted towards the west and quite narrow in the north-west, where it is partly characterized by reef structures. The southern extension of the marginal environment south of Stapleton is unknown, but we consider that it was narrow and ran south at least to about the latitude of Adelaide River, where it may have swung south-east parallel to the main axis of the geosyncline, like the Noltenius Formation in the Fletchers Gully area (see Fig. 13).

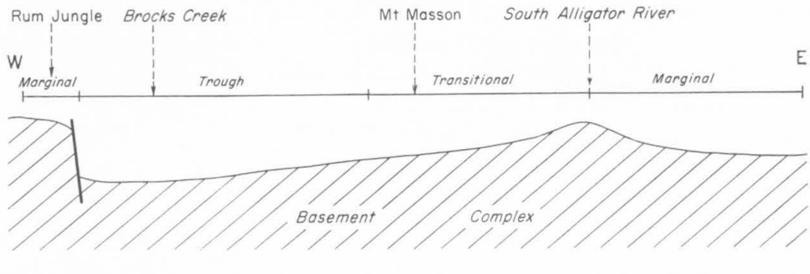

Fig. 11. Possible original profile of Primary Basin, Pine Creek Geosyncline

Figure 11 is a schematic interpretation of a cross-section of the basement profile of the Primary Basin. The interpretation has been borne out to some extent by the gravity survey of the basin (Langron & Stott, 1959, unpubl.). The sharp fall-away into the Central Trough on the western side, which is to some extent hypothetical, was probably due to a fault or fault zone. Thus we envisage the Primary Basin as an asymmetrical structure with a steep western flank and a floor sloping gradually up to the east with a ridge or hinge-line in the area of the South Alligator River, which later developed into a fault zone (or may have been one originally). In the Rum Jungle area, the Golden Dyke sediments overlie the Batchelor Group and contain a tongue of the Masson Formation. This is interpreted as a result of the regeneration of faulting on the western margin while sedimentation was still in progress, causing the marginal area to be depressed and allowing the Golden Dyke Formation to transgress across the previously deposited Batchelor Group. The tongue of Masson rocks is interpreted as due to a spasmodic uplift of the north-eastern margin which caused a sharp tongue of arenites to extend farther west than normally.

This hypothesis requires that there was very little or no supply of Golden Dyke sediments, and none of Masson material, from the west. All evidence supports an easterly and north-easterly provenance.

SEDIMENTATION IN THE WESTERN FAULT ZONE AND THE CENTRAL TROUGH

The deposition of the Finniss River Group represented the second episode in the evolution of the Pine Creek Geosyncline. The group was deposited in the Western Fault Zone and in the Central Trough and overlies the Goodparla and Batchelor Groups: in places the contact is gradational, but elsewhere there is a disconformity.

Finniss River Group

The Finniss River Group includes the Noltenius and Burrell Creek Formations and the Berinka and Dorothy Volcanics. It is essentially an assemblage of greywacke and siltstone. The subdivision of the group is based on the preponderance of fine arenite in the Burrell Creek Formation and the presence of medium to coarse arenite and rudite in the Noltenius Formation: the Burrell Creek Formation is distinguished by the absence of rudite and coarse arenite, but fine arenite is also present in the Noltenius Formation. Lutite is common to both units. The interrelationships between the units are illustrated diagrammatically in Figure 12.

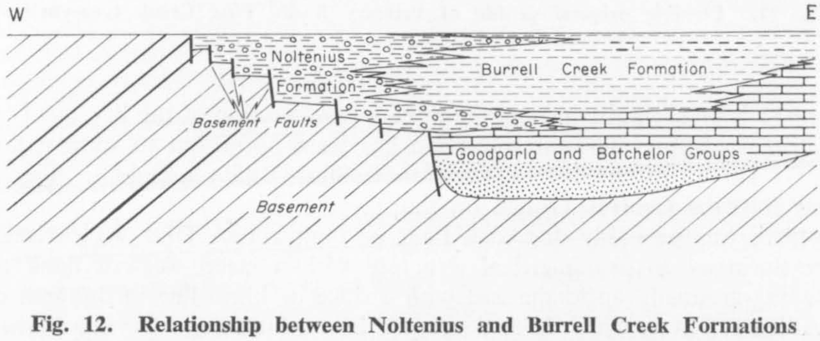

Fig. 12. Relationship between Noltenius and Burrell Creek Formations

Noltenius Formation

The Noltenius Formation is confined to the western section of the geosyncline in a belt extending south from Darwin to the Muldiva Creek area and east to the Adelaide River. A few minor lenses crop out about 15 miles south of Marrakai homestead.

The formation consists of turbidites, mainly quartz greywacke, greywacke, and siltstone, but also includes irregular deposits of conglomerate, graded sandstone, arkose, claystone, micaceous greywacke siltstone, and quartz siltstone. The pebble and cobble conglomerate are characteristic of the formation and constitute about 5 to 10 percent of the succession. They consist of rounded to subangular quartz and quartzite pebbles in a matrix of fine to medium greywacke. The cobbles are commonly disc-shaped and range up to 4 inches in diameter. The smaller fragments are more nearly equidimensional, but less well rounded. Cobble conglomerate, in places silicified, is mainly restricted to the western part of the area of outcrop, where it produces the most prominent topographic features. In the western area, the quartz cobbles are elongated parallel to the axis of folding around the noses of some folds, and the plate-like recrystallized quartz cobbles lie at angles of up to 90° to the bedding. Very coarse greywacke breccia, with angular boulders of dolomite up to 2 feet in diameter*, crops out in the Mount Hayward area, where the formation is 4000 feet thick. Arkose crops out in the Muldiva area.

Quartz greywacke, quartz sandstone, and greywacke may constitute about 40 percent of the formation. The quartz greywacke is commonly a medium to coarse-grained friable rock, with an argillaceous or, less commonly, ferruginous matrix. In places, muscovite is present in the finer-grained quartz greywacke, which commonly contains more argillaceous material than the coarse-grained rocks. In places the rocks, and particularly the quartz sandstone, are silicified, and superficial silicification parallel to bedding and joint surfaces is common.

Siltstone is the most abundant rock type in the Noltenius Formation. It constitutes about half of the succession, but only a small proportion of actual outcrop, and includes quartz siltstone, carbonaceous siltstone, and greywacke siltstone, which contains detrital mica in places. The grainsize ranges from coarse siltstone to claystone, and the colour ranges from red to banded green and black or brown.

Well developed graded bedding, cut-and-fill structures, and other features of density current deposits are characteristic of the Noltenius Formation (Pl. 8, fig. 2). Load casts and sand volcanoes (Pl. 9, fig. 1) are also common. Ripple marks are not common, but are found in places in association with the sand volcanoes.

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* The only other dolomite breccia known in the region occurs in the Beestons Formation, which lies directly on Archaean basement at Rum Jungle. Similar Archaean rocks crop out west of the Mount Hayward area (Hermit Creek Metamorphics). Dolomites are not exposed in the basement rocks in either area.

Robertson (1962) has described some problematica in greywacke near the George Creek uranium prospect (Pl. 9, fig. 2).

Intercalations of argillaceous sediments are intimately associated with the arenaceous rocks throughout the succession, except for some local occurrences of irregular masses of conglomerate and coarse-grained quartz greywacke, such as those to the south of Adelaide River township.

In the west, arkose and coarse greywacke breccia are minor local constituents, but elsewhere medium-grained quartz greywacke is the dominant arenite. A local variant of the Noltenius Formation occurs in the Stapleton Siding area. It consists of carbonaceous siltstone, interbedded with quartz greywacke, siltstone, and minor pebble conglomerate, and is interpreted as a combination of the typical carbonaceous sediments in the Golden Dyke Formation and the typical greywacke and siltstone of the Noltenius Formation and, to a less extent, of the Burrell Creek Formation. A similar (and more convincing) combination is present at the contact of the Burrell Creek and Golden Dyke Formation in the Burrundie area, and near Mount Bundey.

The regional gradation from coarse to fine material from west to east, the east-pointing tongues of Noltenius Formation in the Adelaide River area, and measurements on minor sedimentary structures, all clearly indicate a westerly provenance for this formation.

Burrell Creek Formation

The Burrell Creek Formation crops out between the Mary River in the east and the Daly River in the west, and extends from Marrakai homestead in the north to Maranboy in the south. It consists mainly of medium to fine-grained greywacke and quartz greywacke, greywacke siltstone, and siltstone; with minor lenses of claystone, quartz sandstone, quartz siltstone, and conglomerate in places. The greywacke and siltstone occur as lenses, ranging from a few feet to over 300 feet thick.

Siltstone is the most abundant rock type. It is red, brown, or yellow in outcrop, and in many areas it is sheared or lineated. It crops out as blocks or slabs, bounded by shear planes, protruding from shallow soil cover; soil creep is common. Bedding may be revealed by colour banding. The siltstone commonly has an argillaceous matrix and contains irregular quartz grains, mica flakes, and flecks of iron oxide and chlorite. The siltstone grades into greywacke siltstone with an increase in the percentage of chert and other rock fragments.

Massive greywacke constitutes much of the outcrop of the Burrell Creek Formation. It is similar to that within the Noltenius Formation, but is commonly finer in grain.

The grainsize of the greywacke is typically fine to medium, but individual grains vary widely. It commonly contains subangular to rounded grains of quartz,

PLATE 1.

Fig. 1: Northern Plains, looking north towards Mount Cahill (left) and Mount Brockman (right), Mount Evelyn and Alligator River Sheets.

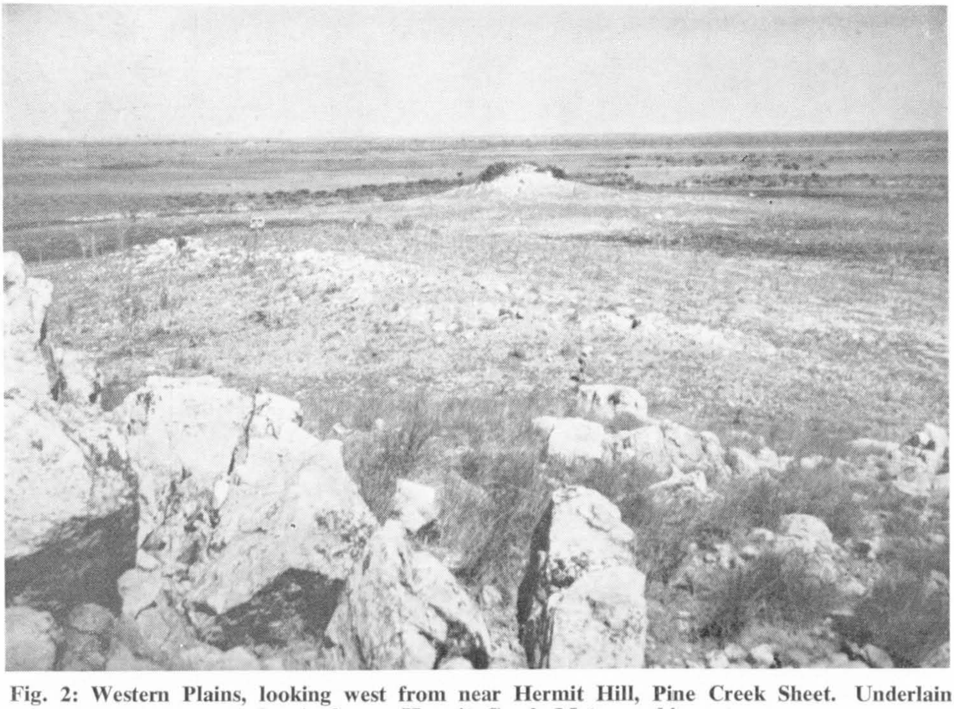

Fig. 2: Western Plains, looking west from near Hermit Hill, Pine Creek Sheet. Underlain by Archaean Hermit Creek Metamorphics.

PLATE 2.

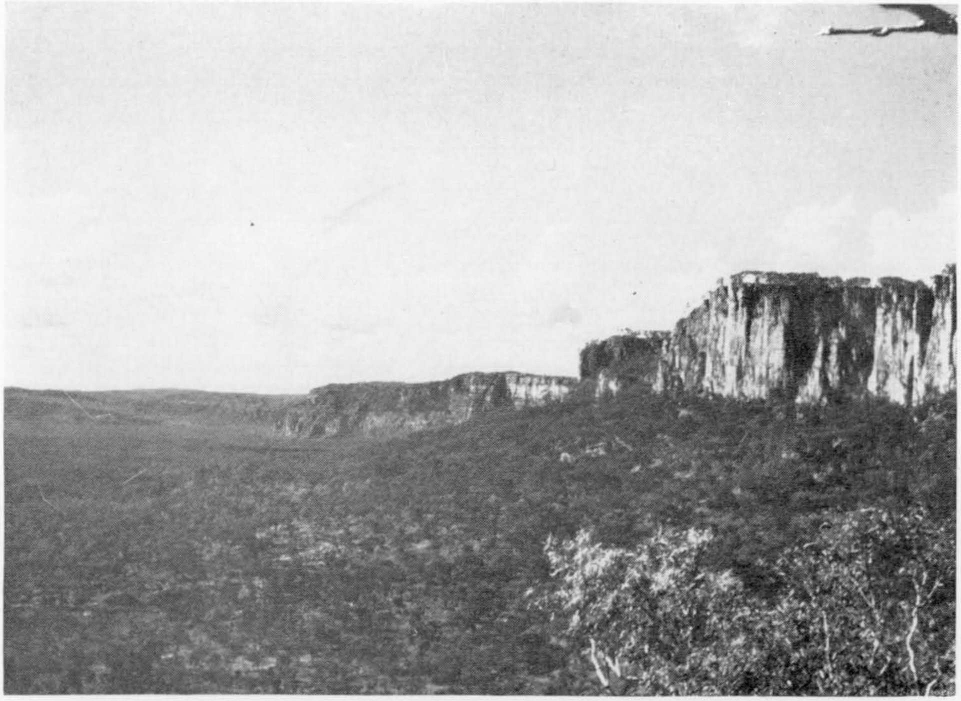

Fig. 1: Looking east along the bold scarp on the northern edge of the Arnhem Land Plateau east of Mount Partridge, Mount Evelyn Sheet. The cliffs are Kombolgie Formation which unconformably overlies the South Alligator Group forming the low rises in the foreground.

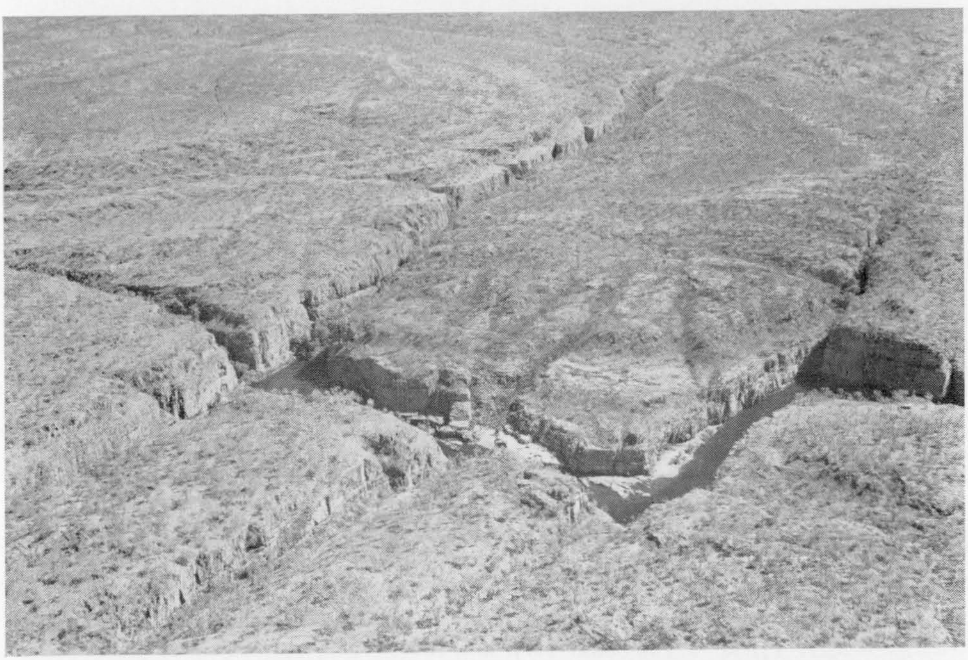

Fig. 2: Aerial view of Arnhem Land Plateau near Katherine Gorge, Katherine Sheet. Gorge follows joints in gently dipping massive sandstone. (By courtesy of Australian News and Information Bureau.)

PLATE 3.

Fig. 1: Typical topography in the Fitzmaurice River Basin developed on Angalarti Siltstone near Twins Mountain, Fergusson River Sheet.

Fig. 2: Katherine Gorge, a deeply entrenched joint-controlled section of the Katherine River where it transgresses a barrier of Kombolgie Formation rocks 20 miles east of Katherine township, Katherine Sheet. (By courtesy of Australian News and Information Bureau.)

PLATE 4.

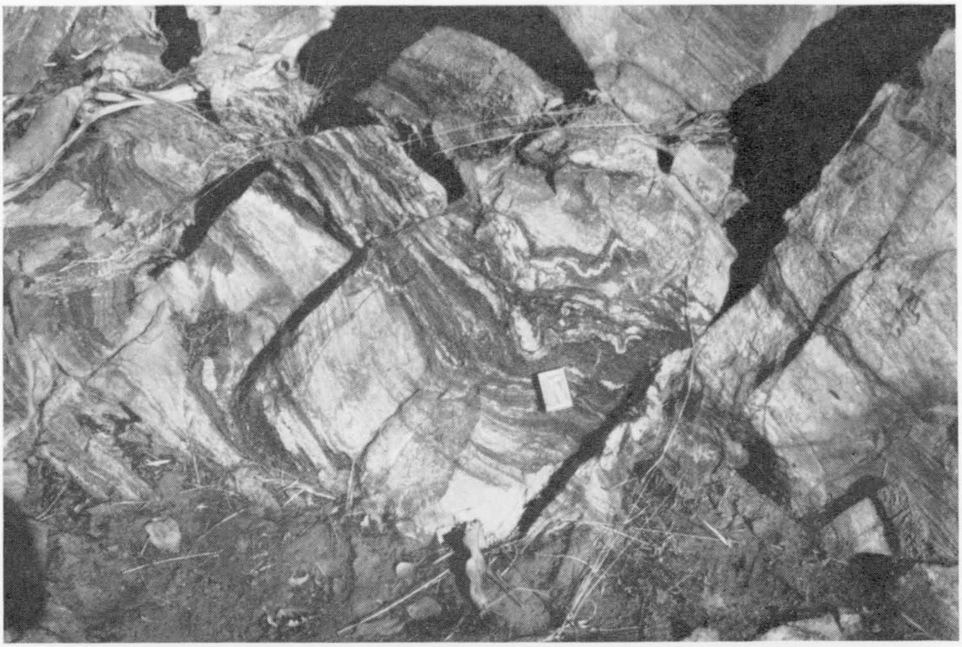

Fig. 1: Granite gneiss, Rum Jungle Complex, 3 miles east-north-east of Whites mine, Darwin Sheet.

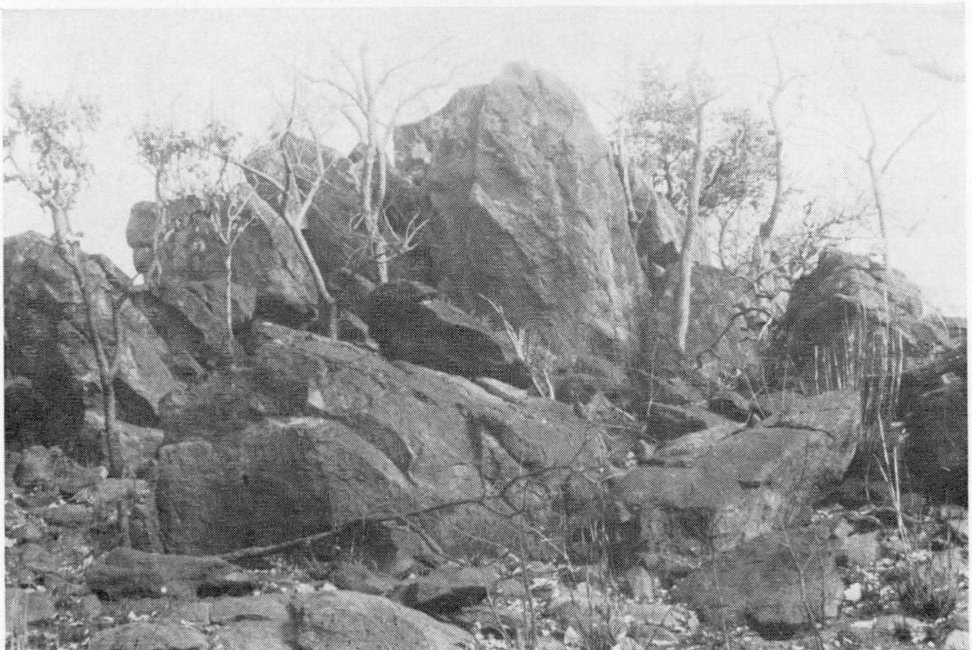

Fig. 2: Stag Creek Volcanics north-west of Coirwong Gorge, Mount Evelyn Sheet. Outcrop consists of agglomerate; fragments of carbonate material have weathered out of the rock in the foreground.

quartzite, chert, slate, and rare siltstone in a chloritic or sericitic matrix. Fine quartz grains and clay particles may be present in the matrix. Feldspar is uncommon.

Features of the Noltenius Formation missing from the Burrell Creek Formation are well developed graded bedding of the arenite and the presence of quartz pebble and cobble conglomerate.

Quartz siltstone, quartz sandstone, and claystone are minor components of the Burrell Creek Formation. Calcareous greywacke occurs in a number of places and, like many carbonate-rich rocks in the Katherine-Darwin Region, it is commonly silicified at the surface. It is commonly known as 'tombstone greywacke' (Pl. 10, fig. 1) because of its mode of outcrop, and occurs mainly near the base of the formation. Some of the 'tombstones' are minor slump rolls modified by fracture cleavage. The coarse fraction of the tombstone greywacke consists of subangular to angular fragments of quartz, feldspar, calcite, chert, and rock fragments. The matrix is extremely fine-grained, and is commonly sericitic and siliceous, with varying amounts of calcareous material.

Greywacke and siltstone are predominant and probably constitute over 90 percent of the formation. Tuffs have been identified in the Burrell Creek Formation at Maranboy (Walpole, 1958a), and a sequence of basic lavas and pyroclastics 14 miles east of Katherine, the Dorothy Volcanics (Rattigan & Clark, 1955, unpubl.), overlie the Burrell Creek Formation and are folded with it. Minor lenses of conglomerate crop out near Wolfram Hill, and north of Mount Douglas, where the pebbles include rhyolite and jaspilite. Elsewhere, jaspilite pebbles are known only in the basal arkose conglomerate of the Beestons Creek Formation near Manton Dam.

The Burrell Creek Formation is in contact with the Noltenius and Golden Dyke Formations. Lithology and field relationships indicate that it is a lateral facies change of the Noltenius Formation. With a provenance in the west the coarser sediments were deposited to form the Noltenius Formation and the finer fraction was carried farther east into the main trough of the geosyncline to form the Burrell Creek Formation.

Dorothy Volcanics

The Dorothy Volcanics are a sequence of folded basic lavas, pyroclastic rocks, and tuffaceous sediments which crop out near the Carpentaria and Maude Creek mines about 14 miles east of Katherine. They overlie the Burrell Creek Formation and appear to have been folded with it; they are apparently intruded by Lower Proterozoic basic rocks (Rattigan & Clark, 1955, unpubl.). Rattigan & Clark have suggested that the Dorothy Volcanics are Lower Proterozoic; no further work has been done and we have tentatively included them in the Finniss River Group.

Berinka Volcanics

The Berinka Volcanics crop out over an area of about 6 square miles west of the headwaters of Chilling Creek. They consist of granophyre, tuff, ashstone, agglomerate, metarhyolite, spherulitic acid volcanics, and amygdaloidal intermediate flows. The volcanics appear to be interbedded with siltstone of the Noltenius Formation, but the beds are poorly exposed and the relationships are somewhat conjectural. In the west, the granophyre is in contact with a gabbro intrusion. At the contact, there is a macropegmatitic mixture of gabbro and granophyre, and the granophyre is contaminated with gabbro. The field relationships suggest that the granophyre intrudes the gabbro, but the evidence is inconclusive. In adjacent areas the gabbro intrudes the Noltenius Formation, and is probably intrusive into the granophyre also.

Sedimentary Environment of the Finniss River Group

The deposition of the Finniss River Group represents the second episode in the evolution of the Pine Creek Geosyncline. It contrasts sharply with the Goodparla and Batchelor Groups in that it is a flysch facies; the group was developed only on the western side of the geosyncline and had a westerly provenance.

The Finniss River Group includes the Noltenius and Burrell Creek Formations, and two minor volcanic units — the Berinka and Dorothy Volcanics. The Noltenius Formation comprises arkose, greywacke conglomerate, greywacke, quartz pebble conglomerate, sandstone, and coarse conglomerate interbedded with siltstone and quartz siltstone. Common features include graded bedding, flow casts, load casts, incipient pull-aparts, and washouts — all indicative of deposition by turbidity currents (Kuenen, 1953); in places the Noltenius Formation consists of alternating beds of quartz siltstone and quartz greywacke, but the bulk of the rocks were deposited by turbidity currents.

The relationship of the Noltenius Formation to the Burrell Creek Formation differs from place to place. In some areas the Noltenius Formation overlies the Burrell Creek Formation, in others it underlies it; near Adelaide River (Pl. 28) it is clearly interfingered.

The boundary between the formations is transgressive in time and was arbitrarily chosen when the importance of the change in facies was recognized. Working west from typical Burrell Creek sediments, the Noltenius boundary was chosen at the first bed of coarse arenite or bed of rudite encountered. In a few areas, it is difficult to distinguish between the two formations, but in most places the boundary is easily recognized.

The Burrell Creek Formation consists almost entirely of greywacke, quartz greywacke, greywacke siltstone, and siltstone. A few small lenses of conglomerate are present, but they are only of local importance. The arenites are much finer

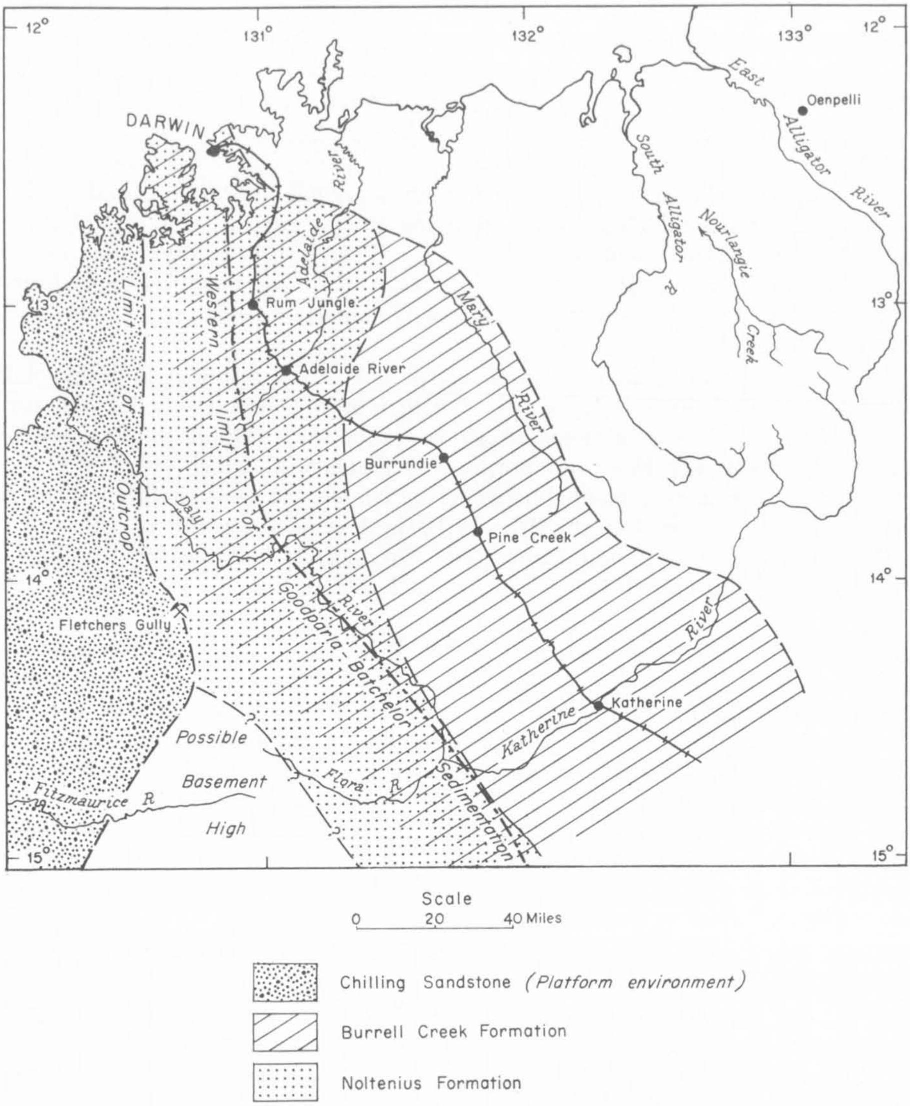

Fig. 13. Distribution of sediments of Finniss River Group and Chilling Sandstone, Pine Creek Geosyncline

in grain than those in the Noltenius Formation; they are believed to represent the finer fraction of the material of which the coarse fraction, the Noltenius Formation, was deposited closer to the source.

The westerly source of the sediments is demonstrated by the presence of prominent east-facing tongues of the Noltenius Formation as indicated by sedimentary structures, and the gradation from coarse arenite and rudite with lutite (Noltenius Formation) to fine arenite, rare rudite, and lutite (Burrell Creek Formation) from west to east.

The Noltenius Formation represents both marginal and transitional environments, and the Burrell Creek Formation the trough environment of the Finniss River Group phase of sedimentation in the Pine Creek Geosyncline; but the boundaries between the environments, by reason of the character of the sediments involved, is not as clearly defined as in the Goodparla Group.

The Finniss River sedimentation is interpreted as the result of faulting on the western margin of the Primary Basin. There is now a broad zone of high-angle normal faults and discontinuous shear zones between Mount Shoobridge and the Daly River Police Post and northwards to Darwin, which could well be a reflection of such a movement, but whatever caused the western foreland to rise and discharge sediments into the Primary Basin developed towards the close of the first episode of sedimentation (Goodparla Group). It had the further effect of extending the depositional area westwards at least 20 miles.

The Finniss River Group was deposited in the Western Fault Zone and extends into and occupies part of the Central Trough. Within the Central Trough it overlies the Goodparla rocks: but in the Daly River area, which is west of the predicted margin of the Primary Basin, it is faulted against the basement Hermit Creek Metamorphics. There is no evidence that earlier sediments, such as the Batchelor Group, lie between the Finniss River Group and the basement metamorphics in this area. If these earlier sediments were present they would probably be exposed, as the Finniss River Group is nowhere particularly thick.

Within the Central Trough, the Burrell Creek Formation lies directly on the Golden Dyke Formation. The boundary between them is gradational or interfingered, but the interfingering or grading is commonly confined to a zone a few hundred feet thick. A well marked gradational contact has been mapped in the Mount Bundey area, and a gradational and interfingered contact is present in the Brocks Creek/Burrundie area.

East and south-east of the Rum Jungle area (Pl. 30), the Burrell Creek Formation directly overlies the Golden Dyke Formation without gradation.

The Noltenius Formation in the Stapleton area has a mixed lithology; it includes sediments similar to those of the Golden Dyke Formation, into which it probably grades, and is overlain by the Burrell Creek Formation.

North of Rum Jungle, the Noltenius Formation directly overlies the Golden Dyke Formation; farther north, at Knuckeys Lagoon, it overlies the Masson Formation.

In general, therefore, the Finniss River Group is separated by a regional disconformity from the underlying Goodparla and Batchelor Groups. In places, however, the contacts between the Golden Dyke and the Burrell Creek and Noltenius Formations are gradational and interfingering, which indicates that the Central Trough continued to receive sediment from the east for some time after deposition of the Finniss River Group commenced. Thus the Eastern Trough (a modification of the Primary Basin on the eastern side of the geosyncline, described on p. 50) was formed after the start of Finniss River Group sedimentation.

Metamorphism Within the Western Fault Zone

The degree of metamorphism in Finniss River rocks along their western margin has been commented on by earlier workers (Noakes, Voisey, and others), and we feel that undue emphasis has been given to it. The metamorphism is due largely to shearing stress and serves to help delineate the Western Fault Zone.

The rocks of the Noltenius and Burrell Creek Formations have been strongly sheared in zones within an irregular belt about 10 miles wide, extending for 120 miles south from Darwin to the Muldiva Creek area. In places, the rocks have been altered to andalusite and mica schists and injected with the numerous tin and tantalite-bearing pegmatite veins (see Summers, 1957, unpubl.). Some of the andalusite-mica schists in the Burrell Creek Formation contain andalusite crystals up to 6 inches long (Pl. 10, fig. 2). Near the granite intrusions, tourmaline-mica schist is common, and cordierite and rare sillimanite were noted in a few places.

SEDIMENTATION IN THE EASTERN TROUGH

The Eastern Trough is occupied by the sediments of the South Alligator Group. The eastern margin of the trough is covered by the Carpentarian rocks of the Katherine River Group, but probably did not extend beyond Magela Creek. The southern limit is unknown.

The western limit is clearly exposed along the valley of the South Alligator River, and is marked by three main features: the discontinuous reef facies which forms part of the Koolpin Formation of the South Alligator Group, the South Alligator Fault Zone (Walpole, 1953, unpubl.), and the line of discontinuous outcrops of the Archaean Stag Creek Volcanics. Along this boundary, the South Alligator Group is commonly faulted against the Coirwong Greywacke

Member of the Masson Formation: in part the boundary is a regional disconformity against Masson Formation.

The northern boundary of the South Alligator Group is obscured by Cainozoic sediments, but the northern limit of the trough probably did not extend much beyond the outcrops of Mount Partridge Formation to the north.

South Alligator Group

The rock units recognized in the South Alligator Group are the Koolpin Formation, the Gerowie Chert, and the Fisher Creek Siltstone. The relationship of the formations is shown diagrammatically in Figure 14. The group is characterized by a marked predominance of lutite, and the presence of a discontinuous reef facies along the western boundary.

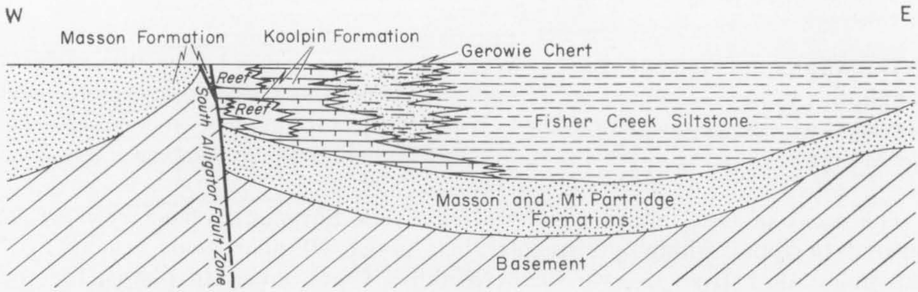

Fig. 14. Relationships between Koolpin Formation, Gerowie Chert, and Fisher Creek Siltstone

Koolpin Formation

The Koolpin Formation is composed of two main members — discontinuous dolomitic algal reefs, and a pyritic carbonaceous siltstone with bands, lenses, and nodules of silicified dolomite.

The reef structures crop out at or near the base and along the western boundary of the formation in the Turnoff Creek and Coronation Hill/Saddle Ridge areas and north of Coirwong Gorge (Pls 28 and 31). They are rare or absent between Saddle Ridge and Coirwong Gorge: only a few minor algal deposits have been mapped in this area. The bioherms range in thickness from about 1000 feet (the Pul Pul bioherm) to less than 50 feet and intertongue with the carbonaceous member. The reefs are formed mainly of *Collenia*-type algae (Pl. 12, fig. 1), ranging from structures about ¼ inch high to large structures up to 3 feet high. The small structures commonly give the rock a banded appearance, and in many places where they are not well preserved the rock resembles a normal thin-bedded silicified dolomite. Other types of algae are present, but none of them have been described in detail. 'Reef' breccias may occur in places, but have not been positively identified. Terrigenous material, if present, is rare — probably because the reefs grew on a basement ridge within the Pine Creek Geosyncline and not on the margin, where such material would have been more readily available. The reefs in the Coirwong area are commonly silicified but the preservation of some algal structures and the character of the outcrops clearly indicate that they represent bioherms.

The pyritic carbonaceous dolomitic member consists of carbonaceous siltstone containing bands, lenses, and nodules of chert (Pl. 11, figs 1 and 2). Thin sections of the chert from near Rockhole uranium mine have a relict dolomite texture which indicates that it was formed by the silicification of dolomite (see App. 3). The rock is similar to some of the sediments in the Golden Dyke and Masson Formations. The lenses are commonly not more than ½ inch to 2 inches thick, but the nodules may range from ¼ inch to, in extreme cases, 6 inches in diameter. They are commonly between ½ inch and 1½ inches in diameter. Carbonaceous siltstone lenses, without chert bands and nodules, are also present. This member is the host rock for most of the uranium occurrences in the South Alligator River area.

Gerowie Chert

The Gerowie Chert overlies and interfingers with the Koolpin Formation. It crops out near the junction of Gerowie Creek and the South Alligator River and extends over a strike length of about 25 miles. The formation consists mainly of siliceous siltstone, impure chert (in places rich in albite), and chert, all of which are regarded as possibly diagenetically altered dolomitic sediments. The formation commonly contains bands, lenses, and nodules of chert, and in places contains rounded boulders of chert, up to 2 feet across, which are, apparently, silicified calcareous concretions. The siliceous siltstone is intensively veined with quartz in a few places.

Discrete lenses of the pyritic carbonaceous dolomitic member of the Koolpin Formation are interbedded with the Gerowie Chert throughout the lower part of the formation.

Breccias, containing angular chert fragments in a ferruginous siliceous matrix, are interbedded in places with the siliceous siltstone and impure chert. This is probably the result of a local mingling with Koolpin Formation. In places, the siliceous siltstone is red and ferruginous, but generally it is grey, green, or white. Towards the top of the formation, the siltstone is dominant and chert becomes rare. Massive chert crops out in lenses up to 100 feet long and 10 feet thick; most of the chert, however, is contained in discontinuous lenses and nodules and in bands up to 12 inches thick, and probably constitutes only 10 to 20 percent of the formation as a whole. A continuous gradation from chert to impure chert to siliceous siltstone can be seen in some outcrops.

Fisher Creek Siltstone

The Fisher Creek Siltstone probably contains the bulk of the sediments in the South Alligator Group, but its outcrop area is limited. It overlies and interfingers with the Koolpin and Gerowie Formations. It is composed mainly of siltstone, minor greywacke siltstone and micaceous greywacke occur in places, the latter at the base of the formation and interfingered with Koolpin Formation in the El Sherana mine area. There has been no drilling in the Fisher Creek Siltstone, and it is not known whether the rocks are carbonaceous at depth or not.

In the Fisher Creek area, the formation consists of a thick monotonous sequence of brown, mauve, or red siltstone with minor greywacke siltstone and micaceous greywacke. As the siltstone is not well bedded and is poorly exposed, the structure and thickness are difficult to determine. The sediments have been contact-metamorphosed by the Malone Creek Granite and by the sills and dykes of the Zamu Complex.

In the north-western outcrops, near the confluence of Gerowie Creek and the South Alligator River, the Fisher Creek Siltstone grades laterally into the Gerowie Chert. Here, it consists of thinly interbedded green and white banded siliceous siltstone and mauve siltstone and some beds, up to 2 feet thick, of mauve fine-grained greywacke and grey-green medium-grained greywacke. The sediments in this area are complexly folded.

Sedimentary Environment of the Eastern Trough

The Eastern Trough contains the sediments of the South Alligator Group. The lithology of the South Alligator Group, the relationships to the older Goodparla Group, and the features marking the western boundary of the trough, particularly the South Alligator Fault Zone and the line of outcrops of the Stag Creek Volcanics, give some indication of the environment within the trough and suggest a possible mechanism for its development.

The South Alligator Fault Zone extends north-west from the Sleisbeck area to Coirwong Gorge (Pl. 28); it consists of a number of high-angle normal and reverse faults, most of which displace rocks of both Lower Proterozoic and Carpentarian age. It is most probable that the faulting was initiated in the Lower Proterozoic and was largely responsible for the development of the Eastern Trough.

The Stag Creek Volcanics are a basement ridge in the South Alligator River area, and form a belt of discontinuous outcrops parallel to the western edge of the Eastern Trough. At Mundogie Hill (Pl. 28), they crop out in the core of a shallow dome which determines the present margin of the trough in that area. They do not crop out in contact with the South Alligator Group, but occur as inliers within the Masson and Mount Partridge Formations — roughly along the boundary between the two, suggesting the possibility of a hinge-line along a zone of weakness in the floor of the Primary Basin. Whatever the original feature, movement along this line was the main factor in the formation of the Eastern Trough.

The relationship of the South Alligator Group to the underlying Masson and Mount Partridge Formations is best interpreted as a regional disconformity. The rocks were folded together, and the relationships can be interpreted as a normal feature of sedimentation in a large composite basin which was affected by differential vertical movements during the course of its depositional history. Similar vertical movements have already been suggested as the cause of the Finniss River Group phase of sedimentation. They affected the loci of sedimentation as well as the source, volume, and type of sediment. In the Eastern Trough the faults were active within the Primary Basin and not astride the margin as presumably was the case with the Finniss River Group phase. Had the eastern margin been much affected, it is logical to assume that the South Alligator Group would contain, if not a flysch facies, at least a moderate proportion of arenaceous rocks. In fact it contains neither — there is so little greywacke in the group that it can be disregarded. There is no evidence to suggest that the Masson or Mount Partridge Formations supplied sediment to the Eastern Trough.

The reef structures of the Koolpin Formation indicate a local shallow-water environment along the western margin of the trough, and their existence precludes the possibility of sediments derived from the Masson Formation being supplied from the west to the Eastern Trough. The South Alligator Group is dominated by chemical and organic sediments (mainly dolomitic) in the western part of the trough, mixed dolomitic and detrital sediments in the central part of the trough and detrital sediments in the east, where the Fisher Creek Siltstone crops out. This suggests a supply of sediment from a relatively low provenance area to the east and deposition in a somewhat restricted environment.

The sediments in the South Alligator Group, particularly those of the Koolpin Formation, are markedly similar to those of the Golden Dyke Formation. The carbonaceous and pyritic nodular dolomitic siltstone and chert of the Koolpin Formation and the Gerowie Chert are more or less identical with some of the rocks in the Golden Dyke Formation: this suggests that the Eastern Trough contains sediments which represent the last phase of the Goodparla episode — the sediments were prevented from entering the Central Trough by a seaward barrier initiated by faulting.

DEPOSITION ON THE CHILLING PLATFORM

The Chilling Platform is in the south-western corner of the Katherine-Darwin Region; it extends south-west as a narrow belt of moderately folded arenites, about 30 miles wide and 200 miles long, to the East Kimberley area in Western Australia.

We have evidence of the age of the Chilling Sandstone only in the Fletchers Gully area, where it is a sharp facies change of the Noltenius Formation. Whether a second arenite unit is present (as some geologists think), which we have mistaken for Chilling Sandstone, will not be known for certain until the mapping of the Victoria River Basin has been completed.

Chilling Sandstone

The Chilling Sandstone sediments were included in the Victoria River Group by Traves (1955). Hossfeld (1954) shows part of the outcrop of the Chilling Sandstone as 'Middle Proterozoic', and in an earlier publication (Hossfeld, 1937b) he referred to them as the basal member of the 'Muldiva Stage', which is now included in the Noltenius Formation. Voisey (1939) also considered the Chilling Sandstone as part of the 'Muldiva Stage'. Hossfeld and Voisey did not map the gradational contact between what is now called the Noltenius Formation and the Chilling Sandstone, or recognize that the Chilling Sandstone is higher in the sequence than the Noltenius Formation. Hossfeld (1954) also did not recognize the continuity of the Chilling Sandstone with his 'Middle Proterozoic' Victoria River Beds.

In the type area, the Chilling Sandstone is a lateral and vertical facies change of the Noltenius Formation and hence is part of the sequence in the Pine Creek Geosyncline. The main area of outcrop is in the south-western corner of the Katherine-Darwin Region (Pl. 28), and the formation appears to continue into Western Australia. The formation also crops out north of the general Chilling Creek area in two isolated fault blocks in the Litchfield Complex at Murrenja Hill and near Fog Bay (Pl. 28).

The Chilling Sandstone consists essentially of blocky white silicified quartz sandstone, commonly ripple-marked, cross-bedded, and jointed, and containing rare quartz pebble conglomerate bands. About 3000 feet of the formation crops out in a south-pitching syncline about 4 miles north-west of Fletchers Gully gold mine. No marked variation in lithology was seen in this section; the sandstone is commonly medium-grained, but may range from fine to coarse. At the base of the formation, in the Fletchers Gully area, there is a narrow transitional zone where the greywacke and siltstone of the Noltenius Formation grade up into the Chilling Sandstone.

South-west of Fletchers Gully the area of outcrop is wider and the formation is thicker; in the Fitzmaurice River area it is about 4500 feet thick.

In the Fog Bay exposure it comprises 500 feet of coarse-grained sheared greywacke, quartz greywacke, and quartz pebble conglomerate at the base, overlain by 1000 feet of white ripple-marked quartz sandstone. The basal part of the sequence may represent the transition from the Noltenius Formation, but is included in the Chilling Sandstone because the interbedded siltstone typical of the Noltenius Formation is absent.

TABLE 3: STRATIGRAPHIC TABLE, CARPENTARIAN ROCK UNITS

Rock Unit	Thickness (ft)	Lithology	Distribution (Incl. 1:250,000 Sheets)	Reference Area	Stratigraphic Relationships	References
MOUNT RIGG GROUP			Katherine Sheet		Unconformably overlies Katherine R. Gp	
'Beswick Creek Formation'	300	Marl, medium-grained pink quartz sandstone, basalt, and siltstone	Beswick Ck and valley of Waterhouse R.: Katherine Sheet	S.W. of Beswick homestead, lat. 14°35'S., long. 133°06'E.	Conformably(?) overlies Dook Ck Fm.	Walpole (1958a), Ruker (1959, unpubl.), Randal (1963)
Dook Creek Formation	1000	Dolomitic limestone with *Collenia*-type algae, sandstone, and chert; in places, the limestone is brecciated and glauconitic. Red and grey oolitic limestone, shale, siltstone, and marl	N. of Beswick homestead; Katherine Sheet	Between Waterhouse R. and W. Branch, lat. 14°27'S., long. 133°07'E.	Conformably overlies Bone Ck Fm.	Ruker (1959, unpubl.), Randal (1963)
Bone Creek Formation	500	Oligomictic conglomerate and quartz sandstone	N. of Beswick homestead, and upper Waterhouse R.: Katherine Sheet	Reference section: 1 mile W. of Bone Ck, lat. 14°25'S., long. 132°58'E.	Overlies Margaret Hill Conglomerate with local disconformity	Ruker (1959, unpubl.), Randal (1963)
Margaret Hill Conglomerate	1250	Polymictic conglomerate, purple tuffaceous greywacke, and quartz greywacke	Dook Ck and upper Waterhouse R.: Katherine Sheet	Reference section: Margaret Hill, lat. 14°27'S., long. 132°59'E.	Unconformably overlies W. Branch Volcanics	Walpole (1958), Ruker (1959, unpubl.), Randal (1963)
KATHERINE RIVER GROUP	9000		Arnhem Land Plateau and environs: Alligator R., Mt Evelyn, and Katherine Sheets	Drainage area of Katherine R.		Walpole (1958a), Randal (1963)
West Branch Volcanics	5300	Tuffaceous greywacke, arkosic sandstone, amygdaloidal basalt, conglomerate, and quarz greywacke	Headwaters of Waterhouse R.: Katherine Sheet	Between W. Branch and Waterhouse R., lat. 14°25'S., long. 133°05'E.	Unconformably overlies Gundi Greywacke in places and is unconformably overlain by Mt Rigg Gp	Ruker (1959, unpubl.)
Gundi Greywacke	450	Tuffaceous quartz greywacke	Upper reaches of Waterhouse R. and W. Branch: Mt Evelyn and Katherine Sheets	Reference section: N. of Waterhouse R. above Waterhouse Waterfall, lat. 14°25'S., long. 133°10'E.	Disconformably overlies Diamond Ck Fm.	
Diamond Creek Formation	700	Basic volcanics, limestone, siltstone, and conglomerate	Mainly in upper basin of Waterhouse R.: Mt Evelyn and Katherine Sheets	Reference section: S. of Waterhouse R. above Waterhouse Waterfall, lat. 14°26'S., long. 133°10'E.	Conformably overlies McKay Sandstone or Kombolgie Fm.	Walpole (1962), Randal (1963) Ruker (1959, unpubl.)
McCaw Formation	—	Dolomite and dolomitic sediments	Does not crop out in Katherine-Darwin Region: crops out in Mt Marumba Sheet (Roberts & Plumb, 1964)	—	Conformably overlies Shadforth Sandstone; lateral equivalent of upper part of Diamond Ck Fm.	Roberts et al. (in prep.)
Shadforth Sandstone	—	Medium-grained quartz sandstone, glauconitic near top	Does not crop out in Katherine-Darwin Region: crops out in Arnhem Land	—	Unconformably overlies Cottee Fm.; lateral equivalent of part of Diamond Ck Fm.	Roberts et al. (in prep.)
Cottee Formation	—	Dolomite and dolomitic sediments	Does not crop out in Katherine-Darwin Region: crops out in Arnhem Land	—	Conformably overlies McKay Sandstone or Kombolgie Fm.	Roberts et al. (in prep.)
McKay Sandstone	(?)	Fine to medium-grained flaggy ferruginous or feldspathic sandstone	Widespread in E. parts: Katherine and Mt Evelyn Sheets	Mt Marumba Sheet	Conformably overlies, and in places laterally equivalent to, Kombolgie Fm. Previously mapped as Diljin Hill Fm. (Walpole, 1962; Randal, 1963); in part included in Kombolgie Fm. (Randal, 1963)	Roberts et al. (in prep.), Ruker (1959, unpubl.)
Kombolgie Formation	5200	Alternating sediments and volcanic rocks: quartz greywacke, conglomerate, feldspathic sandstone, quartz sandstone, quartz siltstone, and tuff. Volcanic members listed below	Arnhem Land and environs: Alligator R., Mt Evelyn, and Katherine Sheets	Kombolgie Ck, S. Alligator R. area, lat. 13°30'S., long. 132°23'E.	Unconformably overlies Archaean and Lower Proterozoic rocks in places; elsewhere, conformably and disconformably overlies Edith R. Volcanics	Raggatt (1958)
Henwood Creek Volcanic Member	370	Basic and intermediate lavas and pyroclastics	E. of Edith Falls: Katherine Sheet	Henwood Ck, E. of Edith Falls, lat. 14°12'S., long. 132°12'E.	Interbedded with Kombolgie Fm. sandstone above McAddens Ck Volcanic Mbr	Stewart (1965)
McAddens Creek Volcanic Member	800	Amygdaloidal basalt, and acid lavas and pyroclastics	E. of Edith Falls and E. of Katherine: Katherine Sheet	McAddens Pocket, N. of Katherine, lat. 14°18'S., long. 132°19'E.	Interbedded with Kombolgie Fm.	Stewart (1965)
Birdie Creek Volcanic Member	700	Mainly andesite, amygdaloidal in places, and pyroclastics	Between Katherine R. and Waterhouse R. W. Branch: Mt Evelyn and Katherine Sheets	Birdie Ck, lat. 13°53'S., long. 132°58'E.	Interbedded with Kombolgie Fm.	Stewart (1965)
Nungbalgarri Volcanic Member	200	Basic volcanics	Arnhem Land Plateau: Alligator R. and Mt Evelyn Sheets	Milingimbi Sheet	Interbedded with Kombolgie Fm.; includes most of the unnamed volcanics on Katherine and Mt Evelyn Sheets	Roberts et al. (in prep.)
Plum Tree Creek Volcanic Member	1200	Andesite, rhyolite, dacite, and pyroclastics	Headwaters of S. Alligator R.: Mt Evelyn Sheet	Plum Tree Ck, lat. 13°35'S., long. 132°27'E.	Overlies Kurrundie Mbr and overlain by undifferentiated Kombolgie Fm.	Stewart (1965)
Kurrundi Member	420	Purple or buff quartz greywacke; some conglomerate bands	Headwaters of S. Alligator R.: Mt Evelyn Sheet	Kurrundie Ck, lat. 13°30'S., long. 132°29'E.	Basal member of Kombolgie Fm. in Callanan Basin	
Goomadeer Volcanic Member	100+	Basalt, amygdaloidal in places	S.E. of Oenpelli mission: Alligator R. Sheet	Milingimbi Sheet	Base of Kombolgie Fm.	Roberts et al. (in prep.)
Edith River Volcanics	4000	Mainly rhyolite and dacite with minor basic volcanics; lenses of tuff, ashstone, tuffaceous sandstone, conglomerate, and silicified calcarenite breccia near base.	Discontinuous outcrops from Fergusson R. to Edith Falls Basin; thence E. to Yeuralba area and N. to S. Alligator area: Mt Evelyn, Katherine, and Fergusson R. Sheets	Edith R., just below Edith Falls, lat. 14°11'S., long. 132°10'E.	Unconformably overlies Lower Proterozoic rocks. Forms discontinuous base of Katherine River Gp	Woolnough (1912), Noakes (1949), Walpole (1958b), Raggatt (1958), Stewart (1965)
Phillips Creek Member	900	Medium-grained purple greywacke, red and purple shale, and conglomerate	Edith R.: Katherine Sheet	Phillips Ck, lat. 14°10'S., long. 132°10'E.	Basal member of Edith R. Volcanics W. of Edith Falls Basin; unconformably overlies Burrell Ck Fm.	Rattigan & Clark (1965, unpubl.)
Hindrance Creek Member	50	Purple tuffaceous sandstone	N. and N.E. of Yeuralba: Katherine Sheet	Hindrance Ck, lat. 14°13'S., long. 132°35'E.	Basal member of Edith R. Volcanics in Yeuralba area	
Pul Pul Rhyolite Member	Variable	Mainly rhyolite	S. Alligator R. between Coronation Hill and Rockhole mine: Mt Evelyn Sheet	Pul Pul Hill, lat. 13°34'S., long. 132°35'E.	Overlies Scinto Breccia and Coronation Mbr	Pl. 31
Scinto Breccia Member	300	Silicified calcarenite breccia, in places rich in hematite; grades into sandstone and conglomerate in places	S. Alligator R. between Coronation Hill and Rockhole mine: Mt Evelyn Sheet	Scinto mine area, S. Alligator R. valley, lat. 13°34'S., long. 132°33'E.	Irregular lenticular deposit; overlies or grades into Coronation Mbr	Pl. 31
Coronation Member	200	Rhyolite, agglomerate, greywacke conglomerate, greywacke pebble conglomerate, coarse sandstone, and polymictic conglomerate	S. Alligator R. area between Coronation Hill and Pul Pul: Mt Evelyn Sheet	Coronation Hill, lat. 13°36'S., long. 132°36'E.	Basal member of Edith R. Volcanics in S. Alligator area; unconformably overlies Lower Proterozoic rocks	Pl. 31

The Murrenja Hill exposure is about 15 miles south of the Fog Bay outcrop and consists of over 2000 feet of white quartz sandstone with minor bands of sheared quartz pebble conglomerate.

Evolution of the Chilling Platform

The Chilling Platform is on the western side of the geosyncline. The structure is not well defined, and the margins are mostly obscured by younger Adelaidean and Palaeozoic rocks. Where the margins are exposed they are formed by vertical or high-angle faults or there is a sharp contact between the Chilling Sandstone and the Noltenius Formation. It is classified as a platform area on the basis of the lithology (generally ripple-marked quartz sandstone), and because it appears to extend back over what was probably the western foreland to the Pine Creek Geosyncline.

The sharp lateral and vertical gradation from the Noltenius Formation to the Chilling Sandstone in the Fletchers Gully area contrasts with the gradation between the Noltenius and Burrell Creek Formations in that the lateral component in the Chilling Sandstone is south-west instead of east; and as the source area is west it must be younger than the Burrell Creek Formation. The gradation in the Fletchers Gully area suggests a lapping back of medium-grained sandstone on to basement.

In the Soldiers Creek area south of Fletchers Gully (Pl. 28) the strike of the Noltenius Formation swings to the south-east, whereas the Chilling Sandstone trends south-west; it is probable that the eastern margin of the Chilling Sandstone is determined by faulting. The western boundary is overlain by Palaeozoic rocks.

The gradation from the Noltenius Formation to the Chilling Sandstone in the Fletchers Gully area occurs over a vertical distance of only about 200 feet and emphasizes the sharp variations which occur where sedimentation is largely controlled by faulting — as compared to, for example, the previously described Masson/Mount Partridge Formation environment, where such movements were not critical. The formation might be regarded as part of the Finniss River episode; but the lack of significant variation in the type of sediment and its distribution in a belt, possibly marking a platform branching off the main geosynclinal area, suggests that it is a distinct, late-stage development.

Carpentarian System

The Katherine-Darwin Region lies on the north-western flank of the McArthur Basin, which is an integral part of the Limmen Geosyncline, a Carpentarian structure which extends south and east for several hundred miles to the Mount Isa/Cloncurry area in north-west Queensland. The McArthur Basin and Limmen

Geosyncline are being described by Dunn et al. (in prep.) and Roberts et al. (in prep.). The geosyncline was identified as a structural and depositional entity only in recent years (Walpole et al., 1965); the sedimentary succession was previously regarded as including both Lower and Upper 'Proterozoic' rocks (as shown on published geological maps of the Katherine-Darwin and Mount Isa/Cloncurry Regions): these rocks are now identified as Carpentarian and Adelaidean, and rest on Lower Proterozoic and, in places, Archaean strata.

The first Carpentarian event in the Katherine-Darwin Region was the intrusion of the numerous granitic plutons (see p. 127). The granites are regarded as the physical expression of instability in the basement, which resulted in the elevation of the north-western foreland of the McArthur Basin. They were associated (on geochronological evidence — P. J. Leggo, pers. comm.) with an acid volcanic suite — the Edith River Volcanics — which is the basal Carpentarian sequence in the region. The igneous activity was also responsible for most of the mineral occurrences in the region. Radiometric data obtained from most of the intrusions, and the Edith River Volcanics, lie on the 1760 m.y. Rb/Sr isochron. The Pine Creek Geosyncline was not a main source for McArthur Basin sediments, although there may have been some local contribution.

The second event, which was in part penecontemporaneous with the igneous activity, was the deposition of a mixed arenite-rudite-volcanic sequence (here represented by the Katherine River Group), which forms part of a vast sheet spreading apparently across the whole width of the McArthur Basin and over most of its length.* Roberts et al. (in prep.) quote a maximum development of 20,000 feet for this assemblage in the Parsons Range area of Arnhem Land: it is thinnest and most irregular on the shelves and thickest in the trough zone; and the rudites lens out and the arenites become finer in grain, better sorted, and more thinly bedded towards the centre of the basin, as might be expected. Part of the western shelf is in the Katherine-Darwin Region.

Correlates of this assemblage occur in the Carpentarian throughout northern Australia. Its source area or areas are not known — probably there are many — but the general lithology is remarkably consistent. The assemblage has been identified in different places and in different depositional structures from north-west Queensland to the Kimberley area in Western Australia over a distance of more than 1000 miles. The McArthur Basin contains possibly 120,000 cubic miles of rocks belonging to this basal assemblage. It is succeeded by a carbonate-lutite facies, again readily recognizable in widely separated localities, and commonly separated from the basal assemblage by an unconformity in the shelf zones; and in conformable sequence with it in the trough zone of the basin. In the Katherine-Darwin Region the carbonate-lutite assemblage is represented by the Mount Rigg Group.

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* In places, carbonate rocks constitute up to 25 percent of the section in this assemblage, e.g., McCaw and Cottee Formations on the Mount Marumba 1 : 250,000 Sheet area (H. G. Roberts, BMR, pers. comm.).

The third major event in the development of the McArthur Basin was the deposition of the Roper Group (see p. 79), composed mainly of arenites and lutites, and again with a remarkably consistent lithology over a large area, highlighted in places by the presence of beds of sedimentary iron ore. These rocks belong to the Adelaidean System; in the Katherine-Darwin Region they crop out only in the south-eastern corner of the Katherine 1 : 250,000 Sheet area (Randal, 1963). The Roper Group is separated from the underlying Carpentarian rocks by a regional unconformity.

Granitic intrusions mark the commencement of the Carpentarian, and the latest isotopic age determination on the Grace Creek Granite indicates that there was also igneous activity within or at the end of the Carpentarian.

Katherine River Group

Nomenclature

The Katherine River Group is the western shelf facies and basal stratigraphic unit in the northern part of the McArthur Basin, the axis of which lies in Arnhem Land 160 miles east of the Katherine-Darwin Region. It is overlain uncomformably by the Mount Rigg Group.

The following discussion of the nomenclature of the Katherine River Group has been written with the assistance of H. G. Roberts (BMR). Knowledge of the regional geology of northern Australia grew slowly: it was not until 1962 that the Katherine-Darwin work could be connected with that in Arnhem Land, and it is only in recent years that isotopic geochronology became a reliable technique which could be used for correlation purposes. In the attempt to resolve some of the nomenclatural problems we have drawn on work as yet unpublished. The changes we have made from past nomenclature are summarized in Table 4.

The Katherine River Group is now included in the Carpentarian System. For many years it was regarded as part of the Buldiva 'Quartzite' or 'Buldivan Series' (the type area for which is the Buldiva area on the western margin of the Daly River Basin), which is overlain by Cambrian rocks. Noakes (1949, p. 17) has reviewed the nomenclature of this unit, and gives the thickness as probably over 1000 feet. Hossfeld (1954) considered this to be excessive, and grouped all of the Carpentarian and Adelaidean rocks with Cambrian units into a 'Buldivan Series', on the assumption that they were conformable. In fact, no previous workers had given more than cursory attention to the rocks of the Arnhem Land Plateau. The Buldiva Sandstone, as it is now more correctly known, is Adelaidean, and is confined to the margins of the Daly River Basin and the Tolmer Plateau, with a few small outliers in the Rum Jungle area. Elsewhere the main areas of rocks included by earlier workers as Buldiva 'Series' or 'Quartzite' — the Mount Douglas outlier and the Arnhem Land Plateau — are now known to contain Carpentarian rocks of the Katherine River Group and succeeding units.

The first published use of the name Katherine River Group was by Noakes (1956, p. 229), who wrote 'Walpole (unpubl.) 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 (1958a) informally described 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 & Clarke, 1955, unpubl.); and the West Branch Volcanic Member north of Beswick homestead.

Ruker (1959, unpubl.) divided the Katherine River Group into three formations; the upper formation he subdivided into three members.

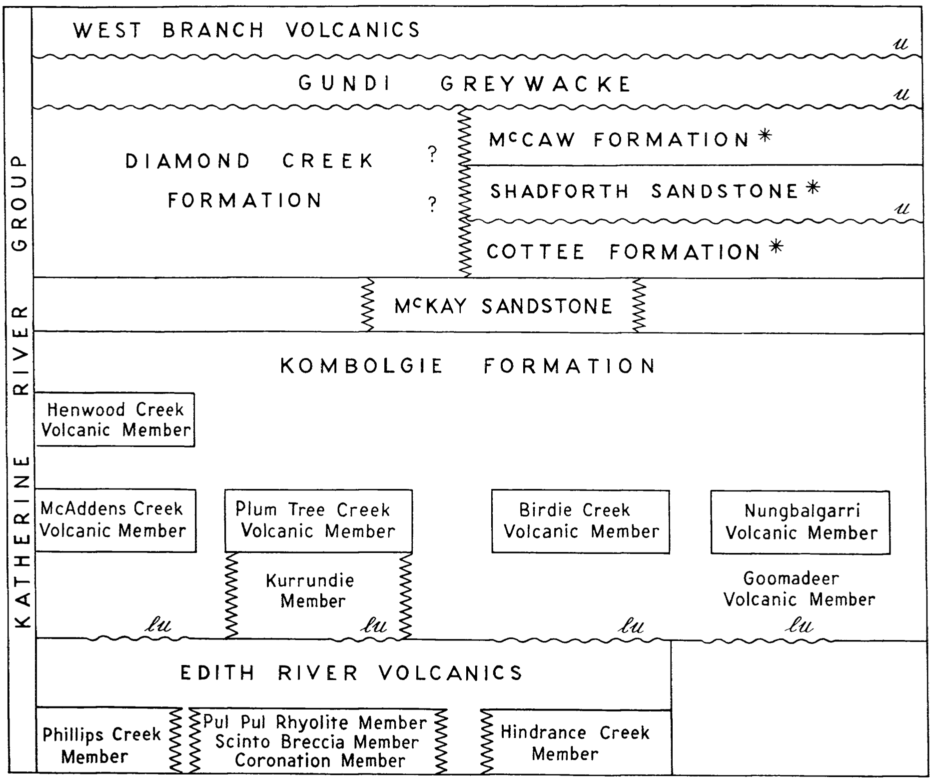
Randal (1963) adopted most of Ruker's terminology (Table 4), and applied the term 'Birdie Creek Volcanic Member' to volcanics in the Kombolgie Formation. Subsequent mapping in the adjoining Mount Marumba Sheet area (Roberts & Plumb, 1964) has shown that a substantial thickness of rock overlies the Kombolgie Formation. Three formations — the McCaw Formation, Shadforth Sandstone, and Cottee Formation — are now recognized. 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 area by Ruker's 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 at the base of the Gundi Greywacke Member in the Mount Marumba Sheet area, it is necessary to revise the nomenclature of Walpole (1958a) and Randal (1963). The name Diljin Hill Formation has been abandoned, and its original constituent members have been raised to formation rank and other units added, as shown in Table 4.

TABLE 4: REVISION OF STRATIGRAPHIC NOMENCLATURE, KATHERINE RIVER GROUP

<table>
<tr><th colspan="2">Walpole (1958)</th><th colspan="2">Ruker (1959, unpubl.), Randal (1963)</th><th colspan="2">Present authors and Roberts et al. (in prep.)</th></tr>
<tr><td rowspan="6">Kombolgie Formation</td><td rowspan="6">West Branch Volcanic Member</td><td rowspan="6">Diljin Hill Formation</td><td>West Branch Volcanic Member</td><td colspan="2">West Branch Volcanics</td></tr>
<tr><td>—— u ——</td><td colspan="2">u —— u —— u —— u —— u —— u</td></tr>
<tr><td>Gundi Greywacke Member</td><td colspan="2">Gundi Greywacke</td></tr>
<tr><td>—— ? —— ? ——</td><td colspan="2">? —— ? —— ? —— u —— u —— u</td></tr>
<tr><td>Diamond Creek Member</td><td>Diamond Creek Formation†</td><td>McCaw Formation*
Shadforth Sandstone*
—— u —— u ——
Cottee Formation*</td></tr>
<tr><td></td><td colspan="2">McKay Sandstone</td></tr>
<tr><td colspan="2"></td><td colspan="2">Kombolgie Formation</td><td colspan="2">Kombolgie Formation</td></tr>
</table>

—— u —— u —— unconformity. † Katherine-Darwin Region only. * Arnhem Land only

Roberts et al. (in prep.) have added new members to the Kombolgie Formation and given formal names which can be applied to some of the 'Undifferentiated Volcanics' shown on the Mount Evelyn (Walpole, 1962) and Alligator River (Dunn, 1962) maps. They have also split off a unit shown as 'Undifferentiated Diljin Hill Formation' on the Mount Evelyn and Katherine (Randal, 1963) maps. This is the McKay Sandstone, which also includes part of the Kombolgie Formation on the Katherine 1 : 250,000 Sheet.



**—Units which crop out only in Arnhem Land; u—Unconformity; lu—Local unconformity in places*

Fig. 15. Stratigraphic relationship of units in the Katherine River Group

The relationships of the various components of the group are shown in Figure 15. The full Carpentarian succession in the region is shown on Table 3.

General Stratigraphy

The Katherine River Group has a maximum estimated thickness of about 9000 feet in the Katherine-Darwin Region, but the thickness varies widely from place to place. On the western side of the outcrop area, the rocks were deposited in two basins (where they are thickest) and on platforms separating the basins.

Inliers of basement are exposed in a number of places. The two basins are the Edith Falls and Mount Callanan Basins: although the rocks have been extensively faulted in places, folding is very gentle and appears to have been mainly caused by gentle subsidence during deposition. The thickest sections coincide with the distribution of the Edith River Volcanics, and consist mainly of the Kombolgie Formation.

A much larger structure, a syncline near the upper reaches of the Waterhouse River in the south-eastern corner of the region, is occupied mainly by sediments which are younger than the Kombolgie Formation. This is a complicated structure and was apparently developed in an unstable area. The sequence is marked by a number of local unconformities, changes in facies, and variations in thickness of the contained rocks.

North-east of the South Alligator River, the Katherine River Group consists only of strongly jointed (as in Pl. 2, fig. 1) flat-lying or very gently dipping arenites and rudites and minor interbedded volcanic rocks of the Kombolgie Formation. The margin of outcrop is an abrupt escarpment (Pl. 2, fig. 2) trending north-north-east, with a few outliers of coarse arenites in places. The lack of faulting is in direct contrast to the areas farther south. The Edith River Volcanics are, significantly, absent, and the outliers suggest that the original margin was once farther to the north-west.

The general geological setting of the Katherine River Group therefore is that of an unstable shelf zone on the western margin of the McArthur Basin. Parts of this zone, marked by the Edith River Volcanics, were more unstable than others; and the thickness of the sequence varies markedly from place to place according to variations in the profile of the underlying basement and the degree of local instability.

Edith River Volcanics

Woolnough (1912, p. 17) first referred to the Edith River Volcanics as Edith Creek Volcanics, and described them as ranging from dacite to basalt, with tuff, agglomerate, and tuffaceous sandstone. (The Edith Creek of Woolnough is now known as Edith River.) Jensen (1915b, p. 21) refers to them, and also Noakes (1949, 1954), Hossfeld (1954), Rattigan & Clark (1955), and Walpole (1958a). Stewart (1965) has made a detailed petrographic study of the volcanics.

The age of the Edith River Volcanics has been given as Precambrian (Woolnough, 1912), Permo-Carboniferous (Jensen, 1915) Lower Cambrian (Noakes, 1949), Lower Proterozoic (Hossfeld, 1954), Upper Proterozoic (Rattigan & Clarke, 1955; Noakes, 1954; Walpole, 1958a), and Middle Proterozoic (Stewart, 1965). Samples dated by P. J. Leggo give concordant dates of 1760 m.y. They are therefore Carpentarian.

The Edith River Volcanics have been studied in the type area at Edith River and in the South Alligator River valley: the relationships to older and younger strata were first established by Rattigan & Clarke (op. cit.) at Edith River; Stewart (1965) has studied the petrography of the volcanics at both localities.

The Edith River Volcanics are an assemblage of lavas, ignimbrite (Stewart, 1965), pyroclastic rocks, sediments, and tuffaceous sediments with marked lateral and vertical variations. Near Phillips Creek, the *Phillips Creek Member* is locally the base of the Edith River Volcanics, and consists of '900 feet of sandstone, conglomerate, shale and tuffaceous sediments . . . The most typical rock type is a dense, even and medium-grained purple sandstone with dark crescentic markings. Red and purple shales are interbedded. Conglomerates, which are very lenticular and variable in thickness, are important in the section. They comprise pebbles and boulders of Lower Proterozoic sediments and reef quartz embedded in a heterogeneous unsorted sandy matrix. The typical lithology of the Phillips Creek Sandstone Member is not developed at the base of the Edith River Volcanics in areas north-east of Katherine. However, the base of the Edith River Volcanics in these areas is commonly a heterogeneous conglomerate with a pyroclastic or volcanic matrix, which probably corresponds with the Phillips Creek Member' (Rattigan & Clark, 1955).

Above the Phillips Creek Member near Edith Falls and unconformably above the Lower Proterozoic in other areas are acid, intermediate, and basic flows, ignimbrite, pyroclastic rocks, and tuffaceous sandstone, breccia, slate, and conglomerate. These have not been everywhere subdivided into members. A section measured by Stewart west of Edith Falls is given in Table 5.

TABLE 5: SECTION OF EDITH RIVER VOLCANICS, WEST OF EDITH FALLS

Thickness (ft)	
	Kombolgie Formation above
1200	*Quartz-feldspar porphyry,* weathered: with one minor occurrence of *olivine dolerite*
1100	*Ignimbrite,* red-brown, devitrified, with well marked streaks
80	*Tuff* and *tuffaceous sediments*
800	*Dolerite*
700	*Greywacke, conglomerate, shale,* and *tuffaceous sediments* (Phillips Creek Member) Major unconformity

Rattigan & Clark (1955, unpubl.) measured a similar section nearby, but with only 50 feet of dolerite or basalt: the dolerite is lenticular and lenses out completely at Phillips Creek. Rattigan & Clark did not recognize the presence of ignimbrite. At other localities in the Edith River area tuff and tuffaceous sediments form an important part of the sequence; they include red, green, and grey-green tuffaceous sandstone, shale, and conglomerate, and agglomerate, tuff, and ash-stone with well developed fracture cleavage and joints.

The ignimbrite is homogeneous from bottom to top and no scoriaceous or amygdaloidal horizons have been seen. Although massive in outcrop, the rocks generally have a distinct foliation due to the presence of dark green subparallel lenticular bodies which probably represent fragments of flattened pumice.

The quartz-feldspar porphyry has a characteristic purple colour and is poorly exposed; it is too deeply weathered to determine whether it is a lava, ignimbrite, or air-fall tuff. In places it is replaced by hematite.

Ruker (1959, unpubl.) describes the Edith River Volcanics in the Dook Creek and Diamond Creek areas in the Katherine 1 : 250,000 Sheet as 'represented by dominantly red coloured sediments: greywacke, sandstone, grit, conglomerate, tuff and rhyolite. Owing to the small areas of exposure the relative position of these members has not been established. It is likely that the volcanics and pyroclastics are the lower members. The base is concealed and the thickness is therefore unknown'.

Edith River Volcanics crop out as pendants (?) in the Grace Creek Granite and as outliers in the nearby Lower Proterozoic rocks; at Hindrance Creek near Yeuralba, an indeterminate thickness of purple tuffaceous sandstone has been called the *Hindrance Creek Member.*

In the Turnoff Creek and Sleisbeck areas on the Mount Stow 1-mile Sheet the formation is mainly composed of rhyolite, ignimbrite, and tuffaceous sediments. At Sleisbeck, lenses of radioactive phosphate rock, pink silicified dolomite breccia, and minor conglomerate and sandstone are now also included in the Edith River Volcanics.

Dykes and sills occur in the Fergusson River area, where the Edith River Volcanics appear to have pierced the Cullen Granite and been extruded as hoods over it. The volcanics are toscanites in this locality. The extrusive rocks have a maximum thickness of 350 feet; they are commonly flow-lined and chilled near the base, but the central part is relatively coarse in grain. Some of the dyke rocks are markedly porphyritic. These extrusive and hypabyssal rocks have previously been called 'Fergusson Toscanite' (Carter, 1952, unpubl.) — and Fergusson Volcanics (Rattigan & Clarke, 1955, unpubl.).

The Edith River Volcanics are well exposed in the South Alligator River valley (Pl. 31). On the western and southern flanks of the Malone Creek stock, they comprise about 3500 feet of ignimbrite, rhyolite, dacite, ashstone, tuff, and minor basalt. North of Big Sunday, the sequence thins out markedly and consists of mixed arenite, rudite, and volcanic rocks filling old valleys and thinning out over the topographic ridges in the basement (Pl. 12, fig. 2). The formation extends about 13 miles north-west of the Rockhole uranium mine, and in the area between Coronation Hill and Rockhole it has been subdivided into three members. These are, oldest to youngest, Coronation, Scinto Breccia, and Pul Pul Rhyolite Members.

The *Coronation Member* commonly crops out on the floor of the South Alligator River valley, but in places it has been upfaulted or is draped over the crests of the smaller ridges (Pl. 13, fig. 1). The member ranges from a few feet to over 200 feet in thickness, and comprises rhyolite, including a typically greenish white variety, ignimbrite, agglomerate, greywacke conglomerate, greywacke pebble conglomerate, coarse sandstone, polymictic conglomerate with rhyolite pebbles, and fragments of Lower Proterozoic rocks. The distribution is irregular, and the member is confined mostly to the main valley of the South Alligator River between Coronation Hill and Pul Pul, and the sharp hills on the eastern side of the river between Pul Pul and Rockhole. The greenish white rhyolite lenses out near Coronation Hill. In one place, about 300 yards south-east of the Coronation Hill open cut, there is a very small lens of limestone. The different rock types grade into one another over short distances, and the thicknesses measured in any one place do not have much meaning even a few hundred yards away. In many places the member is absent and younger members rest directly on the Lower Proterozoic rocks.

Three centres of eruption have been identified in the South Alligator River area. At Coronation Hill, a vent 60 feet in diameter was exposed during mining operations for uranium and gold. The vent is filled with agglomerate composed of fragments, up to several feet long, of acid and basic volcanic rocks and Lower Proterozoic sediments. Similar agglomerates occur at Pul Pul and about 4 miles east-south-east of Coronation Hill.

The Coronation Member underlies, in places conformably, in other places with local unconformity, or interfingers with, an irregularly distributed siliceous and in places phosphatic breccia — the *Scinto Breccia Member*. The thickness is very variable, and the maximum is probably less than 1000 feet. It crops out on the Scinto Ridge between Fisher Creek and the Scinto No. 5 uranium deposit, on Coronation Hill, and as isolated residuals on the flats and ridges immediately north and south of Coronation Hill.

Rocks similar to the Scinto Breccia crop out at Sleisbeck and also, although much higher in the stratigraphic column (Adelaidean), at Rum Jungle (Pl. 13, fig. 2). The Scinto Breccia consists of angular fragments of quartzite in a matrix of hematitic siltstone, mudstone, and sandstone with varying proportions of apatite. Finely divided hematite is characteristic, giving the matrix a pinkish brown or lilac colour in which the white quartzite fragments stand out clearly. The quartzite fragments are angular blocks up to 15 inches in diameter, but are commonly from ½ an inch to 2 inches. For many years this rock was referred to at Rum Jungle as Hematite Quartzite Breccia, and was believed to be part of the Lower Proterozoic sequence. In 1954 the breccia in the Sleisbeck area was regarded as a silicified limestone or dolomite breccia, and was believed to be a reef breccia of Lower Proterozoic age associated with the bioherms of the Koolpin Formation along the South Alligator hinge-line (Condon & Walpole, 1955). In 1955 the South Alligator breccias were definitely established as part of the basal valley-fill Edith River Volcanics. The unconformity between the breccia and underlying Lower Proterozoic rocks has been observed in a number of places, and interfingering of breccia with arenites and volcanics of the Katherine River Group can be seen on the northern end of Coronation Hill.

The breccias at Sleisbeck, South Alligator River valley, and Rum Jungle have one thing in common apart from their identical lithology; they all occur, and only occur, close to or in contact with Lower Proterozoic dolomitic rocks, many of which are silicified, and which may be either bioherms or carbonaceous shales with dolomite or silicified dolomite bands. One current theory on the origin of the breccia is that it was derived in situ from the breakdown of dolomite on an old land surface (pre-Carpentarian or pre-Adelaidean); in the Rum Jungle area the breccias in places appear to conform with the Coomalie Dolomite and are possibly of the same age as the dolomite; a third alternative is that the breccias represent deposition from a local source at the base of the Carpentarian Katherine River Group or Adelaidean Tolmer Group.

Most of the breccias were probably formed in the third way; but the other two may have been operative in some areas.

Most of the breccia is regarded as a breakdown product of the Lower Proterozoic pyritic carbonaceous siltstone with silicified dolomite bands, and perhaps dolomite beds or reefs deposited close to the source rocks. The pyritic carbonaceous siltstone with silicified dolomite bands contains all the required constituents of the breccia — 'quartzite' bands of similar dimensions to the breccia fragments, a source of iron and, at Rum Jungle (which is the only place where these rocks have been examined for phosphate), up to 5 percent of apatite.

The Scinto Breccia is overlain by the *Pul Pul Rhyolite Member* in the South Alligator River valley. In places, this member is markedly radioactive owing to the presence of uranium. It contains more than one flow. The member has not been studied in detail, but the main rock type is a purple and white rhyolite (Stewart, 1965).

Relationship Between the Edith River Volcanics and Kombolgie Formation

The relationships between the Edith River Volcanics and the Kombolgie Formation vary from place to place. Near Edith Falls the Kombolgie Formation is transgressive over the Edith River Volcanics, and the basal conglomerate contains boulders of the underlying volcanics: the formations are separated by a minor unconformity (Rattigan & Clarke, 1955, unpubl.). In the South Alligator River valley, there is a strong angular unconformity between the two formations in places, but elsewhere they are conformable; at Coronation Hill the Edith River volcanics are mixed in with coarse arenite of the Kombolgie Formation, indicating contemporaneous deposition. Ruker (1959, unpubl.) has noted a similar mixture of Edith River Volcanics and Kombolgie sandstone near Diamond Creek (Pl. 14, fig. 1), but near Dook Creek the basal breccia conglomerate in the Kombolgie Formation rests unconformably on the Edith River Volcanics (Pl. 14, fig. 2).

The variable relationships of the two formations are a reflection of the instability of the areas in which the Edith River Volcanics have been deposited, and Ruker (op. cit.) has already noted that the areas where unconformities occur are almost invariably strongly faulted.

In the South Alligator River valley, immediately north-east of El Sherana and about 4 miles north-east of Pul Pul, unconformities also occur in the lower part of the Kombolgie Formation; in places beds dipping at 50° to 70° are unconformably overlain by younger beds dipping at 15°, but when traced along strike the sequence becomes concordant. This also appears to indicate instability in some areas during deposition of the Kombolgie Formation. North-east of El Sherana large-scale cross-beds are present; the foresets are up to 20 feet thick with individual beds up to 18 inches thick, and the foresets intersect the topsets at angles of up to 35°.

Kombolgie Formation

The Kombolgie Formation is composed mainly of coarse arenites, with minor rudites, pyroclastics, and acid to basic volcanics. It crops out on the Arnhem Land Plateau on the eastern side of the Katherine-Darwin Region and extends eastwards into Arnhem Land. Folding is very gentle, and the basins outlined on Plate 29 are believed to be depositional structures; but the rocks are very strongly jointed and, in some areas, faulted, giving rise to spectacular gorges and abrupt escarpments (Pl. 3, fig. 2; Pl. 2, fig. 2). The formation was deposited in a series of separate basins, and on a basement platform. The thickness varies markedly from place to place, and the members within each basin cannot be correlated with those elsewhere, or with rocks on the intervening platform.

The Kombolgie Formation in the South Alligator River valley is divided by the South Alligator Fault Zone (Pl. 15, fig. 1). To the south-west of the fault zone is the Mount Callanan Basin, which has two synclinal structures at its northern end and probably contains over 5000 feet of coarse sediments and volcanic rocks. On the opposite side of the fault zone, a distance of less than 1 mile, the section contains some of the lower members of the sequence in the Mount Callanan Basin, but the succession is probably less than 2000 feet thick. The discrepancy in thickness is probably due to subsidence of the block to the south-west of the fault zone during the deposition of the formation.

The *Kurrundie Member* is a distinctive purple quartz greywacke composed of rounded grains of quartz and a little feldspar in a silty matrix. It is the basal member of the Kombolgie Formation in the Mount Callanan Basin. In places, e.g., near Dinner Creek and Goodparla homestead, the member contains numerous small pebbles (Pl. 15, fig. 2), and about 1 mile north of Dinner Creek it is predominantly a quartz pebble conglomerate. The member ranges in thickness from about 400 feet near the head of the South Alligator River to almost 700 feet on the bluffs to the south-east of Goodparla homestead. Near the Little Mary River the Kurrundie Member overlaps the Edith River Volcanics and rests directly on Lower Proterozoic rocks. Elsewhere, it overlies Edith River Volcanics or is faulted against the Masson Formation.

The *Plum Tree Volcanic Member* conformably overlies the Kurrundie Member. It is between 1100 and 1200 feet thick, and is composed predominantly of reddish brown devitrified ignimbrite, with pink or white phenocrysts of feldspar (Stewart, 1965). Dark-coloured amygdaloidal flows occur in places near the middle of the member.

The arenites above the Plum Tree Volcanic Member consist of alternating beds of quartz greywacke and cobble conglomerate, and are about 3500 feet thick. They have not been formally subdivided. The rock types in the Mount Callanan Basin are typically those listed in the section given in Table 6.

The succession in the Edith Falls Basin given by Rattigan & Clarke (1955, unpubl.) differs from that in the Mount Callanan Basin in that in place of the Kurrundie Member there is a thick section of mixed arenites and rudites; and there are two volcanic members, the McAddens Creek Volcanic Member and the Henwood Creek Volcanic Member.

The *McAddens Creek Volcanic Member* has a maximum thickness of about 800 feet at the ABC uranium prospect, and consists of chloritized basalt and andesite flows with minor tuff and rhyolite. The basalts are commonly amygdaloidal; the amygdales are filled with chalcedony, zeolites, and carbonates, and in places they contain secondary copper minerals. At the ABC uranium prospect the vesicles are coated with meta-autunite. The member is overlain by about 650 feet of arenites and rudites, which in turn are overlain by the *Henwood Creek Volcanic Member.* This member is also composed mainly of basaltic and intermediate flows with minor tuff. It is about 370 feet thick and is overlain by 1000 feet of rudite and ripple-marked and cross-bedded arenite. South-east and north-east of the Edith Falls Basin are two smaller basins which contain no Kombolgie rocks younger than the McAddens Creek Volcanic Member.

North and east of the South Alligator River valley, the Kombolgie Formation consists mainly of arenites and rudites, and the *Nungbalgarri Volcanic Member* which has not been examined in the Katherine-Darwin Region; the volcanic member is an albite basalt in the Milingimbi Sheet area (Rix, 1965). Dips are very gentle, and in four places inliers of Lower Proterozoic rocks are exposed. The thickness of the succession has not been measured, but is probably less than 2000 feet and in places only a few hundred feet. The arenite assemblage includes medium, coarse, or fine-grained feldspathic sandstone, and cobble and pebble conglomerate.

In the Birdie Creek, Turnoff Creek, and Sleisbeck areas the Kombolgie Formation below the Birdie Creek Volcanic Member is up to 2400 feet thick, and consists mainly of cross-bedded quartz sandstone with some feldspathic sandstone and interbeds of pebble conglomerate and medium-grained tuffaceous sandstone; volcanic agglomerate occurs locally at the base of the succession near Sleisbeck and north of Turnoff Creek. The agglomerate may form part of the Edith River Volcanics.

TABLE 6: SECTION OF KOMBOLGIE FORMATION NEAR PLUM CREEK, SOUTH ALLIGATOR RIVER VALLEY*

Thickness (ft)	
	Top of outcrop
80	*Quartz greywacke,* medium-grained, buff-coloured
25	*Cobble conglomerate* with quartz greywacke matrix. Cobbles about 6 inches in diameter, well rounded; of volcanics, quartz greywacke, and quartz
100	*Quartz greywacke,* medium-grained, buff-coloured
105	*Cobble conglomerate* with quartz greywacke matrix. Cobbles 4 to 6 inches in diameter, rounded; of volcanics, quartz greywacke, and quartz
390	*Quartz greywacke,* fine to medium-grained, pinkish buff, thin-bedded (about 12 inches), ripple-marked
620	*Cobble conglomerate* with quartz greywacke matrix. Cobbles well rounded; of quartz greywacke, volcanics, quartz, and minor siltstone, hematite-rich siltstone, and quartz greywacke (Coirwong Greywacke ?). Outcrop poor
510	*Quartz greywacke,* medium-grained, buff, with some discontinuous horizons of well rounded quartz pebbles
150	*Cobble conglomerate* with quartz greywacke matrix. Cobbles about 6 inches, well rounded; of volcanics, quartz greywacke, quartz, and in places of siltstone and quartz greywacke (Coirwong Greywacke ?)
1600	*Quartz greywacke,* medium to coarse-grained, buff; cross-bedded in sets of 5 to 10 feet; numerous thin bands of well rounded quartz pebbles
3580	*Upper part of the Kombolgie Formation*
1200	Lavas, acid to intermediate, red-brown, massive, feldspar phenocrysts, in places dark and amygdaloidal, purple at top
1200	*Plum Tree Volcanic Member*
200	*Quartz greywacke,* hard, medium-grained, light-coloured
170	*Quartz greywacke,* medium-hard to friable, medium-grained, partly massive, partly thin-bedded, in places cross-bedded
25	*Quartz greywacke,* fine-grained, purple, massive, irregular close joints
10	Interbedded *quartz greywacke* and *conglomeratic tuff* (1-foot beds); tuff contains angular pebbles of quartzite, jasper, and in places quartz in fine-grained purple matrix
15	*Quartz greywacke,* medium-grained, with scattered small angular pebbles
420	*Kurrundie Member over dark purple weathered Edith River Volcanics*
5200	Total thickness of Kombolgie Formation

* 'Quartz greywacke' as used in this table can also be interpreted as feldspathic sandstone grading in places into arkosic sandstone.

Farther south in the Waterhouse River West Branch area, 12 miles east of Eva Valley homestead, the basal arenite succession appears to lens out and the Birdie Creek Volcanic Member rests directly on the Edith River Volcanics. Ten miles east-north-east of Beswick homestead the succession up to the base of the Birdie Creek Volcanic Member, according to Ruker (1959, unpubl.), is as shown in Table 7.

TABLE 7: SECTION OF KOMBOLGIE FORMATION BELOW BIRDIE CREEK VOLCANIC MEMBER, 10 MILES EAST-NORTH-EAST OF BESWICK HOMESTEAD

Thickness (ft)	
	Birdie Creek Volcanic Member
320	*Quartz sandstone,* white, pink, and buff, fine to medium-grained, cross-bedded, ripple-marked, well sorted. A kaolinitic matrix occurs locally
60	*Quartz greywacke,* purple, fine to medium-grained, poorly bedded
20	Silicified *breccia conglomerate* containing pebbles and cobbles of pink sandstone, purple quartz greywacke, and volcanics. This bed lenses out within a short distance

About 15 miles north of this locality the stratigraphic equivalent of the breccia conglomerate is a 50-foot lens of slumped silicified white sandstone breccia.

The *Birdie Creek Volcanic Member* comprises about 1100 feet of altered amygdaloidal andesite and possibly basalt in the Birdie Creek area (Stewart, 1965). To the south-east of Birdie Creek, Ruker (op. cit.) has recorded a maximum thickness of 660 feet which lenses out completely farther south. Ruker also recognized laminated tuff beds which are kaolinized and, in the Dook Creek area, are more abundant than the lava. The member is intersected by quartz-chert and hematite-bearing veins, and contains lenses of white sandstone breccia up to 30 feet thick (Pl. 16, fig. 1).

The sandstone overlying the Birdie Creek Volcanic Member is similar to that which underlies it. The sandstone has a maximum thickness of 1800 feet. In places, a bed of boulder conglomerate up to 30 feet thick is present at the base, and slump folding and brecciation occur within the section. Intraformational conglomerate has been observed near Dook Creek. Some of the upper beds of the Kombolgie Formation have a slightly tuffaceous matrix.

The similarity of the volcanic members of the Kombolgie Formation tempts correlation between the different basins. However, no direct correlations have been possible and no distinctive marker beds have been mapped. Each volcanic member was probably confined to the neighbourhood of the basin in which it occurs, and because its time of extrusion was probably dependent on the subsidence characteristics of that basin it was not necessarily contemporaneous with other volcanic members.

McKay Sandstone

The Kombolgie Formation is overlain by the McKay Sandstone in the south-eastern corner of the Mount Evelyn 1 : 250,000 Sheet area, where it is shown on previous maps (Walpole, 1962) as 'undifferentiated Diljin Hill Formation'. The formation was not examined during this survey, and is defined by Roberts et al. (in prep.) from the adjoining Mount Marumba 1 : 250,000 Sheet area. They have provided the following description:

'The McKay Sandstone is about 1200 feet thick in the reference area (McKay Hills, Mount Marumba Sheet area), where it consists mainly of white cross-bedded medium-grained quartz sandstone interbedded with fine to medium-grained ferruginous sandstone and feldspathic sandstone. However, away from the reference area the dominant rocks are ferruginous sandstone or feldspathic sandstone. Lateral variation in rock types is pronounced.'

In the Upper Waterhouse Basin, Ruker (1959) has noted that north-east of Waterhouse Waterfall the white sandstone of the Kombolgie Formation is succeeded by a 500-foot-thick lens of soft laminated micaceous sandstone interbedded with grey siltstone. The lens is overlain by a hard granular sandstone 300 feet thick, which is a lateral variation of the topmost 100 feet of the Kombolgie Formation. In the Diamond Creek area, he noted that the stratigraphic equivalents of these two units are soft purple, fine-grained quartz greywacke, and hard pink sandstone with slightly tuffaceous matrix.

Diamond Creek Formation

The Diamond Creek Formation is exposed along the Waterhouse River, 3 miles north-east of the Waterhouse Waterfall; west and south-west of Diamond Creek; and in a narrow belt north of the Maranboy/Diljin Hill track. It consists of volcanics and interbedded limestone, siltstone, and conglomerate, which conformably overlie either the Kombolgie Formation or the McKay Sandstone.

The formation is 700 feet thick in the type locality on the Waterhouse River, but thins laterally within a short distance to 100 feet. The average thickness south-west of the Diamond Creek/West Branch junction is 240 feet. The formation is absent in the upper reaches of Gundi Creek, where the Gundi Greywacke lies directly on Kombolgie Formation.

The formation begins with 500 feet of alternating limestone and siltstone. The limestone is pink, grey, and purple, crystalline or microcrystalline, and well bedded. The thickness of the beds is generally 6 to 12 inches; in places they are laminated, and thin layers of secondary calcite are present. The associated siltstone is laminated, mottled in purple, green, pink, and grey, and in places it is calcareous. The upper 200 feet of the succession consists of black amygdaloidal basalt with thin beds of soft tuffaceous material. In a restricted area along the Waterhouse River, polymictic conglomerate is interfingered with the limestone; it has been formed in an anomalous depositional environment connected with warping of the underlying Kombolgie Formation. Near Diljin Hill on the eastern bank of the Waterhouse River, thin beds of grey chert interbedded with limestone have been found. In places, either limestone-siltstone or volcanics predominate, or make up the whole of the formation.

In Arnhem Land to the east of the Katherine-Darwin Region the interval between the McKay Sandstone and the Gundi Greywacke is occupied by three formations, the McCaw Formation, Shadforth Sandstone, and Cottee Formation (Roberts et al., in prep.). The three formations in part, at least, are regarded as lateral equivalents of the Diamond Creek Formation.

Gundi Greywacke

The Gundi Greywacke crops out north of Gundi Creek; in a strip north of the Maranboy/Diljin Hill track; in extensive areas between the Waterhouse River and the West Branch; and at Diljin Hill. It extends east into the Mount Marumba and Milingimbi 1 : 250,000 Sheet areas.

The thickness of the formation is fairly constant; in a measured section it was 460 feet. The rock is a purple tuffaceous quartz greywacke; it is medium to coarse-grained, with minor pink feldspar, and isolated pebbles of sandstone and quartz. It is cross-bedded, and has rough fracture surfaces and medium hardness. The matrix consists of fine pyroclastic material. To the east of the Waterhouse River, the greywacke is generally yellow or brown and the proportion of tuffaceous material is considerably smaller; 100 feet of flaggy sandstone is present at the base.

On the air-photographs the formation is characterized by the presence of a network of closely spaced vertical joints. Plate 16, figure 2 shows one of the joints from ground level.

West Branch Volcanics

The West Branch Volcanics crop out in the synclinal basin between the West Branch and Waterhouse Rivers; in the Gundi Creek and Dook Creek areas; and in the area east of the Waterhouse River; they also extend east into Arnhem Land. They comprise interbedded basalt, tuff, conglomerate, and tuffaceous quartz greywacke overlain unconformably by the Margaret Hill Conglomerate. The thickness of the formation is variable, with an estimated maximum of 5300 feet.

Four units in the West Branch Volcanics have been mapped: the first and lowest is exposed along the edges of the Upper Waterhouse Basin, and consists of conglomerate interbedded with sandstone, quartz greywacke, and greywacke.

The conglomerate is polymict with a predominance of sandstone elements; the fragments are of pebble to cobble size with a strongly silicified sandstone matrix. The sandstone is white, hard, fine to medium-grained; and in places well sorted and bedded. The quartz greywacke is pink, tuffaceous, and coarse, with rough broken surfaces; the greywacke is purple, tuffaceous, and also coarse-grained. The thickness ranges from about 200 feet to a maximum of 2300 feet in the area south of the Maranboy/Diljin Hill track. It is absent in the Dook Creek area.

The second unit is composed of basalt interbedded with tuff, greywacke, and locally with agglomerate. The basalt is black or dark green, and amygdaloidal; the amygdales are filled with white quartz or green zeolites. The tuffs are dark purple or dark brown, very fine-grained, and locally laminated. They occur in beds up to 5 feet thick. The greywacke is purple and coarse-grained, and occurs in beds or lenses from 2 to 30 feet thick. South-west of Bone Creek, there is a lens of agglomerate composed of angular fragments of sandstone and tuffaceous material. The maximum thickness of the second unit is estimated at 2000 feet south of the Maranboy/Diljin Hill track. This unit rests on or interfingers with the conglomerate of the first unit, but where the first unit is absent it rests on the Gundi Greywacke or the Kombolgie Formation. The upper boundary is gradational and has been mapped at the top of the uppermost basalt flow.

The third unit is exposed in the central area of the Upper Waterhouse Basin. It comprises dark brown and purple greywacke, which is fine to medium-grained, and laminated or flaggy. Some beds of pink sandstone and numerous interbeds of fine-grained purple tuff occur through the section. The top is obscured by the Cretaceous capping, but the thickness is estimated at over 1000 feet.

The fourth unit crops out west of the Waterhouse River near Diljin Hill, and consists of about 100 feet of pink arkosic sandstone; it is medium-grained and well bedded, and contains white and pink feldspar. The relationship with the lower part of the formation is uncertain, and it possibly represents a lateral lithofacies of the third unit.

In the Gundi Creek area the basal conglomeratic unit lies on the Kombolgie Formation, which suggests that the Gundi Greywacke has been removed by erosion (the Diamond Creek Formation may have not been deposited in this locality). In the Bone Creek/Dook Creek areas the conglomerate is absent and the basalt rests on the Kombolgie Formation. North of the Maranboy/Diljin Hill track, the transition between the Gundi Greywacke and the conglomerate is apparently continuous. In the first locality there is probably an unconformity, in the second a disconformity at the base of the West Branch Volcanics. The top of the West Branch Volcanics is not exposed in the area investigated.

A Tectonic History of the Katherine River Group in the Upper Waterhouse Basin

The shelf zone of the McArthur Basin in the Katherine-Darwin Region can be divided into three tectonic zones: the unstable zone marked by the western area of Edith River Volcanics and the Mount Callanan and Edith Falls Basins; the stable platform area north-east of the line of the South Alligator Fault Zone; and the unstable south-eastern corner of the region which we have named the Upper Waterhouse Basin. The tectonic setting of the Upper Waterhouse Basin is similar in many respects to the unstable eastern sector; Edith River Volcanics crop out at the base of the sequence, and the overlying rocks contain many sharp local unconformities, slump breccias in coarse arenites (Pl. 16, fig. 1), volcanic rocks and boulder beds — features which illustrate the instability of the area during the deposition of the Katherine River Group. The relationships between Edith River Volcanics and Kombolgie Formation have been discussed on p. 62. The contact is partly conformable, and in places unconformable; in other places the two formations are intermixed by penecontemporaneous slumping (Pl. 14, fig. 1).

To the west of the Upper Waterhouse Basin, the Katherine River Group rocks are apparently intruded by the Grace Creek Granite. P. J. Leggo (BMR, App. 2) has obtained an age of 1470 m.y. for the granite. We found no evidence in the field that the granite intrudes the Katherine River Group, although J. R. Stewart (pers. comm.) has suggested that it is a laccolith, but the contacts are very poorly exposed. We accept the geochronological evidence; the intrusion may have been emplaced during the break between the Katherine River and Mount Rigg Groups, which is defined by the boulder beds of the Margaret Hill Conglomerate, or during the period represented by the Mount Rigg Group/Roper Group unconformity.

In the Upper Waterhouse area the shelf deposits of the McArthur Basin are preserved in synclinal basins, of which the Upper Waterhouse Basin is the largest. Its axis trends north-east, and the structure is complicated by faulting and folding. West and south-west of Beswick homestead it has been obscured by the Mount Rigg Group, and to the north-east by a monocline involving Mount Rigg and Roper Group sediments.

The chronological order of the tectonic events and the superposition of sedimentary environments can be recognized by the combined structural and sedimentary records as illustrated in Figure 16.

Deposition of the Edith River Volcanics began with a rapid accumulation of detrital and volcanic clastics and a flow of rhyolitic lava. Two structural trends are evident in the Edith River Volcanics. In the Dook Creek area, strong faulting is associated with a dominantly south-east-trending monocline with average dips of 40°. The faults are roughly parallel to the strike. In the upper reaches of Diamond Creek, the formation is affected by a monocline striking south-west, with average dips of 30° to the south-east. Only minor faults have been observed. We believe that this contrast is due to different degrees of instability on the margin of the basin, and the sedimentary record indicates that the instability affected the later sedimentation. A synclinal pattern was developed between Diamond Creek and the Waterhouse River, and it was accentuated by further subsidence during the deposition of the Kombolgie Formation. The rate of sedimentation balanced the rate of subsidence, and a shallow shelf environment persisted through-

System	Group	Classification	Environment	Sedimentation	Macro Fossils	Tectonics	Vulcanism	Thickness in Feet
CARPENTARIAN SYSTEM	MT RIGG GROUP	Beswick Creek Formation	CONTINENTAL SEA: Shallow water	Sandstone, chert; siltstone and submarine flow of basalt	Nil	Mount Rigg Basin: Stable, possibly minor subsidence	Effusive phase	>500
		Dook Creek Formation	Neritic	Dolomite, shale, fine sandstone, chert. Slow sedimentation and precipitation	Collenia	Stable	Possible minor eruptive activity	>600
		Bone Creek Formation	Littoral	Conglomerate and sandstone. Rapid deposition	Nil	Stable	Inactive	500
			? UNCONFORMITY ?					
		Margaret Hill Conglomerate	Littoral	Conglomerate and tuff-greywacke. Rapid deposition. Transgression of continental sea	Nil		Minor eruptive activity	1260
		UNCONFORMITY	Subaerial	Not recorded in this area. Erosion		UPLIFT. Jointing. Faulting Diljin Hill Fault - Morey Fault (?)	Not recorded	
	KATHERINE RIVER GROUP	West Branch Volcanics	EPICONTINENTAL SEA: Littoral	Arkosic sandstone. Silting of syncline	Nil	Upper Waterhouse Basin: Stable	Inactive	>100
			Submarine	Fine detrital clastics and tuffs		Possible minor subsidence	Decreasing	>1000
			Submarine	Flows of basalt; detrital clastics; tuffs		Possible minor subsidence	Major effusive phase	2000
			Littoral	Conglomerate and coarse sandstone. Rapid deposition. Possible local transgression			Inactive	2300
		LOCAL UNCONFORMITY IN PLACES	Local erosion (Gundi Creek)			Strong faulting and possible UPLIFT. Diamond Creek and West Branch Faults	Not recorded	
		Gundi Greywacke	SHELF: Littoral environment	Detrital and volcanic clastics. Rapid deposition	Nil	Stable (Unstable shelf; intermittent vertical movements forming local depressions; associated slump folding, brecciation, tilting and faulting of partly consolidated sediments)	Inactive	460
		Diamond Creek Formation	Quiet environment Neritic(?)	Basalt and tuffs. Fine terrigenous and chemical sediments		Stable	Effusive phase	700
		McKay Sandstone		Granular or coarse sandstone. Partial levelling of bottom topography		Subsidence	Inactive	450
			Local depressions Quiet environment	Siltstone		Subsidence	Possibly eruptive activity	630
		Kombolgie Formation		Sandstone and intraformational conglomerate		Folding and faulting	Inactive	1800
		Birdie Creek Volcanic Member		Tuff and basalt		Slumping	Minor effusive	660
				Sandstone Breccia - conglomerate Rapid deposition		Slumping		>500
		LOCAL UNCONFORMITY IN PLACES		Local erosion (Dook Creek)		Strong folding and faulting (Dook Cr) Relatively stable (Diamond Cr). Upper Waterhouse basin possibly outlined	Not recorded	
		Edith River Volcanics	Possible shelf environment. Transgression	Rhyolite and tuffs. Rapid deposition detrital and volcanic clastics	Nil		Major effusive phase	
		UNCONFORMITY	Subaerial	Erosion		UPLIFT		
		B A S E M E N T						

Fig. 16. Geological history of the Upper Waterhouse Basin, Katherine 1: 250,000 Sheet (after Ruker, 1959, unpubl.)

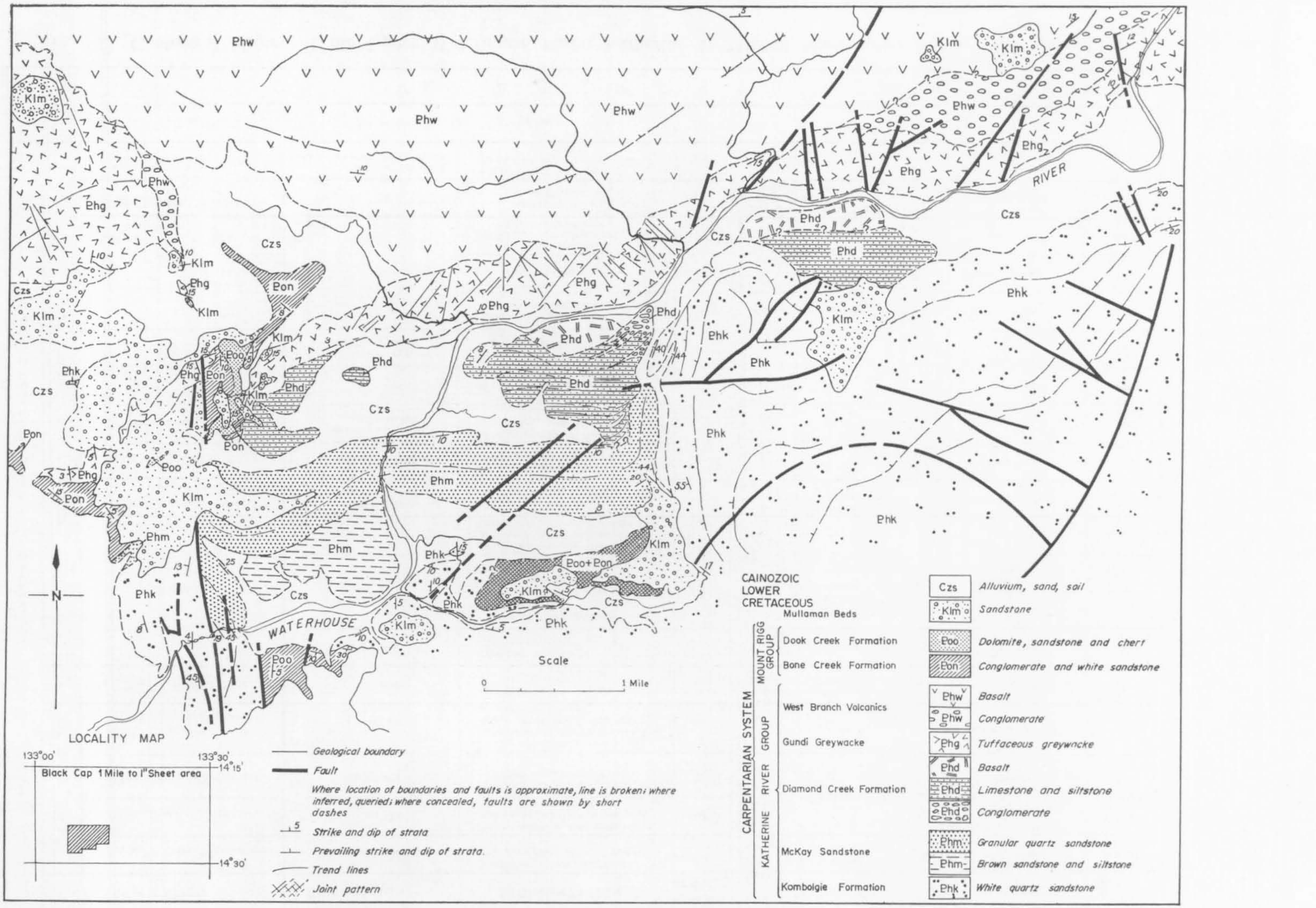


Fig. 17. Geological map of the Waterhouse Waterfall area, Katherine 1: 250,000 Sheet

out the deposition of the Kombolgie Formation. The axis of the syncline trends north-east. The syncline gradually flattens out to the north-east, but it branches into two arms towards the south-west. One arm is directed west (Gundi Creek area), and the other, directed south, is partly obscured by the Mount Rigg Group basin. The arms are separated from the central part of the syncline by a transverse anticline with dips of 5° to 10°. The average dips along the north-western flanks of the syncline are 5° to 10°, and along the southern and south-western 20° to 30°: the steeper dips are associated with folding and slump brecciation of the Kombolgie Formation. During and after the deposition of the Kombolgie Formation, diastrophic activity was more intense on the southern and south-western flanks than on the northern and north-western flanks. Taking into account the analogous structural features in the underlying Edith River Volcanics, it appears that the southern and south-western parts of the syncline (the area between Dook Creek and Waterhouse Waterfall) lie in a marginal mobile belt bordering to the south the relatively stable synclinal area between the Waterhouse River and Diamond Creek.

A typical example of the gravitative displacement of the partly consolidated Kombolgie Formation occurs north-east of the Waterhouse Waterfall (Fig. 17). A tight fold in a sandstone brecciated by slumping formed a rise on the sea floor, with the flanks dipping at 60°. This rise isolated a neighbouring depressed area in a quiet depositional environment (siltstone and shale). The uppermost beds of the Kombolgie Formation have only partially levelled these irregularities.

A similar feature has been observed in the area north of the track from Maranboy to Diljin Hill, where the lower part of the Kombolgie Formation has been tightly folded and is unconformably overlain by the uppermost part of the sequence.

The faults observed in the Kombolgie Formation are closely spaced, with a small throw and a general north-easterly strike. Two sets of joints are present, one striking north-east, the other east-north-east. They are particularly well developed where the formation overlies volcanic rocks.

Tectonic activity decreased after the deposition of the Kombolgie Formation, and there was a general levelling of the submarine topography, except in the Gundi Creek area, where portions of Kombolgie Formation remained uncovered. However, the synclinal structure still persisted: this phase is characterized by a calm, possibly shallow marine environment; by fine terrigenous and chemical sediments; and by the eruption of basaltic lavas. This was followed by the rapid deposition of unsorted detrital and volcanic clastics in a shallow sea, within wave action range (the Gundi Greywacke).

Two sets of faults of considerable throw have been observed in the Gundi Greywacke. The faults trend north-east and east-south-east, and include the Diamond Creek Fault, West Branch Fault, and some faults in the Waterhouse Waterfall area. They affect the formations underlying the Gundi Greywacke, but movement ceased before the West Branch Volcanics were laid down. The throw of the Diamond Creek Fault increases to the west; the tilting probably resulted from a general uplift, perhaps connected with the Grace Creek intrusion. Moreover, since these faults do not affect the West Branch Volcanics, there was probably a phase of tectonic activity between the deposition of the Gundi Greywacke and the West Branch Volcanics. It would imply a time break and explain the unconformity observed in the Gundi Creek area at the base of the West Branch Volcanics.

The cobble conglomerate at the base of the West Branch Volcanics indicates a new phase of rapid deposition accompanied and succeeded by the eruption of submarine basaltic lava. The deposition of tuffaceous greywacke and arkosic sandstone which followed almost completely filled the synclinal structure.

The geological history between the close of the West Branch Volcanics and the transgression of the Mount Rigg Group is imperfectly known. The Diljin Hill Fault and minor north-east-striking faults in the Diljin Hill area are attributed to this period. The Diljin Hill Fault is a regional line of weakness, and comprises the closely spaced subparallel faults exposed between Diljin Hill and Beswick homestead. The probable extension to the south of Beswick homestead is named the Morey Fault (Walpole, 1958a; Pl. 29). The faults are subvertical and have throws of several hundred feet; the south-westerly trend in the Diljin Hill area swings to south-west in the Beswick area. The faults have locally controlled the form of the depositional basins of the Mount Rigg Group and Roper Group, and they are, in part, hinge-lines.

The Katherine River Group is unconformably overlain by the Mount Rigg Group. We have not been able to date this unconformity, apart from inferring that the intrusion of the Grace Creek Granite may have taken place about this time.

Mount Rigg Group

The Mount Rigg Group occupies a shallow synclinal basin between Dook Creek and the Waterhouse River; it also occupies a zone trending north-east from near Diljin Hill across the north-west corner of the Urapunga Sheet area (Dunn, 1963) into Arnhem Land (Roberts et al., in prep.). Correlation of the two areas of outcrop is based on the lithology and stratigraphical succession.

Fine terrigenous and chemical sediments, dolomite, limestone, siltstone, and chert, are dominant; stromatolites are common in the dolomite and limestone. Conglomerate and sandstone occur at the base and sandstone and volcanics near the top of the group.

The Mount Rigg Group unconformably overlies the Katherine River Group and in part, at least, is correlated with the McArthur Group, which occurs through most of the McArthur Basin (Dunn et al., in prep.; Roberts et al., in prep.). The Mount Rigg Group is unconformably overlain by the Lower Cambrian Antrim Plateau Volcanics in the Waterhouse River area, but in Arnhem Land it is unconformably overlain by the Roper Group (Roberts et al., in prep.).

PLATE 5.

Fig. 1: Poorly preserved *Collenia*-type algae in coarsely crystalline marble of the Coomalie Dolomite. Exposure 200 yards south of Batchelor/Stuart Highway road, 2½ miles east of Batchelor.

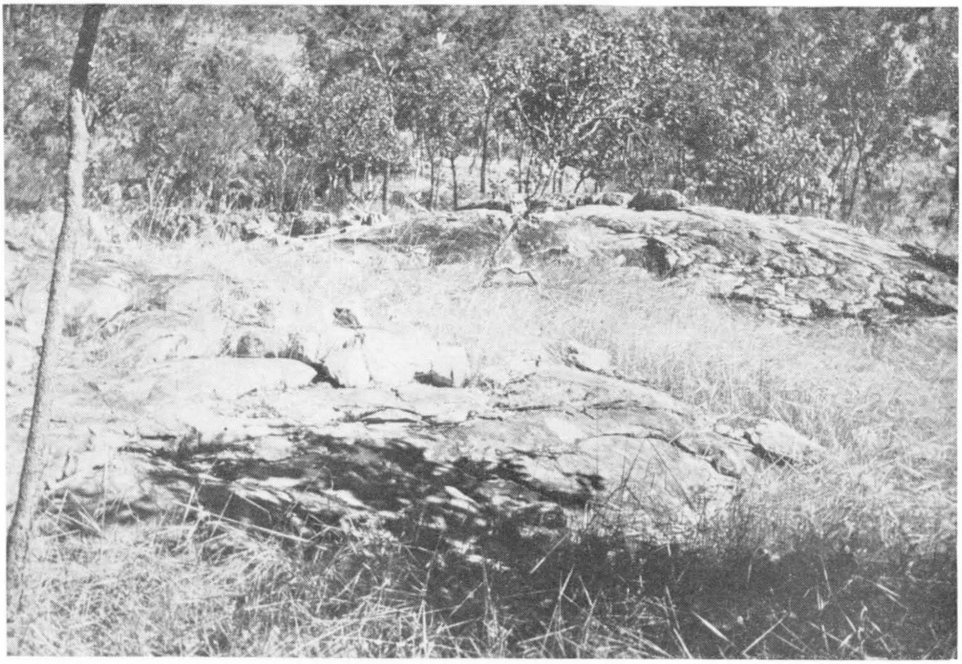


Fig. 2: Coarse arkose, Mount Partridge Formation near Jim Jim Creek, Mount Evelyn Sheet. The rock lacks bedding and closely resembles a slightly weathered granite.

PLATE 6.

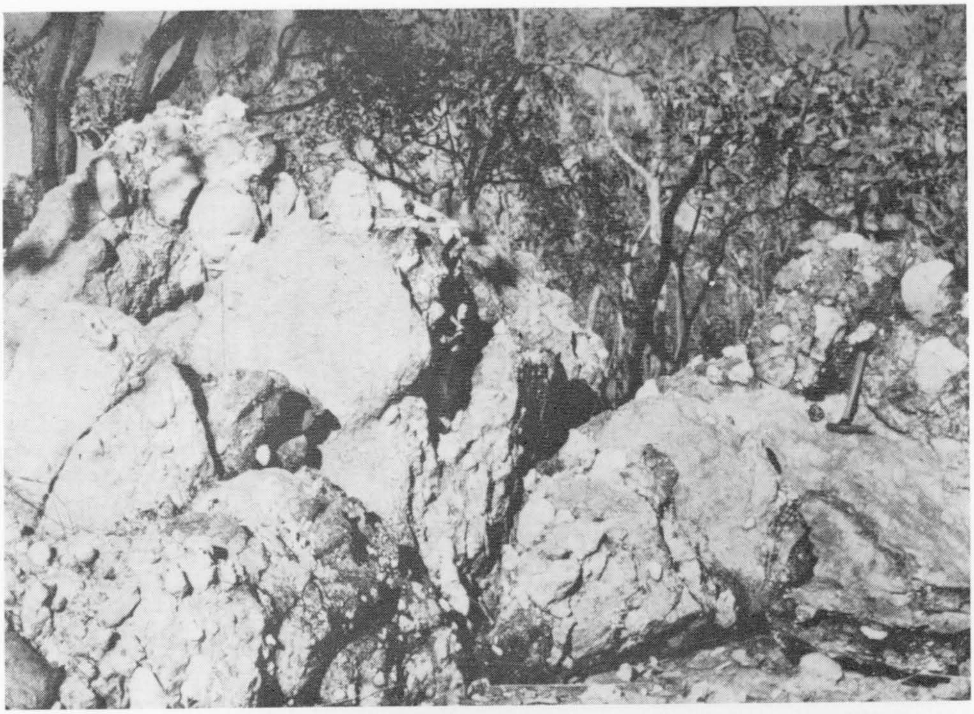


Fig. 1: Coarse arkose conglomerate, Mount Partridge Formation, Mount Evelyn Sheet. Fragments of feldspar up to 1½ inches in diameter occur in the matrix.

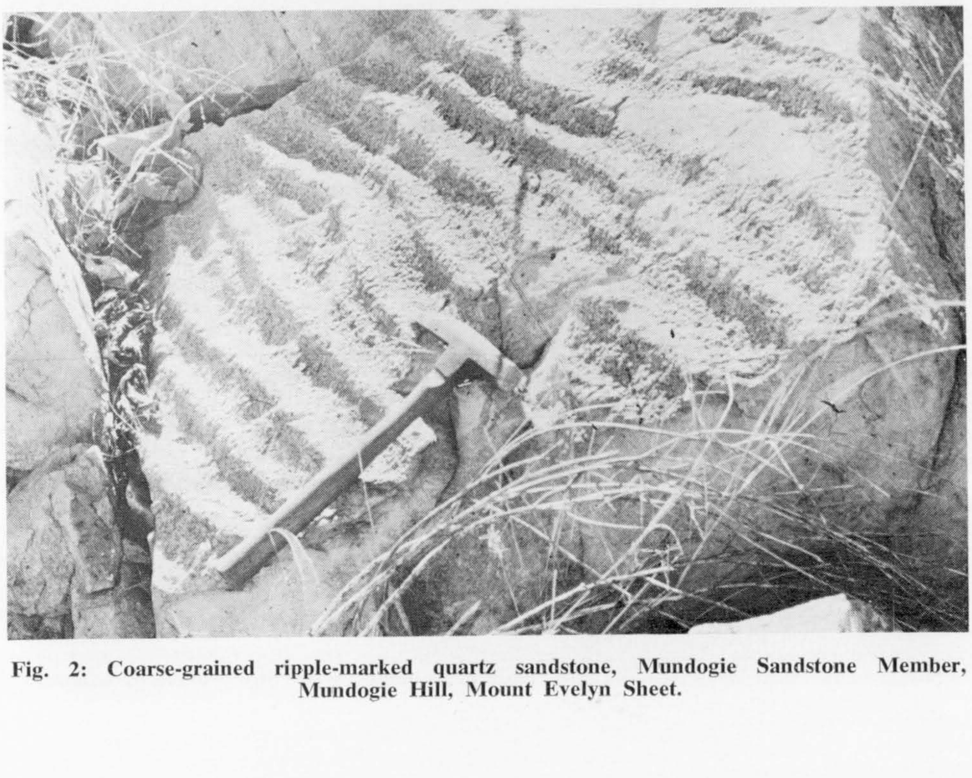


Fig. 2: Coarse-grained ripple-marked quartz sandstone, Mundogie Sandstone Member, Mundogie Hill, Mount Evelyn Sheet.

PLATE 7.

Fig. 1: Slump breccia, Golden Dyke Formation, Mount Minza area, Rum Jungle district, Pine Creek Sheet. The breccia is developed from coarsely banded rock of equivalent composition to that shown in Figure 2 (below).

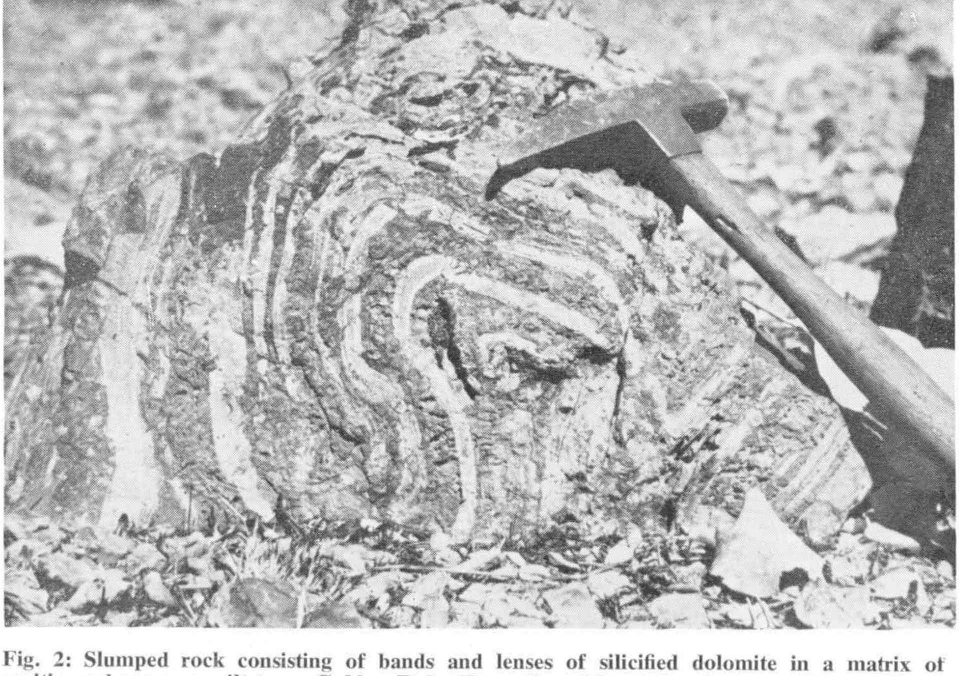


Fig. 2: Slumped rock consisting of bands and lenses of silicified dolomite in a matrix of pyritic carbonaceous siltstone, Golden Dyke Formation, Mount Bundey area, Darwin Sheet.

PLATE 8.

Fig. 1: Bedded silicified dolomite, Golden Dyke Formation, near the Evelyn lead mine, Moline area, Mount Evelyn Sheet.

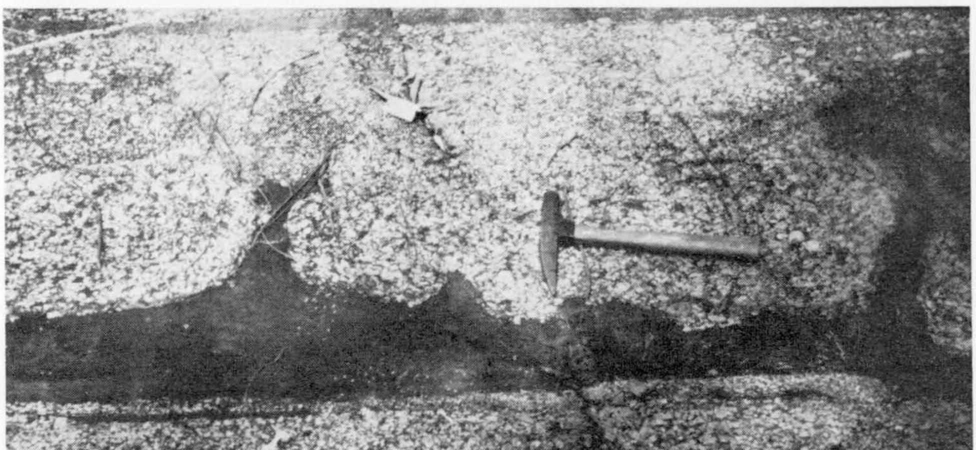


Fig. 2: Graded bedding, load casts and incipient pull-aparts with injections from below. Interbedded siltstone greywacke and pebble conglomerate, Noltenius Formation, Finniss River area, Darwin Sheet.

Walpole (1958a) first reconnoitred the Mount Rigg Group and tentatively subdivided the sequence into three rock units, which he believed were part of the Middle Cambrian Daly River Group. More detailed mapping by Ruker (1959, unpubl.) established that the succession was Precambrian; he named it the Beswick Group; he also recognized an additional formation in Walpole's lowest subdivision. Randal (1963) has revised Ruker's terminology. The changes of nomenclature are summarized in Table 8.

TABLE 8: REVISION OF STRATIGRAPHY, MOUNT RIGG GROUP

Walpole (1958a)		*Ruker (1959, unpubl.)*		*Randal (1963) and Present Authors*	
Daly River Group	Beswick Creek Formation	Beswick Group	Mount Rigg Formation	Mount Rigg Group	'Beswick Creek Formation' (may be Roper Group in part and Antrim Plateau Volcanics in part)
	Tipperary Limestone		Dook Creek Formation		Dook Creek Formation
	Margaret Hill Conglomerate		Bone Creek Formation		Bone Creek Formation
			Margaret Hill Conglomerate		Margaret Hill Conglomerate

The transgression of the continental sea in which the Mount Rigg Group was deposited was marked by a period of rapid deposition of coarse clastics (the Margaret Hill Conglomerate and part of the Bone Creek Formation). This event was succeeded by a calm and relatively shallow sea and the deposition of clean beach sandstone, fine terrigenous materials, and chemical and biochemical deposits (part of the Bone Creek and Dook Creek Formations). A submarine effusion of basaltic lava followed, and was topped by siltstone and cherty sandstone ('Beswick Creek Formation').*

The sediments of the Mount Rigg Group crop out in a broad and shallow basin west of Beswick homestead. The basin pitches to the south, with dips generally less than 10°. It is mainly a sedimentary feature, and the irregularities of its margins reflect the undulations of the original depositional surface. In the Maiwok/Flying Fox Creek area a few miles east of the Katherine-Darwin Region, the Mount Rigg Group is disposed in a monocline dipping at an average of 10° to the east and south-east. On the Waterhouse River, 19 miles above the waterfall, a syncline has been observed in the lowermost member of the group. This is also a depositional feature.

Margaret Hill Conglomerate

The Margaret Hill Conglomerate crops out in the Bone Creek watershed

* The Beswick Creek Formation may actually be part of the Roper Group.

and in a narrow strip between Gundi Creek and the Waterhouse Waterfall; an isolated outcrop in the upper reaches of the Waterhouse River is attributed to it.

The formation consists mainly of polymict conglomerate and purple tuffaceous greywacke. It rests unconformably on the Katherine River Group. The section near the type area at Margaret Hill is as shown in Table 9.

TABLE 9: SECTION OF MARGARET HILL CONGLOMERATE NEAR MARGARET HILL

Thickness (ft)	
360+	*Tuffaceous quartz greywacke,* purple, coarse-grained, poorly sorted, with lenses of conglomerate containing pebbles of quartz and quartz sandstone; cross-bedding common
100+	*Tuff or siltstone,* dark purple, laminated, very fine-grained and partly kaolinized
650+	*Quartz greywacke,* purple, coarse-grained, poorly sorted, tuffaceous, with lenses of conglomerate containing pebbles of quartz and quartz sandstone; cross-bedding is common
50	*Cobble to pebble conglomerate,* well rounded cobbles and pebbles of quartz sandstone with subordinate basic volcanics and metamorphic rock, in a matrix of coarse-grained purple quartz greywacke

North of Margaret Hill the formation consists of boulder and pebble conglomerate (Pl. 17, fig. 1), alternated with pink quartz greywacke and purple tuffaceous greywacke. To the east, the dominantly conglomeratic facies grades into a quartz greywacke facies in which the conglomerate is restricted to the bottom 20 feet of the succession. In the isolated outcrop on the Waterhouse River the formation comprises coarse-grained cross-bedded pink quartz greywacke containing pebbles of quartz and quartz sandstone. The matrix is feldspathic.

The Margaret Hill Conglomerate is lenticular: it is 960 feet thick at Margaret Hill and at least 1250 feet thick just north of Margaret Hill, but lenses out completely 4 miles to the south and about 5 miles to the east.

The conglomerate unconformably overlies both the Edith River and West Branch Volcanics; the contact is sharp and irregular.

Bone Creek Formation

The Bone Creek Formation is exposed along the north-western and northern margins of the basin near the Waterhouse River. It also crops out from Diljin Hill north-eastwards into Arnhem Land (Roberts et al., in prep.).

The formation comprises a conglomeratic member overlain by sandstone. The lower member is a grey oligomictic and unbedded conglomerate; the boulders and cobbles are well rounded and mostly spherical, and consist predominantly of hard white sandstone, subordinate rhyolite, green fine-grained quartzite, and amygdaloidal basalt. The matrix is grey coarse-grained poorly sorted silicified sandstone. The overlying sandstone is a white medium-grained rock containing some muscovite. It is hard, well bedded, and flaggy to blocky. Weathered bedding planes are stained red.

The conglomerate member is about 50 feet thick and the sandstone about 170 feet thick near the West Branch. North-east of Diljin Hill, in Arnhem Land, the conglomerate is absent and the sandstone is nearly 600 feet thick (Roberts et al., in prep.).

The Bone Creek Formation was included by Walpole (1958a) in his Margaret Hill Conglomerate, but Ruker's (1959, unpubl.) later work showed a disconformity between them. Where the Margaret Hill Conglomerate is absent the Bone Creek Formation rests unconformably on the West Branch Volcanics or older rocks.

TABLE 10: GENERALIZED SECTION OF DOOK CREEK FORMATION, WATERHOUSE RIVER AREA

Thickness (ft)	
400+	*Marl* and *siltstone*, buff and purple. Some shale and fine sandstone. Grey, pink, and purple dolomite, bedded and algal; interbedded chert and chert nodules, in part brecciated. Glauconitic dolomite
80	*Chert*, white, ivory or grey, slump brecciated; texture ranges from fine grit to coarse breccia (coarse fragments consist of laminated chert); forms a prominent ridge
100	*Dolomite* and *dolomitic limestone*, purple and grey, microcrystalline, containing stromatolites, interbedded with grey carbonate rocks which are laminated and locally slump brecciated
400	*Micaceous sandstone*, brown and grey, very fine-grained, flaggy; interbedded with soft, laminated, partly calcareous, green glauconitic *shale*. Shaly greywacke, siltstone and marl are also present. Beds of pink and grey dolomite are partly slump brecciated. Oolitic dolomite occurs in the rubble

Dook Creek Formation

The Dook Creek Formation unconformably overlies the Bone Creek Formation; it crops out between Dook Creek and the Waterhouse River, and immediately east of the Waterhouse River near Beswick homestead. It also crops out extensively in Arnhem Land (Roberts et al., in prep.).

The formation consists mainly of dolomite* and dolomitic limestone, sandstone, and chert. It can be divided into four units based on lithology; the generalized succession from youngest to oldest is as shown in Table 10.

The upper unit is the most widespread of the four, although outcrop is patchy. It generally has a low dip or is horizontal, but collapse features have caused local steepening of dips. In one locality vertical beds of pink dolomite form small ridges (1 to 2 feet high) on which nearly horizontal stromatolite-rich dolomite beds have been deposited.

Several outcrops of cross-bedded arkosic conglomerate and coarse sandstone are apparently lenticular interbeds in the upper unit. Immediately west of the West Branch, they are overlain by a blocky quartz sandstone.

'Beswick Creek Formation'

The 'Beswick Creek Formation' crops out in a triangular area between Beswick Compound, Beswick homestead, and Alligator Waterhole on the Waterhouse River.

The formation has been divided into three lithological units:

(i) White cherty medium-grained well sorted ripple-marked flaggy sandstone, underlain by grey and purple laminated locally cherty siltstone containing small star-shaped impressions of unknown origin (see Dunn, 1964).

(ii) Black or green locally amygdaloidal basalt interbedded with sandstone. Close to the base, the basalt includes contorted veins of sandstone and lenses of brecciated sandstone.

(iii) Coarse to medium-grained blocky to flaggy pink and red sandstone. Slump folding and brecciation occur in the upper part.

No thicknesses have been measured, but Randal (1963) suggests about 300 feet. The area mapped as Beswick Creek Formation just south-east of Beswick Compound (Randal, 1963) probably includes some Antrim Plateau Volcanics.

Ruker (1959, unpubl.) considered that the formation conformably overlies the Dook Creek Formation. His opinion cannot be confirmed or contradicted directly: the structure of the lowest unit in the Beswick Creek Formation seems concordant with the underlying formations, as might be expected in an unfolded area, but no contacts are exposed. However, there is no similar sandstone-volcanic formation conformably overlying the Dook Creek Formation or its equivalents elsewhere in the McArthur Basin (Dunn et al., in prep; Roberts et al., in prep.), and we now believe the sandstone units in the 'Beswick Creek Formation' are part of the Roper Group and that the interjacent volcanics are actually Lower Cambrian Antrim Plateau Volcanics in a valley eroded between the two sandstones. The siltstone and sandstone of the upper unit are remarkably similar to the Corcoran Formation and Bessie Creek Sandstone of the Roper Group just east of Elsey homestead. On the other hand, Ruker (pers. comm.) argues

* Ruker (1959, unpubl.), Randal (1963), and the published maps refer only to limestone. Subsequent work has shown that the carbonates have a high magnesia content.

TABLE 11: STRATIGRAPHIC TABLE, ADELAIDEAN ROCK UNITS

Rock Unit	Thickness (ft)	Lithology	Distribution (Incl. 1:250,000 Sheets)	Reference Area	Stratigraphic Relationships	References
TOLMER GROUP			Daly R. Basin and Tolmer and Wingate Plateaux: Pine Ck and Fergusson R. Sheets	Name derived from the Tolmer Plateau S.W. of Rum Jungle, but best exposures occur E. of Buldiva and N.E. of Collia	Comprises Waterbag Ck Fm., Hinde Dolomite, and Buldiva Sandstone	Walpole (1958a)
Waterbag Creek Formation	500	Ferruginous sandstone, vari-coloured siltstone, silicified limestone and marl; halite pseudomorphs	Pine Ck and Fergusson R. Sheets	Waterbag Ck. S.W. of Dorisvale homestead, lat. 14°48′S., long. 131°08′E.	Youngest unit of Tolmer Gp, conformably overlies Hinde Dolomite; in places overlaps Hinde Dolomite and Stray Ck Sandstone Mbr and rests directly on Depot Ck Sandstone Mbr	Noakes (1956), Malone (1962a), Randal (1962)
Hinde Dolomite	200	Dolomite and dolomitic limestone, silicified in parts	Discontinuous belt on W. side of Daly R. Basin, and isolated outcrop at head of Adelaide R.: Pine Ck and Fergusson R. Sheets	Mt. Hinde, headwaters of Adelaide R.: lat. 13°25′S., long. 131°04′E.	Conformably overlies Stray Ck Sandstone Mbr	Noakes (1956), Malone (1962a)
Buldiva Sandstone	2000	Mainly sandstone; some siltstone		Buldiva, lat. 14°12′S., long. 130°48′E.	Basal formation of Tolmer Gp.	Used by Hossfeld (1937), Noakes (1949) Redefined: Noakes (1956), Malone (1962), Randal (1962)
Stray Creek Sandstone Member	1000	Flaggy quartz sandstone with minor siltstone and shale	N.E. and W. margins of Daly R. Basin: Pine Ck and Fergusson R. Sheets	Tributaries of Stray Ck, lat. 13°53′S., long. 131°38′E., but best developed in Rock Candy Range and E. of Buldiva	Conformably overlies Depot Ck. Sandstone Mbr.	Malone (1962a)
Depot Creek Sandstone Member	1000	Pink ripple-marked quartz sandstone, silicified in parts	N.E., N. and W. margins of Daly R. Basin, Tolmer and Wingate Plateaux: Pine Ck, Fergusson R., Cape Scott, and Port Keats Sheets	Depot Ck., N.E. of Douglas homestead, lat. 13°10′S., long. 131°35′E., better exposures in Umbrawarra Gorge and E. of Buldiva	Unconformably overlies sediments and granites of Pine Ck. Geosyncline, and 'Victoria River Gp.' Nowhere in contact with other Carpentarian and Adelaidean rocks	Malone (1962a), Randal (1962)
'VICTORIA RIVER GROUP'	4500		S.W. corner of Katherine-Darwin Region	Ord-Victoria region (Traves, 1955)		Traves (1955), Randal (1962)
Laurie Creek Beds	500	Silicified medium-grained quartz sandstone and silicified limestone	About Laurie Ck, a tributary of Fitzmaurice R.: Fergusson R. Sheet	Laurie Ck. at Coolaman homestead, lat. 14°37′S., long. 130°35′E.	Overlies Yambarra Beds with probable unconformity	Randal (1962)
Yambarra Beds	2000	Quartz sandstone, feldspathic sandstone, siltstone, dolomite, and limestone	About the Fitzmaurice R.: Fergusson R. and Port Keats Sheets	Yambarra Range, S. of the Fitzmaurice R., lat. 15°20′S., long. 130°25′E. (S. of Katherine-Darwin Region)	Conformably overlies Angalarri Siltstone	Randal (1962)
Angalarri Siltstone	1000	Mainly colour-banded siltstone; red sandstone and some carbonate rocks	W. of Collia and S. of Wingate Plateau: Fergusson R. and Port Keats Sheets	Plains between Fitzmaurice R. and Angalarri R., lat. 14°56′S., long. 130°45′E.	Conformably overlies the Palm Ck Beds, and unconformably overlies L. Proterozoic rocks	Randal (1962)
Palm Creek Beds	1000	Ripple-marked quartz sandstone, silicified in places; black silicified limestone	Divide between Fitzmaurice R. and Daly R. drainage systems: Fergusson R. Sheet	Palm Ck, headwaters of Fitzmaurice R., lat. 14°56′S., long. 131°06′E.	Oldest unit of 'Victoria R. Gp' in this region	Randal (1962)
ROPER GROUP			E. of Waterhouse R.: Katherine Sheet	Roper R. Basin in Urapunga Sheet (Dunn, 1963)	Unconformably overlies the Mt Rigg Gp	Randal (1963), Dunn et al. (in prep.)
Maiwok Subgroup			E. of Waterhouse R.: Katherine Sheet		Conformably overlies Bessie Ck. Sandstone, and unconformably overlain by Antrim Plateau Volcanics	Randal (1963), Dunn et al. (in prep.)
Chambers River Formation	2500	Medium-grained quartz sandstone, siltstone, and shale	E. of Waterhouse R.: Katherine Sheet	Chambers R., lat. 14°38′S., long. 133°15′E.	Conformably overlies Bukalorkmi Sandstone Mbr of McMinn Fm.	Randal (1963), Dunn et al. (in prep.)
McMinn Formation	1000	Fine to medium-grained quartz sandstone, siltstone, shale, and ironstone	E. of Waterhouse R.: Katherine Sheet	Urapunga Sheet (Dunn, 1963)	Conformably overlies Velkerri Fm.	
Bukalorkmi Sandstone Member	40-200	Friable quartz sandstone	E. of Waterhouse R.: Katherine Sheet	Reference section: Urapunga Sheet (Dunn, 1963)	Conformably overlies Kyalla Mbr	Randal (1963), Dunn et al. (in prep.)
Kyalla Member	150-400	Micaceous quartz sandstone, siltstone, and greywacke	E. of Waterhouse R.: Katherine Sheet	Reference section: Urapunga Sheet (Dunn, 1963)	Conformably overlies Moroak Sandstone Mbr or Sherwin Ironstone Mbr	Randal (1963), Dunn et al. (in prep.)
Sherwin Ironstone Member	25	Pisolitic and oolitic ironstone, and ferruginous sandstone	E. of Waterhouse R.: Katherine Sheet	Reference section: Urapunga Sheet (Dunn, 1963)	Conformably overlies or is interbedded with Moroak Sandstone Mbr	Randal (1963), Dunn et al. (in prep.)
Moroak Sandstone Member	200	Quartz sandstone, siltstone, and shale	E. of Waterhouse R.: Katherine Sheet	Reference section: Urapunga Sheet (Dunn, 1963)	Conformably overlies Velkerri Fm.	Randal (1963), Dunn et al. (in prep.)
Velkerri Formation	700	Siltstone, shale, and greywacke	E. of Waterhouse R.: Katherine Sheet	Urapunga Sheet (Dunn, 1963)	Conformably overlies Bessie Ck Sandstone	Randal (1963), Dunn et al. (in prep.)
Bessie Creek Sandstone	40	Medium to coarse-grained quartz sandstone	E. of Waterhouse R.: Katherine Sheet	Reference Section: Bauhinia Downs Sheet (Smith, 1963)	Conformably overlies Corcoran Fm.	Dunn et al. (in prep.)
Corcoran Formation	(?)	Colour-banded siltstone	Minor outcrops in Katherine Sheet near Elsey homestead Not on map	Bauhinia Downs Sheet (Smith, 1963)	Conformably overlies Abner Sandstone	Dunn et al. (in prep.)
Abner Sandstone	(?)	Medium to coarse-grained sandstone; also siltstone, shale, and greywacke in Carpentaria area	Ridge S. of Roper R. near Elsey homestead: Katherine Sheet	Reference section: Bauhinia Downs Sheet (Smith, 1963)	Conformably overlies Crawford Fm. Appears on Katherine Sheet as undifferentiated Roper Gp	Dunn et al. (in prep.)
Crawford Formation	(?)	Medium-grained quartz greywacke, glauconitic sandstone, and siltstone	Does not crop out in Katherine-Darwin Region	Reference section: Bauhinia Downs Sheet (Smith, 1963)	Conformably overlies Mainoru Fm.	Dunn et al. (in prep.)
Mainoru Formation	(?)	Siltstone, shale, fine-grained sandstone, glauconitic sandstone, limestone, and chert	Does not crop out in Katherine-Darwin Region	Urapunga Sheet (Dunn, 1963)	Conformably overlies Limmen Sandstone	Dunn et al. (in prep.)
Limmen Sandstone	(?)	Medium-grained quartz sandstone, siltstone, and fine-grained pebble conglomerate	Outcrop E. of Waterhouse-Roper R. junction: Katherine Sheet	Reference section: Urapunga Sheet (Dunn, 1963)	Unconformably overlies Mt Rigg Gp Appears on Katherine Sheet as Kombolgie Fm.	Dunn et al. (in prep.)

that the intermixing of sandstone and basalt near the contact between the lower and middle unit suggests that they are conformable. There is therefore some doubt about the conformity of the Dook Creek and 'Beswick Creek Formation', and even the existence of the latter as a valid formation; and for this reason 'Beswick Creek Formation' is used here informally.

ADELAIDEAN SYSTEM

Adelaidean System is now used in place of 'Upper Proterozoic' for those rocks younger than about 1400 million years and older than the Cambrian. A general review of the geochronological, lithostratigraphic, and structural data indicates that three rock units in the Katherine-Darwin Region, the Roper Group, 'Victoria River Group', and Tolmer Group, can be referred to the Adelaidean System. The Roper Group is positioned in the time-scale by isotopic dating; the other two are placed in the Adelaidean System on lithostratigraphic and structural evidence.

The Roper Group crops out over an area of about 750 square miles in the south-eastern corner of the region (Katherine 1 : 250,000 Sheet), where it is separated from the older (Carpentarian) Mount Rigg Group by an old hinge-line now marked by the Morey Fault. The outcrops are in the north-west of the McArthur Basin, which is described in more detail by Dunn et al. (in prep.) and Roberts et al. (in prep.).

The 'Victoria River Group' is not adequately defined. It is used here in the sense of Traves (1955) for rocks in the Fitzmaurice River area, even though we are now certain his original ranking is incorrect. The 'Victoria River Group' in the Katherine-Darwin Region forms only a small proportion of the total area covered by these rocks, and we prefer not to change the nomenclature on the restricted evidence available.

The Tolmer Group crops out around the margins of the Daly River Basin, in the Tolmer Plateau, and near Rum Jungle. It unconformably overlies the 'Victoria River Group' and Lower Proterozoic strata, and is unconformably overlain by the Antrim Plateau Volcanics — of presumed Lower Cambrian age — and by Middle Cambrian sediments.

On the evidence available, the Roper Group can be confidently placed in the lower part of the Adelaidean System; and the part of the 'Victoria River Group' exposed in the Katherine-Darwin Region, and the Tolmer Group, both in the upper part. The Roper Group is nowhere in contact with the 'Victoria River' or Tolmer Groups.

Roper Group

The Roper Group consists mainly of thin-bedded siltstone, shale, and fine sandstone with interbedded medium to coarse-grained quartz sandstone; minor dolomitic sediments and ironstone are present. Ten formations have been recognized, of which the uppermost three constitute the Maiwok Subgroup (see Table 11); the rocks in the Maiwok Subgroup form the main part of the Roper Group cropping out in the Katherine-Darwin Region. Dunn et al. (in prep.) define and describe all the units and discuss their relationships throughout the McArthur Basin (including the Katherine-Darwin Region), and we shall only describe here the units that occur in the Katherine-Darwin Region, with minimum reference to the McArthur Basin as a whole.

The lower part of the section is poorly exposed in the Katherine-Darwin Region, and the total thickness of the group is uncertain. The topmost unit, the Chambers River Formation, develops its maximum observed thickness (2500 feet) near the Morey Fault hinge-line, i.e., along its western margin: but evidence from the adjacent Urapunga Sheet area (Dunn, 1963) suggests that the rest of the group thins westwards and does not exceed 3500 feet. Throughout most of the McArthur Basin the group is about 6000 feet thick; it rises to a maximum of 15,000 feet in the Tanumbirini area (Paine, 1963). The Roper Group has not been positively identified to the west of the Morey Fault hinge-line, and it is possible that the hinge-line formed the western margin of the area of deposition: however, parts of the 'Beswick Creek Formation' may belong to the Roper Group.

The Roper Group rests unconformably on the Mount Rigg Group and its equivalents. In Grabau's (1905) terminology the break is a disconformity with local unconformities; the local unconformities generally occur near zones such as the Morey Fault hinge-line which were tectonically active during sedimentation; along the hinge-line the topmost sediments of the Roper Group are faulted against and possibly overlap sediments as low in the sequence as the Kombolgie Formation of the Katherine River Group. The Roper Group is unconformably overlain by the Lower Cambrian(?) Antrim Plateau Volcanics and the Lower Cretaceous Mullaman Beds.

Age determinations on glauconite from the Roper Group sediments (1390 m.y.) and on dolerites (1200 m.y.) which intrude them (McDougall et al., 1965) place the group in the Adelaidean System.

The *Limmen Sandstone* is the basal unit of the Roper Group. The formation was not recognized during the mapping of the Katherine 1 : 250,000 Sheet area (Randal, 1963), but later mapping in adjacent areas suggests that an outcrop on the north bank of the Roper River near Elsey homestead, shown as Kombolgie Formation on the Katherine map, is Limmen Sandstone. The outcrop is a red blocky medium-grained sandstone surrounded by black-soil and sand-covered flats which conceal the Middle Cambrian Tindall Limestone. The sandstone dips gently to the east.

Two other outcrops of sandstone east of Elsey homestead, which were mapped as undifferentiated Roper Group, are now known to be *Abner Sandstone*. The *Mainoru* and *Crawford Formations,* which overlie the Limmen Sandstone and underlie the Abner Sandstone farther east, do not crop out in the Katherine-Darwin Region.

The *Bessie Creek Sandstone* is a white and red friable medium to coarse-grained sandstone; it occurs in several small outcrops near the Roper River and east of the outcrops of Abner Sandstone. It is less than 100 feet thick, and easily eroded, but elsewhere in the geosyncline it forms prominently jointed ridges and plateaux, and has a maximum thickness of over 1000 feet in the Tanumbirini area (Paine, 1963). The Bessie Creek Sandstone conformably overlies the *Corcoran Formation,* which, in turn, conformably overlies the Abner Sandstone. The Corcoran Formation does not appear on the map of the Katherine 1 : 250,000 Sheet area, but small exposures of typical purple and white banded shale and siltstone do occur below some of the outcrops of Bessie Creek Sandstone. The close resemblance of the banded shales to those near the top of the 'Beswick Creek Formation' suggests that the inclusion of the 'Beswick Creek Formation' in the Mount Rigg Group may be incorrect.

Maiwok Subgroup

The Maiwok Subgroup conformably overlies the Bessie Creek Sandstone, and is confined to an area north of latitude 15°30'S. South of this latitude, the beds overlying the Bessie Creek Sandstone constitute a separate formation (Dunn et al., in prep.). The Maiwok Subgroup crops out in two basins: one centred on the Roper River and a smaller one farther to the south-east. Only the western part of the western basin is in the Katherine-Darwin Region.

The sediments in the Maiwok Subgroup are similar to the rest of the Roper Group, but the proportion of medium-grained sandstone to shale, siltstone, and fine-grained sandstone appears to be smaller, and the sandstone is more thinly bedded; the subgroup is also distinguished by the presence of oolitic ironstone. The constituent formations, in ascending order, are the Velkerri, McMinn, and Chambers River Formations.

The limited areal extent of the subgroup, relative to the rest of the group, suggests that it was developed in a sub-basin or possibly in a deltaic environment. The McMinn and Chambers River Formations both show features of cyclic sedimentation (Weller, 1960): the McMinn Formation grades in a symmetrical cycle from sandstone through finer sandstone and siltstone to shale and carbonate rock, and then back to sandstone; the Chambers River Formation grades upwards from carbonate rock and shale to sandstone in an asymmetrical cycle. Although sedimentary cycles are usually considered to be due to alternating marine and non-marine conditions, we believe that the cycles in the Maiwok Subgroup are entirely marine and are controlled by regular fluctuations in the depth of water and tectonic movement in the provenance area.

Velkerri Formation

The Velkerri Formation comprises poorly exposed fine-grained and argillaceous sediments which are mostly covered by black-soil flats. The formation crops out as low rubble-covered rises, and small outcrops occur in washouts below scarps of the overlying sandstone and near dolerite sills at the base of the formation.

The lower beds consist of pink and brown flaggy siltstone and fine-grained quartz greywacke; some of the pink beds resemble a leached calcareous rock, but no carbonate was detected in surface samples. The beds in the middle of the formation do not crop out, but the presence of deep black soil containing nodules of travertine suggests they are carbonate sediments. The upper beds crop out as flaggy and fissile grey and khaki siltstone and shale. The cores from drilling by the Broken Hill Pty Co. Ltd in the Hodgson Downs area (Dunn, 1963) indicate that the fresh material is fissile carbonaceous siltstone and shale. One creek exposure shows several feet of finely laminated black and grey shale near the top of the section.

The total thickness of the formation has not been measured, but evidence obtained farther east suggests that it does not exceed 500 feet in the Katherine-Darwin Region.

McMinn Formation

The McMinn Formation is the predominant unit in the Maiwok Subgroup outside the Katherine-Darwin Region. In the Katherine-Darwin Region it is exposed along a series of step faults between the Roper River and the Cretaceous tableland to the north, and in two low ridges near Cave Creek to the north of the Roper River.

The McMinn Formation represents a period of cyclic sedimentation with a gradual change from one rock type to another. However, four members can be recognized: the Moroak Sandstone, Sherwin Ironstone, Kyalla, and Bukalorkmi Sandstone Members.

The *Moroak Sandstone Member* at the base of the McMinn Formation crops out in long prominent cuestas east of the Chambers River, and in several smaller outcrops near the Roper River, the most prominent of which is Rendezvous Hill. The unit consists of red and grey friable medium-grained quartz sandstone and interbedded flaggy siltstone and shale; in places near the base the sandstone is very coarse, with angular poorly sorted grains. It is blocky, commonly ripple-marked and cross-bedded, and the bedding is roughly graded in places. The thickness ranges from 40 to 100 feet in the Katherine-Darwin Region, but farther east in the Urapunga area, the member is up to 300 feet thick (Dunn, 1963).

The Moroak Sandstone rests conformably on the Velkerri Formation, but the contact is generally concealed by rubble below the scarp of the cuestas. The contact is sharply defined by a change in grainsize of the sediments. The upper contact is gradational; the grainsize and proportion of sandstone decrease upwards into the Kyalla Member or, where present, there is a gradual increase in ferruginous material at the boundary with the Sherwin Ironstone Member. The boundary with the Kyalla Member has been mapped along the physiographic break between the resistant dip-slope of the Moroak Sandstone and the rounded rubble-covered hills of the less resistant Kyalla Member. In places, east of the Katherine-Darwin Region the Sherwin Ironstone and Kyalla Members are interfingered with the Moroak Sandstone.

The *Sherwin Ironstone Member* crops out as scattered ferruginous cappings on the dip-slope of the Moroak Sandstone; the unit is lenticular, but its absence from many parts of the dip-slope is probably due to erosion. The dark red soil on the ironstone makes it easy to recognize on the air-photographs. The outcrops consist of beds of oolitic and pisolitic hematite containing scattered quartz grains, and medium-grained blocky purple ferruginous sandstone with interbedded siltstone and shale. Diamond-drill core from the Roper Bar area (east of the Katherine-Darwin Region) shows that the unweathered material consists of oolites of hematite and granules of chamosite and greenalite in a matrix of siderite which has completely replaced some of the oolites and granules (Cochrane & Edwards, 1960).

In the Katherine-Darwin Region the Sherwin Ironstone Member contains only one oolitic zone and is less than 15 feet thick; in the Roper Bar area several oolitic zones are present, and the member is over 150 feet thick.

In places the Sherwin Ironstone is interbedded with the top of the Moroak Sandstone Member, elsewhere it overlies this member or occurs completely within the lower part of the Kyalla Member. In the Katherine-Darwin Region it generally overlies the Moroak Sandstone, but in several places it is overlain by thin lenses of quartz sandstone belonging to this unit.

The *Kyalla Member* forms the greater part of the McMinn Formation, but it is not as well exposed as the other members. The unit generally crops out in rubble-covered hills or is covered by soil.

The proportion of clastic sediments in the Kyalla Member gradually decreases upwards, but increases again towards the top. The lower part consists of flaggy fine-grained micaceous sandstone, siltstone, and shale, with interbedded blocky medium-grained quartz sandstone. The blocky sandstone is ripple-marked and load casts are common in the finer-grained sediments. The sandy beds become thinner and finer in grain higher up the section, and in places the sediments are calcareous — outcrop or even rubble are rare in this part of the section, but flaggy fine-grained calcareous greywacke and siltstone and lenses of cone-in-cone limestone have been seen; in one place carbonaceous shale crops out. The upper part of the Kyalla Member above the calcareous sequence consists of fine-grained flaggy micaceous quartz sandstone, quartz greywacke, and siltstone. In the upper part there is a discontinuous bed composed of closely packed flattened discs of sandstone, up to 1 inch in diameter, set in a ferruginous matrix; although the bed is only a few inches thick it stands out in the rubble or outcrop. Most of the sediments in the Kyalla Member are red-brown or purple in outcrop, but at depth the sandstone and siltstone are grey, and in places pyritic; a large proportion of the section is composed of carbonaceous shale and mudstone which do not crop out.

The thickness of the Kyalla Member averages about 500 feet, but in the northernmost outcrops in the Katherine-Darwin Region it is only about 150 feet thick.

In many places the Kyalla Member is separated from the underlying sediments by a dolerite sill.

The *Bukalorkmi Sandstone Member,* a white and red blocky quartz sandstone, is the uppermost member of the McMinn Formation. It forms similar, though less prominent, cuestas to the Moroak Sandstone. The member is split near the top by a dolerite sill; the upper part forms small buttes in the Black Cap area.

The quartz sandstone is composed of medium-sized subrounded quartz grains; some weathered white rounded grains are probably kaolinized feldspar; there is little matrix and the rock is very friable. (Surface silicification has helped to preserve the outcrop.) The red colour of the sandstone is probably due to staining by iron derived from the weathering of the dolerite. Cross-bedding is common, and most surfaces show ripple marks which range in wave length from 1 to 8 inches. Interference ripple marks up to 6 inches across are associated with the normal ripple marks. Cylindrical holes up to 1 inch in diameter and 4 inches deep, perpendicular to the bedding, were found in several localities; their origin is unknown. In places, lenses of more massive quartz sandstone occur immediately below the friable sandstone. Near Goose Lagoon, north-east of Elsey homestead, a 200 foot-thick lens, consisting of several beds of medium-grained massive red sandstone, underlies the more friable sandstone; the massive sandstone lenses out a mile north of its point of maximum development.

The thickness of the Bukalorkmi Sandstone generally ranges from 50 to 100 feet; in the Black Cap area it averages 40 feet; locally, as at Goose Lagoon, it is over 200 feet.

Chambers River Formation

The Chambers River formation is the only formation of the Roper Group which is best exposed in the Katherine-Darwin Region. The most important outcrop area is west and south of the Chambers River, but it also occurs in small basins to the east of the river and south-east of the Katherine-Darwin Region.

The sediments in the Chambers River area were first mapped by Walpole (1958a). Lacking detailed information, he referred to them informally as Chambers River Beds. Subsequent mapping has shown that the lower part of the beds belong to the McMinn Formation.

The Chambers River Formation overlies the McMinn Formation, and consists of fine-grained and lutitic sediments near the base, which grade upwards into medium and coarse-grained quartz sandstone and ferruginous sandstone at the top.

The lower part of the formation includes calcareous and micaceous green and purple siltstone, veined in places by calcite and siderite. The sediments are usually covered by soil. The contact with the underlying Bukalorkmi Sandstone Member is not exposed. A succession of flaggy micaceous fine-grained sandstone and siltstone grades up from the lower beds and forms rubble-covered rises. The lowest bed to crop out consistently is a thin-bedded red-brown medium-grained micaceous quartz greywacke which forms a prominent outcrop of large thin slabs within areas of rubble. Higher in the section, beds of blocky ripple-marked, silicified quartz sandstone appear interbedded with the flaggy sediments. The quartz sandstone beds become thicker and more numerous until they constitute about one-half of the sequence. The quartz sandstone consists of well sorted medium to coarse grains of quartz with some muscovite. The rock is generally grey to buff, and in the higher parts of the section is friable. Some interbedded massive red quartz greywacke contains a large amount of labile material. At the top of the formation the sandstone is ferruginous.

Throughout the formation the sandstone is strongly cross-bedded, and ripple marks, clay pellet impressions, and other surface markings are common. The ripple marks vary considerably in size and direction between overlapping surfaces and, in places, interference ripple marks have been formed.

The maximum thickness of the Chambers River Formation occurs adjacent to the Morey Fault hinge-line; this is the only place where the upper, predominantly sandstone, part of the formation is completely exposed. The upper part is over 1500 feet thick and the rest of the formation is estimated to be about 1000 feet thick.

'Victoria River Group'

The rocks in the Fitzmaurice River area in the south-western part of the Katherine-Darwin Region were included by Traves (1955) in his Victoria River Group. Randal (1962) retained the name, but the unconformable Chilling Sandstone below and the unconformable Buldiva Sandstone above, which were included in the group by Traves, have now been split off from the group.

The nomenclature used for the Victoria River Group by Traves, and later by Laing & Allan (1956, unpubl.), will almost certainly require revision when the Victoria River region has been mapped in detail. For this reason, and also because the mapping in this area was only on a reconnaissance basis, the units described here are given informal names only. 'Victoria River Group' is retained, although its constituent formations have not been properly identified.

In the Katherine-Darwin Region the group is a mixed arenite-lutite-carbonate assemblage of unknown thickness and extent. It unconformably overlies the Lower Proterozoic Noltenius Formation and Chilling Sandstone, and unconformably underlies the Adelaidean Tolmer Group. The lithology of the major rock units in the Carpentarian and Adelaidean sequences in northern Australia appears to be remarkably consistent; the 'Victoria River Group' in the Katherine-Darwin Region appears to fit best with the upper part of the Adelaidean, and more precisely with the succession in the Osmond Range, in the Kimberley area of Western Australia (Dow et al., 1964, unpubl.); and the overlying Tolmer Group with the Albert Edward Group of the Kimberley area (op. cit.). These correlations, however, are only tentative.

In the Katherine-Darwin Region the 'Victoria River Group' crops out south of the Wingate Plateau in the Fergusson River Sheet area, where four units have been recognized by Randal (op. cit.). Farther south, in the Victoria River area proper, Laing & Allen recognized five units. A tentative correlation with the units mapped by Randal is given in Table 12.

TABLE 12: TENTATIVE CORRELATION WITHIN 'VICTORIA RIVER GROUP'

Victoria River Area (Laing & Allen, 1956, unpubl.)		*Fitzmaurice River Area* (Randal, 1962)	
Unit	*Approximate Thickness* (ft)	*Unit*	*Approximate Thickness* (ft)
No equivalent		Laurie Creek Beds	500
Pinkerton Beds	1000	Yambarra Beds	2000
Auvergne Shale	500-1000	Angalarri Siltstone	1000
Jasper Gorge Sandstone	600	Palm Creek Beds	1000
Coolibah Formation	500	No equivalent	
Unconformity			
Skull Creek Limestone	900	No equivalent	

Noakes (1956) correlated the Victoria River Group with the Mount House Beds in the Kimberleys, the Wilpena Pound Sandstone of the Adelaide Geosyncline, and the Tolmer Group on the basis of the presence of *Collenia* and 'Jellyfish'. However, not enough is known of either form to use them as diagnostic fossils.

No complete section of the 'Victoria River Group' is exposed, either in the Katherine-Darwin Region or in the Ord-Victoria region. Traves (1955) estimated its thickness as at least 2000 feet, and our work has shown that it is at least double this figure. South of the Victoria River, Laing & Allan (1956, unpubl.) have determined a composite thickness for the group of between 3500 and 4000 feet. In the Fitzmaurice River area it is probably 4500 feet thick.

Palm Creek Beds

The oldest unit in the 'Victoria River Group' in the Katherine-Darwin Region is the Palm Creek Beds, which crop out on a dissected and gently sloping tableland on the divide between the Fitzmaurice and Flora Rivers; the rocks form cliffs of ripple-marked cross-bedded quartz sandstone in gorges cut by tributaries of Palm Creek and the Flora River.

The weathered surfaces are generally coated with iron oxide; the fresh rock is friable and composed of well rounded quartz grains with minor hematite. The sandstone is medium to coarse-grained with some beds of fine sandstone and siltstone up to 6 inches thick. In places the rocks have been silicified by surface waters and near fault planes. The rocks are jointed, more strongly along bedding planes than in the vertical plane.

South of the Flora River about 100 feet of black silicified limestone with sandstone interbeds is overlain by cliffs of massive ripple-marked quartz sandstone. The contact is hidden by 30 feet of scree and talus, but the dips and strike are conformable. This limestone is considered to be the lowermost part of the Palm Creek Beds.

The only exposed contact of the Palm Creek Beds with Lower Proterozoic rocks is at the head of the Angalarri River, where gently dipping Palm Creek arenites are faulted against steeply dipping siltstone and greywacke of the Noltenius Formation. The east-trending fault has displaced at least 500 feet of sandstone. The Palm Creek Beds commonly dip at less than 20°.

In the headwaters of the Flora River, the Palm Creek Beds are unconformably overlain by the red sandstone and siltstone belonging to the upper part of the Tolmer Group. Immediately east of Wombungee homestead the unit appears from air-photographs to be faulted against the basal beds of the Tolmer Group. The contact has not been examined on the ground, and it may be an unconformity rather than a fault.

The Palm Creek Beds may extend southward to the Victoria River, where rocks showing the same pattern on the air-photographs have been mapped as the Jasper Gorge Sandstone.

Angalarri Siltstone

The Palm Creek Beds are conformably overlain by the Angalarri Siltstone. The contact is exposed north and north-east of the Angalarri River, where the medium to coarse arenaceous sediments of the Palm Creek Beds grade into the fine-grained Angalarri Siltstone over a distance of 10 to 15 feet.

The Angalarri Siltstone crops out as rubble-covered rises, and as weathered material in the beds and banks of creeks in the plains along the Fitzmaurice and Angalarri Rivers. J. E. Harms* (pers. comm.) has traced chocolate and green siltstone with minor limestone south from The Twins, along the Angalarri River and the Yambarra Range escarpment to the Victoria River, where the unit appears to be equivalent to the Auvergne Shale (Laing & Allen, 1956, unpubl.). Similar rocks in the same stratigraphic position have been traced from the Victoria River to the Wingate Plateau along the western escarpment formed by the Yambarra Beds.

Calcareous siltstone and lenses of limestone are reported by Harms to be interbedded with the chocolate and green siltstone near The Twins. The siltstone is characterized by the presence on the bedding planes of pale yellow areas up to 5 mm in diameter; they are probably deoxidation centres and are most common where the siltstone appears as loose shingle through black soil. In a few localities the deoxidation is complete, and the siltstone is buff to grey in colour.

It is difficult to measure the dip of the Angalarri Siltstone, owing to the disintegration of the outcrops, and to assess the thickness of the unit. The thickness calculated from the dips in widely scattered outcrops in the Fitzmaurice River area ranges from 1000 to 2000 feet: the lower value is the more probable.

Yambarra Beds

To the west of The Twins, the Angalarri Siltstone is overlain by a sequence of arenaceous and fine-grained rocks. The contact is not exposed in the Katherine-Darwin Region, but Harms (pers. comm.) considers that the rocks in the Yambarra Range escarpment farther south are conformable with the Angalarri Siltstone. The basal member of the sequence is medium to coarse-grained sandstone; it forms the well defined strike scarp, 200 to 300 feet high, of the Yambarra Range, which extends from the Wingate Plateau to the Victoria River.

The basal sandstone is massive and well jointed. Ripple marks, cross-bedding, and slumping are common. Mud pellets and worm tracks have been observed in the scarp to the west of The Twins. Numerous gorges have been cut into the unit, and the stream pattern appears to be controlled by strong vertical joints. The extensive dip-slope to the west of the escarpment is inclined at 10 to 15° to the west. The basal sandstone is overlain by flaggy well bedded micaceous quartz sandstone, feldspathic sandstone, and beds of grey and buff siltstone. These in turn are overlain by ferruginous sandstone, chocolate and buff siltstone and sandstone, and calcareous rocks.

Farther west, towards the tidal limit of the Fitzmaurice River, the sequence is repeated, but with easterly dips. Again, the massive basal sandstone forms a

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prominent escarpment extending from the Wingate Plateau to the Victoria River. The air-photographs show that the Yambarra Beds form a wide syncline which closes to the north under the Wingate Plateau. The structure has been examined only in the north, where a few helicopter traverses were made across it. No suitable landing places were found and no detailed sections were obtained. A study of the air-photographs suggests that more detailed work will lead to the recognition of a number of formations within the Yambarra Beds.

On the eastern side of the syncline, the basal sandstone appears to be continuous with the basal part of the Pinkerton Beds in the Pinkerton Range. N. J. McKay (pers. comm.) reports a wide variation in the lithology of the Pinkerton Beds. The relationship between the upper parts of the Pinkerton Beds and the Yambarra Beds is uncertain.

The Yambarra Beds are unconformably overlain by the Tolmer Group near the headwaters of Alligator Creek on the Port Keats 1 : 250,000 Sheet area. Fine-grained pink quartz sandstone (Buldiva Sandstone) rests horizontally on feldspathic and quartz sandstones dipping at 15° to the south-east. The two units were included by Traves (1955) in the Victoria River Group. The unconformity can be traced westwards to near the Moyle River, where the Tolmer Group overlaps the Yambarra Beds and directly overlies the folded Chilling Sandstone. To the east, the unconformity can be traced to the Laurie Creek area, where the Tolmer Group unconformably overlies the Laurie Creek Beds, which appear to overlie the Yambarra Beds.

Laurie Creek Beds

The relationship of the Laurie Creek Beds to the other units of the 'Victoria River Groups' is uncertain. North of the Fitzmaurice River they appear to overlie the Yambarra Beds; the contact is not exposed and it is difficult to draw a boundary between the two units. The Laurie Creek Beds have a distinctive pattern on the air-photographs and hence have been regarded as a separate unit. They consist of white to buff silicified medium-grained quartz sandstone with interbedded silicified stromatolithic limestone; they appear to be about 500 feet thick.

Tolmer Group

Tolmer Group was first referred to by Noakes (1956) from our unpublished material, and derives its name from the Tolmer Plateau adjacent to the north-western end of the Daly River Basin. The type area is at Buldiva, on the Fergusson River 1 : 250,000 Sheet area. It is an arenite-carbonate-lutite assemblage, about 3000 feet thick, and is subdivided into three formations: the Buldiva Sandstone, the Hinde Dolomite, and the Waterbag Creek Formation.

Like so many other stratigraphic units in the Katherine-Darwin Region, the units of the Tolmer Group have had a varied nomenclatural history.

Hossfeld (1937c) recognized probable Upper Proterozoic rocks between Buldiva and the Reynolds River, but he believed they were conformable with the overlying Cambrian limestone, sandstone, and shale. He named the complete sequence the Buldivan Series and the sandstone unit at the base of the sequence the Buldiva Quartzite. Noakes (1949) queried the continuity of the sequence and gave cogent evidence for an unconformity, since confirmed, between the 'quartzite' and the overlying Cambrian limestone. Noakes retained the term 'Buldiva Quartzite' but extended it to include rocks now included in the older Katherine River Group on the Arnhem Land Plateau. Hossfeld in 1954 again considered the sequence to be continuous and re-affirmed his concept of the Buldivan Series. This is no longer acceptable.

The Tolmer Group is best exposed on the western margin of the Daly River Basin, where the group unconformably overlies the Finniss River Group, Chilling Sandstone, and 'Victoria River Group'. Flat-lying Buldiva Sandstone rests on Chilling Sandstone in the most westerly exposures. Farther east on the edge of the Daly River Basin, the group dips gently east. Near Buldiva, the Lower Cambrian(?) Antrim Plateau Volcanics fill old erosion valleys cut in the Tolmer Group. Dips are basinwards and gentle, and the preservation of old morphological features suggests that the beds have been only very gently folded. They have, however, been severely disturbed by the transcurrent Giants Reef Fault, which can be traced for 140 miles from the head of Chilling Creek north-north-east through Rum Jungle; and by other smaller faults, on the north-western margin of the basin.

The relationships between the Tolmer Group and the underlying 'Victoria River Group' and Lower Proterozoic rocks are best seen on the northern, western, and southern edges of the Wingate Plateau. Near the head of Alligator Creek, the basal beds of the Tolmer Group rest unconformably on the Yambarra Beds. Farther west, the Tolmer Group overlaps these rocks, and near the Moyle River they rest directly on the folded Chilling Sandstone with a marked angular unconformity. The same relationship obtains on the northern margin of the Wingate Plateau at the headwaters of Hermit Creek, and also to the west of the Buldiva tin field, and north-east of Collia Waterhole.

Neither the Tolmer Plateau nor the Wingate Plateau contains the complete sequence of the Tolmer Group: on the Tolmer Plateau only the Buldiva Sandstone is present, and on the Wingate Plateau the Depot Creek Sandstone Member only is present. The best section occurs north-east of Collia Waterhole near Lilyarba Creek, where massive quartz sandstone and flaggy micaceous sandstone (Depot Creek and Stray Creek Members of the Buldiva Sandstone) are conformably overlain by the Hinde Dolomite, which in turn is overlain by red quartz sandstone and siltstone of the Waterbag Creek Formation. The contacts are clearly exposed and show no signs of erosional breaks. The units, however, are not as thick as elsewhere.

South of this section, the Hinde Dolomite and the upper member of the Buldiva Sandstone — the Stray Creek Sandstone Member — appear to lens out under the Lower Cretaceous rocks covering the eastern part of the Wingate Plateau. The Depot Creek Sandstone Member and the Waterbag Creek Formation continue in a south-easterly direction to the headwaters of the Flora River, where the Depot Creek Sandstone Member abuts against the Palm Creek Beds. The Waterbag Creek Formation extends farther south-east to beyond Hayward Creek.

On the eastern side of the Daly River Basin, rocks of the Tolmer Group crop out 6 miles south of Adelaide River township. All units of the group are present here, but the contacts are not exposed. The Buldiva Sandstone crops out in a continuous belt from Hayes Creek, where it is faulted against Lower Proterozoic rocks, to a point about 15 miles west of Fergusson River Siding, where it appears to lens out. The upper beds of the Tolmer Group do not crop out along this belt, except for one small isolated outcrop of red ferruginous sandstone with halite pseudomorphs near the southern end of the Hayes Creek Fault.

The geographical position of the Tolmer Group in relation to the Daly River Basin suggests that the group forms the floor of the basin from north of the Fergusson River to beyond the Daly River road. It seems unlikely that the Tolmer Group did not extend to the west and south of Mount Shoobridge and along the northern edge of the Daly River Basin; particularly as the Buldiva Sandstone is actually thickening where it is cut by the Hayes Creek Fault. It is probable, however, that the upper formations of the group were not so widely distributed throughout the basin. They are restricted to the western side of the basin and to small areas in the north-east. The Buldiva Sandstone also thins from 2000 feet in the west to 1000 feet in the east.

There is no evidence to suggest that the Tolmer Group extended eastward to cover all the Cullen Granite. The source of the Tolmer Group sediments appears to have been mainly from the north-east and north-west.

Buldiva Sandstone

The Buldiva Sandstone is the basal unit of the Tolmer Group, and was referred to by Noakes and others as the Buldiva 'Quartzite'. Quartzite is not a good name as the formation consists essentially of friable pink massive and well jointed quartz sandstone overlain by flaggy quartz sandstone, with minor beds of shale near the top. Like many other rocks in northern Australia, in places it has been intensely silicified for a few inches below the surface by weathering processes; in other places it is silicified along fault lines.

The Buldiva Sandstone contains a lower Depot Creek Sandstone Member and an upper Stray Creek Sandstone Member. The *Depot Creek Sandstone Member* is a pink, well bedded, and in places ripple-marked, quartz sandstone. It forms massive rocky tablelands, and has well developed vertical joints trending north-west and north-east, which produce a characteristic tessellated pattern on the air-photographs.

Drainage is controlled by the jointing, with steep rocky gorges as deep as 250 feet, which provide excellent sections of the unit (Pl. 17, fig. 2). It has a maximum thickness of about 1000 feet on the western side of the Daly River Basin 10 miles north of the Daly River. Hossfeld (1937c) records a thickness of several hundred feet at Buldiva, which probably includes the upper member of the Buldiva Sandstone.. On both the Tolmer and Wingate Plateaux, the Depot Creek Sandstone Member appears to be less than 500 feet thick.

The Depot Creek Sandstone Member is extensively silicified in faulted areas. Along the Hayes Creek Fault it forms a sheer cliff 450 feet high of a highly silicified pink quartz sandstone which may be termed a quartzite: but within a quarter of a mile the quartzite grades along strike into a clean quartz sandstone of medium hardness, which persists until the unit appears to lens out 40 miles to the south-east. Near the Daly River, the Rock Candy Range Fault has formed an inlier of the Depot Creek Sandstone Member at the northern end of the range. To the north-west, the outcrop is bounded by the fault line, and the rocks are hard and quartzitic; in the centre of the inlier well-jointed sandstone is exposed. The eastern margin of the Tolmer Plateau, which is bounded by the Giants Reef Fault, contains silicified sandstone, but in the centre of the plateau the rock is friable and weathers into honeycombed pillars and tessellated blocks.

The Depot Creek Sandstone Member rests on Lower Proterozoic rocks with a marked angular unconformity (Pl. 18, fig. 1), as can be seen in a number of places. In a gorge on the headwaters of Stray Creek, 14 miles west-south-west of Pine Creek, the gently dipping Depot Creek Sandstone rests on steeply folded and sheared greywacke and siltstone of the Burrell Creek Formation. The contact is exposed in a cliff on the southern side of the gorge. The basal beds of the Depot Creek Sandstone Member are highly ferruginous and fill small gaps and fissures in the surface of the older rocks. Ten to fifteen feet above the contact the sandstone contains large subangular and rounded quartz pebbles. Hossfeld (1937c) describes similar beds near Collia and Buldiva.

Near Collia Waterhole the Depot Creek Sandstone Member rests unconformably on the uneven surface of the Soldiers Creek Granite. The same relationship has been observed on the western side of the Cullen Granite near Mount Shoobridge, and in the Umbrawarra Gorge, west of Pine Creek. In these localities the iron content of the sandstone is higher than usual, and thin bands with rounded quartz pebbles have been noted.

Despite the angular unconformity at the base of the Depot Creek Sandstone Member and the implied large time break, very little basal conglomerate has been noted in this member — other than the sporadic occurrence of quartz pebble bands. Malone (1958, unpubl.) has reported the presence of local basal breccia and conglomerate in the Rum Jungle and Tolmer Plateau area. On the north-western edge of the Tolmer Plateau, small lenses of conglomerate occur in the member where it directly overlies pebble and cobble conglomerate beds in the Lower Proterozoic rocks. The pebbles and cobbles in the sandstone were derived from the older conglomerates and redeposited with little lateral dispersion.

In the Rum Jungle area and around the Waterhouse Dome lenses of phosphatic breccia grade upwards into a ripple-marked clean pink quartz sandstone. The possible origin of the phosphatic rock has been discussed on p. 62. In this case it is regarded as Adelaidean and part of the Depot Creek Sandstone Member.

The upper member of the Buldiva Sandstone — the *Stray Creek Sandstone Member* — rests conformably on the Depot Creek Sandstone Member on the eastern and western margins of the Daly River Basin and in the southern part of the Tolmer Plateau, where the Depot Creek Sandstone passes upwards into a slightly harder flaggy sandstone. The flaggy and fissile rocks are of medium grainsize and in places contain abundant sericite and muscovite. Minor siltstone and shale occur at the top.

Vertical jointing is not well developed in the Stray Creek Sandstone Member; but it is well jointed parallel to the bedding. This produces a characteristic 'ribbon' pattern on the air-photographs, and it is easier to trace the boundary on the air-photographs than on the ground.

The member is named from Stray Creek, where, in Umbrawarra Gorge, 100 feet of flaggy quartz sandstone with interbedded siltstone lenses are conformable with the pink Depot Creek Sandstone. The Stray Creek Sandstone Member is thickest on the western side of the Daly River Basin, where sections aggregating over 1000 feet have been observed in folds on both sides of the Rock Candy Range Fault. It is possible, however, that some of the beds are repeated by minor faulting and monoclinal folding associated with the major fault. Near the confluence of Hayward Creek with the Daly River, the gently dipping flaggy sandstone is about 1000 feet thick.

The Stray Creek Sandstone Member is not as widespread as the Depot Creek Sandstone. In the west, it extends from south of the Reynolds River across the Daly River, and then lenses out to the south under the Lower Cretaceous rocks covering the eastern extension of the Wingate Plateau. On the eastern side of the basin, it crops out along the south branch of the Adelaide River and also as discontinuous outcrops from near Hayes Creek to a few miles east of Jindare homestead. An isolated outcrop occurs on the Tolmer Plateau in a small basin cut by the Giants Reef Fault.

There are numerous lenses of siltstone in the Stray Creek Sandstone, and they become more prominent towards the top. The chocolate, green, light grey, and buff siltstones form a useful marker bed at the top of the unit, but they can be confused with similar rocks in the Waterbag Creek area, where the succession is faulted. At the north-western end of the Rock Candy Range traces of fossil jellyfish of the *Beltanella* type occur in a dolomitic siltstone which appears to be one of the uppermost beds of the Stray Creek Member. However, the succession is uncertain as the area is extensively faulted, and it is possible that the fossil beds are in the Waterbag Creek Formation.

The Buldiva Sandstone was deposited in shallow water: Hossfeld (1937c) records ripple marks, worm tracks, rain prints, and sun cracks in the Buldiva-Collia area, and in places for 40 miles to the north. Noakes (1949) has reported similar features at most localities where the rocks were examined.

The ripple marks in the Buldiva Sandstone include oscillation ripple marks with gently rounded symmetrical crests and troughs, and current ripple marks with a long backslope and a sharp lee-slope. Coarse material in the troughs is common. The oscillation ripple marks appear to be the most common, and in many places the orientation of the ripples in beds separated by fractions of an inch shows a marked change in direction. Cross-bedding is common in the Buldiva Sandstone (Pl. 18, fig. 2), particularly in the massive Depot Creek Sandstone Member. Although no detailed studies have been made, the cross-beds on the western side of the basin indicate a westerly or north-westerly direction of sedimentation, and a north-easterly or easterly direction in the east. This agrees with the general concept that the Daly River Basin was formed during the Adelaidean and that it did not extend much beyond its present limits to the east, west, and north.

The Buldiva Sandstone is an excellent aquifer, providing good water from numerous springs and soaks. Large pools fed by hot springs are associated with faults in the Depot Creek Sandstone Member at the headwaters of the Reynolds River; they warrant development as a tourist attraction.

Hinde Dolomite

The Hinde Dolomite rests conformably on the Buldiva Sandstone; it crops out discontinuously along the western side of the Daly River Basin from near the headwaters of Hayward Creek south to the headwaters of Lilyarba Creek. The only outcrop seen on the eastern side of the basin is in the type area on the south branch of the Adelaide River. There, pink and grey flaggy dolomite with siltstone interbeds is overlain by a massive pink jointed dolomite with abundant remains of *Collenia*-type algae (Pl. 19, figs 1 and 2).

The cryptozoan 'limestones' reported by Hossfeld (1937a) in the Collia-Buldiva area are part of the Hinde Dolomite.

In most of the sections examined algal reefs composed of *Collenia* in a hard pink dolomite constitute much of the rocks. The organisms are separated in some localities by ferruginous silty material and are elongated along an axis which varies in strike from 005° to 030°. The reefs appear to be discontinuous; the maximum observed thickness is on the western side of the basin north of the Daly River, where 200 feet of massive and flaggy black-grey and pink dolomite is exposed. The type area is the only outcrop on the eastern side of the basin. The formation lenses out south of the western margin of the Daly River Basin; and the reefs probably do not extend far into the basin from the western margin.

In the headwaters of Lilyarba Creek the Hinde Dolomite is overlain by basalts of the Antrim Plateau Volcanics. Nearby, the basalts also overlie red sandstone and siltstone which rest conformably on the Hinde Dolomite. The basalt has hardened and silicified the dolomite near the contact and has filled small fissures and cracks in the older rocks; it crops out in valleys between the dolomite ridges.

Waterbag Creek Formation

Six miles south-east of the Lilyarba Creek crossing on the Collia-Dorisvale track ferruginous sandstone and siltstone of the Waterbag Creek Formation rest conformably on silicified blocky grey limestone and dolomite of the Hinde Dolomite. The contact is exposed and there is no erosional break.

The Waterbag Creek Formation consists of interbedded ferruginous sandstone, varicoloured siltstone, and silicified limestone and marl. Both sandstone and siltstone contain pseudomorphs after halite.

The formation crops out extensively on the western side of the Daly River Basin and extends from north-west of the Rock Candy Range for 90 miles in a south-easterly direction to east of Mount Freda near the Wyndham road. It is thickest in the Waterbag Creek/Bradshaw Creek area, where it crops out over an area about 30 miles long by 20 miles wide. Numerous undulations and changes of dip tend to exaggerate the thickness, which is probably no more than 500 feet.

The formation contains numerous lenses of limestone and marl, and along the Flora River a lens of black silicified limestone about 60 feet thick can be traced for over 30 miles. In places, the formation is faulted against the Antrim Plateau Volcanics, which elsewhere rest unconformably on it.

Near the headwaters of Waterbag Creek the formation directly overlies the Depot Creek Sandstone Member with no structural disconformity. The relationship here is probably overlap; both the Stray Creek Sandstone Member and the Hinde Dolomite thin out near the eastern edge of the Wingate Plateau, and it is probable that they were not deposited in the Waterbag Creek area. Between Banyan and Hayward Creeks the Waterbag Creek Formation directly overlies the Palm Creek Beds of the Victoria River Group with angular unconformity.

Only two occurrences of the formation have been observed on the eastern side of the Daly River Basin. Along the south branch of the Adelaide River ferruginous sandstone containing halite pseudomorphs conformably overlies *Collenia*-bearing dolomite and abuts against the Adelaide River Fault. East of the Hayes Creek Fault and 6 miles north of the Douglas River, there is a low rise, covered with a scree of ferruginous sandstone with halite pseudomorphs; the lithology and field relationships to the nearby Stray Creek Sandstone Member indicate that it is probably a remnant of the Waterbag Creek Formation.

In the Collia area, the outcrops of the Waterbag Creek Formation and Hinde Dolomite were considered by Hossfeld and Voisey to be part of the Cambrian limestone and sandstone succession which crops out farther east. In fact they are separated by the Lower Cambrian(?) Antrim Plateau Volcanics, which unconformably overlie the Tolmer Group.

PALAEOZOIC

During the Palaeozoic era, most of the Katherine-Darwin Region was a land area on which no sedimentation occurred.

The Lower Cambrian* in northern Australia was marked by the widespread outpouring of tholeiitic basalt — the Antrim Plateau Volcanics. The northernmost extension of the volcanics lies in the Katherine-Darwin Region near the junction of the Daly River road and the Stapleton track on the Pine Creek 1 : 250,000 Sheet.

The Middle Cambrian sediments which overlie the volcanics in the Daly River Basin represent a period of quiet chemical and fine clastic sedimentation in a shallow epeiric sea. They are probably connected with the carbonate rocks of the Barkly Tableland and the Georgina Basin to the south-east, as are the recently discovered Lower Ordovician strata of the Daly River Basin (Öpik, 1966). They are also connected with rocks in the Ord-Victoria region to the south and south-west.

Small outliers of Middle Cambrian rocks crop out 10 miles west of Litchfield homestead.

Earth movements near the end of the Palaeozoic involved the western part of the region, and Permian and Triassic rocks were deposited in the Bonaparte Gulf Basin, but there was no sedimentation in the eastern part of the region. These movements took place along the rectilinear belt of Chilling Sandstone which runs south-south-west from the Katherine-Darwin Region through the Ord-Victoria region to the East Kimberley region of Western Australia. The Permian and Triassic rocks were not mapped during the present survey, and will therefore only be briefly mentioned.

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* The age of the Antrim Plateau Volcanics has not been precisely fixed by isotopic dating. They overlie uppermost Adelaidean and underlie Middle Cambrian strata.

TABLE 13: STRATIGRAPHIC TABLE, PHANEROZOIC UNITS

Era or Period	Rock Unit	Thickness (ft)	Lithology	Distribution (Incl. 1:250,000 Sheets)	Reference Area	Stratigraphic Relationships	Reference
Cainozoic			Coastal sediments, alluvium, swamp deposits, sand, soil, ferricrete, and laterite	Throughout Katherine-Darwin Region			
Lower Cretaceous	MULLAMAN BEDS	300	Sandstone, shale, conglomerate, and porcellanite. Extensively lateritized	Throughout Katherine-Darwin Region	Mullaman Tableland, lat. 13°49′S., long. 131°47′E.	Unconformably overlies all older rock units	Noakes (1949), Skwarko (1966)
	Baker Creek Formation	30	Sandstone	Beswick area: Katherine Sheet	Baker Ck, lat. 14°28′S., long. 130°11′E.	Basal unit of Mullaman Beds	Ruker (1959, unpubl.)
Permian	PORT KEATS GROUP			W. part of region: Port Keats and Cape Scott Sheets			Traves (1955)
Ordovician-Cambrian	'DALY RIVER GROUP'						
	'Oolloo Limestone'	200	Pink, grey, and white flaggy silicified limestone, with chert bands	Central part of Daly R. Basin: Pine Ck, Fergusson R., and Katherine Sheets	Daly R., W. by N. of Oolloo homestead, lat. 13°55′S., long. 131°12′E.	Top unit of 'Daly River Gp'; conformably overlies 'Jinduckin Fm.'	Randal (1962, 1963), Malone (1962a)
	'Jinduckin Formation'	200	Ferruginous sandstone and siltstone, with halite pseudomorphs; silicified limestone and dolomitic limestone; some marl	Daly R. Basin: Pine Ck, Fergusson R., and Katherine Sheets	Headwaters of Jinduckin Ck, N.W. of Dorisvale homestead, lat. 14°18′S., long. 131°15′E.	Conformably overlies Tindall Limestone	Malone (1962a), Randal (1962, 3)
	Manbulloo Limestone Member	200	Silicified limestone and dolomitic limestone; dolomite and marl; some sandstone and siltstone	S.W. and S.E. parts of Daly R. Basin: Fergusson R. and Katherine Sheets	Astride the Katherine R. near Manbulloo homestead, S.W. of Katherine, lat. 14°31′S., long. 132°12′E.	Lateral equivalent of and interfingers with the 'Jinduckin Fm.'	Malone (1962a), Randal (1962, 3)
Middle Cambrian	Tindall Limestone	500	Lutitic and crystalline limestone, with nodules and bands of chert; some sandstone and arkose in places	Periphery of Daly R. Basin: Pine Ck, Fergusson R., and Katherine Sheets	Tindall airfield S.E. of Katherine, lat. 14°32′S., long. 132°22′E., best exposures N.E. of Katherine	Basal unit of 'Daly River Gp'; unconformably overlies L. Proterozoic, Carpentarian, and Adelaidean rocks, and disconformably overlies Antrim Plateau Volcanics	Öpik (1956), Malone (1962a), Randal (1962, 3)
Lower Cambrian	Antrim Plateau Volcanics	200	Vesicular and fine-grained basalt; some dolerite, tuffaceous sandstone	Discontinuous belts on W. and S.E. margins of Daly R. Basin, and isolated outcrops at Collia and in headwaters of Fitzmaurice R.: Pine Ck, Fergusson R., and Katherine Sheets	Antrim Plateau in Ord-Victoria region (Traves, 1955); best exposures in Katherine-Darwin Region are around Collia and S. of Flora R.	Unconformably overlies L. Proterozoic, Carpentarian, and Adelaidean rocks	Traves (1955), Malone (1962a), Randal (1962, 3)
	Witch Wai Conglomerate	30	Boulder and pebble conglomerate; some sandstone	Headwaters of Reynolds R. on Daly R. track and N. end of Rock Candy Range: Pine Ck Sheet	Witch Wai Ck, Rock Candy Range, lat. 13°50′S., long. 130°55′E.	Minor local valley-fill deposits overlying Tolmer Gp	Malone (1962a)

Lower Cambrian(?)

The two rock units — Witch Wai Conglomerate and Antrim Plateau Volcanics — assigned to the Lower Cambrian in the Katherine-Darwin Region unconformably underlie fossiliferous Middle Cambrian strata and unconformably overlie the Tolmer Group. As the age of the Tolmer Group is inferred only by indirect correlations with other areas, the range in time of the rocks described here as Lower Cambrian has not been established.

Witch Wai Conglomerate

The Witch Wai Conglomerate is composed of boulders and pebbles in a ferruginous sandstone matrix. It overlies the Buldiva Sandstone and Waterbag Creek Formation; the boulders and pebbles are unsorted and have been derived from the underlying formations.

Ten feet of conglomerate overlies the Depot Creek Sandstone Member near the junction of the Stapleton track and the Daly River road. Near the headwaters of Hayward Creek (Pine Creek Sheet area), the formation overlies the Stray Creek Sandstone Member, and the boulders consist of angular fragments of the flaggy sandstone characteristic of this member; the conglomerate is overlain by the Antrim Plateau Volcanics. At the northern end of the Rock Candy Range it overlies both the Stray Creek Sandstone and the Waterbag Creek Formation.

The maximum thickness of the Witch Wai Conglomerate is 30 feet. It is most probably a local conglomerate produced by scouring and filling.

Antrim Plateau Volcanics

In 1912, Woolnough examined the basalts between Edith River and Maude Creek, and considered them to be older than Cambrian; Jensen (1915b) regarded them as Permo-Carboniferous; Noakes (1949) followed Woolnough's interpretation and placed the volcanics to the north-west of Katherine below the Cambrian sediments. He has described a locality north-west of Katherine where Cambrian limestone overlies tuffaceous sandstone and intercalated basalt. However, he did not realize that the volcanic rocks near Edith River are a different suite from those in the immediate vicinity of Katherine. Rattigan & Clarke (1955, unpubl.) mapped both areas and placed the volcanics near Edith River in the Upper Proterozoic (now Carpentarian) and the basalts which crop out between Helling Hill and Maude Creek in the Lower Cambrian; they named the latter Leight Creek Volcanics. Petrologically, the volcanic rocks are identical with those on the western side of the Daly River Basin, and they occupy the same stratigraphic position. Our map shows Rattigan & Clarke's 'Leight Creek Volcanics' as Antrim Plateau Volcanics.

Hossfeld (1937c) and Voisey (1939) refer to a sequence of volcanic rocks in the Collia and Buldiva areas as the Collia Series; this was later changed by Noakes (1949) to Collia Creek Volcanics. Both Hossfeld and Voisey noted that the volcanic rocks are younger than their Buldiva 'Quartzite' and are overlain by the 'Plateau Sandstone' of Jurassic age (now the Lower Cretaceous Mullaman Beds). They therefore placed the volcanics between the Cambrian and Jurassic. Voisey, however, suggested that the Collia Series was possibly contemporaneous with the volcanic rocks near Katherine and also with those in the Victoria River area. Because of his belief that the 'Buldiva Series' extended into the Cambrian, Voisey regarded all the volcanics as post-Cambrian.

Noakes (1949) agreed with this correlation, but disagreed with the age proposed and correctly (we believe) correlated the volcanics with Lower Cambrian Antrim Plateau Volcanics of Matheson & Teichert (1946) in the Kimberley area.

In the Katherine area the Antrim Plateau Volcanics can be traced in a discontinuous belt from 5 miles south of the Edith River Crossing, beyond Maranboy to east of Elsey homestead on the Roper River. The formation contains basaltic and doleritic rocks with well bedded brown tuffaceous sandstone and a thin basal conglomerate in places. Near Helling Hill, north of Katherine, conglomeratic brown sandstone interbedded with basalt overlies the Burrell Creek Formation with a marked angular unconformity. Rattigan & Clarke (1955, unpubl.) have described the contact between the Edith River Volcanics and the Cambrian volcanics in the Leight Creek area where thin 'horizontal' conglomerate, sandstone, and interbedded basalt unconformably overlie folded Edith River Volcanics; in the Waterhouse River/Roper River area, the Antrim Plateau Volcanics unconformably overlie the Mount Rigg and Roper Groups.

In the Collia-Buldiva area, the Antrim Plateau Volcanics unconformably overlie the Lower Proterozoic sediments, granite, and all units of the Tolmer Group. Voisey has described the rocks as basic to intermediate volcanics and tuff with a basal 'quartzite' containing beds of arkose probably derived from the Soldiers Creek Granite.

The basal 'quartzite' is not everywhere present. To the west of Collia the volcanics overlie the Depot Creek Sandstone Member, and the base of the formation contains large angular and rounded blocks of pink quartz sandstone picked up by the moving flow (Pl. 20, fig. 1).

East of Collia the volcanics are covered by Lower Cretaceous rocks on the Wingate Plateau. They reappear on the eastern margin of the plateau in the headwaters of Lilyarba and Bamboo Creeks, where they appear to fill narrow erosion valleys in the surface of the Depot Creek Sandstone Member.

Between Lilyarba Creek and the headwaters of Bradshaw Creek, the volcanics unconformably overlie the Waterbag Creek Formation; the basalts fill erosion valleys, and the relief of the old land surface on which they were deposited is in places 120 feet.

The unconformity between the Antrim Plateau Volcanics and the Tolmer Group is also evident north of the Rock Candy Range. South of the Daly River, the trend of the volcanics is parallel to the strike of the Tolmer Group, i.e., north-west to north-north-west. However, north of the Daly River, near the Rock Candy Range, the strike of the Tolmer Group swings north and north-north-east, but the volcanic belt maintains a north-westerly trend, and transgresses the Waterbag Formation, the Hinde Dolomite, and the Stray Creek Sandstone Member.

Outcrops of basalt similar to the Antrim Plateau Volcanics have been mapped around the headwaters of the Fitzmaurice River, where they rest unconformably on the Buldiva Sandstone and units of the 'Victoria River Group'.

The Antrim Plateau Volcanics are overlain by fossiliferous Middle Cambrian limestone with a slight disconformity. The relationship is best observed in the eastern part of the Daly River Basin. Four miles east of Katherine Aerodrome fossiliferous limestone overlies a fine-grained brown tuffaceous sandstone which, nearby, is interbedded with basaltic rocks. In the same area, limestone directly overlies medium-grained basalt.

The Cambrian lavas are tholeiitic throughout the Katherine-Darwin Region, but textural variations are common. The plagioclase ranges from andesine to labradorite, and is associated with pigeonite; olivine is scarce or absent. Traces of ilmenite have been noted. Prehnite and sulphate minerals are common. The lavas range from fine-grained basalts to coarse-grained ophitic dolerites; they may be porphyritic or amygdaloidal.

The thickness of the Antrim Plateau Volcanics in the Katherine-Darwin Region appears to be everywhere less than 200 feet. Near Katherine it is less than 100 feet, and the thickness exposed in individual outcrops may range from 20 to 100 feet. There appears to be only one flow in this area. Traves (1955) records 3000 feet, consisting of a number of flows, in the Antrim Plateau area of the Ord-Victoria region.

The amygdaloidal or vesicular varieties of basalt appear to be restricted to the top of the unit. Traves reports a similar feature in the Ord-Victoria region.

Minor mineralization occurs in the Antrim Plateau Volcanics 13 miles west-north-west of Tipperary homestead, where malachite and azurite occur in basalt near the contact with underlying ferruginous sandstone. Traves (op. cit.) records copper staining and mineralization in the main mass of the volcanics. Veinlets of quartz and barite occur in many places, and the vesicles and other cavities in the basalt are commonly filled with quartz, barite, chlorite, gypsum, carbonates, and zeolites.

Near Katherine, and the Roper and Flora Rivers, the basalt forms areas of high-level, poorly drained, cracked black soils with scattered boulders or slabs of basalt or brown tuffaceous sandstone, and pebbles of quartz and gypsum.

Vegetation is generally sparse and stunted. Elsewhere the basalt crops out as low rocky hills with rounded contours. Vertical and horizontal jointing is well developed (Pl. 20, fig. 2).

Cambrian and Ordovician

The presence of Cambrian sediments in the Daly River area was established by Etheridge (1906), who described the fossiliferous limestone found by H. Y. L. Brown 2 miles west of Noltenius Billabong. He identified *Salterella* (*Biconulites*) *hardmani,* and inferred that the rocks were probably Middle Cambrian. Tenison Woods (1886) had previously described the limestones around Katherine, but did not date them. The Ordovician strata were not recognized until 1964. Gray & Jensen (1915) erroneously described rocks near Maranboy as Cambrian but did not name any formations, and Walpole (1958a) followed them. Jensen (1915b) recorded Cambrian rocks around the Katherine and Flora Rivers. Wade's map (1924) shows Cambrian sediments to the north of the Daly River.

Voisey (1938) referred to the Cambrian sediments as the Daly River Limestones and, following Hossfeld's (1937c) concept of the Buldivan Series, he regarded them as Lower Cambrian and conformable with the 'Buldiva Quartzite'. Voisey (p. 149) states 'the overlying calcareous beds consist mainly of bluish-grey limestones, with other fine-grained sediments and occasional sandstones. The limestones contain abundant remains of marine fossils, but these are generally fragmental and difficult to collect. More common are Cryptozoans, including *Girvanella,* which, in some places, occupy whole bands of the limestone'.

Noakes (1949) recognized that the sandstone and shale components of Voisey's Daly River Limestone were not minor constituents; he considered that detailed mapping would show the existence of units of the rank of formation, and changed the name to Daly River Group — of upper Lower Cambrian age.

Öpik (1956) listed the fossils then available from the limestone and assigned a lower Middle Cambrian age to them. He also refers to the paper by Etheridge (1906) reporting the occurrence of *Biconulites hardmani,* but erroneously attributes fragments of *Redlichia* to Etheridge's list; *Redlichia* is, however, widespread in the area. Öpik mentions the discovery by A. D. M. Bell (1953, unpubl.) of ptychopariids in the Elsey area, and Walpole (1958a) refers to fossil determinations made by Öpik on a collection from near Maranboy.

We used 'Daly River Group' on the relevant published 1 : 250,000 maps of the Katherine-Darwin Region (Malone, 1962; Randal, 1962, 1963). All show the group as Middle Cambrian. This is only partly correct. In 1964, geologists of Australian Aquitaine Petroleum Pty Ltd discovered fossils within the unit named by Randal (1962) the Jinduckin Formation, which were identified by Öpik (1966) as Lower Ordovician in age. We do not know the precise boundary of the Ordovician strata in the Daly River Basin, but at this stage of the mapping of northern Australia it appears that correlation or connexion of these rocks with the sequence in the Georgina Basin of central Australia and with some of the rocks in the Ord-Victoria region will be possible. In this Bulletin therefore we have discontinued the formal use of Daly River Group and refer to it informally. The nomenclature of the formations listed by Randal and by Malone (op. cit.) must also be regarded as subject to modification. We do not attempt to define them here.

The Lower Palaeozoic sediments of the Daly River area occupy a structural basin called the Daly River Basin by Noakes (1949) (Daly Basin of Condon et al., 1958). It is over 150 miles long and 40 to 60 miles wide, with the long axis trending north-west; it is drained by the Daly River and its tributaries in the north, and by tributaries of the Roper River in the south. The margins of the basin are formed by the Tolmer Group to the west and north-east; to the north by Lower Proterozoic rocks; to the east by Lower Proterozoic rocks, and by the Katherine River, Mount Rigg, and Roper Groups, together with a basinward fringe of discontinuous outcrops of the Antrim Plateau Volcanics. The southern limits are unknown.

The rocks include limestone, sandstone, shale, and siltstone, and have been divided by Randal and by Malone into three formations: the Tindall Limestone, Jinduckin Formation, and Oolloo Limestone. The Tindall Limestone is Middle Cambrian, and the boundary between the Cambrian and Ordovician strata appears to be somewhere within the 'Jinduckin' rocks. Not more than 200 feet of sediment is exposed at any one point and no type sections are available. The nature, size, and distribution of outcrops depend on the lithology. The massive fluted and pinnacle limestone, such as near Katherine and in the northern part of the basin, crops out as karst hills with local relief up to 100 feet, and contrasts with thin-bedded calcareous and arenaceous rocks, which are exposed as low rises and as lines of scattered slabs extending over large areas. The siltstone commonly crops out in creek banks or, less commonly, on hill exposures where it is interbedded with more resistant sediments.

The Middle Cambrian rocks unconformably overlie and are in contact with Lower Proterozoic rocks, the Carpentarian Mount Rigg Group, and the Adelaidean Tolmer and Roper Groups. The unconformity below them postulated by Noakes (1949) has been confirmed by this survey.

On the northern and north-eastern edge of the basin they overlie Lower Proterozoic rocks. On this point Noakes states: 'If the two groups (i.e., the Palaeozoic limestones and the 'Buldiva Quartzite') are conformable then the Cambrian limestones must have overlapped the Buldiva Quartzite, but this supposition appears untenable when the distribution of the Buldiva Quartzite in this region is taken into account.' Although Noakes erroneously thought that the Buldiva Sandstone extended farther to the east, it is still apparent that the Tolmer Group underlies much of the northern part of the Daly River Basin. The Buldiva Sandstone is thickening northwards at the point where it is cut off by the Hayes Creek Fault;

this indicates a period of faulting and erosion before the limestones were laid down, as they are not affected by the fault.

In the Adelaide River south branch area, north of the Daly River road, scattered outcrops of Cambrian limestone transgress the strike of the Tolmer Group. They were deposited in embayments in an old land surface cut into the Tolmer Group.

The Antrim Plateau Volcanics rest unconformably on the Tolmer Group. In the Mathison Creek and Moon Boon (Bamboo) Creek areas, Cambrian limestone overlies the volcanics with a slight disconformity. Basalts appear to dip under Cambrian limestone south of the junction of the Stapleton track with the Daly River road. Traves (1955) reports that the Montejinni Limestone, of Middle Cambrian age, probably overlies the Antrim Plateau Volcanics. The lithology and the geographical distribution of the unit strongly suggest that it is a southerly extension of the Tindall Limestone.

The major faults cutting the Tolmer Group — Hayes Creek Fault, Rock Candy Fault, Giants Reef Fault, and Adelaide River Fault — have no apparent effect on the Cambrian strata. In some areas they appear to have controlled Cambrian sedimentation, but nowhere have they been seen to displace the Cambrian beds.

The fossils in the Tindall Limestone are lower Middle Cambrian, but the *Collenia* and jellyfish in the upper beds of the Tolmer Group indicate an 'Upper Proterozoic' age. Diagnostic Lower Cambrian fossils have not yet been found in the Katherine-Darwin Region, and Lower Cambrian time may therefore be represented only by the Antrim Plateau Volcanics.

The Palaeozoic strata contain no coarse basal beds and this, together with the conformity of dips, has been one factor leading to the original belief that the sequences were conformable. Other probable reasons are the possible incorrect correlation of Hinde Dolomite and Tindall Limestone; and non-recognition of the interposition of Antrim Plateau Volcanics between the Tolmer Group and Cambrian limestone.

As with the Tolmer Group, most dips in the Palaeozoic strata appear to be depositional.

Tindall Limestone

The basal unit of the Middle Cambrian sequence is the Tindall Limestone, which crops out as a narrow discontinuous belt around the basin. In the south-eastern part of the region its area of outcrop is much wider, and horizontally bedded limestone extends south of Elsey homestead and Mataranka, eventually disappearing under the sand, laterite, and Cretaceous cover on the Wiso Tableland (Hossfeld, 1954). The Montejinni Limestone (Traves, 1955), which crops out along the Wave Hill road, appears to be the southern extension of the Tindall Limestone on the western side of the basin.

The formation consists mainly of fine-grained and coarsely crystalline limestone, with some lenses of sandstone and siltstone. Bands and nodules of chert are common throughout. The black fine-grained limestone smells strongly of hydrogen sulphide when struck with a hammer. The limestone in places is jointed horizontally and vertically, and a characteristic karst topography is developed on it (Pl. 21, fig. 1). Ironstaining and concretions are common on the surface of the limestone. In the Katherine and Maranboy areas a white sugary 'sandstone' mixed with fragments of chert is a common surface weathering product on the limestone; it is caused by the replacement of the lime by silica. In places this 'sandstone' resembles the sandstone of the Cretaceous Mullaman Beds, and it is possible that small outcrops which have been mapped as residuals of the Mullaman Beds are in fact altered Cambrian rocks. Arkose occurs at the base of the unit where it overlies granite.

At Tindall Aerodrome, 8 miles south-east of Katherine, slabs of a grey and white crystalline and fossiliferous limestone are scattered over a wide area of plain. Less than 20 feet of section is exposed in this locality. The best outcrops of the Tindall Limestone are along the railway north-west of Katherine, along the old track from Katherine to Maranboy, and in the Tipperary and Roper River areas.

Springs, sinkholes, and caves are common. In the large outcrops, solution cavities and cave-ins, up to 30 feet deep, are common, and much larger caves exist in places. Brown (1895) refers to the Kintore Caves north-west of Springvale homestead. This station no longer exists, but from the description in Brown's journal it was a few miles upstream from Manbulloo homestead on the Katherine River. Extensive caves 16 miles south-east of Katherine have been reported by the townspeople, but the entrance is difficult to locate in the tall grass, and the caves were not examined during the recent survey. A sinkhole alongside the main street in Katherine acts as a natural stormwater drain.

Warm springs occur at Mataranka and on the Douglas River, where they are associated with minor faults in the Cambrian limestone.

The majority of the fossils recovered from the Tindall Limestone have been examined by A. A. Öpik (BMR), who has reported the following genera: *Girvanella, Biconulites hardmani, Lingulella, Obolus, Paterina, Acrotreta, Chancelloria, Helcionella, Hyolithes,* fragments of *Redlichia* and *Xystridura,* and unidentified ptychopariids.

Öpik (1956) has reported the discovery near Elsey of ptychopariids, which indicate the probable existence of rocks younger than the *Redlichia* beds.

During the recent mapping ptychopariids were also found near Mount Litchfield, in an horizon above the beds in the same area containing *Redlichia*. *Paterina*-like brachiopods occur in the same beds, which consist of fine to medium-grained buff and yellow siltstone, overlying limestone. The Palaeozoic rocks in the Mount Litchfield area were previously examined by Noakes (1949), who named them the Elliott Creek Formation, a name we do not use, because of their identity with the rocks in the Daly River Basin proper. He found no evidence of their exact age, but because of their similarity to both the Cambrian and Permian sandstones near Port Keats, marked them on his map as Palaeozoic. The recent fossil discoveries show that part of the beds are equivalent to the Tindall Limestone (Gatehouse, 1968). The upper beds of the 'Elliott Creek Formation' consist of ferruginous sandstone and siltstone with halite pseudomorphs and are similar to the 'Jinduckin Formation', which in the Daly River Basin overlies the Tindall Limestone.

'Jinduckin Formation'

The sequence referred to by Randal (1962) as 'Jinduckin Formation' consists of ferruginous sandstone, siltstone, silicified limestone, and dolomite. Halite pseudomorphs are common throughout the sequence, and have been previously referred to by Öpik (1956), who saw them in shale interbedded with dolomite west of Katherine. Siltstone, interbedded with dolomite and ferruginous sandstone with halite pseudomorphs, occurs in Station Creek north of Tipperary homestead and in the Gypsy Creek area; and siltstone and sandstone occur extensively in the Jinduckin Creek area.

The sequence crops out in low hills and mesas; the siltstone beds commonly occur as rubble-covered rises or as eroded outcrops in the creek beds. In places the beds are covered by a protective cap of lateritized Lower Cretaceous Mullaman Beds, and with them form prominent hills rising up to 180 feet above the general level of the plain. Noakes (1949) records 150 feet of alternating flaggy silicified limestone and sandstone near the old Daly River road. He believed that they were the basal beds of the 'Daly River Group'; however, on an adjoining mesa the same beds rest conformably on 50 feet of black oolitic and crystalline fossiliferous limestone which is considered to represent the upper part of the Tindall Limestone (Pl. 21, fig. 2).

Silicified lenses of dolomite and limestone are predominant near Manbulloo homestead, and also north-west of Dorisvale homestead. They can be mapped as a separate unit, which is tentatively called the *Manbulloo Limestone Member.* It is commonly more resistant to erosion than the interbedded sandstone and siltstone, and forms prominent hills, rising to 200 feet above the plain, with characteristic benches and platforms formed by erosion of the interbedded sandstone. North-west of Manbulloo the member interfingers with other rocks of the Jinduckin sequence.

From the description given to Öpik (1968) by the Aquitaine Petroleum geologists we conclude that the Ordovician fossils in the Daly River Basin came from the 'Jinduckin Formation', but we are not able to determine where in the sequence.

Oolloo Limestone

Near Jindare homestead, west of Oolloo homestead, and along the Cullen-Claravale track near Dead Horse Creek, the Jinduckin sequence is conformably overlain by flaggy pink and grey silicified limestone named the Oolloo Limestone. It is shown on previous maps as Middle Cambrian, but it is now believed to be Ordovician.

PERMIAN AND TRIASSIC

The Bonaparte Gulf Basin was not visited during this survey, and the boundaries of the Permian rocks in the basin in the Katherine-Darwin Region are taken from those of Noakes (1949). A survey of this basin is currently (1966) in progress.

The Permian strata rest unconformably on the Precambrian Chilling Sandstone and the Litchfield Complex, and dip gently off them about 5° to the west. Noakes (p. 25) records outcrops of sandstone and sandy shale at Mount Greenwood and inland from the coast at Red Cliffs, but most of the area is covered by Recent alluvium. The best section available is in the Port Keats area, 40 miles west of the western boundary of the Katherine-Darwin Region. The summary below has been taken from the most recent publication on the area (Thomas, 1957).

In the Port Keats area, the Port Keats Group dips gently westward, and unconformably overlies the Precambrian in the east. Outcrops consist of sandstone and siltstone, commonly ferruginized. Thomas recognized four fossil assemblages in the Permian: at the base, brachiopods and marine molluscs, succeeded by land plants (including *Glossopteris*), and a second brachiopod and molluscan assemblage, which passes upwards into beds with old haminid brachiopods. These assemblages indicate correlation with the Liveringa Formation of the Fitzroy Basin.

Grey and yellow cross-bedded siltstone overlies the Permian at Hyland Bay, 15 miles north-north-east of Port Keats Mission. No fossils have been found in outcrop, but in one of the Cape Hay bores similar rocks are correlated on the basis of estheriids with the Triassic Blina Shale of the Fitzroy Basin.

Cretaceous sediments overlie the Permian sediments, presumably unconformably, in the Docherty Hills, in the Katherine-Darwin Region, 50 miles west-south-west of the Daly River Police Post (Pl. 28).

MESOZOIC *(by S. K. Skwarko)*

Mesozoic rocks crop out over most of the Katherine-Darwin Region mainly as isolated residual mesas, or as broad flat tablelands (Pl. 22, figs 1 & 2). They

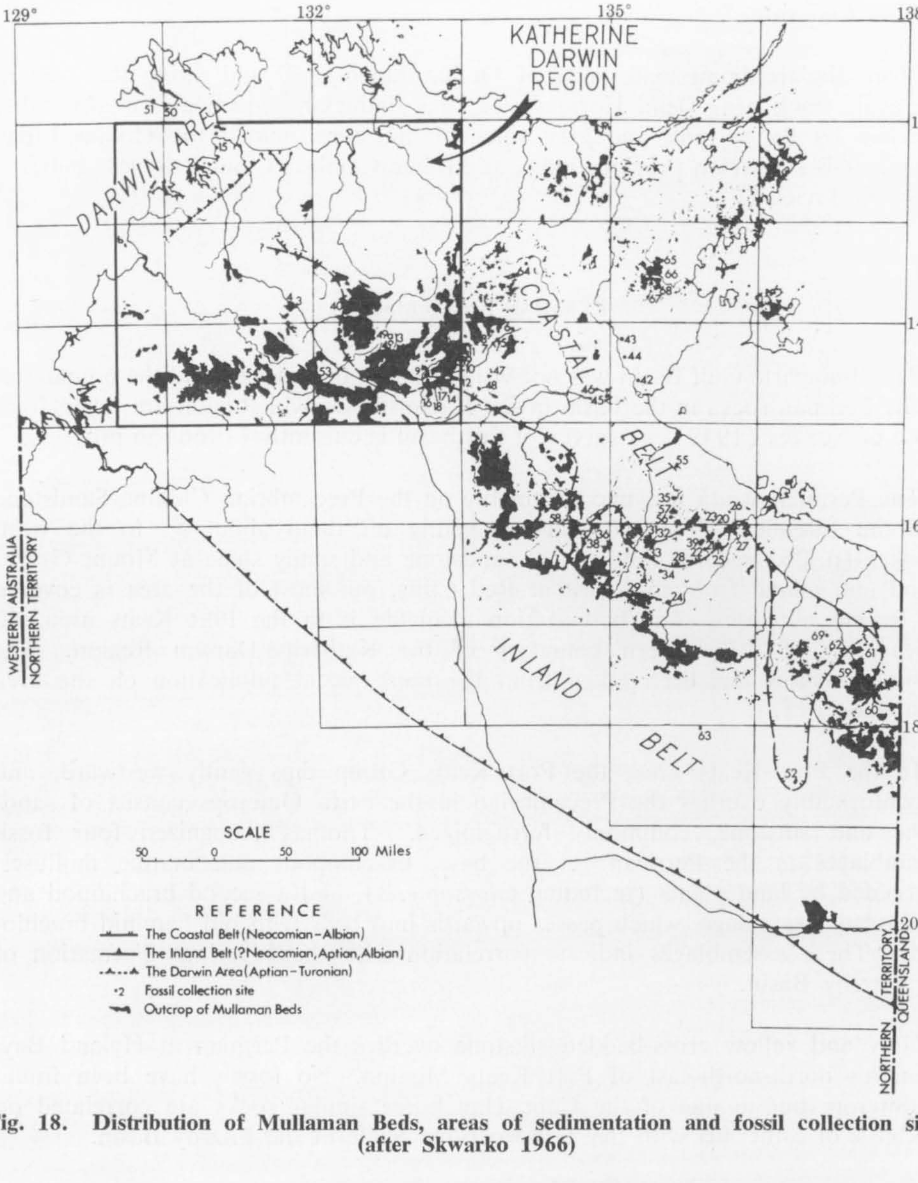

Fig. 18. Distribution of Mullaman Beds, areas of sedimentation and fossil collection sites (after Skwarko 1966)

are Lower Cretaceous in age, have a maximum thickness of about 200 feet (near the head of the South Alligator River), and have not been folded — although in a few places they are cut by minor faults. Both non-marine and marine facies are present. The rocks are commonly strongly lateritized.

Noakes (1949) named these rocks the Mullaman Group, but they are now known as the Mullaman Beds. They form part of a very much wider province covering much of northern Australia, which probably represents a cratonic platform bordering the Indonesian Mesozoic geosyncline.

PLATE 9.

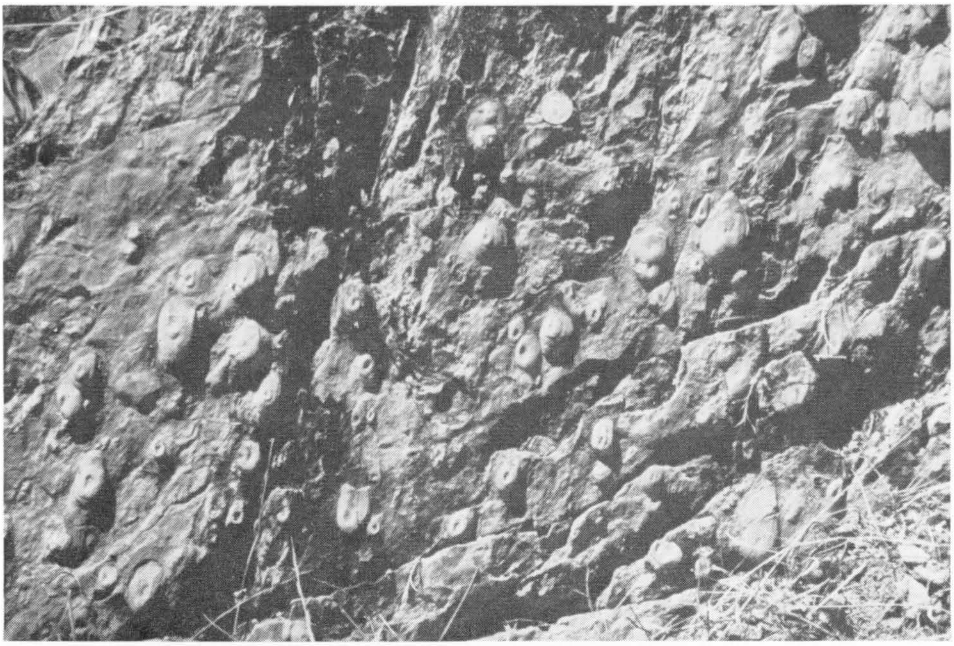

Fig. 1: Sand volcanoes in greywacke of Noltenius Formation, 2 miles west of Adelaide River, Pine Creek Sheet.

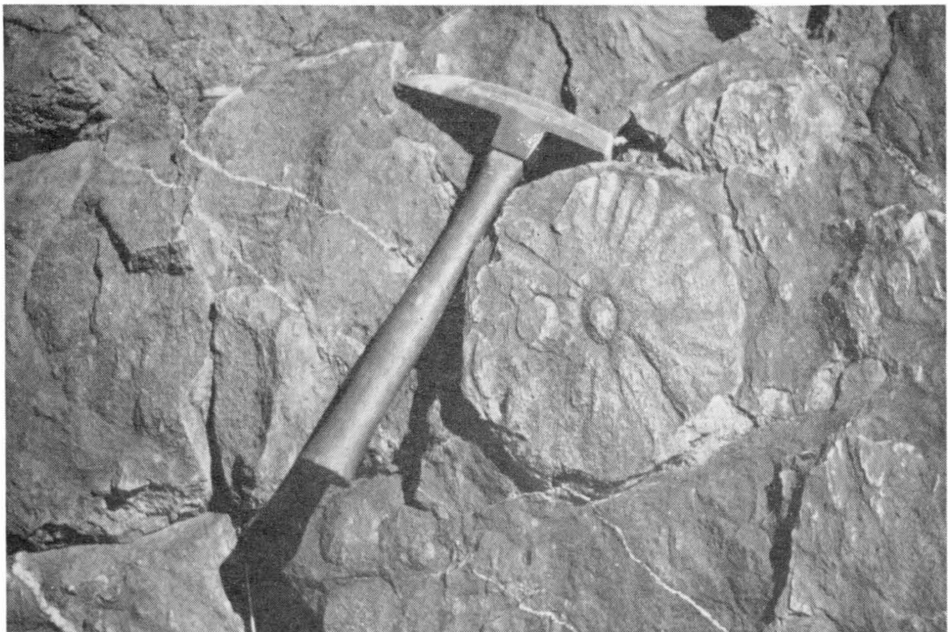

Fig. 2: Problematicum in greywacke of Noltenius Formation, near George Creek uranium mine, Pine Creek Sheet (after Robertson 1962).

PLATE 10.

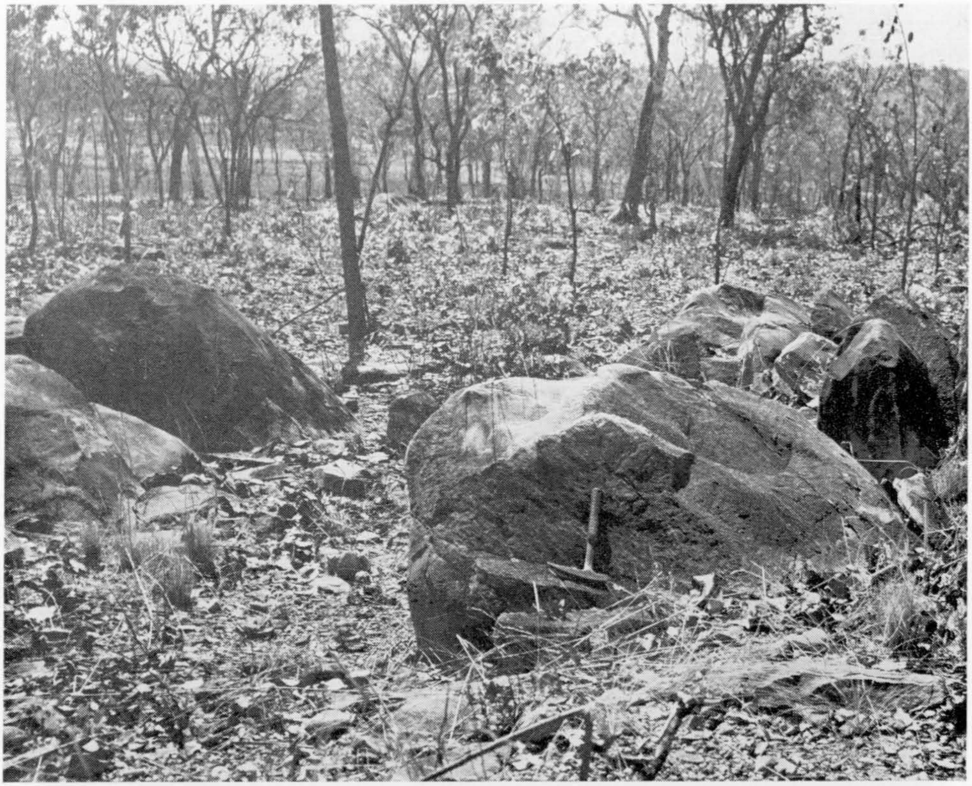

Fig. 1: Typical exposure of tombstone greywacke, Burrell Creek Formation, Mary River area, Mount Evelyn Sheet.

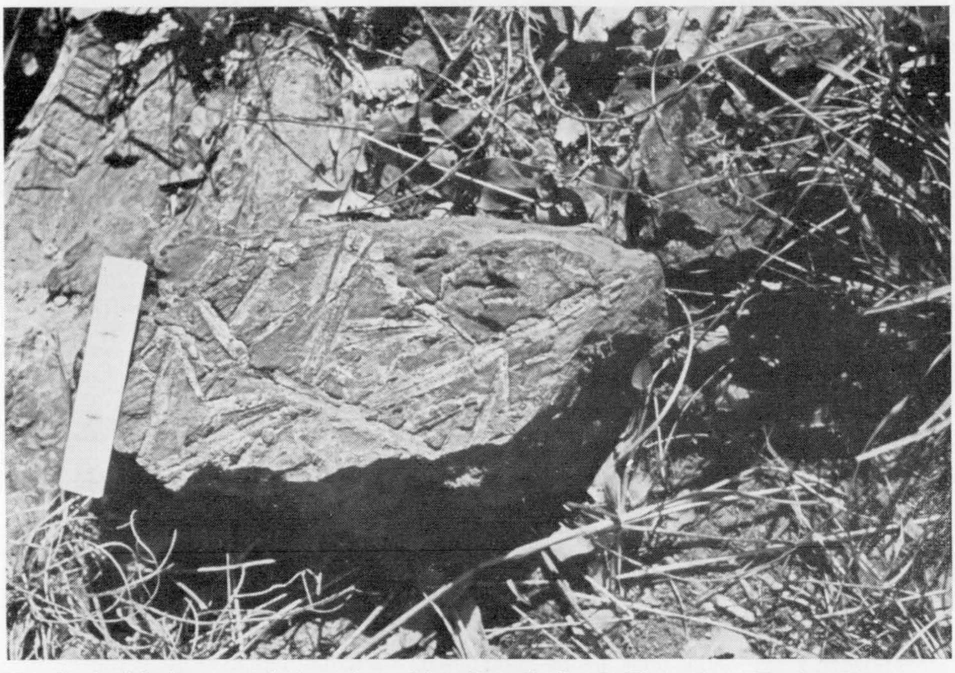

Fig. 2: Andalusite crystals in mica schist, Burrell Creek Formation, Finniss River area, Darwin Sheet.

PLATE 11.

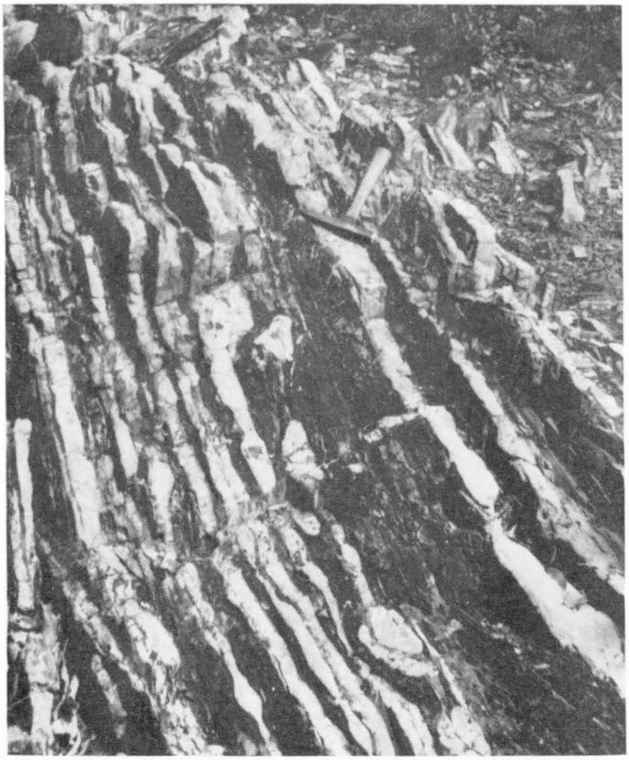

Fig. 1: Pyritic carbonaceous siltstone with bands, lenses, and nodules of chert, Koolpin Formation, South Alligator River area, Mount Evelyn Sheet.

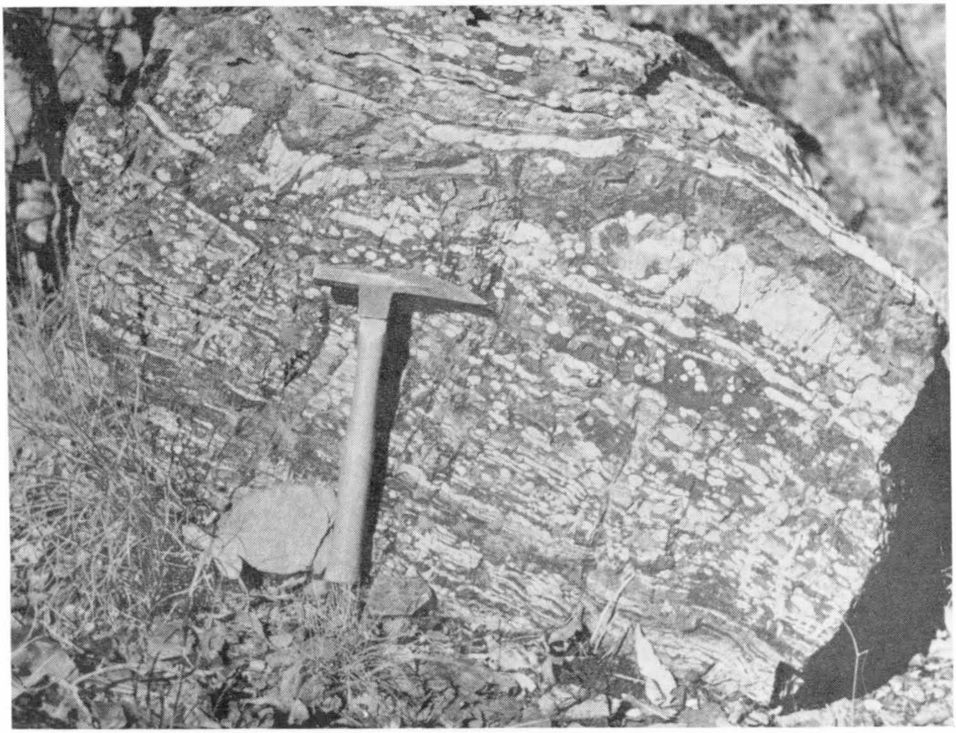

Fig. 2: Koolpin Formation, South Alligator River area, Mount Evelyn Sheet. Outcrop near Rockhole mine and in the same area of outcrop as Figure 1 above. Together these photographs show the variations in the nodular rock type.

PLATE 12.

Fig. 1: Poorly preserved algae, Pul Pul bioherm, South Alligator River area, Mount Evelyn Sheet. Vertical section.

Fig. 2: South Alligator River Valley looking south from near the Saddle Ridge uranium mine. Pul Pul volcanic neck in the middle distance with the twin peaks of Coronation Hill behind. Steeply dipping Koolpin Formation in the foreground is overlain by Scinto Breccia in the foreground ridge. Kombolgie Formation sandstone on the edge of the Callanan Basin forms the escarpment on the extreme right. Maximum relief is about 500 feet.

The first comprehensive study of the stratigraphy of the Cretaceous rocks of the Northern Territory was made in 1960-62, and its results were published recently (Skwarko, 1966). This survey covered an area of about a quarter of a million square miles and, therefore, did not include much detailed work: the collecting sites were scattered, and later work may well modify the conclusions. Nevertheless, a coherent picture of the complex events represented in the sporadic outcrops of Cretaceous rocks is apparent, and is here summarized in relation to the Katherine-Darwin Region.

On lithogenetic and palaeontological grounds the rocks are divided into three sequences differing in provenance and geological history. Parts of all three sequences are found in the Katherine-Darwin Region. The 'Darwin Area', a small area of outcrops of upper Albian or lower Cenomanian marine rocks, includes the coast around Darwin (Fig. 18); and the two main sequences, the 'Coastal Belt' and the 'Inland Belt', are separated by a line running sinuously, but on the whole diagonally, from north-west to south-east of the region (see Figs 18 and 19).

The 'Coastal Belt' sequence is divided into seven units, ranging from Neocomian to early Albian, and the 'Inland Belt' into three, which are mainly Aptian and early Albian, but may also range from the late Neocomian (Fig. 19). Not all the units of both suites are represented in the Katherine-Darwin Region; the collecting sites (listed, with their fossils, in Appendix 4) almost all lay in 'Unit 2' of the Coastal Belt, and 'Unit A' of the 'Inland Belt'.

Previous Work

The first fossils found in what were later to be known as Cretaceous rocks were some Radiolaria from Fanny Bay, Darwin, listed by Hinde (1893); but they did not yield an unequivocal age. Two years later, Etheridge (1895) described, and dated as Lower Cretaceous, ammonites and other fossils collected by Brown at Point Charles, near Darwin. In later papers, Etheridge (1902, 1904, 1907) described other collections from the coast around Darwin, which he ascribed to a common zone in the Lower Cretaceous.

Brown, whose collections Etheridge described, was the first geologist to map and describe in detail outcrops of Mesozoic rocks both on the coast and inland (Brown, 1895, 1908; Brown & Basedow, 1906); he correlated outcrops at Pine Creek and Katherine with those at Darwin. Woolnough (1912) followed the same pattern of correlation, but Jensen (1914, 1915b) regarded the inland rocks ('Plateau Sandstone') as the equivalents of the 'Borroloola Beds', which he thought to be Permo-Carboniferous.

Walkom (*in* Hossfeld, 1937c) identified a plant from Buldiva as *Otozamites bengalensis,* whose range at that time was thought to be limited to Jurassic, and this led Voisey (1938) to consider the inland plant-bearing sediments as Jurassic. Noakes (1949) restored the plant-bearing beds to the Lower Cretaceous, and mapped them as an unnamed lower (lacustrine) unit of a Cretaceous unit which

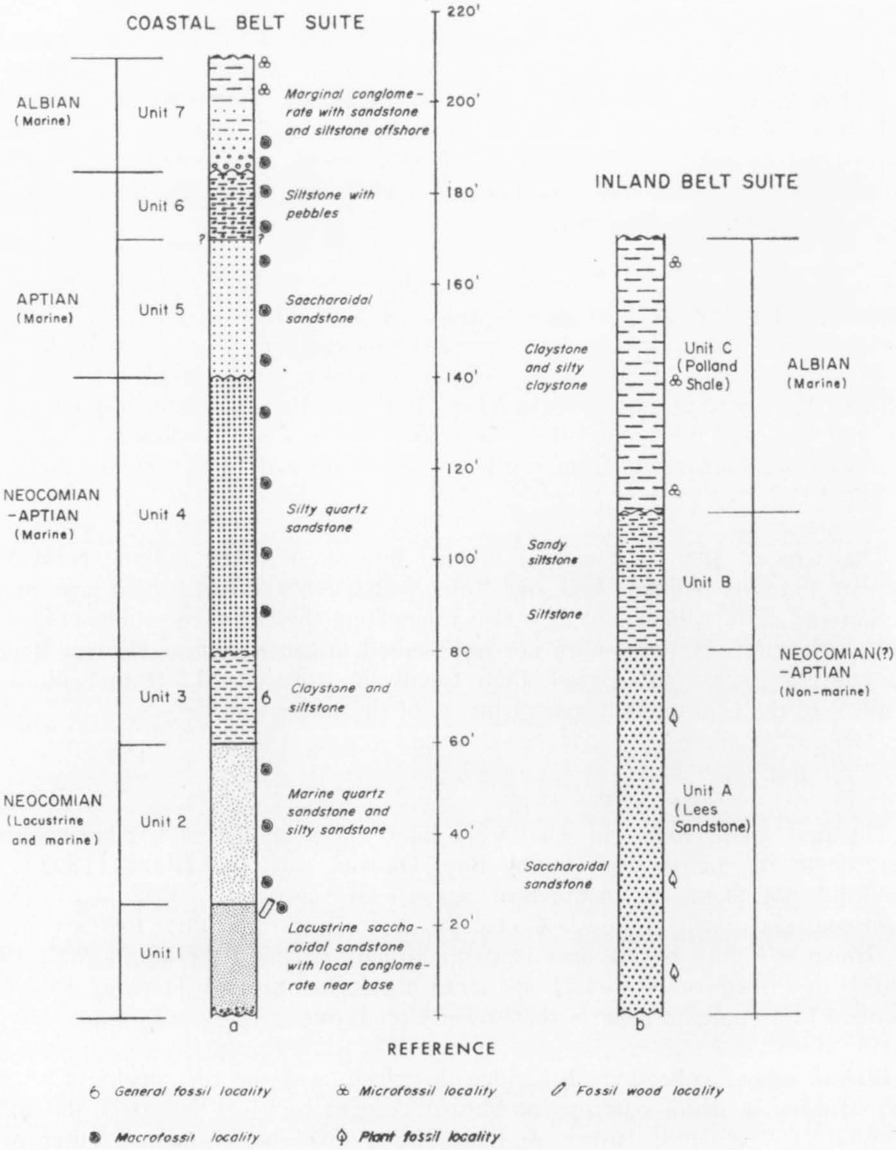

Fig. 19. Composite sections of Coastal and Inland Belt suites

he called the Mullaman Group — a name which, amended to the less formal 'Mullaman Beds', has persisted. Noakes correlated the lower unit of the Mullaman Group with part of the Blythesdale 'Series' of central Queensland, and the upper, marine unit, which he called the Darwin Formation, with part of the Roma 'Series'. Walpole (1958a) accepted this interpretation of the beds at Maranboy; but Hossfeld (1954) returned to the suggestion that deposition of the Mullaman Beds may have begun in late Jurassic time and continued into the Lower Cretaceous.

Finally, my effort to resolve the differences of opinion resulted in a fairly comprehensive survey, and, as can be seen from Figure 19, the entire sequence was dated as Lower Cretaceous. Lloyd (1967) has made a further study of Radiolaria from the Darwin area, but has not been able to make any definite age correlations.

Lithology and Structure of the Mullaman Beds

The sections on Melville and Bathurst Islands are considerably thicker than those on the mainland; they are slightly inclined and, except for sections exposed by wave-action, are covered by a continuous layer of younger sediments. The mainland sediments, on the other hand, are thin, flat, and scattered remnants of what were once extensive sheets. They consist of conglomerate, sandstone, siltstone, and claystone, and few single sections are more than 120 feet thick. Only in a few places are they covered by younger sediments, which mostly consist of their weathering products.

Although an unknown, but probably not very great, thickness and large area of the mainland Mullaman sediments has been removed by erosion and weathering — mostly by successive scarp retreat of individual layers — the flatness of the upper erosion surface is in most cases maintained. This is due to the near horizontal bedding and vertical preferential splitting planes, which ensure steepness of eroded edges and give rise to mesa-type topography so characteristic of areas where Cretaceous rocks crop out (Pl. 22, fig. 2; Pl. 26, fig. 2). Porcellanites which develop on the fine-grained Cretaceous sediments by excessive impregnation with silica form a resistant cover, and may have been partly instrumental in the formation of the mesa topography.

Cretaceous sediments have been laid down on a surface of considerable relief. They have been exposed for a long time to weathering and erosion; lateritization, ferruginization, and silicification have all left their imprint, but very markedly in degree in the different parts of the area. Folding, even of non-tectonic origin, is not common, and faults other than small-scale gravitational slips are seldom observed. But the crust sagged in the Inland Belt in (?)Neocomian and Aptian times, and was uplifted again in the late Aptian. Since the margins of the Inland Belt correspond fairly closely to those of the earlier Daly River Basin, it seems possible that these movements occurred along rejuvenated faults.

The coarser marine sediments appear to have been laid down in shallow water; many of the sandstones are graded, and cross-bedding is common in both marine and lacustrine deposits, though ripple marks are rare.

The Coastal Belt

Cretaceous sediments in the Katherine-Darwin section of the 'Coastal Belt' belong to Unit 2. Unit 2 consists of up to 35 feet of saccharoidal sandstone, silty quartz sandstone, and some conglomerate. In most outcrops the sandstone is fairly pure, loosely packed, and saccharoidal. It has an admixture of grains of larger or smaller size, which are concentrated in lenses or occur individually throughout the sequence. Larger solitary pebbles and cobbles are also present. Some sections show a rather poorly developed gradation in the size of grains, finer towards the top, extending over thicknesses of up to 10 feet. Cross-bedding is quite common, but ripple-marking rare. Grains of quartz are loosely packed and percolating solutions can migrate freely, coating the individual grains with a film of iron oxides and bringing about movement of carbonate and silica. Silica is concentrated in surface and subsurface bands and layers, which protect the inner sediments from further leaching; and in some places it is concentrated in considerable thickness, forming silica-rich massive rock.

The conglomerates which are found associated with the Unit 2 sandstone are probably of two different types. The first type, such as that found at locality TT10 (App. 4; Fig. 18), is not obviously marine and seems to be associated with old river courses which fed coarse detritus into the shallow sea from the nearby ranges. This conglomerate is very poorly sorted, and coarsely cross-bedded, and the individual pebbles and boulders are poorly rounded. It contains associated plant remains apparently brought in by rivers. The second type of conglomerate seems to be associated with the old coastlines. A good example of it has been encountered just west of locality TT40 (App. 4; Fig. 19) in the Mount Evelyn 1 : 250,000 Sheet area, where it increases in coarseness westward and presumably marks the limit of penetration of the sea in this area. Farther from the coastline (i.e., towards the east) its constituents are of more uniform size and are better rounded, and constitute the true basal conglomerate.

In most cases observed, however, the floor which received Cretaceous sediments in the Coastal Belt seems to have been swept clean of the weathered material by the advancing sea; but angular slabs of unweathered older rocks which are found embedded in the base of the Mullaman Beds have not been moved laterally, and were apparently enveloped where they lay by the younger sediments.

Unit 2 is the most richly fossiliferous unit in the Coastal Belt suite. It contains 66 species of molluscs — not all of them, of course, from the Katherine-Darwin Region — brachiopods, corals, bryozoans, echinoids, and some plant remains. The age of Unit 2 is late Neocomian.

The Inland Belt

The 'Inland Belt' is a belt of flat-lying initially non-marine sediments which embraces the south-western portion of the Katherine-Darwin Region. Most of the sediments in the region are plant-bearing saccharoidal sandstone belonging to 'Unit A'. In outcrop it is massive and structureless apart from cross-bedding and, in places, extremely friable. The friable sandstone commonly breaks down completely and is found only as a sand cover or weathers to form irregularly shaped outcrop (Pl. 22, fig. 1). In the Waterhouse River area, Ruker (1959, unpubl.) has differentiated the Unit A sandstone and called it Baker Creek

Sandstone. White (1959, unpubl.) has described plant remains from basal sandstones between the Waterhouse River and Black Cap, but was unable to give them a more precise age than Lower Cretaceous. 'Unit A' grades rapidly upwards into siltstone included in 'Unit B'.

The flora of Unit A, though prolific, consists of long-ranging forms that generally indicate an upper Mesozoic age; but in one locality in the Mount Evelyn Sheet area (TT40, App. 4; Fig. 18), a Neocomian sandstone with a poor marine fauna is overlain by a sandstone of Unit A. Other evidence from elsewhere in the Northern Territory supports the interpretation of Unit A as (?)Neocomian to Aptian. No determinable plants have been recovered from Unit B, but on stratigraphic evidence, it is placed in the Aptian.

Unit C, otherwise known as the Polland Shale, consists of Foraminifera-bearing shale which is represented, though by only a few remnant outcrops, in the Katherine-Darwin Region. Microsamples collected from the top layers of Cretaceous outcrops at locality TT40, and 12 miles west-north-west of Katherine, yielded assemblages of arenaceous Foraminifera similar to those from other parts of the northern region, as well as from the Wallumbilla Formation (Aptian-Albian) of the western Great Artesian Basin in Queensland. It appears, therefore, that in Albian times most of the northern region — including a large portion of the Katherine-Darwin Region — was submerged by the sea which was a continuation of the waters of the Great Artesian Basin.

The Darwin Area

In the Katherine-Darwin Region Mullaman sediments of the Darwin area crop out at Darwin, on Cox Peninsula east of Darwin, at Shoal Bay 24 miles north-north-east of Darwin and at Point Charles, 16 miles west-south-west of Darwin. Outside the Katherine-Darwin Region they crop out in the Bathurst and Melville Islands, where they seem to have been laid down in an elongate rapidly sinking trough with an east-south-easterly axis. The beds at Darwin are nearly horizontal, and overlie Precambrian rocks. In several sections a basal gravel or conglomerate overlies the steeply undulating contact. It is succeeded by up to 25 feet of deeply weathered quartz sandstone, and this by 35 feet of silicified fossiliferous claystone. Bedding planes are not readily discernible, but several persistent bands with belemnite casts made it possible to determine the gentle northerly dip. All outcrops are strongly coloured by lateritization.

The beds at Darwin cannot be precisely dated by their contained fossils (Radiolaria and belemnites), but the Shoal Bay and Point Charles sections are upper Albian, and on stratigraphic grounds the Darwin sections appear to be slightly younger.

Etheridge's original collection (1895) was from Point Charles, and was taken from a submarine bed: the 25 feet of Cretaceous sediments above the waterline are unfossiliferous claystone, mottled, leached, and silicified.

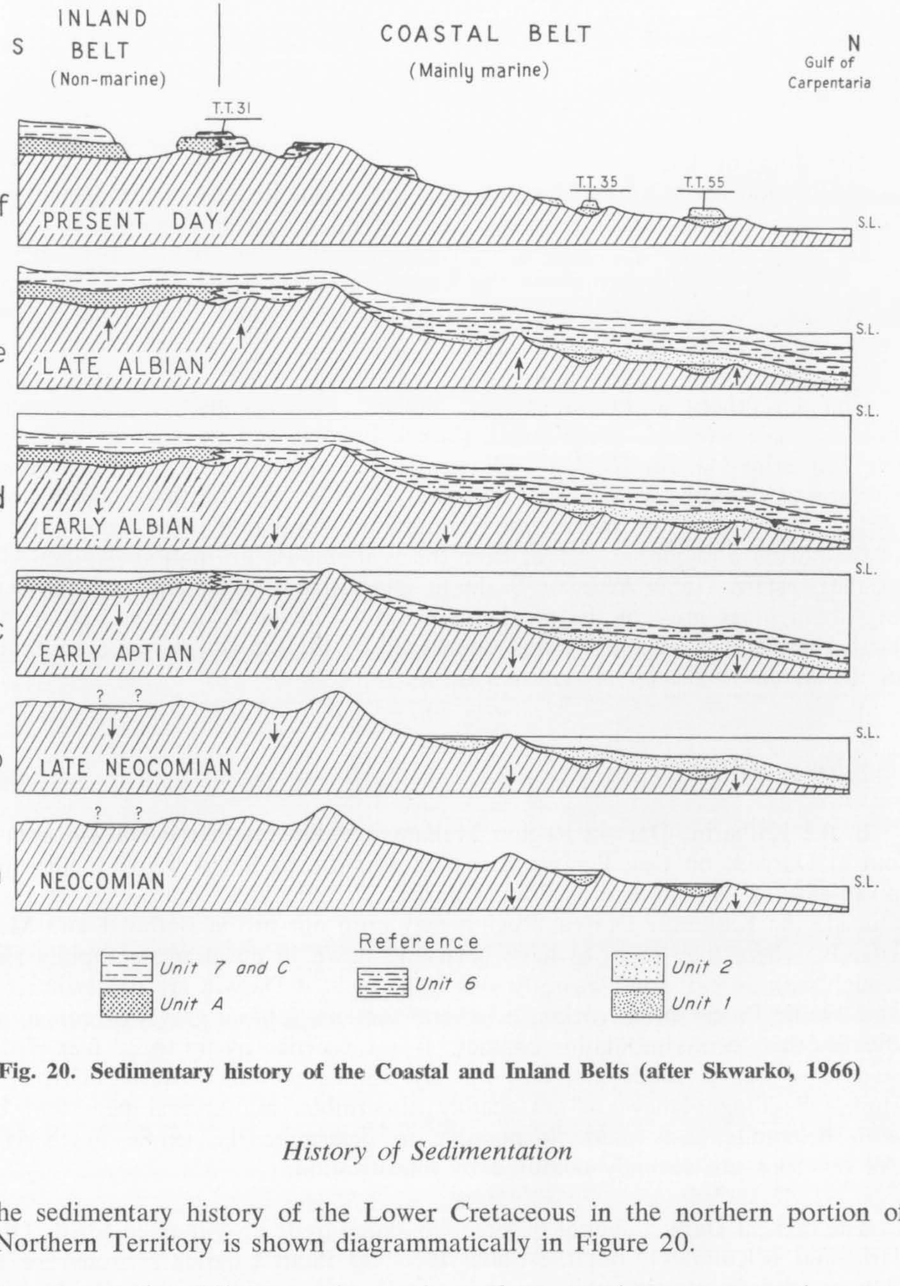

Fig. 20. Sedimentary history of the Coastal and Inland Belts (after Skwarko, 1966)

History of Sedimentation

The sedimentary history of the Lower Cretaceous in the northern portion of the Northern Territory is shown diagrammatically in Figure 20.

The extracts that follow are the portions of my previous account relevant to the Katherine-Darwin Region:

'Even before Upper Jurassic time, the palaeogeography of the area around the western and south-western margin of the Gulf of Carpentaria, and for some distance inland, may have differed little from the geography of today.

'On the other hand, the Neocomian-Albian sediments which occur in this area as scattered remnants of the once probably continuous sheet or sheets indicate that during the earlier half of the Cretaceous, the sea occupied a considerably larger area than it does today. Sedimentary structures in these beds, as well as their fossil content . . . ., point to the existence of a shallow epicontinental shelf from Neocomian to Aptian along the coast, and farther inland a belt or trough in which non-marine sediments were laid down in the (?)Neocomian and Aptian. In Albian times the sea seems to have covered most of the northern part of the Northern Territory and a considerable portion of north-western Queensland. Direct connection between the sea of the Great Artesian Basin and the sea covering the Northern Region existed only in the post-Neocomian times.

'Fossils suggest that Cretaceous sedimentation began in the Neocomian. The two areas first to be inundated seem to be those along the coast on both sides of the present-day Roper River mouth. The northern coast of Arnhem Land may also have been inundated [Fig. 21], but because of the dearth of fossils not very much is known about this region.

'Gradual subsidence along the coastal plain gave rise initially to shallow sea, lagoons or lakes for a short distance inland [Fig. 20, phase a], when quartz sandstone with plant remains accumulated. Absence of preserved endemic forms of life suggests brackish rather than freshwater environment. About this time or more probably a little later gentle downwarping or small scale down-faulting may have initiated the formation of the Inland Belt. In this belt quartz sandstone with plant remains was deposited in a non-marine, possibly shallow-water, environment [Fig. 20].

'Continued rise of the sea-level rapidly flooded brackish lakes and lagoons along the coast [Fig. 20, phase b; Fig. 21, 2a]. Plant fossils are preserved in these in close contact — or even intermingled — with marine shell remains. Plants are indeterminate, but shells are of Neocomian age. The typical fossils are the new subgenus *Zaletrigonia* and *Pterotrigonia*. Farther inland the somewhat different marine assemblages lack *Zaletrigonia,* and are probably a little younger, though still Neocomian, and occupy a distinct horizon topographically above the plant-bearing layers. Finally, towards the close of Neocomian times the sea overlapped from the lakes directly on to the old Proterozoic surface [Fig. 21, 2b].

'Judging by present outcrop in the area a Cretaceous sea covered a large portion of the Northern Territory in the Neocomian. [Figure 18] shows its probable extent. It seems to have covered most of Arnhem Land, a large portion of the Katherine-Darwin area, and a wide belt along the south-western periphery of the Gulf of Carpentaria.

'Little remains of sediments laid down in Aptian time, but the few outcrops which have been found . . . . give evidence that shallow-water marine conditions continued during at least the early Aptian. The areal extent of the sea in the Aptian is not known, but there is nothing to suggest that it covered an area smaller than in the Neocomian.

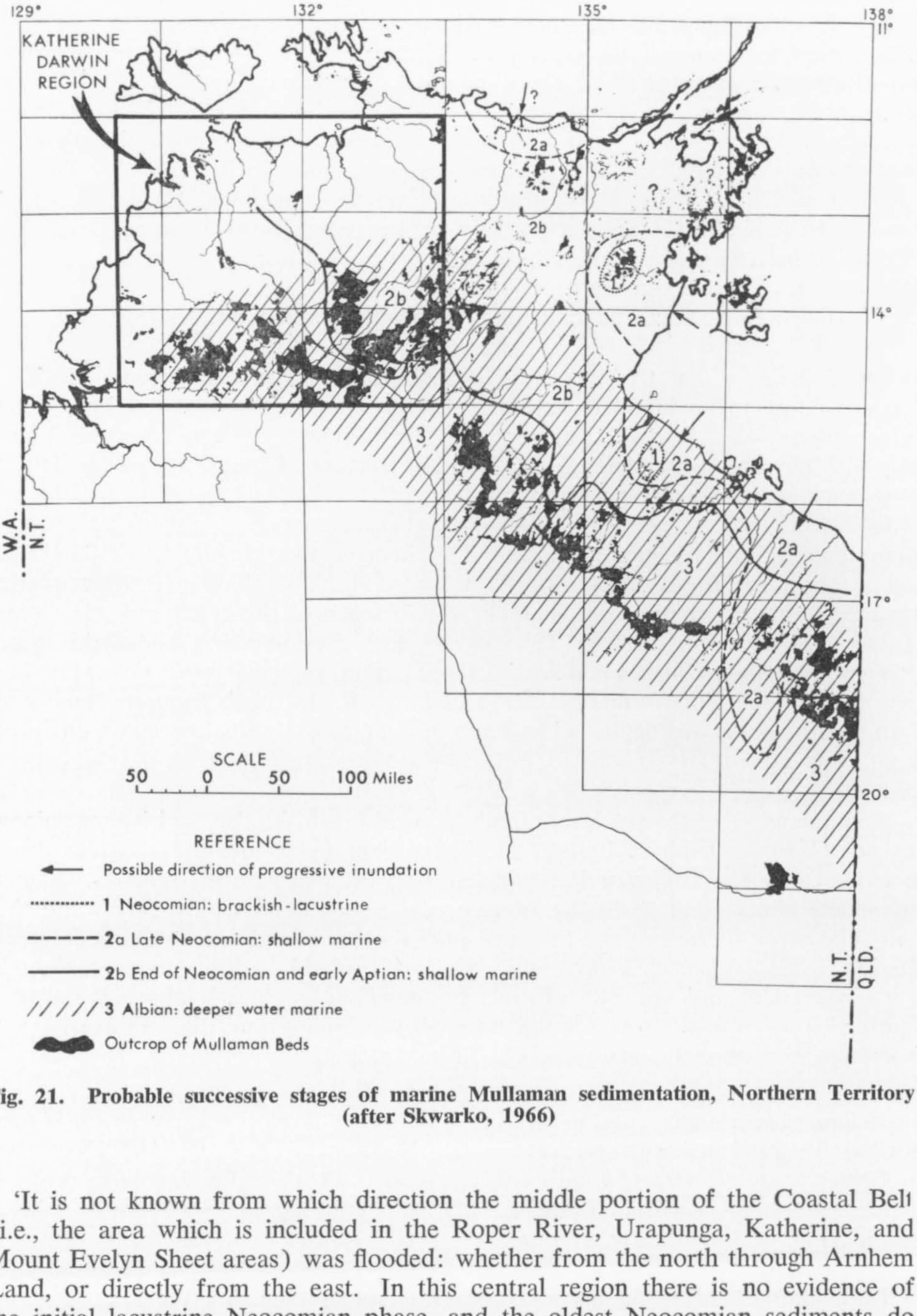

Fig. 21. Probable successive stages of marine Mullaman sedimentation, Northern Territory (after Skwarko, 1966)

'It is not known from which direction the middle portion of the Coastal Belt (i.e., the area which is included in the Roper River, Urapunga, Katherine, and Mount Evelyn Sheet areas) was flooded: whether from the north through Arnhem Land, or directly from the east. In this central region there is no evidence of the initial lacustrine Neocomian phase, and the oldest Neocomian sediments do not contain *Zaletrigonia*. It would seem that in this area the shallow-water marine environment did not become established until some time after areas to the north and to the south-east had been flooded by the sea [Fig. 21, 2b].

'Only a small thickness of Cretaceous sediments accumulated during the Neocomian and Aptian; it consisted of sandstone, siltstone, claystone, and conglomerate. Sedimentary structures in sandstone, as well as the irregularity in grainsize, common admixture of pebbles and cobbles, and the presence of abundant molluscs as well as other forms of life, suggest a shelf, deltaic, or epicontinental environment with the source of sediment at no great distance. The rather abrupt passage from sandstone to claystone and siltstone observed in many sections may indicate change in the source of sediment: alternatively it may reflect a sudden change in the depth of the sea. Virtually no macrofossils have been found in the finer-grained sediments.

'Islands of older rock projected above the surface of the sea, and rivers and streams coming down from these, as well as from surrounding areas of high relief, brought in the coarse detritus and plant remains which are found closely associated with the sediments containing marine fossils. There is no evidence of volcanic activity.

'This shallow epicontinental environment was replaced by a deeper-water marine environment in Albian times, when a large part of the Northern Region became submerged [Fig. 21]. This sea was an extension of the Albian waters of the Great Artesian Basin. A layer of fine-grained sediments was deposited over the Coastal Belt and Inland Belt [Fig. 20, phase d], but most of this has since been removed from the Coastal Belt by weathering and erosion.

'However, well before the onset of the widespread deeper-water conditions, possibly in the late Neocomian, but definitely in Aptian times, the crust sagged in an elongate belt extending south-eastwards from the central portion of the Pine Creek Sheet area in the Northern Territory to the Duchess Sheet area in north-western Queensland — a distance of about 900 miles. Perhaps significantly, the limits of this belt closely correspond to those of the Georgina, Barkly, and Daly River Basins.

'The sedimentary environment in this Inland Belt was non-marine, as suggested by the complete lack of marine fossils and common occurrences of plant remains, and was brackish rather than freshwater. The Inland Belt was thus occupied by a lake, or, more likely, a chain of lakes, before it was flooded by the Albian sea. The ubiquitous occurrence of cross-bedding and poor sorting of sediments may be indicative of shallow rather than deep water. Mainly quartz sandstone and some conglomerate were laid down initially, but these were followed apparently conformably by siltstone and some finer-grained sandstone . . . some evidence in the Mount Evelyn Sheet area [Fig. 18; TT40] suggests that lacustrine sedimentation in that area may have begun even before Aptian time.

'The Albian sea which flooded a large part of the northern region covered probably the whole of the Inland Belt of lacustrine sedimentation, and most if not all the Neocomian-Aptian beds of the Coastal Belt were probably also under the sea. The northern, north-western, and western limits of this sea are not well defined, as erosion which followed emergence has removed indications of the limits of the transgressions. The known distribution of Cretaceous beds suggests, however, that boundaries of the flooded area may have coincided more or less with those of the early Palaeozoic seas in this region.

'Near Darwin, coastal sections contain upper Albian fossils, which probably represent a higher horizon than the upper Albian faunas of the Great Artesian Basin (Whitehouse, 1926).

'Consideration of the regional picture in the Darwin area reveals that the land there was flooded from the north-west, but the lateral extent of flooding seems to have been limited. It seems fairly certain that the north-westerly Albian flooding which proceeded from the Great Artesian Basin and the south-easterly transgression which proceeded from the Darwin area did not meet, and the two seas were always distinct.

'The final marine regression, which probably occurred still before the end of Albian time, exposed the accumulated sediments to weathering and erosion. It is not known with certainty whether the uplift which raised the Inland Belt sediments was a simple upheaval affecting the whole of the belt, or whether it involved complex differential movements at more than one time.

'There is some evidence in favour of a complex upward movement or a series of upheavals. In the Fergusson River Sheet area, as well as in some other parts of the Northern Territory, outcrops of Cretaceous strata are found preserved at varying altitudes within short distances. Differences in elevation as large as 600 feet in 35 miles have been noted. This may be due to the relief in the surface which received Cretaceous sediments, or alternatively may be a result of post-Cretaceous block-faulting. In the Fergusson River Sheet area, the cover of Cretaceous strata, though strongly dissected by streams, is more continuous than in other parts of the region. Sections are thick and deeply weathered, and it seems that in comparison with the duration of the weathering cycle the dissection by headward migration of streams started fairly recently. It is conceivable that the sections were sheltered from dissecting action of streams, possibly by their low altitudes, for some time after their emergence, while still being exposed to the weathering process. This would imply at least two separate uplifts; the first would have brought the sediments slightly above sea-level, exposing them to weathering, and the second elevated them to a higher level, thus exposing them to an accelerated erosion by stream-action' (Skwarko, op. cit.).

CAINOZOIC

The region emerged after the deposition of the Lower Cretaceous sediments, and was subjected to at least three main erosional cycles, delineated by three land surfaces (see 'Geomorphology') developed during the Cainozoic Era. The older rocks have been deeply weathered, laterite and soil profiles developed, and alluvial detritus deposited along the stream courses and in low-lying coastal areas. In addition sand, colluvial rubble, and in small areas marine sediments, have been deposited during the Cainozoic Era.

The oldest recognizable Cainozoic process was the formation of laterite on the earliest of the three land surfaces (Tennant Creek Surface). Complete laterite profiles have been preserved only in the south of the region, mainly on mesas of Cretaceous sediments, but truncated laterite profiles are perserved on Cretaceous-capped mesas north of Pine Creek and on the coastal plains. Extensive areas of detrital laterite (White, 1954) and lake laterite (Christian & Stewart, 1953) have been formed by the erosion and redeposition of iron from the original laterite surface on to one or other of the later land surfaces. Detrital laterite crops out in places throughout the coastal plains, and in some places caps the truncated older laterite profile, giving it the appearance of a complete profile. Detrital laterite is also found in the banks of rivers and streams in the uplands of the region.

The development of soil has been a continuous process: continual erosion has stripped older soil horizons and redeposited the soil in alluvial deposits. Christian & Stewart (1953) have divided the soils into four main groups: (i) skeletal soils which are closely related to the parent rock and contain numerous rock fragments; they occur mainly in the upland areas. (ii) Residual soils, generally of limited extent, which have developed on rocks with gentle topography and are, almost without exception, strongly leached; they include various podsols and red soils developed on limestone and amphibolite. (iii) Soils of the lateritic land surface, including red earths and grey sandy podsols which have formed on the ferruginous zone of laterite, detrital laterite, and lake laterite. (iv) Soils of the alluvia, including heavy grey pedocals derived from limestone and amphibolite terrain, which commonly show gilgai structure. They also include the sandy arable levee soils found on the main river banks and the dark, heavy, cracked soils of the estuarine plains.

The deep weathering during the Cainozoic has produced considerable variations in the appearance of some of the fine-grained Lower Proterozoic sediments in outcrop and at depth. Red siltstone has developed at the surface from dark grey commonly carbonaceous pyritic siltstone; heavy hematitic and limonitic gossanous cappings are locally developed over particularly pyritic material mainly in the Golden Dyke and Koolpin Formations. A. Vanderplank (1964, unpubl.) has suggested that a deposit of yellow clay over 35 feet thick, 32 miles south of Darwin, is the product of weathering of Noltenius siltstone in situ.

Alluvium is the most extensive rock unit in the Katherine-Darwin Region; it covers large areas of the coastal plains and the Daly River Basin, and extends up most of the river valleys. The alluvium includes gravel, sand, sandy silt, silt, and clay; the greater proportion is silt and clay, which during the wet season becomes extremely boggy and restricts vehicle travel off the main roads. On the banks of the Adelaide River near Humpty Doo drill holes have encountered up to 55 feet of black silt and sandy silt. The banks of some rivers to the south of the coastal plains commonly expose silt and sand up to 50 feet thick. Even small valleys in the uplands which have no definite stream channel are filled with thick accumulations of alluvium, which have been derived by sheet erosion of soil from the neighbouring steep slopes by heavy seasonal rains. The clay deposits in swamps and stream valleys just south and east of Darwin may be more than 24 feet thick.

Sand other than that of definite alluvial origin is found as a thin layer over many of the laterite and detrital laterite surfaces both on the coastal plains and on the Cretaceous mesas. These sands are fine, white, and well sorted; they were probably derived from Precambrian and Cretaceous sandstones; particularly thick accumulations occur near outcrops of the clean friable sandstone at the base of the Mullaman Beds near Goodparla homestead, and above the headwaters of the South Alligator River. The occurrence of the thin layer of sand over flat ferruginous surfaces at both high and low elevations suggests that it was deposited by wind action during an arid period with little vegetation. Sand also occurs in dunes along the present coastline and along old strandlines, which now occur some 20 feet above and up to 10 miles inland from the present coastline. Recent coastal lime-sands have been recognized near Gunn Point and near Buffalo Creek, both on Shoal Bay.

Colluvial rubble is widespread; it commonly masks the boundaries at the base of outcrops of more resistant rocks. The boundary between the Edith River Volcanics and the Grace Creek Granite is obscured by rubble from the Kombolgie Formation, and the relationships of the units were not fully realized until isotopic age determinations had been obtained. Many of the low-lying occurrences of cleaved siltstone of the Burrell Creek Formation consist entirely of rubble, and in most cases they have been mapped as outcrop.

Marine deposits other than sand include present-day mangrove muds and beach gravels. Mangroves occur along most of the northern and north-western coastline. The presence of older marine sediments is indicated by the occurrence of crayfish skeletons in some estuarine deposits (Noakes, 1949).

No attempt is made to trace the history of the deposition of the Cainozoic sediments. Most of the alluvium and soil is probably of Quaternary origin, but relics of the land surfaces described by Hays (this Bulletin) may preserve older alluvium and soil. Noakes' (1949) reconstruction of the history of the alluviation of the coastal area is probably valid for the Quaternary period, but a much more detailed geological and geomorphological study than that presented here will be necessary to complete the Cainozoic picture for the region.

INTRUSIVE IGNEOUS ROCKS

The igneous rocks of the Katherine-Darwin Region were not studied in detail during the present survey, but the main igneous masses were mapped on a reconnaissance basis, and the relationships of the different types of igneous rocks to each other and to the intruded sediments have been established. A number of the granitic bodies have been dated (see App. 2), and silicate analyses of these and other samples are listed in Appendix 5. Bryan (1962, unpubl.) has studied the petrography of the basic igneous rocks.

The intrusive igneous rocks include, in order of age: (i) Granites and associated gneissic rocks of possible Archaean age which may, during the early Carpentarian, also have been intruded by granites or remobilized.

(ii) Lower Proterozoic basic sills and dyke swarms, some of which were folded with the sediments (mainly in the Central Trough), and some intruded after the folding (mainly in the Eastern Trough).

(iii) Discordant granitic plutons of early Carpentarian age intruding Lower Proterozoic sediments. They range from large transgressive batholiths (e.g., Cullen Granite) to small transgressive stocks which occupy the cores of domes (e.g., Shoobridge Granite).

(iv) Acid volcanic rocks, plugs, and sills associated with the early Carpentarian granites (see Edith River Volcanics, p. 58).

(v) A granitic intrusion, possibly of late Carpentarian age.

(vi) Adelaidean dolerite sills and dykes.

Basic Intrusive Rocks

Lower Proterozoic

The Lower Proterozoic basic intrusives of the Katherine-Darwin Region have been studied by Bryan (1962, unpubl.), who has listed previous minor investigations.

Basic rocks are scattered throughout the region, but most of them occur in six general localities; sampling was confined to these areas. Most of the following descriptions have been prepared by R. Bryan (BMR).

Oenpelli Area

Basic rocks intrude the Myra Falls Metamorphics and Nimbuwah Complex to the east of the East Alligator River. They are generally poorly exposed, and their presence in many places is inferred from the typical red soils and gilgai soils which are normally found on basic rocks in the Katherine-Darwin Region. The intrusions in the Myra Falls 'window' follow the trend of the bedding in the Myra Falls Metamorphics, and in the Nimbuwah Complex the intrusion is parallel to the margin of the complex. Elsewhere, there is no obvious structural control of the intrusions.

The basic rocks in the Oenpelli area appear to be generally less altered and coarser in grain than the rocks to the west; they also commonly contain feldspar phenocrysts. The common rock types are augite gabbro containing olivine in places, porphyritic microgabbro, and dolerite. The feldspar in all types is labradorite; it occurs as laths and phenocrysts which are twinned and in places zoned. The feldspar is saussuritized to a varying degree. The clinopyroxene is colourless to pale purple augite, which is commonly partly uralitized to blue-green pleochroic amphibolite; some of it is chloritized. The dolerite contains laths of hypersthene, but orthopyroxene has not been noted in the gabbro. Other minerals present include yellow to red-brown biotite, magnetite, and ilmenite. The olivine in some of the gabbro forms subhedral crystals surrounded by augite, and is generally partly serpentinized.

All the basic rocks in the Oenpelli area appear to be comagmatic.

South Alligator River Area

In the South Alligator River area the basic intrusive rocks cover an area of 130 square miles. They crop out in a belt, 70 miles long and up to 10 miles wide, which extends from Coirwong Creek south-east to the upper reaches of the Katherine River (Pls 28 and 31). The belt is aligned roughly along the South Alligator River valley, and the north-west trend is parallel to the major fault lines and fold axes in the area. The dolerite belt lies entirely within the Eastern Trough of the Pine Creek Geosyncline; there is a break in the belt in the Rockhole/El Sherana area, but this is probably due to faulting.

The name Zamu Complex was applied by Stewart (1959, unpubl.) to the predominantly basic intrusions in the Zamu Creek area, east-south-east of El Sherana; and subsequently by Walpole (1962) to the whole belt of basic intrusives in the South Alligator River area.

All the basic rocks were probably intruded during a single phase of igneous activity.

Typical intrusions crop out in the Coirwong Creek/Gerowie Creek area, where the main rock type is a dark grey to black fine to medium-grained massive altered dolerite. The original constituents were andesine-labradorite, augite (in places diallage), and hypersthene, with accessory biotite, magnetite, ilmenite, sphene, and apatite; the matrix consisted of fine-grained quartz and feldspar. The rock has generally been extensively sericitized and uralitized; the alteration products include sericite, tremolite-actinolite, chlorite, epidote, calcite, and serpentine. The rock from the Coirwong Creek area is illustrated in Plate 23, figure 1. The texture is commonly ophitic, but may be intergranular, or a combination of both.

Dull black massive homogeneous variolitic dolerite occurs as patches, up to 60 feet across, adjacent to the normal dolerite. The rock was probably intruded before the main mass of dolerite.

Isolated outcrops of fine-grained hornblende granophyre crop out in the Gerowie Creek area, but they are always close to the normal medium-grained dolerite. The granophyre represents an acid differentiate of the basaltic magma, and W. B. Dallwitz (BMR, pers. comm.) reports some albitization of the sediments adjacent to the granophyre.

The intrusive rocks in the south-eastern part of the belt are much less altered and somewhat coarser in grain than the dolerite in the north-west. A section near the Zamu Creek mine shows the uniformity of the dolerite. The rock originally consisted of labradorite, diallage, hypersthene, and some hornblende, with accessory biotite, quartz, magnetite, ilmenite, and apatite. Deuteric alteration has resulted in the partial saussuritization of the plagioclase and the alteration of the pyroxenes to bastite and tremolite-actinolite (Pl. 23, fig. 2). The texture ranges from ophitic to intergranular.

Patches of medium-grained pegmatite, up to 100 feet across, are associated with the dolerite in the Zamu Creek area. The pegmatite is a late-stage acid differentiate of the basic magma, and is intrusive into the dolerite. The pegmatite consists of sericitized oligoclase(?) and uralitized diallage, with some hornblende, biotite, and quartz; the accessories include apatite, sphene, ilmenite, and rutile, and the matrix is composed of quartz and anorthoclase.

The dolerite in the Coirwong Creek/Gerowie Creek area in the north-west is much more altered than the dolerite at Zamu Creek to the south-east. The sediments in the dolerite belt have been subjected to a single uniform phase of mild regional metamorphism; and it is probable that the more intense alteration of the dolerite to the north-west is due to more severe deuteric alteration rather than regional metamorphism. Nevertheless the dolerites appear to have been derived from a parent magma of uniform composition.

Because of the absence of layering in the dolerite and the poor exposure of the adjacent sediments, the mode of intrusion could not be definitely established. Both dyke swarms and sills, intruded parallel to the major tectonic trend of the area, appear to be present.

Mount Masson Area

The altered dolerites in the Mount Masson area occur as a series of north-trending elongate masses, arranged en echelon. They extend from near Mount Masson south to Mount Saunders — a distance of 25 miles (Pl. 28) — and closely follow the contact between the Masson and Golden Dyke Formations. Much of the contact is folded and faulted, but the basic rocks were emplaced before these movements.

The rock is a dark grey massive fine-grained quartz dolerite which has been extensively altered. It consists of albite, actinolite, epidote, and quartz, with a little apatite, calcite, pyrite, and leucoxene. Some remnants of twinned labradorite are preserved.

The sediments of the Golden Dyke Formation have been only mildly metamorphosed; the more intense alteration of the dolerite has probably been produced by autometamorphism. Hays (1960) described these igneous masses as possible spilitic intrusions or subaqueous extrusions. However, we do not consider that the albite is primary, nor that soda was introduced from sea water. It is more probable that the intrusions are deuterically altered dolerites intruded before the regional deformation.

Burrundie Area

The basic rocks in the Burrundie area crop out to the south-west of the Mount Masson intrusives and between Burrundie Siding and the Hayes Creek Store (Pl. 28).* They occur as sheets within the Golden Dyke Formation, and have been folded with the sediments. The sheets are roughly conformable with the bedding.

The predominant rock type is a grey fine to medium-grained massive greenschist. The texture ranges from even-grained to porphyroblastic; the minerals are xenoblastic, commonly ragged, and the actinolite is sieved with inclusions. The rock consists of actinolite, saussuritized labradorite, and quartz, with a little sphene, phlogopite, pyrrhotite, pyrite, and black iron oxide (Pl. 24, fig. 1). In places the actinolite occurs as small euhedra and subhedra, but elsewhere it forms medium-sized ragged porphyroblasts.

A small outcrop of dolerite aplite lies close to the margin of one of the basic intrusives. It consists of kaolinized and sericitized microcline and oligoclase, quartz, and a little augite, sphene, prehnite, and iron oxide. The texture is granitic; all the grains have been strained, and the margins of some of the microcline anhedra have been granulated. The aplite is probably an acid differentiate of the basaltic magma.

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* See also Pine Creek 1 : 250,000 Sheet.

The basic rock in the Burrundie area can be described as greenschist, but lineation is poorly developed even in thin section. The bulk of the minerals are metamorphic in origin, but the composition of the rock, together with the presence of occasional relics of twinned labradorite, shows that it was originally of basic igneous origin.

The Golden Dyke Formation adjacent to the greenschists crops out very poorly, and it is not known whether the siltstone and shale have been metamorphosed by the intrusive, but small lenses of marble close to the contact could have been recrystallized by the basic intrusion. The marble consists of pure calcite, with highly contorted thin bands of diopside, hornblende, pyrite, and oligoclase(?), which indicate that considerable heat was involved in the formation of the rock.

The Burrundie basic rock is more highly metamorphosed than that near Mount Masson, although in both cases the rocks have only just reached the greenschist facies (Turner & Verhoogen, 1960). In both cases deuteric alteration probably played a major role.

Brocks Creek Area

Greenschist occurs in the siltstone and shale of the Golden Dyke Formation encircling the Burnside Granite. At one place the greenschist has terminated against the granite.

The greenschist is a steel-grey massive dense rock which is generally poorly exposed. It is composed of actinolite, albite, phlogopite, and chlorite, with some quartz, pyrite, and sphene; the texture is granoblastic. Actinolite forms irregular anhedra, sieved with inclusions of phlogopite and quartz; in places, however, the actinolite occurs as sheaths of subparallel fibres. The albite is untwinned, and is of secondary origin (Pl. 24, fig. 2).

A greenish grey medium to coarse-grained massive platy rock forms much more conspicuous outcrops than the finer-grained greenschist. It appears to be restricted in extent, but is intimately associated with the finer greenschist. The coarse rock consists predominantly of actinolite, with some hornblende, calcic andesine, and accessory sphene, pyrrhotite, and phlogopite. The minerals are randomly oriented, and many of the actinolite crystals are bent and cracked. The actinolite forms anhedra up to 4 mm long that appear to be pseudomorphs after pyroxene. The cores of some of the pseudomorphs consist of aggregates of very pale tremolite-actinolite fibres, which suggests that the original mineral was zoned. A soda-rich alumina-poor variety of hornblende has developed along the outer edges of a few of the actinolite crystals. A similar sequence of alteration can be seen in the basic rocks in the Rum Jungle area.

The basic rocks in the Brocks Creek area are proved to be igneous and intrusive by the contact relationships of a typical greenschist encountered in a diamond drill hole. The calc-silicate sediments at the upper and lower contacts have been thermally altered over a distance of 10 feet from the contact, with the patchy development of actinolite, biotite, quartz, and some sodic feldspar and pyrite.

Noakes (1949) and Sullivan & Iten (1952) considered that the basic rocks were sills and sheets intruded into the siltstone and pyritic shale of the Golden Dyke Formation before folding; and more recent geological mapping has confirmed this view (Malone, 1962a).

The basic intrusions are generally concordant, though numerous minor transgressions have been mapped. The basaltic magma was intruded on several levels, and the intrusions appear to be genetically related to those in the Burrundie area, 6 miles to the south-east. The marked difference in outcrop pattern of the sills in the two areas is due entirely to the local domed structure in the Brocks Creek area, which contrasts sharply with the more elongate folds in the Burrundie area.

Deposits of gold, copper, lead, zinc, and tin have been worked in the area and a number of uranium prospects have been discovered. Sullivan & Iten (1952) note that the gold and copper mineralization occurs in graphitic slate (Golden Dyke Formation) and that it is normally associated with sills of amphibolite. They also point out that 'extensive hematite and limonite beds are found near the contacts of the amphibolites', and that 'these iron oxides have been derived from weak pyritic mineralization which may be genetically related to the amphibolites'. However, the sulphide mineralization is more likely to be syngenetic, as similar pyritic rocks are widely distributed in the geosyncline and are not everywhere associated with basic rocks.

Rum Jungle Area (Pl. 30)

A number of small outcrops of basic rocks have been mapped in the Rum Jungle area, but there are strong indications that most of the basic rocks are concealed by the thick soil cover, especially immediately to the south of Batchelor, and north of the Dolerite Ridge.

A propylitized basic igneous rock crops out in the Mount Deane area; the outcrop looks like an iron-rich gossan, but Malone (1958, unpubl.) considers that it is part of a sill intruded along the contact of the Acacia Gap Tongue and the overlying Golden Dyke Formation.

Another small area of basic rocks occurs at Dolerite Ridge, to the west of Rum Jungle. Surface samples have been described as sheared and altered microdiorite; similar rocks occur as dykes cutting the youngest phase of the Rum Jungle Complex (Rhodes, 1965).

Diamond drill holes at Rum Jungle Creek South, Browns prospect, and Waterhouse No. 2 prospect have intersected considerable thicknesses of ortho-amphibolite, all of which occur in the Golden Dyke Formation close to the contact with the underlying Coomalie Dolomite.

At Rum Jungle Creek South and Browns prospect, the dolomite and dolomitic siltstone adjacent to the ortho-amphibolite have also been converted to amphibolite by regional metamorphism, but the ortho-amphibolite and para-amphibolite can be distinguished by a careful study of the cores (Bryan, 1962, unpubl.). The ortho-amphibolite is dark grey, massive, and fine to medium-grained; it consists of hornblende, actinolite, plagioclase, and quartz, with accessory sphene, ilmenite, leucoxene, and biotite. Amphibole forms 60 percent of the rock, and ranges from non-pleochroic tremolite-actinolite to strongly pleochroic soda-rich hornblende (Pl. 25, fig. 1). Corroded twinned unzoned laths of oligoclase-andesine are common. The texture of the rock is metamorphic, and many of the minerals have xenoblastic outlines. The presence of corroded laths of plagioclase, and relics of ophitic intergrowths of altered pyroxene and plagioclase, clearly show that the rocks were originally igneous.

At the Waterhouse No. 2 prospect, 7 miles south-south-east of Rum Jungle Creek South, a diamond drill (DDH No. 4) passed through 140 feet of amphibolite. The amphibolite is generally grey to greenish grey, massive, and fine-grained; it consists predominantly of tremolite-actinolite, with subordinate hornblende, iron oxide, a little apatite and rare feldspar. Fibrous weakly pleochroic tremolite-actinolite makes up to 85 percent of the rock. Some of the irregular strongly pleochroic anhedra of brown hornblende are partly replaced by iron oxide (Pl. 25, fig. 2).

A more acid fine to medium-grained amphibolite occurs close to the top of the section in DDH No. 4; it consists of 50 percent albite, actinolite, and chlorite, with a little leucoxene, sphene, iron oxide, and biotite. All these minerals are of metamorphic origin. This upper phase of the amphibolite is separated from the lower phase by a shear zone.

The uppermost 5 feet of amphibolite in DDH No. 4 consists of euhedral crystals of green hornblende and needles of apatite set in a groundmass of albite. The rock contains an unusually high proportion of apatite, and a partial analysis gave 8.62 percent P_2O_5.

The amphibolite at Waterhouse No. 2 prospect has a narrow zone of indurated sediments at the upper contact, which indicate that it is an altered igneous rock. The bulk of the rock is ultrabasic rather than basic in composition.

Because of the thick soil cover, the lateral extent of the amphibolite in the Rum Jungle area can only be inferred, but it generally occurs near the contact between the Coomalie Dolomite and Golden Dyke Formation.

The amphibolite has been formed by low-grade regional metamorphism with moderate stress conditions.

Method of Intrusion

In the Mount Masson/Burrundie/Brocks Creek region the basic intrusives were injected as sills and subhorizontal sheets within the unfolded Lower Proterozoic sediments. Most of the intrusions were confined to the Golden Dyke Formation, which was deposited during the initial stages of sedimentation in the Central Trough.

In the Eastern Trough, the doleritic masses intruded the South Alligator Group, and it is uncertain whether they were intruded as sills before or as dykes after the folding of the sediments. They are regarded as younger than the sills and dykes in the Central Trough, but antedate the Carpentarian Malone Creek granite stock.

The basic intrusions are tholeiitic. Throughout the Katherine-Darwin Region mineralization is found in close association with belts of dolerite intrusives, e.g. copper, lead, and uranium in the Rum Jungle and South Alligator areas, tin and gold in the Mount Masson and Burrundie areas, and gold and base metals in the Brocks Creek area. No direct association has been established between many of these mineral occurrences and the intrusion of the dolerites; the association appears to be due to the tendency of both dolerites and mineralization to favour the Golden Dyke and Koolpin Formations.

Adelaidean

Dolerite sills intrude the Roper Group in the Katherine-Darwin Region and in the adjacent part of the McArthur Basin. In Arnhem Land they also intrude the Mount Rigg and Katherine River Groups. The Roper Group is intruded by five extensive sills and several smaller bodies of dolerite; only the topmost two crop out in the Katherine-Darwin Region, but in many respects they are most interesting. The lower sills are similar in composition and texture, but the upper sills each have distinctive characteristics.

The top sill occurs within about 30 feet of the top of the Bukalorkmi Sandstone Member: it is found in this position at all outcrops of the Bukalorkmi Sandstone Member throughout an area of about 2000 square miles. The dolerite is black, dense, and fine-grained, and is very uniform in composition and texture, except for a decrease in grainsize at the top and bottom contacts. It is a quartz-pigeonite dolerite with an intergranular texture. The plagioclase is calcic andesine or sodic labradorite; the pigeonite is marginally altered to amphibole in places, and has a 'schiller' texture caused by the presence of exsolved laminae of a more calcic pyroxene; the quartz is interstitial and contains microlites of feldspar and apatite. Magnetite is common; the dolerite weathers to a characteristic red soil which contains numerous crystals of magnetite. The average thickness of the sill is about 100 feet, but it is up to 200 feet thick in places.

The next lower sill occurs near the contact of the Moroak Sandstone Member and the Kyalla Member, intruding either one or the other; it lies 500 feet stratigraphically below the top sill and crops out in an area of about 3000 square miles; it is about 200 feet thick. The basal part of the sill is very fine-grained, and the underlying quartz sandstone is silicified for a few inches from the contact. The main portion is medium to coarse-grained, almost gabbroic in places, and is slightly porphyritic with poorly formed crystals of pyroxene; it is cut in several places by a fine-grained strongly porphyritic phase containing long needles of pyroxene; high in the sill, aplitic veins a few inches thick cut the dolerite. Within 10 feet of the top contact the rock is fine-grained, and within 2 inches of the top it is jointed parallel to the contact. The weathered rock from near the top contact has a vesicular appearance.

The mineralogical composition is fairly uniform throughout. Hypersthene appears about 60 feet below the top contact, suggesting slight differentiation within the sill. The pigeonite is mostly subophitic with a 'schiller' texture; many of the pigeonite crystals are bent and twisted. The deformed pigeonite crystals, and the presence of coarse pyroxene and plagioclase crystals surrounded by aggregates of smaller crystals, suggest two distinct phases of crystallization. The vesicular appearance of the weathered upper part of the sill is caused by the weathering out of secondary segregations of carbonate minerals. This is the most basic of all the sills which intrude the Roper Group, and quartz is very rare.

Dykes are rare: one dyke about 10 feet wide and a mile long intrudes the upper sill east of Goose Lagoon, and another small weathered dyke intrudes the Chambers River Formation north of the Beswick-Mainoru track.

The dolerites appear to be genetically related; they intruded the Adelaidean sediments before the final faulting and deformation, and are unconformably overlain by the Antrim Plateau Volcanics. Age determinations on the dolerites (1250 m.y., McDougall et al., 1965) suggest that they were intruded soon after the completion of Adelaidean sedimentation in this area.

Acid Plutonic Rocks

Granitic plutonic rocks intrude the Lower Proterozoic rocks in places throughout the Katherine-Darwin Region. They are referred to under the general term granite. All the granites are shown as Lower Proterozoic on our published 1 : 250,000 and 1-inch maps; but subsequent geochronology and more detailed local mapping has indicated the presence of at least three ages of granite.

The oldest granites are those in the Rum Jungle Complex, which have been described by Rhodes (1965) and dated by Richards et al. (1966) at about 2550 m.y. Granites of similar age may also be present in the Litchfield and Nimbuwah Complexes and the Waterhouse and Nanambu Granites.

The next oldest granites are the most common in the Katherine-Darwin Region. They are generally massive, coarse-grained, or porphyritic, and commonly range from adamellite to granite; exceptions include the fine-grained Malone Creek Granite and the Mount Goyder Syenite. The granites are generally high-level intrusions; some are discordant (e.g., Cullen Granite), and others are partly concordant (e.g., Burnside Granite). The K/Ar age determinations by Hurley et al. (1961) suggested that the granites ranged from 1720 m.y. (Fenton Granite) to 1520 m.y. (Burnside Granite); but more reliable Rb/Sr work (P. J. Leggo, BMR, pers. comm.) has shown that most of the granites lie on a 1760-m.y. isochron, and that they are similar in age to the Edith River Volcanics at the base of the Carpentarian sequence (App. 2). It appears therefore that the intrusion of the granites was associated with earth movements which initiated Carpentarian sedimentation and not necessarily with the folding movements in the Pine Creek Geosyncline. The granites are now regarded as early Carpentarian in age.

The youngest granite is the Grace Creek Granite, which has been dated by P. J. Leggo at 1470 m.y. by Rb/Sr total rock determinations on four samples. The Grace Creek Granite was originally grouped with the main granites in the Katherine-Darwin Region, as it appears to be intruded by dykes of Edith River Volcanics. However, the field relationships are not well exposed, and we have accepted the geochronological evidence for its age. The Grace Creek Granite was probably emplaced as a laccolith at the unconformity between the Lower Proterozoic and Carpentarian during the time-break between Katherine River Group and Mount Rigg Group sedimentation or between Mount Rigg Group and Roper Group sedimentation. The age of the granite is late Carpentarian.

Many of the early Carpentarian granite contacts are faulted, and contact effects are generally confined to a zone a few hundred feet wide. There is one exception on the eastern margin of the Cullen Granite south-east of Pine Creek, where the contact aureole is up to several miles wide, but the presence of numerous porphyry dykes suggests that the granite underlies the area at a shallow depth. Spotted hornfels is common in an aureole of the Burrell Creek Formation and chiastolite-bearing rocks in the Golden Dyke Formation. We have no evidence to support Noakes' (1949) suggestion of granitization in the Litchfield homestead area, and the andalusite-mica schists and pegmatites of the Bynoe Harbour area do not appear to be related to the Litchfield Complex.

No detailed study has been made of the Katherine-Darwin granites, and each intrusion has been given a separate name and is described separately, although many of the granites are probably comagmatic. The granites have been divided into three age groups and described in order from east to west.

Most of the petrographic descriptions have been provided by R. Bryan and S. M. Hasan of the Bureau of Mineral Resources. The nomenclature suggested by Morgan (1964, unpubl.) (after Nockolds, 1954) has been used: in *granites* the alkali feldspar/plagioclase ratio is greater than 3 : 2; in *adamellites* between 3 : 2 and 2 : 3; in *granodiorites* between 2 : 3 and 1 : 10; and in *tonalites* less than 1 : 10. Perthite and albite are regarded as alkali feldspars.

Chemical and modal analyses of the granites are presented in Appendices 5 and 6.

Archaean and/or Proterozoic Granites

Nimbuwah Complex

The Nimbuwah Complex comprises granitic rocks which crop out over an area of about 800 square miles to the north-east of Oenpelli mission in Arnhem Land. Part of the complex crops out in the north-east corner of the Katherine-Darwin Region and extends into the Milingimbi, Junction Bay, and Cobourg Peninsula 1 : 250,000 Sheet areas. The name is derived from Nimbuwah, an isolated monolith of sandstone with a granitic base, at latitude 12°12'S., longitude 133°21'E.

The name Nimbuwah Granite was used by Dunn (1962), but was subsequently modified to Nimbuwah Complex by Rix (1965) when it was found to include both gneissic and massive granitic rocks in Arnhem Land.

In the Katherine-Darwin Region the Nimbuwah Complex crops out mainly as scattered pavements in an area of low relief. Near Coopers Creek where the granite has been contaminated by basic rocks, it forms low hills. Several rugged outcrops have been exposed below the Carpentarian sandstone in the eastern part of the inlier near Myra Falls.

Near Coopers Creek, the granite encloses a gabbroic body similar to gabbroic intrusions in the Myra Falls Metamorphics near Oenpelli. The granite has partially assimilated the basic rocks, and there is a wide zone of hybridization. The granite in the Coopers Creek area is a grey porphyritic hornblende-biotite granodiorite, with large phenocrysts of plagioclase oriented parallel to the outline of the gabbro. The granodiorite is composed of plagioclase, quartz, hornblende, biotite, and pyroxene with a little epidote, calcite, and zircon. The plagioclase is strongly sericitized and saussuritized. The quartz and biotite show some distortion. The hornblende is mainly secondary and replaces pyroxene. The low silica content of 60.42 percent (see App. 5) and the presence of altered pyroxene are probably due to contamination by the nearby basic rocks.

South-east of Nimbuwah the rock is a massive biotite granodiorite with pink and green feldspars. The plagioclase, which constitutes about 45 percent of the rock, is strongly sericitized; the alkali feldspar (about 10 percent) is microcline perthite.

The main mass of the Nimbuwah Complex in the Katherine-Darwin Region and Arnhem Land (Roberts et al., in prep.), both gneissic and massive, consists of granodiorite or tonalite; the isolated intrusions in the inlier near Myra Falls, however, are granitic, and have zones of granulation, and are cut by numerous quartz-feldspar dykes. The granitic rocks may be related to the biotite granulite (or granitic gneiss) of Dunn (1962) to the south of Myra Falls. Dunn included the granulite and the granitic rocks in the Myra Falls Metamorphics on the Alligator River 1 : 250,000 Sheet. We have put the granitic rocks in the Nimbuwah Complex, but have not been able to separate the granulite from the Myra Falls Metamorphics.

The age of the Nimbuwah Complex is uncertain: the granite rocks near Coopers Creek intrude basic rocks similar to Lower Proterozoic basic rocks elsewhere, which suggests that some of the rocks are similar in age to the Carpentarian granites; on the other hand, the gneissic granites are possibly Archaean in age, and the complex is therefore shown as ranging from Archaean to Proterozoic.

Nanambu Granite

The Nanambu Granite crops out between the South Alligator and East Alligator Rivers. The granite is poorly exposed, but probably occupies an area of at least 300 square miles beneath Cainozoic cover rocks. The granite comprises at least two separate intrusions: a small mass near Jim Jim Creek north of Mount Basedow, and a large mass between the estuary of the South Alligator River and Magela Creek; the larger body may be divided by a north-trending tongue of sediment east of Munmarlary homestead.

The name Nanambu Granite was first published by Condon & Walpole (1955) and is derived from Nanambu Creek, which flows into Woolwonga Swamp at about latitude 12°42′S., longitude 132°41′E.

The outcrops consist mainly of deeply weathered leucocratic garnetiferous granite and gneissic granite. Near the headwaters of Nanambu Creek the rock is a massive leucocratic alkaline granite with scattered brown garnet; some of the granite has a granulitic texture suggestive of a metamorphic origin. To the east of Nanambu Creek the granite is gneissic and contains scattered outcrops of altered basalt ('greenstone'). The 'greenstone' is a fine-grained dark green rock with small scattered laths of amphibole. The green matrix consists mainly of chlorite with some calcite showing traces of the original basaltic texture. East of Munmarlary homestead the granite is gneissic and garnetiferous and, in places, it forms lit-par-lit structures with metamorphosed sediments. To the north of Mount Basedow, the granite is similar, but no 'greenstone' has been noted.

The contacts of the Nanambu Granite with the Lower Proterozoic country rocks are not exposed, but the photo-pattern suggests that the bedding in the Lower Proterozoic sediments is concordant with the granite margins. Also, as lit-par-lit gneiss, gneissic granite, and 'greenstone' do not occur in the Carpentarian granites it is possible that the Nanambu Granite forms the basement to the Lower Proterozoic sediments, and is therefore probably Archaean. In many respects the Nanambu Granite is similar to the Bradshaw Granite in north-east Arnhem Land (Dunnet, 1965), which is tentatively referred to the Archaean. In the absence of more definite evidence, the Nanambu Granite is regarded as Archaean to Proterozoic in age.

Rum Jungle Complex

The Rum Jungle Complex occupies about 90 square miles in the centre of a faulted domed structure about 40 miles south of Darwin. The complex is not well exposed, but Rhodes (1965) has distinguished six major rock units, and has established that it is, for the most part at least, basement to the surrounding sediments.

The complex was referred to as the Rum Jungle Granite by Fisher & Sullivan (1954), but was renamed Rum Jungle Complex by Rhodes (op. cit.). The name is derived from the Rum Jungle uranium mining project at latitude 13°1'S., longitude 130°58'E.

The following description of the complex is compiled from Rhodes (1965). His six rock units include schists and gneisses, granite gneiss, metadiorite, coarse granite, large feldspar granite, and leucocratic granite.

The schists and gneisses were probably derived from sedimentary rocks, and were formed under conditions of the almandine-amphibolite facies (Turner & Verhoogen, 1960). They occur in a small area on the eastern side of the complex and as inclusions in the granitic rocks.

The granite gneiss crops out in an arcuate belt in the centre of the complex. It is medium and even-grained and ranges from well banded granite gneiss to homogeneous granite gneiss; it contains microcline, quartz, oligoclase, biotite, muscovite in places, and accessory apatite, fluorite, and zircon. The granite gneiss is extensively contorted and foliation directions vary from 90° to 180°; the most prominent being 110°. The rock contains inclusions of schist and gneiss, and is intruded by leucocratic granite; no contact with the metadiorite or coarse granite has been seen, but its intense folding suggests that it is older than these two rocks; it appears to grade into the large feldspar granite.

The metadiorite occurs in two small areas, and as inclusions in the large feldspar granite. It is a dark fine-grained massive rock composed of oligoclase, biotite, and quartz with minor epidote, sphene, and magnetite. Its relationship to the coarse granite is not known, but it intrudes the schists and gneisses, is intruded by the leucocratic granite, and grades into the large feldspar granite.

The coarse granite is confined to the southern part of the complex. It is a pink massive coarse fairly even-grained adamellite and granite consisting of microcline, quartz, plagioclase, biotite, and sericite with fluorite as a common accessory. Pale blue opalescent quartz is characteristic. It contains xenoliths of schist, is intruded by the leucocratic granite, and grades into the large feldspar granite.

The large feldspar granite is the most extensive unit in the complex. Although it is described as an adamellite by Rhodes (op. cit.), much of it would be classified as granite by Morgan (1964, unpubl.). It is a porphyritic rock containing large phenocrysts of microcline (up to 6 cm long) in a medium-grained groundmass of microcline, quartz, oligoclase or albite, and biotite in varying proportions, with accessory magnetite, abundant sphene, apatite, zircon, and fluorite. Fine-grained aplite inclusions are common, and the plagioclase has commonly been replaced by aplite or microcline. The albite is secondary, and was formed by retrograde metamorphism. The large feldspar granite is intruded by the leucocratic granite, but grades into the other members of the complex.

The leucocratic granite forms a large intrusion in the southern part of the complex; smaller intrusions occur throughout the complex. It is a fine to medium even-grained pink or grey granite which is aplitic and pegmatitic in places. It is composed of microcline, quartz, albite, chloritized biotite, minor muscovite, and a little apatite, magnetite, fluorite, zircon, and epidote. The textural relationships suggest that the microcline and albite crystallized together. The grey granite near Mount Fitch is probably a coarser-grained phase of the leucocratic granite.

Nowhere have any of the rocks of the Rum Jungle Complex been seen intruding the Batchelor Group sediments. The sediments are domed and silicified around the complex, but this appears to have been caused by folding and regional metamorphism rather than by the intrusion of granite. Just north of Batchelor, Ruxton & Shields (pers. comm.) have seen sediments at the base of the Batchelor Group resting unconformably on the coarse granite. The youngest granite, the leucocratic granite, may intrude the sediments, but direct evidence is lacking. Quartz-tourmaline veins near the margin of the complex intrude both the complex and the country rocks. Indirect evidence as presented by Rhodes (1965) suggests that all rocks in the complex are older than the Batchelor Group, but until more definite evidence is available we prefer to tentatively regard the complex as Proterozoic to Archaean in age. Richards et al. (1966) have dated zircons from the coarse and large feldspar granites and obtained an average age of 2550 m.y. The 1610 m.y. age obtained by Richards (1963) by the K/Ar method on biotite from the Rum Jungle Complex is probably a metamorphic age.

Litchfield Complex

The Litchfield Complex includes large areas of granitic rocks on the western margin of the Pine Creek Geosyncline. The complex probably extends southwards from the Finniss River almost to the Moyle River, but it is divided into three by intervening areas of Palaeozoic and Cainozoic rocks. The three main masses are situated between the Finniss and Reynolds Rivers, near Litchfield homestead, and south of the Daly River in the watershed of Hermit Creek. The three masses have a total area of about 1200 square miles. The complex is poorly exposed, except in parts of the Litchfield homestead mass.

The Litchfield Complex is named from Mount Litchfield, west of Litchfield homestead, at latitude 13°32′S., longitude 130°36′E. The term Mount Litchfield Granite was used by Hossfeld (1937a) for the granite in the Mount Litchfield area. Noakes (1949) formalized the name and extended it to include all the granitic rocks on the western margin of the Pine Creek Geosyncline. The name was revised to Litchfield Complex as the regional mapping has shown the complex to include a diversity of rock types, even when the Archaean Hermit Creek Metamorphics are excluded. The name Litchfield Complex was first published by Malone (1962a, 1962b) and Randal (1962).

In the northern mass, between the Finniss and Reynolds Rivers, the rocks generally crop out as scattered tors in a plain with granitic soil (Malone, 1958, unpubl.). The complex includes tonalite, granodiorite, granite, and metamorphosed basic rocks. The granodiorite and tonalite are grey, medium to coarse-grained, and both massive and gneissic. They consist of quartz (30 to 35 percent), oligoclase-andesine (45 percent), microcline and microperthite (5 to 20 percent), and biotite (5 to 15 percent), with accessory muscovite, hornblende, apatite, zircon, magnetite, and fluorite. Sporadic grains of garnet, up to 2 mm across, are present. The quartz is strained and recrystallized; the feldspars are extensively altered; and myrmekite is common. The granite has a similar texture to the tonalite and granodiorite, but contains more alkali feldspar and also muscovite. Albite is present in some of the granites, and myrmekite is common.

The metamorphosed basic rocks are amphibolite and epidiorite. The amphibolite contains 50 to 60 percent green hornblende, a small proportion of pyroxene partly pseudomorphed by amphibole, and a little quartz, albite, magnetite, sericite, and chlorite. The epidiorite consists of 45 percent andesine-labradorite, 35 percent amphibole, and 10 percent quartz, with a little chlorite, sericite, magnetite, and iron oxides.

Near Litchfield homestead the complex is well exposed over an area of about 100 square miles. It consists mainly of grey medium to coarse-grained massive and gneissic adamellite and granodiorite composed of quartz, plagioclase (mainly andesine), microcline, microperthite, biotite, muscovite, and a little apatite, zircon, sphene, fluorite, and iron oxide. Garnet, sillimanite, and cordierite are present in places, and myrmekite and graphic intergrowths are common. The rock contains numerous xenoliths, and the phenocrysts and xenoliths commonly have a platy flow structure on the eastern boundary. Towards the centre of the mass the platy flow structure is less pronounced, and broad patches of light-coloured adamellite and dark feldspathized xenoliths are present. The flow structures trend at about 340°, and are generally parallel to the bedding in the adjacent Lower Proterozoic sediments. The gneissic foliation, due to the alignment of biotite and muscovite in thin bands, trends at 75° and 285°. Pegmatite dykes and quartz veins intrude the complex which transgresses the basic rocks at Marion Hill.

The southern mass of the Litchfield Complex crops out in isolated tors surrounded by deep granitic soil. The most common rock type is a grey garnetiferous granodiorite which ranges from massive to gneissic and contains numerous xenoliths; tonalite, adamellite, granite, and some basic rocks also occur. The granitic rocks are similar in composition to the more basic types in the Litchfield homestead area; they are rich in biotite and in places contain tourmaline. The increase in the proportion of garnet towards the migmatite-schist of the Hermit Creek Metamorphics and the presence of sillimanite and cordierite suggest hybridization with the metamorphics. The basic rocks are dark grey and medium-grained, and range from melagabbro to diorite. They consist mainly of pyroxene and labradorite, with a little quartz, biotite, and potash feldspar.

The contact between the Litchfield Complex and the Lower Proterozoic sediments has not been seen, but many of the eastern contacts appear to be faulted. Noakes (1949) has suggested that most of the Litchfield 'Granite' was formed by granitization of Lower Proterozoic sediments. This seems unlikely, but it is probable that much of the complex is an anatectic granite (Tyrrell, 1930) derived from Archaean rocks such as the Hermit Creek Metamorphics. This hypothesis is supported by the increase in the proportion of the garnet and the presence of sillimanite and cordierite in a broad zone around the Hermit Creek Metamorphics. Similar gneissic granites of anatectic origin, which contain garnet, sillimanite, and cordierite, are well exposed in the Gove area of Arnhem Land (Roberts et al., in prep.).

Hurley et al. (1961), using the K/Ar method, obtained an age of 1630 m.y. on a biotite from granite in the northern mass, 1560 m.y. on biotite from the southern mass, and 1595 and 1605 m.y. on biotite and muscovite respectively from a granite in the Litchfield homestead mass. Leggo (pers. comm.) has obtained total rock Rb/Sr measurements from Hurley's third sample and fitted them to a 1760-m.y. isochron.

The age determinations show that the last movement of granite in the Litchfield Complex took place in the early Carpentarian, but the close association of the complex with the Archaean metamorphics suggests that it may be partly Archaean.

Early Carpentarian Granites

Jim Jim Granite

Most of the Jim Jim Granite is concealed by sandstone of the Katherine River Group on the Arnhem Land Plateau. The granite crops out over an area of 100 square miles in the valley of Jim Jim Creek and in a much smaller area to the south near the headwaters of Fisher Creek. The name Jim Jim Granite was first used by Walpole (1962), and is derived from Jim Jim Creek, a major tributary of the South Alligator River. Leichhardt (1847) recorded the first observations on the Jim Jim Granite. He noted a coarse-grained granite and a high range of pegmatite in the central part of the granite body. This part of the granite has not been examined since. Along the northern margin, the granite intrudes basic rocks in a number of places and is commonly hybridized. It transgresses the strike of the adjacent Lower Proterozoic sediments, and is overlain by the Carpentarian Kombolgie Formation. The smaller southern area consists of fine-grained biotite granite, and is poorly exposed. The stratigraphic relationships of the Jim Jim Granite suggest that it is intrusive into the Lower Proterozoic sediments, and that it is early Carpentarian in age.

Malone Creek Granite

The Malone Creek Granite occupies about 40 square miles near the south-eastern end of the South Alligator River valley; it is an almost circular intrusion which transgresses the north-westerly trend of the country rocks. The granite is rugged in outcrop and is surrounded by a resistant metamorphic aureole.

The name Malone Creek Granite was first published by Raggatt (1958), and is derived from Malone Creek (also known as Coronation Creek and Middle Creek), a small west-flowing tributary of the South Alligator River, which it joins at latitude 13°36′S., longitude 132°37′E.

The granite is uniform in texture except for the presence of porphyritic zones near the margin, and patches of greisen. It is a fine to medium-grained massive aplitic granite composed of kaolinized feldspars, quartz, fluorite, and some biotite and muscovite. The accessories include allanite, sphene, and iron oxide. The quartz and feldspar commonly form micrographic intergrowths. Fluorite is abundant, and forms up to 2 percent of the rock. The presence of monazite in the bed of Malone Creek (W. J. Fisher, United Uranium N.L., pers. comm.) suggests it is also present in the granite.

The granite has hornfelsed the adjacent Fisher Creek Siltstone, and Bryan (1962, unpubl.) found that the dolerite adjacent to the granite is progressively more strongly sheared as the contact is approached. There does not appear to be any contact metamorphism of the overlying Edith River Volcanics, and a thin bed of arkose, presumably of Carpentarian age, rests on the north-western corner of the granite. These relationships indicate that the Malone Creek Granite is early Carpentarian in age. The granite is probably a late-stage high-level phase which may have been intruded not long before the deposition of the Edith River Volcanics.

Yeuralba Granite

The Yeuralba Granite crops out in two small masses adjoining and near the southern margin of the Grace Creek Granite; they are about 9 square miles and 15 square miles in area. The larger mass extends under the Cretaceous sediments. Similar rocks near Maranboy may also be related to the Yeuralba Granite.

The Yeuralba Granite was named by Walpole (1958a) after the Yeuralba mineral field on the western margin of the granite at about latitude 14°15′S., longitude 132°45′E.

The smaller northern mass is a leucocratic porphyritic adamellite. It consists of large phenocrysts of altered oligoclase-andesine, vein perthite with marginal inclusions of quartz, and quartz with inclusions of plagioclase and zircon; the coarse-grained hypidiomorphic groundmass is composed of granular quartz, orthoclase, oligoclase, and altered green biotite, with a little apatite, chlorite, opaques, leucoxene, sphene, and muscovite.

The larger southern mass is similar in texture and composition, but on or near the western margin it is extensively altered to greisen, tourmalite, and topazite. These altered rocks and the associated quartz-tourmaline-cassiterite hornfels lodes are the source of the tungsten, tin, gold, and bismuth mineralization in the Yeuralba district (Walpole & Drew, 1953, unpubl.).

The Yeuralba Granite intrudes the Burrell Creek Formation and is surrounded by narrow metamorphic aureoles. The contacts between the granite and sediments are largely controlled by fractures trending at 50° and 330° parallel to the joints in the granite. The western boundary trends northwards parallel to a set of minor joints in the granite. The Yeuralba and Grace Creek Granites are not seen to be in contact, but it is assumed that the Yeuralba Granite is probably early Carpentarian in age and that it is probably intruded by the Grace Creek Granite.

The igneous rocks in the Maranboy area have not been mapped as part of the Yeuralba Granite, but they have been affected by a similar type of mineralization. They comprise hornblende adamellite porphyry and quartz porphyry. Gray & Jensen (1915) also refer to a red granite which is probably an altered and weathered adamellite porphyry (Walpole, 1958a). The quartz porphyry is extensively altered to greisen and tourmalite.

Wolfram Hill Granite

The Wolfram Hill Granite occupies a subrectangular area 3½ miles by 2 miles in the headwaters of Fergusson River. There are also three small outcrops in the eastern contact metamorphic zone. The granite has a generally rugged outcrop and a well defined resistant contact metamorphic aureole. The granite is named from Wolfram Hill, a mining camp about 1 mile north-west of the granite at latitude 13°57′S., longitude 132°15′E. The name was first published on the Ranford Hill 1-mile Sheet (1958).

The Wolfram Hill Granite includes a grey fine-grained adamellite and a pink medium-grained granite. The grey adamellite occurs in patches in the pink granite and contains xenoliths and clots of biotite up to 5 cm in diameter. In both the granite and the adamellite the quartz forms irregular grains with inclusions of feldspar, mica, and iron oxide; numerous minute fluid inclusions are also present. The potash feldspars are perthite and microcline, and some of the perthite forms phenocrysts up to 5 mm long. The microcline replaces plagioclase in places. Oligoclase and biotite are more abundant in the grey adamellite than in the pink granite. The plagioclase is generally altered, and in places the biotite has been altered to chlorite. Fluorite is common in the biotite; other accessories include magnetite and hematite, and rare zircon and apatite.

The granite intrudes the Burrell Creek Formation and mainly transgresses the bedding, although some doming of the sediments seems to have taken place. The width of the metamorphic aureole of micaceous and siliceous hornfels ranges from about one-third of a mile in the west to 2 miles on the eastern side of the granite. The hornfels contain numerous quartz veins, some of which also cut the granite. Tin mineralization occurs within the granite, and wolfram, tin, copper, and lead mineralization within a distance of several miles.

The Wolfram Hill Granite appears to be a late-stage stock associated with the Cullen Granite.

Cullen Granite

The Cullen Granite forms a large batholith in the centre of the Pine Creek Geosyncline. It is roughly V-shaped and crops out over an area of about 1100 square miles; it may extend well beyond the exposed western margin, where it is covered by younger Adelaidean and Palaeozoic sediments. The small isolated granites to the east of the main mass are cupolas of the batholith. In the eastern part of the batholith just south of Moline, the granite forms rugged hills with almost continuous outcrop; in the north-eastern arm of the batholith and to the north-west of Pine Creek there are few outcrops away from the margin of the granite.

The Cullen Granite is named from the Cullen River, a tributary of the Fergusson River. The Cullen River drains part of the granite to the south-east of Pine Creek. Jensen (1919) restricted the term to the granite in the Cullen River area and used other names for other parts of the batholith, including Mary River, Umbrawarra, Fergusson, Edith, Mount Davis, Margaret, and Douglas granites. Noakes (1949) formalized the name Cullen Granite. The batholith has also been called the Pine Creek Granite (Hossfeld, 1954).

The Cullen Granite has not been studied systematically, but five types of granite have been distinguished; the granites have not been mapped separately except in the southernmost part of the batholith. In the south, Rattigan & Clark (1955, unpubl.) have distinguished three types of granite on the Mount Todd and Lewin Springs 1-mile Sheets (1962). The five types are: pink coarse porphyritic granite (Rattigan & Clark's (op. cit.) 'Edith Crossing Type'); pink and green coarse porphyritic adamellite ('Copperfield Creek Type'); grey coarse porphyritic granite; grey fine porphyritic adamellite ('Meenie Creek Type'); and grey fine even-grained granite.

The pink coarse porphyritic granite crops out in the Edith River area, and its extent beyond this area is unknown. The rock is a massive porphyritic granite or adamellite with an average grainsize of 3 mm; the phenocrysts of pink potash feldspar range up to 5 cm across. In places the rock is sheared. The rock is composed of microcline, microperthite, quartz, albite-oligoclase, and biotite with accessory apatite, strongly zoned zircon, and red iron oxide.

The pink and green coarse porphyritic adamellite occurs about 10 miles south of Grove Hill and in the Copperfield Creek area south of Pine Creek. It is an attractive stone with large pink phenocrysts of microcline microperthite up to 5 cm long set in a matrix of green oligoclase-andesine, quartz, hornblende, and biotite. The accessory minerals include apatite, sphene, iron oxide, clinozoisite, and zircon.

The grey coarse porphyritic granite occurs in the Harriet Creek/Nellie Creek area west of Moline, and is probably widespread in the northern part of the batholith. The rock is massive, with grey subhedral phenocrysts of microcline microperthite up to 2 cm long. The groundmass is medium-grained, and consists of quartz, microcline, albite-oligoclase, biotite, and hornblende. Some marginal recrystallization of quartz has occurred.

The grey fine porphyritic adamellite crops out near the old Lewin Springs homestead, south of Pine Creek, and is possibly related to Rattigan & Clark's Meenie Creek type, which crops out in patches throughout the southern part of the batholith. It is a fine to medium-grained hornblende-biotite adamellite. Some of the scattered phenocrysts of microperthite average 3 cm in length and the remainder range from 0.5 to 1 cm. Small oligoclase phenocrysts also occur. Other minerals present include quartz, biotite, and hornblende, with a little apatite, iron oxide, prehnite, and pyrite. Two generations of potash feldspar phenocrysts appear to be present, and it is possible that the rock is a hybrid between the 'Copperfield Creek' and 'Meenie Creek' types of Rattigan & Clark (op. cit.). The 'Meenie Creek' type does not contain large phenocrysts or much hornblende and biotite; it intrudes the 'Copperfield Creek' type, commonly with hybrid zones nearby (Rattigan & Clark, op. cit.).

The grey fine even-grained granite occurs in the north-eastern limb of the batholith north of Frances Creek, and the cupola near Mount Davis is similar. The rock is massive and fine to medium-grained; late-stage alteration and recrystallization of minerals are common. It is composed of zoned microcline, quartz, zoned plagioclase, and biotite, with accessory iron oxide, apatite, allanite, and zircon. The zoning in the microcline may be due to the presence of soda-rich layers, which suggests potash metasomatism. The granite near Mount Davis also contains fluorite.

Gabbro occurs near the western edge of the Cullen Granite between Frances Creek, Maude Creek, and the Mary River, but its full extent is not known. The gabbro is fresh, and consists of labradorite, pigeonite, and phlogopite with accessory magnetite and apatite. Near the contact with the granite it is metamorphosed to a tremolite-actinolite rock with saussuritized plagioclase.

Quartz porphyry dykes intrude the country rock to the south-east of the Cullen Granite. Stewart (1965) describes them as extremely altered. Aplite dykes are common in the Cullen Granite south of Pine Creek.

The intrusive contacts between the granite and country rock are well exposed; they are sharp and there is only a little thermal metamorphism. Near Mount Masson on the north-eastern lobe of the granite, Hays (1960, unpubl.) has noted that the metamorphic aureole is only about 300 feet wide and that there is no chilled margin in the granite. Walker (in Hays, op. cit.) states that greywacke

PLATE 13.

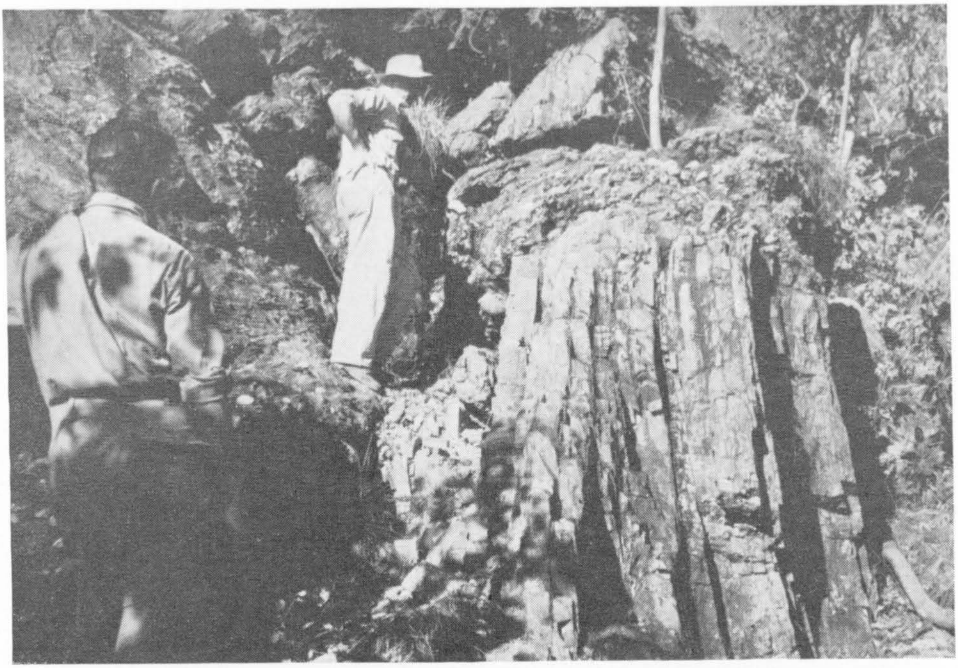

Fig. 1: Unconformity between Koolpin Formation and Coronation Member near the Rockhole uranium mine, South Alligator River area, Mount Evelyn Sheet. Unstressed polymictic conglomerate draped over an irregular surface of steeply dipping carbonaceous dolomitic shale.

Fig. 2: 'Hematite Quartzite Breccia', Buckshee phosphate prospect, Rum Jungle, Pine Creek Sheet. This rock and its variants are identical with the Scinto Breccia.

PLATE 14.

Fig. 1: Sandstone of Kombolgie Formation intermixed with Edith River Volcanics, Diamond Creek area, Katherine Sheet.

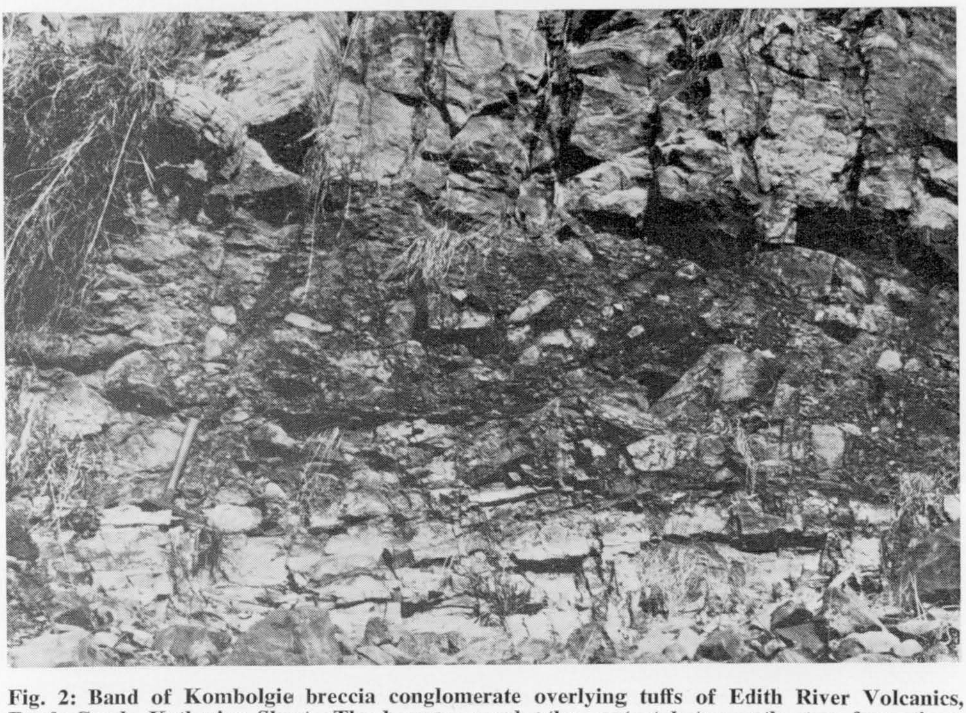

Fig. 2: Band of Kombolgie breccia conglomerate overlying tuffs of Edith River Volcanics, Dook Creek, Katherine Sheet. The hammer marks the contact between the two formations.

PLATE 15.

Fig. 1: View from track to El Sherana mine south-west across the South Alligator River valley, Mount Evelyn Sheet. Dark Kurrundie Member sandstone in the middle distance, massive Kombolgie sandstone in background; the valley follows the South Alligator Fault Zone.

Fig. 2: Quartz pebble conglomerate, Kurrundie Member, near Goodparla homestead, Mount Evelyn Sheet.

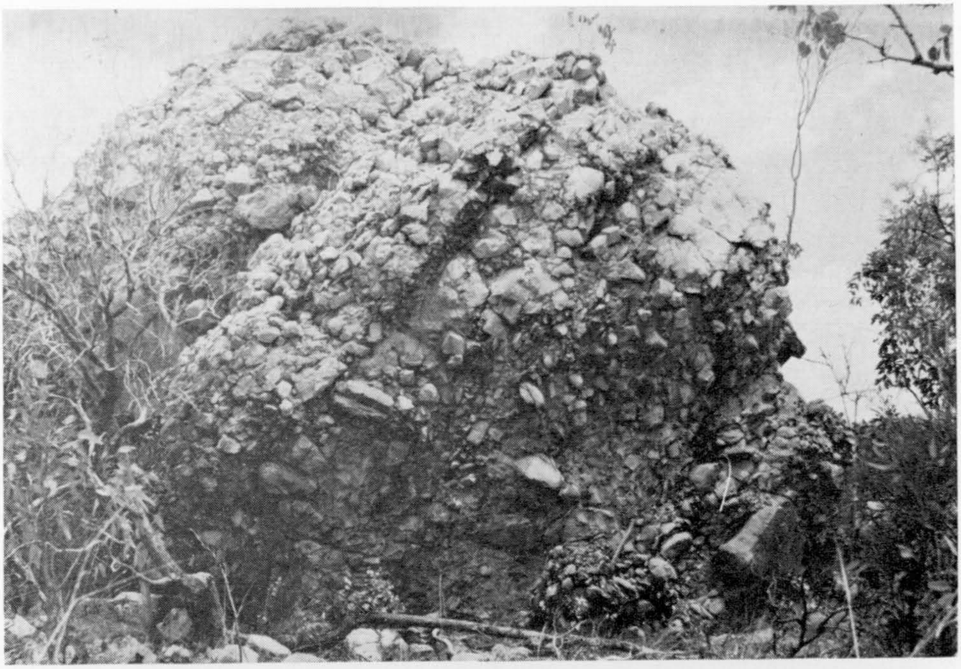

Fig. 1. Slump breccia in sandstone of Kombolgie Formation intercalated in Birdie Creek Volcanic Member, Katherine Sheet. The axe in the bottom right-hand corner gives the scale. In a nearby locality a similar bed can be traced into unbrecciated material.

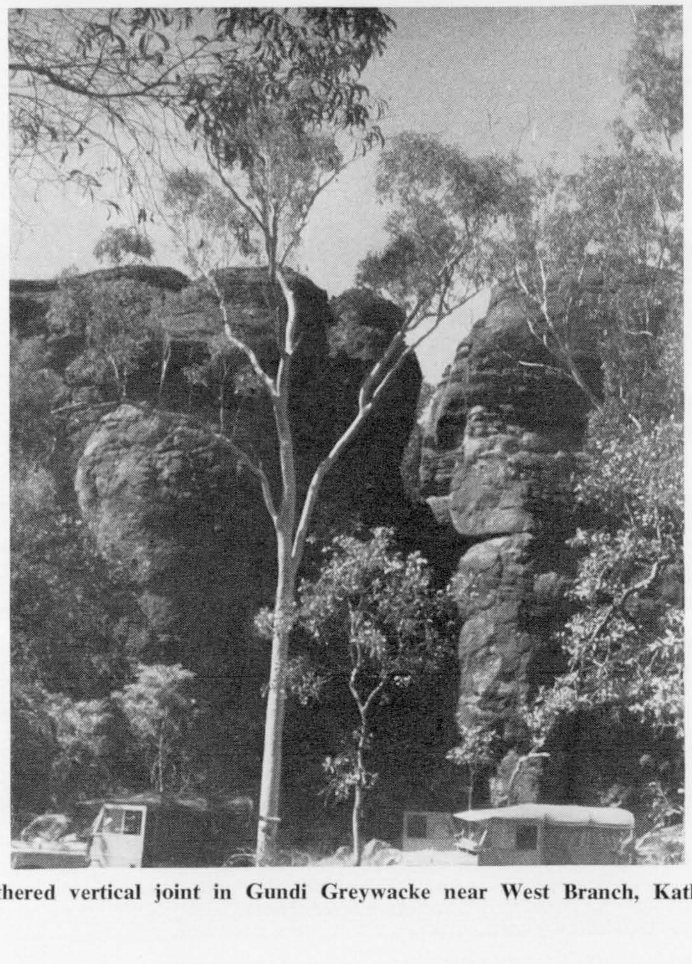

Fig. 2: Weathered vertical joint in Gundi Greywacke near West Branch, Katherine Sheet.

near Mount George has been converted to hornfels composed of biotite, muscovite, chlorite, and albite with some cordierite and andalusite. This assemblage would develop over a temperature range of 550°C to 700°C (Turner & Verhoogen, 1960). On the eastern side of the granite the metamorphic aureole is several miles wide, and the presence of numerous quartz porphyry dykes and granite cupolas within the metamorphic aureole suggests that the main contact of the granite dips at a low angle to the east. In many places the granite contact appears to have been controlled by faults.

Two samples of biotite from the Cullen Granite from near the Edith River and near Pine Creek have been dated by Hurley et al. (1961) at 1695 m.y. by the K/Ar method; a check determination by the Rb/Sr method on the Edith River sample gave an age of 1765 ± 90 m.y. Leggo's (pers. comm.) later work indicates an age of 1760 m.y.

McKinlay Granite

The McKinlay Granite appears to be an offshoot of the Cullen Granite; it intrudes sediments of the Burrell Creek Formation between the two arms of the Cullen mass. It covers an area of about 12 square miles to the south-east of Burrundie, and is well exposed.

The name is derived from the McKinlay River, the upper course of which skirts the western side of the granite; the name was first published on the Burrundie 1-mile Sheet (1959).

The McKinlay Granite is a pale grey medium to coarse-grained homogeneous adamellite. The presence of cracks and undulose extinction in the quartz and bent biotite flakes indicates that there has been some cataclastic deformation. The quartz contains inclusions of feldspar, mica, and iron oxide. The potash feldspars include orthoclase, microcline, and perthite, which have undulose extinction in places. The plagioclase is severely altered. Biotite is scattered through the rock, but in places occurs in fine-grained clots which probably represent xenoliths. The accessory minerals are apatite, allanite, magnetite, ilmenite, and rare fluorite, zircon, and sphene.

On the extreme south-western edge of the granite there is a porphyritic andesite which has been metamorphosed; it was probably an early hybrid phase of the granite.

The McKinlay Granite appears to be an apophysis of the Cullen Granite; it generally transgresses the bedding of the country rock; the linear form of the western boundary suggests control by a fault. The deformation of the crystals also suggests forcible intrusion.

By analogy with the Cullen Granite the McKinlay Granite is considered to be early Carpentarian in age.

Prices Springs Granite

The Prices Springs Granite is a subrectangular mass, about 30 square miles in area, immediately to the north-west of Burrundie. The topography is rugged in places, and about half of the granite is exposed; the remainder is covered by sand and soil.

The Prices Springs Granite is named from Prices Springs homestead or 'The Banyans' situated near the southern margin of the granite at latitude 13°32'S., longitude 131°40'E. The name was first published by Jensen, Gray, & Winters (1916); the granite has been described by Hasan (1958a, unpubl.).

Specimens have been collected only from the southern part of the intrusion, where it ranges from biotite granite to biotite adamellite. The rock is grey, massive, medium to coarse-grained, and porphyritic. Two textural varieties have been recognized: the first contains numerous phenocrysts of potash feldspar up to 2 cm long set in a medium-grained groundmass, the second contains only a few large phenocrysts set in a finer groundmass. The granite is composed of quartz, microcline, perthite, altered zoned plagioclase, and biotite, with a little apatite, zircon, sphene, allanite, and epidote. Hornblende is present in places. The Prices Springs Granite resembles the McKinlay Granite in composition and texture, and there is also evidence of cataclastic deformation. Hasan (1958a, unpubl.) has compared the modal and chemical analyses of the two granites with the Cullen Granite, and found that the Prices Springs and McKinlay Granites are probably a slightly more basic phase of the Cullen Granite.

The Prices Springs Granite intrudes sediments of the Burrell Creek and Golden Dyke Formations and basic sills and dykes. The contact with the basic rocks is diffuse, and hybrid rocks occur over zones up to a quarter of a mile wide. The emplacement of the granite appears to have been largely controlled by fractures trending north-north-west, and to a lesser extent by fractures at right angles.

The Prices Springs Granite was dated by Hurley et al. (1961) at 1695 m.y., using the K/Ar method on biotite. Leggo (pers. comm.) has fitted the Rb/Sr total rock data from the Prices Springs Granite on the 1760-m.y. isochron, which he obtained for most of the Katherine-Darwin granites.

Margaret Granite

The Margaret Granite occupies an almost circular area of about 20 square miles, 10 miles north of Grove Hill. It lies mainly in the floodplain of the Margaret River, and outcrop is rare; only two outcrops have been examined.

The name is derived from the Margaret River, which passes through the granite at about latitude 13°16'S., longitude 131°34'E. Jensen, Gray, & Winters (1916) used the name Margaret granite for two masses in the Grove Hill area which were probably parts of the Prices Springs and Cullen Granites. Sullivan &

Iten (1952) used the name Margaret Granite for the granite south of Hayes Creek mine, but it was later proved to be part of the Cullen Granite (Noakes, 1949). The name is now given to the circular granite 10 miles north of Grove Hill, and was published on the Ban Ban 1-mile Sheet (1960).

The Margaret Granite is similar in appearance to the pink and green coarse porphyritic adamellite of the Cullen Granite south of Grove Hill, but in the Margaret Granite plagioclase is predominant over potash feldspar (App. 6). The Margaret Granite contains phenocrysts of microcline perthite up to 3.5 cm long set in a medium-grained groundmass. The groundmass consists of strongly zoned and altered plagioclase, quartz, biotite, and hornblende, with a little apatite, epidote, sphene, zircon, iron oxide, and fluorite in places.

The contact between the Margaret Granite and the adjacent sediments has not been seen, but the sediments are hornfelsed for a distance of about half a mile on the southern margin.

The Margaret Granite is assumed to be intrusive into the Burrell Creek and Golden Dyke Formations. No age determinations are available, but its lithology and intrusive relationships suggest an early Carpentarian age.

Burnside Granite

The Burnside Granite crops out in a subrectangular mass, about 40 square miles in area, to the north of Brocks Creek Siding. The granite occupies the core of a dome of Lower Proterozoic sediments.

The name is derived from the Burnside 1-mile Sheet on which it occurs; Burnside (or Byrneside) station, one of the earliest settled cattle properties in the region, lies several miles to the south of the granite at latitude 13°28′S., longitude 131°24′E. The granite was referred to as the Brocks Creek granite by Jensen et al. (1916) and later as the Brocks Creek Granite by Sullivan & Iten (1952); as Jensen et al. also referred to the Brocks Creek series and Noakes (1949) extended the term to Brocks Creek Group, the granite was renamed Burnside Granite by Malone (1962a).

The rock is a relatively homogeneous fine to medium-grained grey biotite adamellite. It is generally massive and even-grained, but in places it is porphyritic or foliated.

It is composed of quartz, microcline, microperthite, andesine, and biotite, with accessory muscovite, zircon, fluorite, and apatite. The potash feldspar has been partly replaced by plagioclase. Myrmekitic intergrowths, and inclusions of fluorite in the plagioclase and biotite are common; but iron oxide and sphene are absent.

Veins of quartz, pegmatite, aplite, and microgranite are common on the margin of the granite, and patches of greisen are also present. Molybdenite is found in quartz veins in the granite about 3 miles north-west of Ban Ban Springs.

The Burnside Granite is almost concordant; it lies in the centre of a dome but transgresses some of the lower units of the Lower Proterozoic rocks which form the dome. The narrow metamorphic aureole consists mainly of chiastolite slate and mica schist. Aplite and quartz porphyry dykes are common in the contact zone.

The near-concordance of the granite suggests that it is synkinematic, but as it has been intruded in an area where there is a change in the regional strike of the country rocks it may have been intruded into a pre-existing dome. Hurley et al. (1961) dated the Burnside Granite as 1520 m.y., which was younger than the dates obtained on transgressive intrusions such as the Cullen Granite. Later work by P. J. Leggo (see App. 2) suggests that the Burnside and Cullen Granites are similar in age. Neither of the age determinations indicates that the Burnside Granite is older than the transgressive granites, and it therefore seems unlikely that it is a synkinematic intrusion.

Fenton Granite

The Fenton Granite includes two intrusions separated by Cambrian sediments and alluvium near Fenton and Long airstrips, about 110 miles south of Darwin. The two intrusions have an area of about 50 square miles, but are poorly exposed.

The granite is named after the abandoned Fenton airstrip at latitude 13°37′S., longitude 131°21′E. The name was first published by Joplin (1957).

The eastern part of the intrusion varies considerably in composition, and has generally been sheared. The most common type is a red and black coarse porphyritic hornblende-biotite granite which may or may not be sheared. It consists of quartz, microcline microperthite, oligoclase, biotite and hornblende, with a little apatite, zircon, sphene, and allanite. The microcline has replaced some of the plagioclase. Where the rock has been sheared the biotite is recrystallized and aligned to produce a strong foliation; the quartz is also recrystallized. Other rocks in the eastern mass include sheared leucocratic adamellite and contaminated albitite. The adamellite contains some hornblende and fibrous tremolite-actinolite, but no biotite; epidote, actinolite, and sphene occur along the shear planes. The albitite is a creamy white rock cut by dark veins, and occurs near the leucocratic adamellite. It consists of albite and epidote with some sphene, and has been brecciated and recrystallized. Joplin (1957) does not consider that it is a true albitite because of the high lime content of the albite due to contamination by limestone.

The western intrusion of the Fenton Granite consists mainly of grey medium to coarse-grained foliated biotite granite. It consists of quartz, microcline microperthite, oligoclase, and biotite with minor apatite and zircon. The foliation is due to the alignment of the large microcline phenocrysts and the biotite, but unlike the granites in the eastern mass there is no evidence of shearing.

Intrusive contacts have been seen only on the western margin of the western mass where it intrudes the Burrell Creek and Golden Dyke Formations.

Hurley et al. (1961) obtained an age of 1720 m.y. on biotite, which was the oldest age they obtained on the Katherine-Darwin granites. This was the nearest age to the 1760 m.y. obtained by Leggo (pers. comm.), using the total rock Rb/Sr method, for most of the Katherine-Darwin granites.

Shoobridge Granite

The Shoobridge Granite occupies an almost circular area of 1 square mile in the centre of a small dome structure on the Stuart Highway 100 miles from Darwin.

The name was derived from Mount Shoobridge, a prominent flat-topped hill on the south-east margin of the granite at latitude 13°32′S., longitude 131°17′E. Jensen, Grey, & Winters (1916) first used the name Mount Shoobridge 'granite' and Sullivan & Iten (1952) continued its use. Malone (1962) shortened the name to Shoobridge Granite.

The following brief description was provided by J. M. Rhodes (BMR, pers. comm.). Three varieties have been recognized: leucocratic adamellite, porphyritic hornblende-biotite adamellite, and hornblende-biotite granodiorite. The second variety is the most extensive, and forms a broad zone surrounding the central leucocratic adamellite; it is in turn almost completely surrounded by the marginal hornblende-biotite granodiorite, into which it grades over a distance of about 20 feet. The contact is irregular and has a low dip, which suggests that the present level of erosion is close to the roof of the granite.

The leucocratic adamellite occupies an area of about 30 acres in the centre of the intrusion. The contact with the surrounding porphyritic biotite-hornblende adamellite is sharp, and it is probable that the leucocratic adamellite is younger than the other granites.

The Shoobridge Granite intrudes the Golden Dyke Formation; the sediments are domed and generally concordant with the granite, but they have been thermally metamorphosed and, in detail, are discordant. The granite contains hydrothermal quartz barytes, quartz-malachite, and quartz-muscovite-tourmaline veins; quartz-muscovite and pegmatite veins in the country rock contain lead, tin, and copper.

The Shoobridge Granite has not been dated but belongs to the early Carpentarian suite.

Mount Bundey Granite and Mount Goyder Syenite

The contiguous Mount Bundey Granite and Mount Goyder Syenite crop out over an area of about 30 square miles near the old Mount Bundey homestead and astride the Mary River. The Mount Bundey Granite forms two-thirds of the mass, and the Mount Goyder Syenite the northern third. A small body of Mount Goyder Syenite also crops out 3 miles east of the main mass. The granite forms massive rugged outcrops, but the syenite has less relief and is not so well exposed, as the Mary River floodplain encroaches on the northern part of the mass.

The names are derived from Mount Bundey, a rugged granite hill at about latitude 12°52'S., longitude 131°35'E., and Mount Goyder, a small isolated hill of syenite to the east of the Mary River at latitude 12°51'S., longitude 131°41'E. The names were first published on the Mount Bundey 1-mile Sheet (1959). The granite and syenite have been described by Hasan (1958b, unpubl.) and Dow & Pritchard (1958, unpubl.).

The Mount Bundey Granite comprises mainly pink medium to coarse-grained massive and porphyritic hornblende-biotite granite and adamellite. They are composed of quartz, microperthite, sodic plagioclase, hornblende, and biotite, with a little apatite, sphene, allanite, epidote, and iron oxide. The microperthite forms phenocrysts up to 2 cm across. The Mount Goyder Syenite includes dark pinkish grey porphyritic syenite and quartz syenite; they are composed of the same minerals as the granite, but in different proportions; some zircon and fluorite have also been noted. Both the granite and syenite contain large subhedral and euhedral crystals of sphene and apatite. The similarity of the granite and syenite indicate they were derived from the same source.

The granite and syenite are intruded by aplite and porphyry dykes, and contain xenoliths of country rock up to 3 feet long near their margins. Pritchards lode, a large hematite-magnetite body in the Mount Goyder Syenite (see p. 235), was apparently formed, in part at least, by replacement of a pendant of sediments (Dunn, 1964, unpubl.), although its shape appears to have been controlled by jointing. Both the granite and syenite are well jointed: the joints trending 330° and 50° are related to the intrusion, but other joints related to structures in the country rock are predominant; they trend roughly north and dip steeply to the east.

The granite and syenite occur within an anticlinal structure, but on the western side they are discordant with the sediments. A metamorphic aureole about a quarter of a mile wide surrounds the mass. The sediments of the Burrell Creek and Masson Formations have been silicified or hornfelsed, and the carbonaceous members of the Golden Dyke Formation have been altered to chiastolite schist and black hornfels.

Small sills and dykes, up to 30 feet wide and about half a mile long, occur within a radius of 5 miles of the mass. They are fine to medium-grained and generally deeply weathered; they include hornblende microdiorite, biotite microdiorite, microtonalite, and microsyenite.

Hurley et al. (1961) obtained an age of 1650 m.y. on the Mount Bundey Granite. Leggo (pers. comm.) has been able to fit data for the granite on his 1760-m.y. isochron.

Waterhouse Granite

The Waterhouse Granite is a poorly exposed almost circular mass, about 25 square miles in area, immediately to the south-south-west of Batchelor. This granite has not been studied in detail, and although it is included here in the early Carpentarian granites it probably has a history similar to that of the Rum Jungle Complex. The name was first published by Walpole (1958b), and is derived from the Hundred of Waterhouse, the old land subdivision in which the granite occurs.

Most of the specimens from the Waterhouse Granite are pink and grey slightly porphyritic fine to medium-grained biotite adamellite and granite, generally with a marked lineation. Some of the rocks appear to have been metamorphosed, with albite, muscovite, chlorite, calcite, and epidote replacing many of the original constituents. Fine-grained greyish muscovite-biotite granite containing abundant megacrysts and irregular patches of microcline, and a granitized actinolite-biotite schist have also been recorded.

The contact of the Waterhouse Granite with the adjacent sediments has not been observed. A sequence of Batchelor Group sediments, similar to those enclosing the nearby Rum Jungle Complex, dip off the granite in a domed structure at 40° to 80°.

The age of the Waterhouse Granite is unknown.

Reynolds River Granite

The Reynolds River Granite crops out over an area of about 3 square miles in an elongated east-trending body. The western end of the granite is covered by sediments of the Adelaidean Tolmer Group.

The granite was named after the Reynolds River 1-mile Sheet, on which it occurs. It is situated at about latitude 13°25′S., longitude 130°55′E. The name was first published on the Reynolds River 1-mile Sheet (1960).

The Reynolds River granite comprises pink medium-grained porphyritic sodic adamellite and grey massive medium-grained hornblende-biotite granite. The adamellite consists of perthite, albite, and quartz with a little biotite, muscovite, and iron oxide. The perthite commonly encloses albite, and the plagioclase phenocrysts are much less altered than in most of the Katherine-Darwin granites.

The Reynolds River Granite is elongated perpendicular to the structure of the Lower Proterozoic Burrell Creek Formation sediments which it intrudes.

The granite is assumed to be early Carpentarian in age.

Roberts Creek Granite

The Roberts Creek Granite is a small intrusion, about 7 square miles in area, on the western side of the Pine Creek Geosyncline, about 15 miles west of Batchelor township.

Roberts Creek, from which the granite is named, is a small north-flowing tributary of the Finniss River; its main tributaries flow from the granite at latitude 13°01'S., longitude 130°45'E. The name was first published on the Mount Tolmer 1-mile Sheet (1959).

One specimen is a medium to coarse-grained light grey massive garnetiferous muscovite sodaclase tonalite or sodic granodiorite. It is composed of albite, quartz, and muscovite with accessory garnet, apatite, zircon, and magnetite. Other specimens contain microcline, orthoclase, perthite, and biotite, and have the composition of granodiorite and adamellite. Tourmaline-bearing pegmatite occurs in blebs and patches.

The Roberts Creek Granite intrudes sediments of the Noltenius Formation and resembles the granite in the Litchfield Complex 10 miles to the west. Its intrusive relationship suggests that it is early Carpentarian in age. The granite occurs within the pegmatite-bearing belt of schists which extends from Bynoe Harbour in the north to Collia Waterhole in the south.

Allia Creek Granite

The Allia Creek Granite crops out about 20 miles south of the Daly River police station. One mass is about 20 square miles in area with a smaller outcrop of 5 square miles, 5 miles to the north; two very small apophyses occur near the larger bodies.

The name is derived from Allia Creek, a tributary of Muldiva Creek, which passes through the granite at about latitude 14°4'S., longitude 130°42'E. The name was first published by Randal (1962).

The largest mass comprises medium to coarse-grained grey porphyritic biotite-muscovite adamellite, granodiorite, and tonalite, with a pronounced platy flow structure (Pl. 26, fig. 1), except in the centre, where it is very coarse in grain and almost pegmatitic. In the adamellite, the oligoclase-andesine has been partly replaced by microcline perthite and also contains myrmekitic intergrowths. The microcline perthite forms crystals up to 5 cm long. The biotite and muscovite are intergrown. In the granodiorite and tonalite the plagioclase is andesine-labradorite and biotite is more abundant. A little chlorite, apatite, zircon, epidote, and iron oxide are present. The smaller northern mass is a uniform adamellite with abundant muscovite.

The foliation in the main mass is due to the platy alignment of the large feldspar crystals and tabular xenoliths. The foliation is parallel to the margins of the granite and dips steeply towards the centre. Xenoliths are common; a large tongue of country rock in the granite has been metamorphosed to garnet-mica schist, cordierite schist, and mica schist.

The Allia Creek Granite was dated at 1650 m.y. (biotite) and 1640 m.y. (muscovite) by Hurley et al. (1961). P. J. Leggo (pers. comm.) fitted his total rock Rb/Sr data to the 1760-m.y. isochron.

Soldiers Creek Granite

The Soldiers Creek Granite occupies an area about 15 miles long and 4 miles wide between the Buldiva and Collia tin fields in the south-west part of the Katherine-Darwin Region. It was named from Soldiers Creek, a tributary of the Fish River; the creek cuts the granite at about latitude 14°14'S., longitude 130°48'E. It was named by Hossfeld (1937c).

The Soldiers Creek Granite contains numerous roof pendants and xenoliths and has been extensively greisenized; many hybrids have been formed with the country rocks. One specimen is a slightly foliated medium-grained pinkish adamellite in which the plagioclase has been almost completely sericitized and kaolinized, and heavily stained by hematite. Greisenization has introduced abundant muscovite and some cassiterite. The granite contains numerous pegmatite veins near its margins.

The Soldiers Creek Granite intrudes the Noltenius Formation and has a wide metamorphic aureole of muscovite and andalusite-muscovite schist. The general structure of the adamellite and the country rocks suggest that it represents the roof zone of a large pluton. Part of the intrusion is covered by younger Adelaidean sediments, and its full extent is unknown.

No age determinations are available, but it appears to belong to the early Carpentarian suite.

Late Carpentarian Granite

Grace Creek Granite

The Grace Creek Granite occupies an area of about 600 square miles in the basin of the Katherine River. It is well exposed in rounded hills, and although well jointed it does not form the massive pillars and tors found on the Cullen and other granites.

The Grace Creek Granite (Randal, 1963) was named from Grace Creek, a westerly-flowing tributary of the Katherine River, which it joins at latitude 14°10'S., longitude 132°42′E. It has previously been described as the Mount Harvey Porphyry (Walpole & Drew, 1953, unpubl.) and Grace Creek Porphyry (Walpole, 1958a).

Stewart (1965) has described the northern half of the granite as a porphyritic granophyre or microgranite with equal proportions of orthoclase and acid andesine phenocrysts set in a fine-grained micrographic groundmass. H. W. Fander (AMDL, pers. comm.) has recognized two types from the southern half of the mass, a granophyric adamellite and a subordinate medium-grained slightly porphyritic adamellite. Stewart's and Fander's granophyric rocks appear to be identical: they are generally red-brown in colour and contain phenocrysts of embayed quartz, partly kaolinized orthoclase, sericitized calcic oligoclase or andesine, and aggregates of chlorite set in a groundmass composed almost entirely of micrographic intergrowths of partly kaolinized alkali feldspar and quartz. The accessories include biotite, hornblende, magnetite, zircon, apatite, sphene, and fluorite; some chlorite and calcite are also present. Fander's second type, the medium-grained adamellite, is similar to the granophyre, but only has incipient micrographic texture. A chilled marginal phase and a pegmatite have been noted in the Turnoff Creek area.

Xenoliths are sparsely scattered through much of the granite. The xenoliths are of the hornblende hornfels facies and early pyroxene-hornfels facies (H. W. Fander, AMDL, pers. comm.), which indicate a temperature of formation of about 600°C at 1000 to 2000 atmospheres. The micrographic texture indicates rapid cooling from about 750°C. The granite is a 'subsolvus granite' of Tuttle & Bowen (1958).

The Grace Creek Granite is intrusive into the Lower Proterozoic sediments near Snake Creek, but the contacts with the overlying Carpentarian Edith River Volcanics or Kombolgie Formation are obscured by the deep weathering of the Edith River Volcanics and sandstone rubble. Near Birdie Creek, elongated dyke-like bodies, which are similar to Edith River Volcanics, appear to intrude the granite along major joint planes; they were originally thought to be feeder dykes of the Edith River Volcanics, which would indicate that the granite was older than the overlying volcanics. The age determinations by Leggo (pers. comm.), however, suggest that the granite (1470 m.y.) is much younger than the Edith River Volcanics (1760 m.y.). The joint planes in which the volcanic-like material occurs appear to coincide with major joints in the overlying sandstone; this suggests that the joints postdate the Edith River Volcanics. We therefore regard the Grace Creek Granite as younger than the Edith River Volcanics and of late Carpentarian age.

STRUCTURE

The Katherine-Darwin Region lies within the Precambrian Shield as defined by Cotton (1930), Hills (1956), and Voisey (1959). Most of the structures in the region were developed during Precambrian time; there is evidence that the Pine Creek Geosyncline was an intracratonic structure of limited tectonic activity, and the late Proterozoic sedimentation suggests that the region was a comparatively stable shelf area throughout late Proterozoic time.

The Precambrian structures present many problems which remain unsolved by the latest mapping. No detailed account of the regional structure of the Katherine-Darwin Region has been published, but in a thesis, Walpole (1960, unpubl.) has reviewed the depositional structure of the Pine Creek Geosyncline and discussed its significance within the tectonic framework of northern Australia.

For convenience, the structures are discussed as they affect the rocks of each major time interval even though they may have developed during a later interval.

Archaean

Limited outcrop restricts our knowledge of the structure of the basement Archaean rocks which underlie the Pine Creek Geosyncline, but easterly trends are apparent.

On the western margin of the geosyncline the Hermit Creek Metamorphics have undergone high-grade regional metamorphism and have developed a general east-west foliation. The original bedding has been recognized in only one place, but the attitude of the fold axes is unknown. The foliation in the rocks of the Litchfield Complex which intrude the Hermit Creek Metamorphics trends between 030° and 040° and is probably the result of later movements.

The trends of the foliation and banding in the older rocks of the Rum Jungle Complex range from 270° to 360°, but the most prominent direction is 290°. A later stress has produced shearing with a 320° trend throughout all the rocks of the complex (Rhodes, 1965).

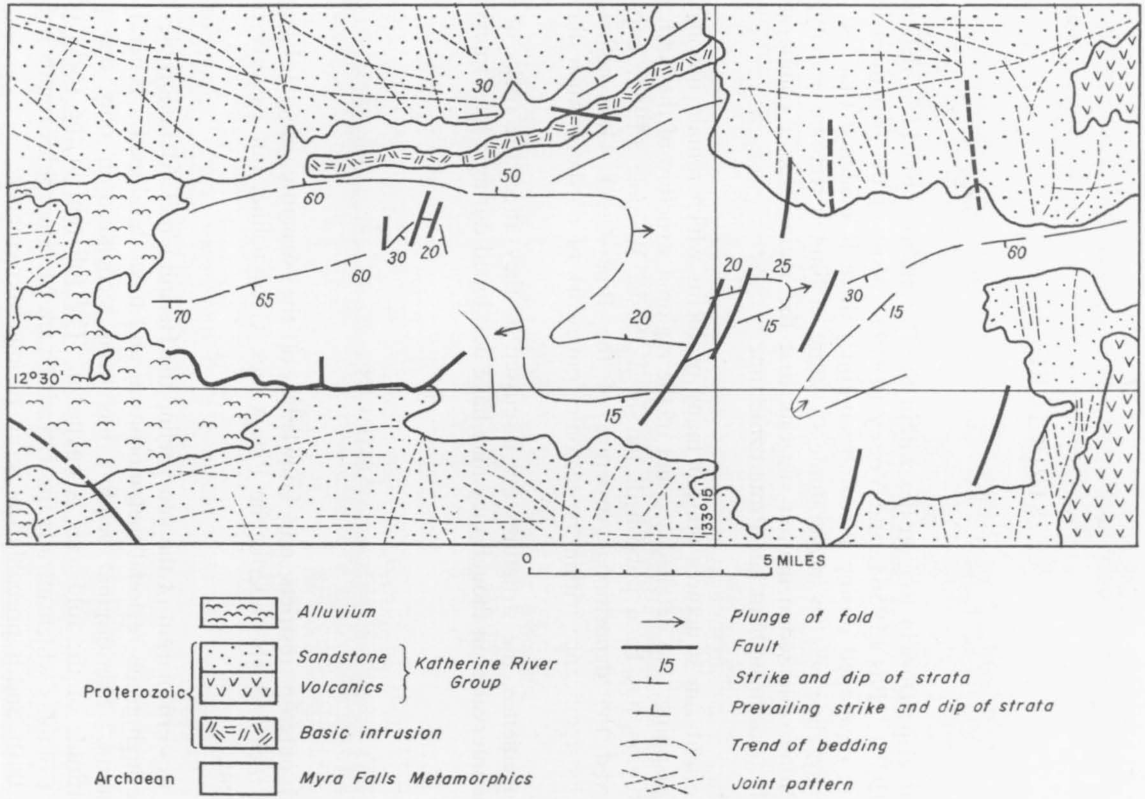

Fig. 22. Structure of Archaean rocks in Myra Falls Window near Oenpelli

In the exposed structures in the Myra Falls Metamorphics the fold axes trend between 045° and 090°. The main fold is a broad east-pitching anticline in which the competent quartzite dips at about 60° to 70° on the limbs and as low as 15° near the nose. Even where the dips are low the quartzite is drag-folded. The interbedded incompetent rocks are intensely folded and crumpled. The anticline has been cross-folded along axes trending at about 045° (see Fig. 22). A system of shear zones and quartz-filled faults, trending between 010° and 030°, cuts the metamorphics.

The Stag Creek Volcanics show no primary structures except for the linearity of their outcrop along the South Alligator River valley. In the Mundogie Hill Dome they are sheared along northerly and north-westerly trends.

The north, north-east, and north-west-trending structures in the Archaean rocks post-date the east-trending features, and are probably associated with the Precambrian movements which affect the overlying rocks.

Lower Proterozoic

The Lower Proterozoic rocks of the Katherine-Darwin Region occupy the Pine Creek Geosyncline. The original structure of the geosyncline influenced the development of the sedimentary pile, and has already been discussed in conjunction with the stratigraphy.

Folding

The Lower Proterozoic sediments have been moderately to tightly folded: the competent beds are mainly folded into open structures with limbs dipping at 40° to 70°; the incompetent beds are more tightly folded and, in places, are isoclinally folded and overturned. The original spatial relationships of the formations are unchanged, with little apparent foreshortening across the geosyncline. The regional trend of the fold axes ranges from 300° in the south-east, through 360° to 020° in the north and west. The disposition of the axes is modified around a number of domes containing cores of granite or basement rocks. The arrangement of fold axes is roughly related to the position of the margins of the trough and to irregularities within the trough developed before and during the deposition of the sedimentary pile.

On the eastern side of the geosyncline several large-scale cross-folds have resulted in regional changes in the pitch of the fold axes; in the western part of the geosyncline a number of basins and domes have been produced by short, steep changes in pitch. Plate 29 illustrates the predominant folds in the sediments.

The South Alligator Trough has been folded parallel to the basement ridge (Stag Creek Volcanics) which forms the western margin of the trough. Farther north, the basement dome at Mundogie Hill has locally modified the structure and marks the area about which the regional strike of the fold axes changes from north-west to north; east of the Mundogie Hill Dome the sediments of the Goodparla Group below the South Alligator Group are severely sheared along north-trending shear planes.

Immediately west of the South Alligator Trough, the sediments in the main trough of the Pine Creek Geosyncline are folded along axes which are also parallel to the basement ridge. Between the basement ridge and the vicinity of Pine Creek the trends in the southern part of the main trough gradually change from north-west to north-north-west. North of a line passing through Hayes Creek and Mount Douglas the trend of the axes swings to the north. This flexure, which is roughly parallel to the trend of later tear faults (e.g., Giants Reef and Hayes Creek Faults), we have called the Grove Hill Cross-flexure. The fold axes in the north-eastern part of the geosyncline swing farther round to about 020°. On the western side of the geosyncline the regional strike of the fold axes is within 20° of north except where it is modified by the Rum Jungle, Waterhouse, and Burnside Domes.

The fold axes do not fit into this regional pattern in the Jim Jim Creek/East Alligator River and Muldiva Creek areas, and south-west of Wolfram Hill. In the first two areas, which are relatively stable shelves or marginal shelves, the structures are probably controlled by the configuration of the basement. The structure south-west of Wolfram Hill more closely resembles that of the north-western part of the geosyncline, with open folds striking north and north-east and rapid changes of pitch.

The changes in pitch in the eastern part of the geosyncline are caused by broad regional cross-folds. The two main structures are a cross-anticline with an adjacent cross-syncline to the north. The axis of the anticline trends easterly from near Hayes Creek on the Stuart Highway to Burrundie; east of Burrundie the axis is offset to a position now occupied by the Cullen Granite, but east of the Mary River it continues along the extension of its original trend to beyond the Mundogie Hill Dome. The offsetting of the axis in the Cullen Granite is probably caused by movements associated with the intrusion of the granite. The cross-syncline also trends east, but does not continue into the South Alligator Trough, where the Mundogie Hill Dome is the dominant structure. The Mundogie Hill Dome or the basement in the vicinity of the dome appears to have acted as a buttress during folding movements in the eastern part of the geosyncline. It is suggested that this buttress helped produce a shear couple, which resulted in rotation and shear folding of the sediments to the west and south. The basement ridge along the South Alligator River valley restricted the rotation of the fold axes, and as the effects of the couple die out to the west away from the buttress, the shear planes and fold axes are more nearly perpendicular to the direction of compression, i.e. with compression from due west the trend of the shear planes and fold axes near Pine Creek trend only 30° west of north compared to 60° west of north near the South Alligator River valley. Where folding has been influenced by the couple, the folds are long and continuous with regional changes of pitch (cf. experiments carried out by Williams (1964)).

The changes in pitch in the north-western part of the geosyncline result in small elongated basins and domes, which may be compared with the anticlines and synclines produced experimentally by Mead (1920) by direct compression.

The Rum Jungle, Waterhouse, and Burnside Domes were in existence before the final folding of the geosynclinal sediments. They appear to have been formed around rigid blocks which were probably moved vertically relative to the neighbouring sediments, thus producing the steep dips which occur on the flanks of the domes.

Immediately north of the granite near Mount Davis all the fold axes are overturned to the east, but to the south of the granite, which has an east-west elongation, the folds are open and symmetrical. The cause of the overturning of the folds to the north of the granite and the sudden change in the attitude of the fold planes south of the granite is unknown.

Faulting

There are three principal sets of faults trending north-westerly (300° to 340°), northerly (350° to 020°), and north-easterly (030° to 045°). The configuration of the Pine Creek Geosyncline suggests that movement occurred along lines of weakness in each of these directions in the initial phases of development of the geosyncline, and at intervals throughout its subsequent history. The fault zones are commonly marked by intense shearing and quartz veining. In many places the fractures are not well defined on the ground, and there may be numerous other faults which are not exposed.

North-westerly Faults. Most of the major north-west faults occur in the eastern part of the geosyncline, and most of them are parallel to the fold axes of the adjacent Lower Proterozoic sediments. The nature of these is unknown. The Coronet Hills Fault appears to be a high-angle reverse fault (Ruxton & Shields, 1962, unpubl.). The trend of the faults is 300° in the South Alligator Fault Zone and is about 340° in the Pine Creek/Burrundie area; the gradual change in trend from east to west follows a similar change in the trend of the fold axes. The major gold-bearing quartz reefs in the Pine Creek district are along shear zones associated with the 340°-faults.

The South Alligator Fault Zone follows a basement hingeline, which during sedimentation marked the change in facies between the Mount Partridge and Masson Formation, and formed the eastern margin of the South Alligator Trough. Subsequent movements in the basement along the fault zone produced high-angle reverse faults in the sediments, and the fault zone later acted as a locus for Carpentarian acid vulcanism and provided a fundamental control of the Carpentarian sedimentation, structure, and uranium mineralization in the South Alligator River area.

The Bulman Fault also belongs to this group: the fault as expressed on the present landsurface is essentially Carpentarian or post-Carpentarian, but it may mark a Lower Proterozoic line of weakness which delineated part of the eastern margin of the Pine Creek Geosyncline. Near Oenpelli mission the fault appears to form a boundary between Archaean to the north-east and Lower Proterozoic to the south-west; in the same area the fault zone shows up as a major gravity gradient (Langron & Stott, 1959, unpubl.).

The only important north-west-trending fault north of the Grove Hill Cross-flexure has been traced intermittently from near the junction of the Margaret and Adelaide Rivers towards Darwin; it transgresses the local trend of the bedding and is displaced by the Giants Reef Fault. The fault along the north-eastern boundary of the Margaret Granite may represent a southerly extension of this fault line.

Northerly Faults. North-trending faults occur in the central and western part of the geosyncline. They are similar to the north-west-trending faults and mainly follow the axial trends of the folds.

North-trending faults mark the western margin of the Litchfield Complex and the Hermit Creek Metamorphics, and similar faults form the boundaries of remnants of Chilling Sandstone at Murrenja Hill and near Fog Bay. The eastern boundary of the Litchfield Complex may have been controlled also by a north-trending lineament which later influenced the trace of the Giants Reef Fault in that area.

West of Rum Jungle a fault zone was encountered in the subsurface at the Mount Fitch prospect; it appears to have a throw of 5000 feet, west block down. The fault zone is not well exposed, but it is probably part of the Mount Fitch Fault Zone, which was active during and after the deposition of the Finniss River Group, and which marks the eastern margin of the Finniss River Graben. The graben influenced the local deposition of sediments of the Finniss River Group and later downfaulted them in the area to the west of Rum Jungle.

The vertical movements on the fault west of Mount Shoobridge were west block down, and over much of its length the Golden Dyke Formation to the east is faulted against the Burrell Creek Formation to the west. Most of the faults in this group are high-angle faults, and probably include both normal and reverse types. Shearing is intensified near some of the faults, but there is little evidence of overturning.

North-easterly Faults. The north-easterly faults occur mainly in the central and western parts of the geosyncline; they appear to be mainly transcurrent faults which were active at a late stage in the history of the geosyncline.

The most prominent is the Giants Reef Fault, which can be traced discontinuously for 130 miles from the headwaters of Chilling Creek northwards to Acacia Gap near the Adelaide River. The fault trends at about 015° between Chilling Creek and the Tolmer Plateau, and is probably parallel to an older lineament. On the Tolmer Plateau it swings farther east until north-east of Rum Jungle it trends at about 040°. It is a dextral wrench fault with a horizontal displacement of about 3½ miles in the Tolmer Plateau area and across the Rum Jungle Complex. The Adelaidean sediments on the Tolmer Plateau and the Archaean rocks in the Rum Jungle Complex (Rhodes, 1965) have been displaced for about the same distance, and it appears therefore that all the transcurrent movement took place after the deposition of the Tolmer Group. In the north, the preservation of larger areas of younger formations on the south-eastern side of the fault indicates a vertical south-east-block-down movement: the relative positions of the Crater Formation north-west of the Waterhouse Granite and near Area 55 (Pl. 30) suggest a throw of between 5000 and 10,000 feet. On the Tolmer Plateau the throw in the Tolmer Group is probably only about 300 feet.

We have no evidence of the type of movement on the southern part of Giants Reef Fault, where it strikes roughly parallel to the fold axes of the adjacent sediments. It may have a high-angle thrust component; it is known that many transcurrent faults pass laterally into thrust faults (de Sitter, 1956). However, the adjacent sediments show no evidence of overturning, and the displacement may be mostly lateral; strike-slip fault movements parallel to the structural grain of the country rocks are probably more common than has hitherto been recorded (King, 1964).

The Stapleton, Adelaide River, Hayes Creek, Mount Douglas, and Rock Candy Range Faults trend north-east, and where the direction of horizontal movement can be determined they are dextral wrenches similar to the Giants Reef Fault. Some vertical movement has also taken place along these faults: the Adelaidean sediments forming Mount Douglas itself have been downfaulted by the Mount Douglas Fault, and similarly Tolmer Group sandstone has been downfaulted by the Adelaide River Fault.

The Hayes Creek and Mount Douglas Faults are parallel to the axis of the Grove Hill Cross-flexure, which is associated with the earlier folding of the Lower Proterozoic sediments.

The Mundogie Hill Fault has a curved trace at the surface and does not belong to any of the three main groups. The adjacent rocks are overturned to the east, and it appears to be overthrust from the east. Mundogie Hill itself comprises a basement knoll overlain by a dome of thick conglomerate and sandstone of the Mundogie Sandstone Member. The sediments to the east were thrust up against the Mundogie Hill Dome during folding.

The arkosic sediments near Mount Partridge, east of Mundogie Hill, were intensely sheared by the same forces responsible for the Mundogie Hill Fault; the shear planes dip eastwards.

Granite Margins

Many of the granite boundaries are rectilinear, and some of them are parallel to the major faults. The eastern and western boundaries of the Prices Springs Granite, the boundaries of the Cullen Granite on either side of Pine Creek, and parts of several other boundaries are parallel to the north-westerly faults, which are parallel to the fold axes in the adjacent sediments. The western and eastern boundaries of the Burnside and Prices Springs Granites and the margin of the Cullen Granite north of Mount Masson have a north-easterly trend. All the boundaries are parallel to the Grove Hill Cross-flexure, and are probably related to this pre-granite feature rather than the post-granite transcurrent faults which follow the same direction. The boundaries of the Litchfield Complex, the elongation of the Allia and Roberts Creek Granites, and the western boundary of the McKinlay Granite have a northerly trend; the eastern and western margins of the Rum Jungle Complex and part of the eastern boundary of the Cullen Granite also have a general northerly trend. The western granites trend parallel to the structures in the country rocks, but the Cullen and McKinlay Granites transgress the local structures and cannot be related to the folds or faults in their vicinity.

Similarly, the boundaries trending east or east-north-east are not generally related to adjacent structures in the country rocks. The east-trending features, like the north-trending eastern boundary of the Cullen Granite, are not rectilinear traces but generalized trends. They possibly reflect easterly trends in the Archaean basement which, although not transmitted to the overlying Proterozoic rocks, have provided lines of weakness for the intrusion of granite.

Boundaries trending west-north-west (the Cullen Granite, west from Burrundi and on both sides of the Mary River near Mount Masson, and the south-western boundary of the Burnside Granite) are roughly parallel to the South Alligator Fault Zone. They possibly represent early wrench faults in the basement rocks which do not affect the overlying sediments except where some movement occurred during the emplacement of the granites; the contact zones around the granites are hornfelsed, but as the zones are narrow the contacts are probably near-vertical.

CARPENTARIAN

Much of the eastern part of the Katherine-Darwin Region appears to have been a stable platform area — the Arnhem Land Platform — during deposition of the Carpentarian sequence. Local areas of more rapid subsidence developed along the western edge of the platform; they formed enclosed elongated basins — the Edith Falls, Mount Callanan, and Birdie Creek Basins. To the south-east, the Arnhem Land Platform is bounded by a linear north-east-trending unstable depositional zone, the Upper Waterhouse Basin, in which the sediments and volcanics overlying the Kombolgie Formation were deposited. Many of the structures in the Carpentarian rocks were developed during deposition.

Folding

The folding in the Carpentarian rocks was caused mainly by vertical movements during deposition; it was modified by later movements.

The *Mount Callanan Basin* consists of two major synclines with an intervening anticline and a smaller anticline and syncline on the north-eastern margin. The axes of the structures are roughly parallel and trend at about 300°, parallel to the trend of the South Alligator Fault Zone and the underlying Lower Proterozoic sediments. The dips on the margins of the basin range up to 70°. Towards the centre of the basin, away from the north-eastern and south-western margins, the dips decrease rapidly. The north-eastern and south-western margins were probably controlled by faults which remained active throughout sedimentation. The history of the anticline in the centre of the basin is uncertain: the lower two units, the Kurrundie and Plum Tree Volcanic Members, do not appear to thin out across the anticline and it is assumed that the anticline was formed after the deposition of the Plum Tree Volcanic Member, and possibly after the entire Kombolgie Formation had been deposited. The lack of overturning or flattening of the dips in the underlying Lower Proterozoic rocks suggests that the structure was formed by faulting and not by warping of the basement.

The Plum Tree Volcanic Member is confined to the basin, and the extrusion of the volcanic rocks was probably associated with the subsidence of the basin.

The *Edith Falls Basin* has an inflected axis; it trends about 340° in the south, changes to about 305° and then back to 360°. The western margin of the syncline trends roughly north; the eastern margin is delineated by the 340°-trending 17-mile Creek Anticline (Rattigan & Clarke, 1955, unpubl.), along the core of which outcrops of Lower Proterozoic sediments are scattered. In the central part of the basin, the synclinal axis trends diagonally between the margins, but at the northern and southern ends it is parallel to the margins. The syncline is asymmetrical, with a steeper eastern limb.

The *Birdie Creek Basin* is a broad structure trending eastwards and open to the east. Dips along the southern margin adjacent to the Grace Creek Granite are about 10° to 20°. Along the western margin dips are generally much steeper and the structure is complicated by a steeply pitching subsidiary syncline: dips in the syncline range up to 80° near Sleisbeck, where the margin is faulted, and the presence of well developed intraformational slump breccia along its western margin indicates that the marginal zone was active during deposition.

The Carpentarian sediments generally dip off the Grace Creek Granite. Recent age determinations on the granite indicate that it is younger than the sediments, and the doming may have been produced by the intrusion of the granite as a laccolithic mass at the Lower Proterozoic/Carpentarian unconformity.

The *Upper Waterhouse Basin* is a large depositional structure which affects the Carpentarian rocks on the south-eastern edge of the Arnhem Land Platform. The axis of the syncline trends north-east and gradually flattens out in this direction; the south-western end of the syncline is delimited by a transverse anticline trending north-west. The syncline is asymmetrical, with steeper dips on the south-east limb. The general structure and stratigraphic relationships (i.e., the lensing out of units and the presence of unconformities), and the penecontemporaneous brecciation of sandstone (Ruker, 1959, unpubl.) indicate the existence of a north-easterly mobile zone along the edge of the Arnhem Land Platform. Figure 17 illustrates the results of movements during and after sedimentation in a small part of the mobile zone.

The earliest movements in the zone caused the uplift of the Edith River Volcanics near Diamond Creek and the lensing out of the lowest part of the Kombolgie Formation, so that the Birdie Creek Volcanic Member abuts against the Edith River Volcanics. The Upper Waterhouse Basin was probably formed during the extrusion of the West Branch Volcanics, which reach their maximum thickness of over 3000 feet within the basin. The transverse anticline at the south-western end of the syncline is a post-depositional feature.

Faulting and Jointing

Faulting in the underlying rocks appears to have been responsible for many of the depositional structures in the Carpentarian rocks, but very few faults are exposed.

The faults in the Carpentarian sediments generally have only a small displacement. On the Arnhem Land Platform and its western margin most of the faults trend between 300° and 330°; the Carpentarian rocks have been affected by renewed movement along the South Alligator and Bulman Fault Zones, and by movement along west-trending faults. In the southern part of Edith Falls Basin and in the mobile zone to the south-east of the Arnhem Land Platform, faults generally trend between 030° and 060°, although some movement has also occurred along several north-westerly and northerly fractures.

The Carpentarian sandstones are extensively and conspicuously jointed (Pl. 2, fig. 1). On the Arnhem Land Platform the longest and most deeply dissected joints trend approximately north, north of east, and north-north-east. There are also numerous shorter joints trending north-west. Some of the joints trending north of east are over 50 miles long. The joints appear to be the product of a homogeneous horizontal stress field.

ADELAIDEAN

The Adelaidean sediments in the Katherine-Darwin Region occur in at least two separate sedimentary basins. The Roper Group in the south-east lies within the McArthur Basin and overlies Carpentarian rocks; the 'Victoria River Group' and Tolmer Group were deposited in a broad shallow basin in the west.

The Roper Group generally dips at low angles to the north and west, but near its western limits it dips steeply east off the Morey Fault hingeline. Several step faults, trending at about 280°, have displaced the Roper Group north-block up and have produced steep dips in the adjacent sediments. Two of the faults continue to the east. They belong to a series of long westerly faults in the Urapunga and Hodgson Downs Sheet areas (Dunn, 1963a,b).

The 'Victoria River Group' generally has a low dip, but adjacent to the Halls Creek Mobile Zone near the Fitzmaurice River the dip may increase to 80°. In the Wingate Mountains and Tabletop Range the Tolmer Group sediments are flat-lying, but on the margins of the Daly River Basin they dip gently inwards. The major north-easterly transgressive faults — the Giants Reef, Rock Candy Range, and Hayes Creek Faults — displace both the Lower Proterozoic sediments and the Tolmer Group; movement along the faults may have taken place in the Palaeozoic, but as the Palaeozoic rocks in the Daly River Basin are poorly exposed this is difficult to prove.

Palaeozoic

The Cambrian Antrim Plateau Volcanics and Cambro-Ordovician limestone, sandstone, and siltstone are the principal Palaeozoic units in the Katherine-Darwin Region. The Lower Palaeozoic units dip inwards from the margins of the Daly River Basin at angles of a few degrees. The Daly River Basin has generally been regarded as a sedimentary basin (Noakes, 1949), but the geomorphology of the Katherine-Darwin Region (pp. 161-170) suggests that Cainozoic warping has been partly responsible for its formation (Hays, pers. comm.).

The Permian sediments on the western margin of the Katherine-Darwin Region dip gently west into the Bonaparte Basin (Traves, 1955).

Mesozoic

The Mesozoic sediments are mostly flat-lying or have been gently warped during the Cainozoic. The minor faulting of Mesozoic sediments in the Katherine Sheet area resulted from further movements on several of the older faults. Minor faulting has also been reported in the Cretaceous sediments at Nightcliff near Darwin (Russell, 1963).

Cainozoic

The development of the present landforms was partly controlled by Cainozoic earth movements, and is discussed more fully on pages 161-170. The movements generally consisted of broad regional warping with gradients of about 10 feet per mile.

From the structural data the following history of earth movements in the Katherine-Darwin Region can be reconstructed.

During Archaean time the rocks were welded together, metamorphosed, migmatized, and intruded by granite; and in the process developed a general east-west foliation. At the end of Archaean time the rocks were integrated in a structurally homogeneous 'shield'.

The Proterozoic era started with segmentation of the shield as suggested by Hills (1956) and modified by Walpole (1960, unpubl.). The segmentation was probably caused by subcrustal convection currents, which produced alternating tensional and compressional stresses. In the Katherine-Darwin Region the compressional stress was initially directed roughly east-west, and resulted in the development of north-north-easterly and west-north-westerly zones of transcurrent movement, in the western and eastern parts of the region respectively. The release of the compressional forces caused the downwarping of the eastern area and the beginning of sedimentation (Goodparla Group); later downfaulting in the western area controlled the second (Finniss River Group) phase of sedimentation*. The basement ridge in the South Alligator River area was developed along part of the west-north-west-trending mobile zone. After deposition of the geosynclinal sediments, renewed east-west compression originated the present fold-pattern in the Lower Proterozoic sediments, together with high-angle reverse faults parallel to the fold axes. This was followed by a period of tension which caused normal fault movements, the intrusion of granite, and the development of the Carpentarian sedimentary basins. A later, though not necessarily the next, compressional phase produced the north-north-easterly transcurrent faults in the western part of the geosyncline. The stresses gradually declined, and many of the compressional and tensional phases may not now be apparent. The axes of Cainozoic warping are parallel to the older trends, and the same forces are probably still active though less intense.

During a compression-tension cycle movements in the north-north-east and west-north-west mobile zones rarely occurred simultaneously, and in some cases only in one of the zones.

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* Moody & Hill (1956) suggested a similar process for the formation of geosynclinal troughs. They envisaged the formation of geosynclines through subsidence of an area on one side of a fundamental transcurrent fault zone.

NOTES ON GEOMORPHOLOGY

by J. Hays

The Katherine-Darwin Region is part of a dissected margin to the main plateau of the Northern Territory. Four old land surfaces, the Ashburton, Tennant Creek, Wave Hill, and Koolpinyah Surfaces, have been recognized in the Northern Territory north of the 22nd parallel (Figs 23 and 24) (Hays, 1965). Of these, only the Wave Hill and Koolpinyah Surfaces are extensive in the Katherine-Darwin Region; the Ashburton Surface is absent, and the Tennant Creek Surface occurs only as residuals standing above the Wave Hill Surface.

Tennant Creek Surface

The Tennant Creek Surface (the Bradshaw Surface of Wright, 1963), so called because it is best developed around Tennant Creek 600 miles south of Darwin, is associated with widespread lateritization * of the rocks across which it was bevelled. Indeed, the main criterion for its identification is the presence of a standard lateritic profile on the underlying rocks. Although it is the oldest land surface in the area its exact age is not known — it is thought to be middle or late Cretaceous in its type area, becoming younger northwards, and is early Tertiary (probably pre-Miocene) on Bathurst and Melville Islands, north of Darwin. It corresponds, therefore, to the 'Australian Surface' of King (1950) and to the 'Miocene Peneplain' of David (1950).

The surface in the Katherine-Darwin Region is one of extreme maturity, largely as a result of erosion, although in many places it probably corresponds closely to the original depositional surface of the Cretaceous sediments. Very little original

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* The term lateritization, as used here, refers to all weathering and alteration processes, pedological or otherwise, that result in the concentration of iron oxides in a subsurface layer. If the resultant weathering profile impressed upon the parent rock can be subdivided into an upper 'ferruginous zone', a middle 'mottled zone', and a lower 'pallid zone', after the classification used by Whitehouse (1940), it is termed the standard lateritic profile. Where the ferruginous zone is easily recognizable as a separate sedentary deposit of vesicular and concretionary ironstone, the term laterite is used. Conglomerates consisting wholly or partly of fragments of reworked laterite are here referred to as detrital laterite (after White, 1934).

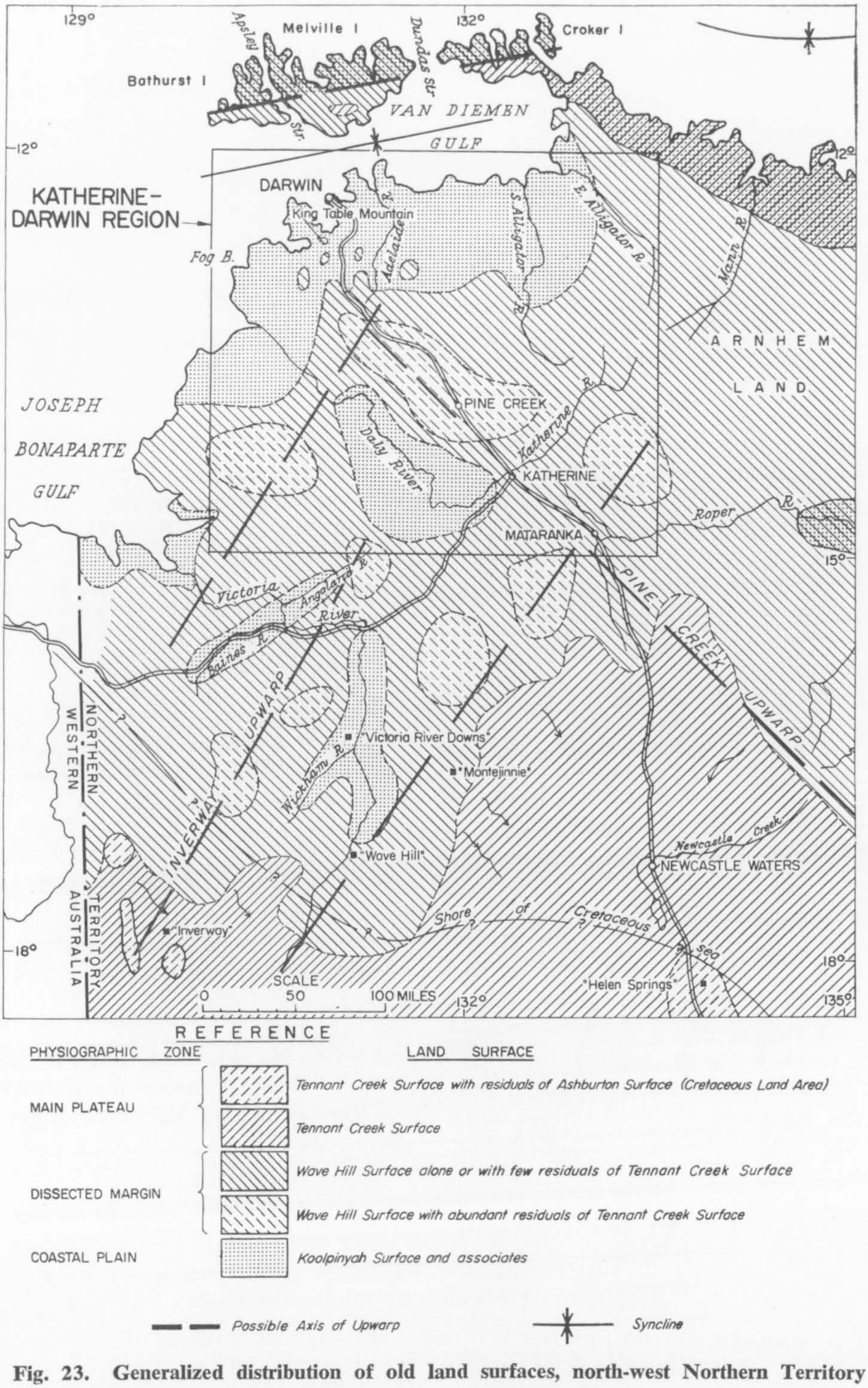

Fig. 23. Generalized distribution of old land surfaces, north-west Northern Territory

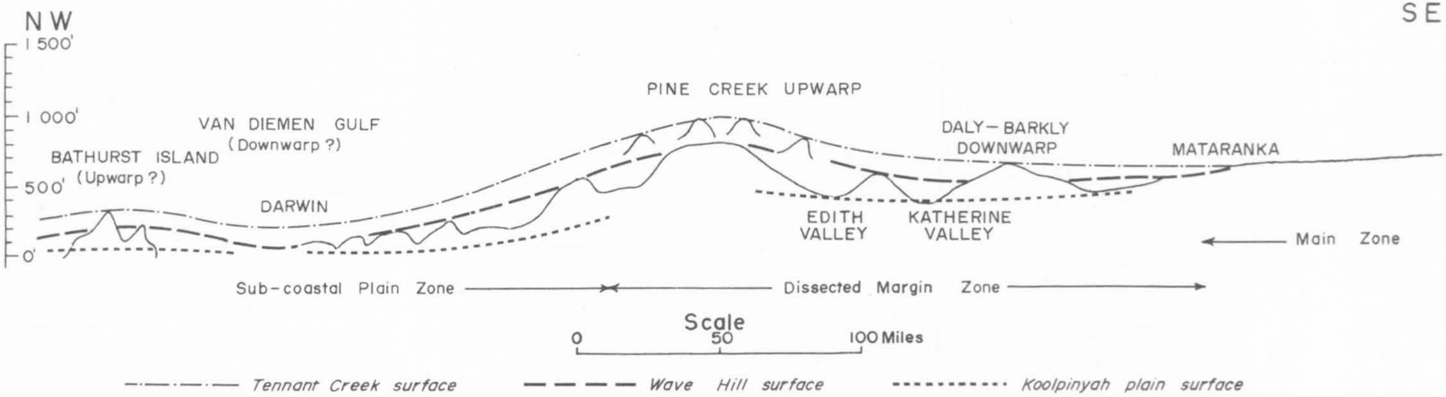

Fig. 24. Generalized section, Bathurst Island to Mataranka (along Stuart Highway)

relief can be detected, and the regional relief of 1000 feet, involving gradients of less than 10 feet per mile, is thought to have been produced by warping along north-west and north-north-east axes.

Residuals of the surface are abundant in the area south of the 14th parallel, where they consist of mesas capped with lateritized Cretaceous sediments (Pl. 27, fig. 1). The height ranges from about 600 feet above sea level, along the axis of the Daly River Basin, to about 1000 feet above sea level, along the north-eastern edge of the basin.

The residuals become smaller and fewer north of the 14th parallel, and the surface has not been identified positively on the mainland north of the 13th parallel in the Katherine-Darwin Region. Its position relative to the modern landscape is inferred from truncated lateritic profiles on Cretaceous sediments. These indicate that the surface was between 100 and 150 feet above sea level at Darwin and perhaps less than 50 feet above sea level at Gunn Point, compared with an elevation of about 1000 feet at Pine Creek.

Wave Hill Surface

The Wave Hill Surface is a mature erosion surface, which is lower than, and encroaches upon, the Tennant Creek Surface, and is extensively dissected. Although broad undulations are thought to occur, there is no evidence of local relief other than that supplied by residuals of the Tennant Creek Surface and by local geological control. The surface is bevelled, for the most part, across calcareous, arenaceous, and argillaceous sediments of the 'Victoria River' and 'Daly River Groups' and across Antrim Plateau Volcanics in the south-west; and across Lower Proterozoic greywacke and phyllite, and Adelaidean rocks similar to the 'Victoria River Group', in the north. The existence of an extensive plain at a lower level than the main lateritized surface was first noted by Jensen (1915b) in the Wave Hill area. Hossfeld (1937c) remarked on a similar surface in the Daly River Basin, but this may be younger than the Wave Hill Surface. The surface is named the Wave Hill Surface because it is best developed at an altitude of about 600 feet on Wave Hill cattle station, from which it extends west, north, and north-east.

The surface can be followed north and east from its type area at a constant height of 600 feet through Camfield station into the Top Springs area, and thence into the Mataranka-Katherine area, where it corresponds to the Maranboy Surface of Wright (1963), and thence into the headwaters area of the Roper River and into Arnhem Land. Near Mataranka, reconnaissance work could not separate the Tennant Creek and Wave Hill Surfaces because of the types of ferruginous deposits on both surfaces, the small difference in altitude (both surfaces being about 600 feet above sea level), and the presence of the exhumed sub-Cretaceous surface west of Mataranka. The surface continues to the east of the Katherine-Darwin Region into Arnhem Land, where it is the dominant surface at a height rising to 1300 feet.

North of Wave Hill station, the surface persists as a deeply dissected plain through Victoria River Downs station, and beyond as accordant summits of scattered ranges and groups of hills. However, the Stokes Range extends almost without interruption north-eastwards from west of Victoria River Downs, at a height of about 600 feet. Wright (1963) has described a Maranboy Surface in the Daly River Basin. This is a direct extension of the Wave Hill Surface on the south side of the basin, and its continuation on the north side in the Pine Creek area is also thought to be the Wave Hill Surface. The Wave Hill Surface is almost 1000 feet above sea level throughout the Pine Creek area. It can be followed northwards and north-eastwards from Pine Creek to the coast, starting as a deeply dissected plateau which gradually is reduced to strings of residuals along interfluves (Pl. 26, fig. 2). The surface has a northerly gradient of 10 feet per mile from Mount Shoobridge to the last distinct residual, King Table mountain, 15 miles south of Darwin, where the height is about 150 feet. The plateau upon which Darwin is built is also a remnant of the Wave Hill Surface, at a height of almost 100 feet above sea level. The gradient flattens north of Darwin, and at Gunn Point, 25 miles north-east, it is negligible, the surface being about 35 feet above sea level; it then rises to almost 200 feet on Bathurst and Melville Islands. North-west from Pine Creek, the surface dips west toward the sea, crossing the coast at about 100 feet near Fog Bay.

Although oxidation was noted in diamond-drill cores at Maranboy and Pine Creek at depths of 200 feet below the modern water-table, it is not related to the lateritic profile, and no particular deep weathering profile has been noted in connexion with the surface, which truncates the Tennant Creek deep weathering profile. In many places a complete Tennant Creek profile is simulated by detrital laterite resting upon the truncated profile.

A distinctive weathering profile analogous with a lateritic profile occurs on detrital laterite deposits on the Wave Hill Surface in many parts of the Katherine-Darwin Region, and Wright (1963) has described a similar profile on detrital laterite deposits on the Maranboy (Wave Hill?) Surface in the Daly River Basin. Similar profiles are common on the Coastal Plain, and are discussed in detail below.

Throughout most of the area in which the Wave Hill Surface has been recognized there is no evidence to relate the surface to a particular lithological or stratigraphic horizon except locally, although Wright (1963) considers that the level of much of the Maranboy Surface is controlled by a zone of silicification low down in the pallid zone of the lateritic profile on the Bradshaw (Tennant Creek?) Surface.

The only evidence of the age of the surface comes from the White Mountain Formation (Traves, 1955) on the Western Australian border north-west of Inverway. This marine Tertiary formation is of Miocene-Pliocene age (Lloyd, 1968a, b), and is here considered to be part of the Wave Hill Surface formed on the northern part of that surface during a temporary southward transgression of the sea. It is here supposed that uplift took place to the present height (1000 feet) of the formation, and that preservation is due to its siliceous nature, other, non-siliceous, deposits being washed away during uplift.

Koolpinyah Surface

This is a multicyclic surface developing at present in the coastal areas on rocks of all ages from Archaean onwards, and in a few inland basins directly connected to the coastal plains. It embraces the Northern Plains and the Western Plains of Noakes (1949), and the Daly River Basin.

The Koolpinyah Surface proper (the Sub-Coastal Plain of Christian & Stewart, 1953) consists of two large plains east and south of Darwin. The main part of the eastern plain extends a maximum of 70 miles inland towards the Pine Creek area, and east from Darwin along the south coast of Van Diemen Gulf to the East Alligator River basin. The main part of the southern plain extends a maximum of 65 miles inland from the coast of the Joseph Bonaparte Gulf; and south from Darwin, to about 30 miles south of the Daly River, ending at the divide between the Daly and Fitzmaurice Rivers. For most purposes the two plains can be considered as one unit. They range in height from sea level to almost 200 feet above sea level at the inland edge of the main part of the plains and to about 250 feet on their extensions up the main valleys. Both have developed primarily as a result of the formation of a large number of valley floor panplains, eroded into northerly and westerly facing slopes, which have coalesced in the coastal areas, but retain their separate identities inland. Near Darwin panplains of streams flowing north on the eastern plain have coalesced with panplains of streams flowing west on the southern plain. Streams, many of them braided, meander across the plains, and many lose themselves in swamps before reaching the sea. Extensive flooding occurs in the low-lying areas during the rainy season.

The surface of the plains is complex, and includes expanses of exhumed sub-Cretaceous surface, Wave Hill, and possibly Tennant Creek Surfaces, surfaces of sedimentation, and modern erosional surfaces, including wave-cut platforms and surfaces caused by geological control. The effects of warping and eustatic changes of sea level are visible over most of the area as benches of restricted extent, valley in valley forms, and incised meanders.

Drowned valleys, raised breaches, and raised strandlines are common around the coast, and with extensive alluviation indicate a substantial rise in sea level (attributed to eustatic Pleistocene changes by Christian & Stewart, 1953), followed by a Recent fall of about 20 feet (indicated by the depth of incised meanders). However, even extensive reconnaissance is insufficient to allow classification of all the factors contributing to the present plains, and it is probable that more than two changes of sea level, each sufficiently important to leave a permanent mark, have taken place. Four depositional episodes can be identified on the Mary River plains, north of Pine Creek, where poorly consolidated sediments of local derivation are overlain by detrital laterite, which is in turn overlain by two generations of alluvium.

There are structural differences between the eastern and southern plains which are reflected in the nature of the bounding scarps. The eastern plain has been formed by closely spaced consequent streams flowing northwards, parallel to the strike of steeply dipping beds, down a surface of great maturity. The interfluves were strike ridges which were dissected by subsequent streams, and persist as strings of residuals decreasing in height and area to the north. Consequently the Koolpinyah Surface on the north is separated from the Wave Hill Surface by an extremely irregular main scarp, and extensions of the coastal plains penetrate as much as 50 miles into the dissected zone.

The southern plain was formed by consequent streams flowing down a west-facing slope containing steeply dipping rocks trending north and north-east, now only partly overlain by flat-lying to generally west-dipping sediments. The major streams were more widely spaced, and structural control only became marked when subsequent streams developed, particularly in the steeply dipping rocks. The interfluves between subsequent streams developed as strike ridges increasing in height to the east. Most of the lower ridges have been removed, and the plains are bounded by fairly well defined scarps, and the encroachment upon the dissected marginal zone is much less pronounced than for the northern plains. A notable exception is the Daly River Basin, a tectonic basin active at several periods since its original formation in Adelaidean time. Down-warping of unknown age has carried flat-lying Palaeozoic and Mesozoic sediments down to a low level and permitted the formation of the modern Daly River Basin simultaneously with the formation of the coastal plain, and directly connected to the coastal plain through a gorge in an unwarped ridge of Adelaidean and Lower Proterozoic rocks.

Weathering on the Wave Hill and Koolpinyah Surfaces

In the coastal areas, truncated standard lateritic profiles are common and form the majority of the available exposures. Inland, the surface has been bevelled across fresh rock and, as erosion is still active, little evidence of modern deep weathering is available. Bore data from near the coast indicate that argillaceous metasediments are completely decomposed to clay at depths between 50 and 200 feet below the surface, but the significance of this decomposition is not fully understood. It is not related to the formation of the standard lateritic profile in the Tennant Creek Surface, truncated examples of which are exposed in the local cliffs near all the bores from which data are available. On the other hand, although the decomposition is within the zone of permanent saturation relative to the sea, it does not seem to be directly related to the sea, because fresh water has been recorded from the interval above the decomposed section and below sea level in some bores. It is thought that the decomposition represents the Ashburton deep weathering, but no supporting evidence for this view is known.

Apart from these occurrences, observations on weathering have been restricted to profiles in the detrital laterite deposits, which are described in detail below.

The processes of pedimentation and scarp retreat have clearly been dominant in many parts of the area at various times either in the dissection or in the formation of the Wave Hill and Koolpinyah Surfaces. These processes have resulted in the deposition of large quantities of eroded material, with a wide range of grain size and composition, on both surfaces. The deposits, to which the term detrital laterite is applied, contain a high proportion of laterite fragments in a sandy matrix with an authigenic ferruginous cement. Locally, the deposits are poorly sorted and contain material from clay grade upwards. Regionally, they show some degree of sorting, but this can be seen to be a function of the height of the parent scarp rather than distance of transport. The grain size and composition of the detrital laterite are clearly related to the height and lithology of the adjacent scarps. High scarps displaying a complete lateritic profile and a substantial thickness of fresh rock are found near deposits having the same proportions of the same lateritized and fresh rock. In areas where scarps are from 400 to 600 feet high, slabs and boulders of fresh rock several feet in diameter may constitute 75 percent of the detrital laterite. As the height of the scarp decreases, the size of the boulders decreases until, in areas where scarps are low and developed only in laterite, individual fragments are less than half an inch across and consist only of laterite; and the detrital laterite is easily mistaken for laterite.

In some areas, the parent scarp is itself capped by detrital laterite and a secondary detrital laterite, containing fragments of the cap from the scarp, may be formed.

Detrital laterite has also been observed on the Tennant Creek Surface, where it has been produced from the reduction of low residuals partly capped with laterite, as at the Cabbage Gum Basin (in the Tennant Creek area).

In places where the proportion of unlateritized rock is low and the detrital laterite rests upon a truncated lateritic profile, a perfect standard lateritic profile may be simulated, particularly where weathering has redistributed the iron oxides in the detrital laterite. Many such simulated profiles have been observed on the Koolpinyah and Wave Hill Surfaces, and Wright (1963) describes similar profiles on the Maranboy Surface. The cliffs near Darwin, long thought to exhibit standard lateritic profiles (David, 1950), are formed from detrital laterite, containing only a few fragments of fresh and weathered rock, resting upon a truncated lateritic profile. Only the original pallid zone remains, and the apparent mottled zone is part of the pallid zone stained by iron solutions percolating down from the detrital laterite cover. Some of the profiles also show signs of having been lateritized to the extent that they are enriched in iron over the top 5 to 10 feet, and impoverished in iron at depth. This is particularly true of the coastal plain with its monsoonal climate. During the hot, wet season, the detrital laterite is saturated, and even flooded, over wide areas, and conditions are ideal for chemical decomposition. During the early part of the dry season, the water table in the detrital laterite falls several feet, owing partly to transpiration and evaporation losses and partly to slow drainage into the underlying rock. This fall is accompanied by precipitation of iron oxides dissolved during the wet season. The rate of precipitation of iron was not measured, but in the Adelaide River Gorge, under similar conditions, magnesite nodules formed at the rate of about 12 to 60 cc per square metre of exposed rock, during the early part of the dry season.

The restriction of the process to detrital laterite deposits may be an illusion. The deposits contain a much greater proportion of iron than most rocks, and in places may be classed as iron ore. The distribution of the detrital laterite on the plains, its very high permeability and porosity, and the fact that it is underlain by rocks of much lower permeability, ensure that saturation and flooding occur very quickly but that subsequent drying is very slow. Consequently a high temporary perched water-table forms during the wet season and persists during the early, and hotter, part of the dry season. Conditions within the detrital laterite are thus much more suitable for extensive solution, and subsequent precipitation of iron than elsewhere. It is possible that while macroscopic changes are taking place in the detrital laterite, similar but microscopic changes are taking place in the adjoining rocks at a rate too low to detect.

The only difference between the weathering profiles on detrital laterite in the Wave Hill and Koolpinyah Surfaces is that there is no evidence that the profile is still being formed on the Wave Hill Surface, whereas there is abundant evidence of current activity on the Koolpinyah Surface. This is not surprising because all the detrital laterite deposits examined on the Wave Hill Surface were well drained and not susceptible to seasonal flooding and saturation.

Warping

So far as is known, geomorphological work in the area has not been sufficiently detailed to allow a pattern of warping to be recognized, or even to confirm beyond doubt that warping has or has not taken place in any particular area or at any particular time. For instance, Christian & Stewart (1953, 1954) assumed warping to have taken place along a north-west axis through Pine Creek, the relative movement being upwards along this axis, implying relative movement downwards along a Daly River Basin/Georgina Basin axis. Wright (1963) on the other hand is non-commital, but directs attention to minor folding of the Cretaceous sediments and to the possibility of uplift, greater in the north than in the south, as the cause of dissection of his Bradshaw Surface in the Daly River Basin. However, despite the difficulty of locating all warp axes, there is some geological and geomorphological evidence to support the view that both minor folding and warping have taken place since Cretaceous sedimentation, before and after the development of the standard lateritic profile.

The north-westerly Pine Creek divide ignores local structure, but is parallel to tectonic lineaments that have been active throughout Australian geological history from at least Lower Proterozoic time, and that have controlled the development of the north Australian shoreline. It seems logical, therefore, to suppose that the divide was formed tectonically.

Endoreic (internal) drainage south of the area reviewed appears to have been caused by warping that was clearly initiated before the Wave Hill Surface reached its present limits, and might even have initiated the formation of that surface. The gradual separation between the Tennant Creek and Wave Hill Surfaces westwards from Mataranka indicates that warping in the west or perhaps tilting towards the east preceded the Wave Hill Surface. The occurrence of marine Tertiary sediments on White Mountain (Traves, 1955) indicates that uplift of the order of 1000 feet has taken place south-west of the area since the Miocene-Pliocene.

Noakes (1949) and Wright (1963) imply that the modern form of the Daly River Basin is due essentially to the presence of resistant quartzites in the gorge area and to more rapid erosion of the softer rocks upstream. This may be true in part, but it is noteworthy that the rocks in the gorge area are topographically higher but stratigraphically very much lower (Adelaidean and Lower Proterozoic) than the softer rocks upstream (Cambrian and Cretaceous), and that the softer rocks show low radial dips into the basin. Thus the modern Daly River Basin ends downstream at a post-Cretaceous upwarp and, being parallel to the Pine Creek upwarp, is considered to be a post-Cretaceous tectonic feature. It is reasonable to suppose that the basin was formed by post-Cretaceous warping, parallel to the Pine Creek upwarp, particularly as dips of more than 10°, north of the Daly River Basin, indicate that some degree of folding has taken place.

The Joseph Bonaparte Gulf is considered to be a basin caused by downwarping because the Wave Hill Surface slopes towards the basin from the south and east, and the Palaeozoic rocks dip radially into the basin. However, the slope of the Wave Hill Surface may be original, into a basin of late Palaeozoic or early Mesozoic age.

PLATE 17.

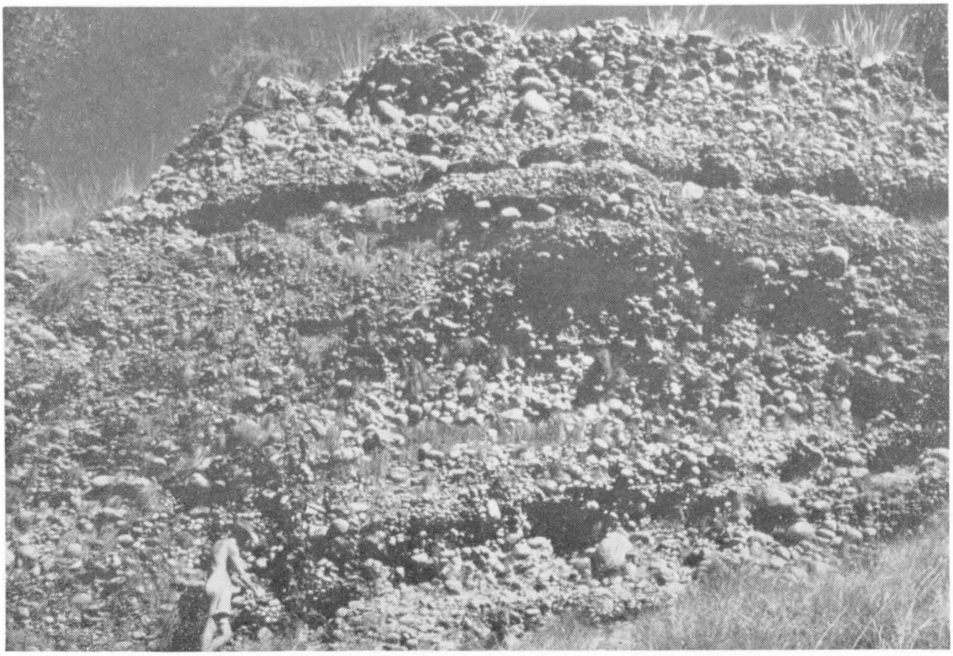

Fig. 1: Boulder beds, Margaret Hill Conglomerate, Dook Creek area, Katherine Sheet.

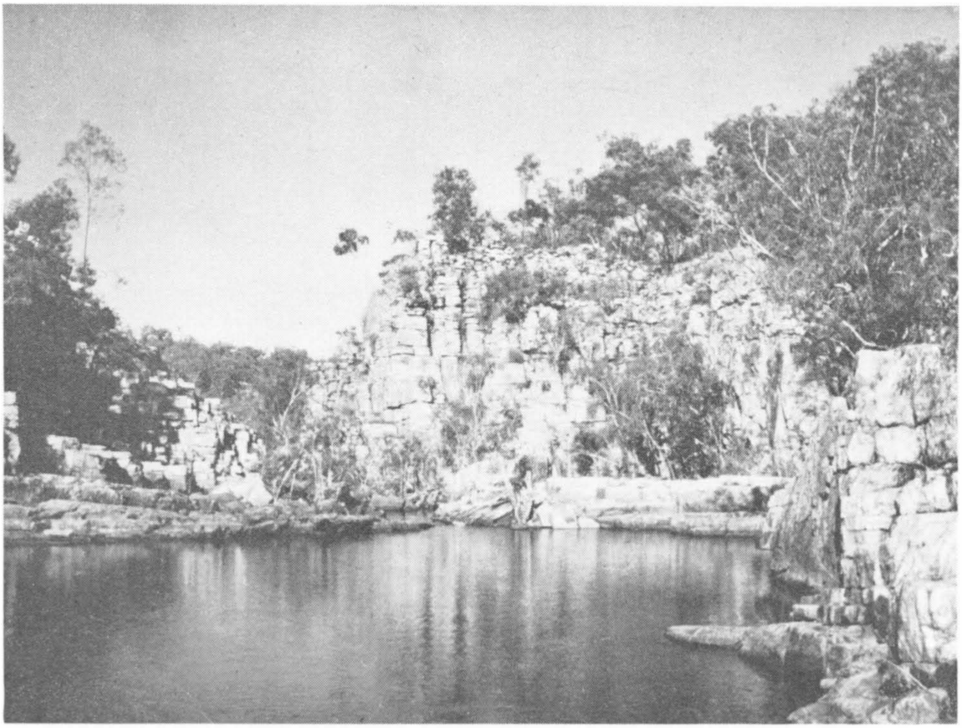

Fig. 2: Depot Creek Sandstone Member, showing vertical and horizontal jointing, Depot Creek, 18 miles west-north-west of Union Siding, Pine Creek Sheet.

PLATE 18.

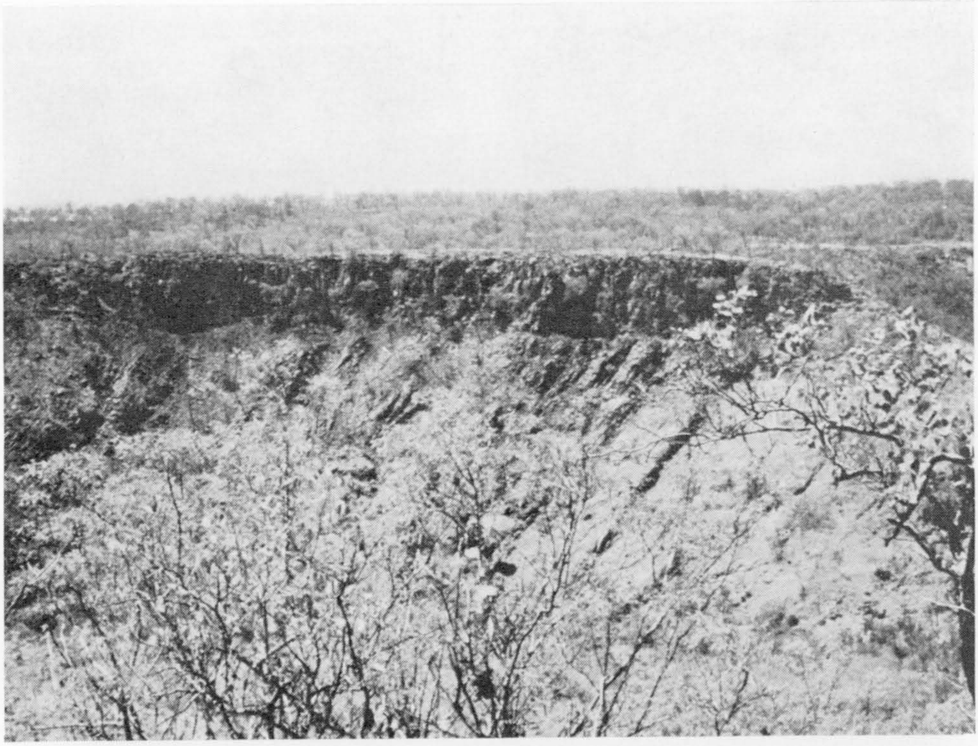

Fig. 1: Flat-lying Depot Creek Sandstone Member overlying steeply dipping greywacke of the Noltenius Formation 3 miles north-east of Collia Waterhole, Fergusson River Sheet.

Fig. 2: Massive cross-bedding in the Buldiva Sandstone, 10 miles west of Collia Waterhole, Fergusson River Sheet.

PLATE 19.

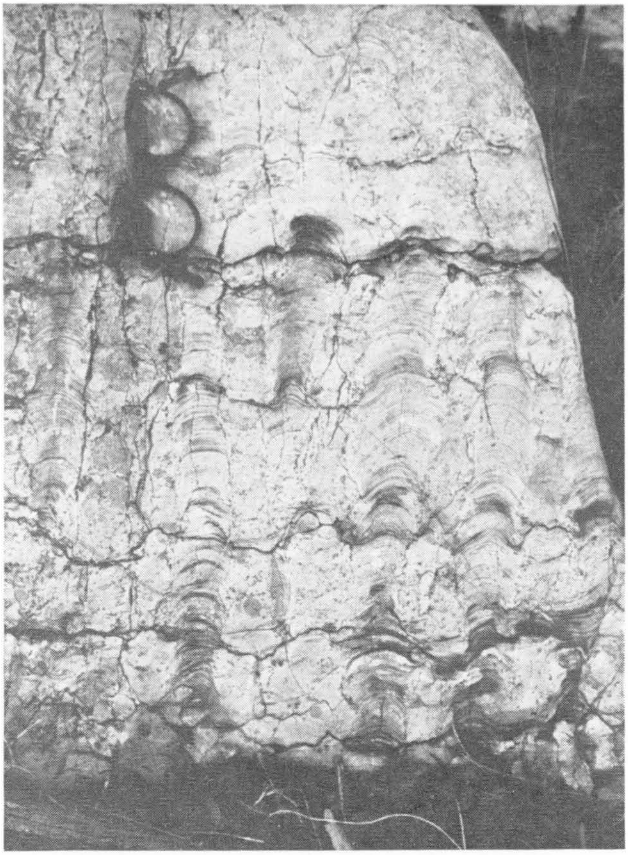

Fig. 1: Vertical sections of *Collenia* in massive pink dolomite of the Hinde Dolomite, headwaters of the Adelaide River, Pine Creek Sheet.

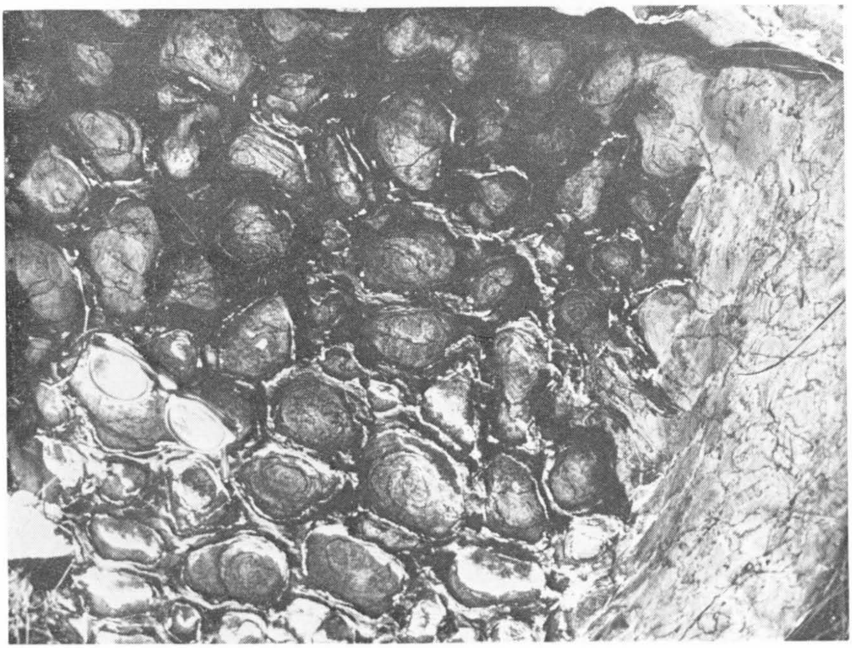

Fig. 2: Transverse section of *Collenia* in Hinde Dolomite, headwaters of the Adelaide River, Pine Creek Sheet.

PLATE 20.

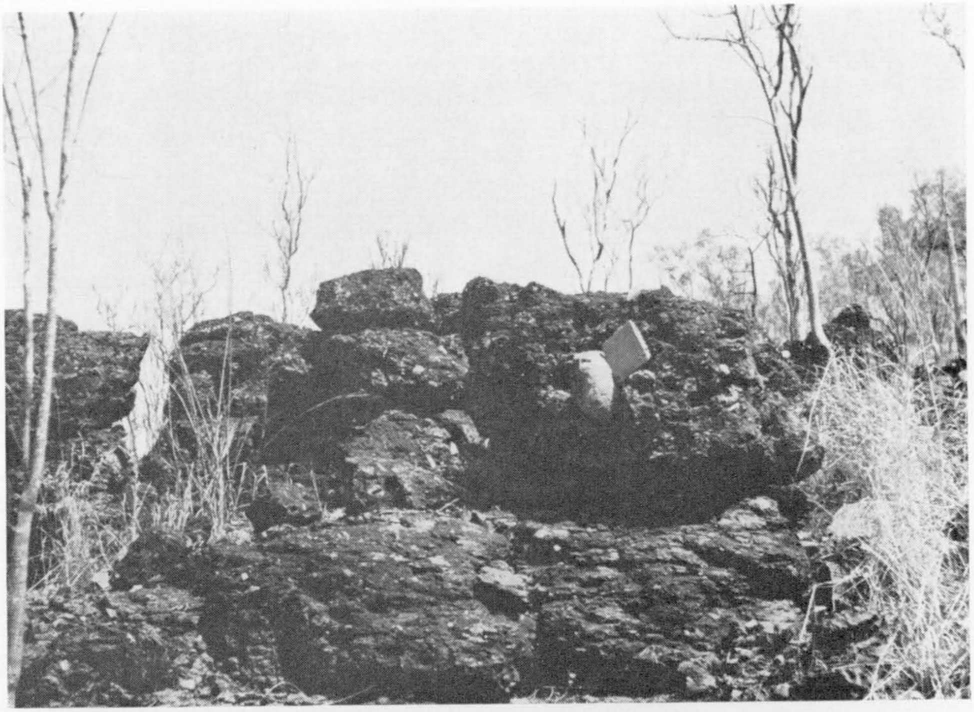

Fig. 1: Antrim Plateau Volcanics containing boulders and angular fragments of Buldiva Sandstone, 10 miles east of Collia Waterhole, Fergusson River Sheet.

Fig. 2: Blocky boulders and jointed outcrop of the Antrim Plateau Volcanics, Fergusson River Sheet.

THE MINES AND MINERAL DEPOSITS OF THE KATHERINE-DARWIN REGION*

by P. W. Crohn

INTRODUCTION

With a few exceptions, the known mines and mineral deposits of the Katherine-Darwin Region fall naturally into a small number of subdivisions, based in part on geographical location, and in part on mineralogical and structural similarities, which are regarded as indicative of genetic relationships.

Gold, copper, silver-lead-zinc, tin, tungsten, uranium, and iron ores are the main minerals which have been produced to date or are known to exist in mineable quantities in the area, either alone or in various combinations.

HISTORY

Gold is reported to have been discovered in 1865, but the discovery was not confirmed till 1869 (Bauer, 1964); by 1881 mining activity appears to have been widespread throughout the area, and by the end of the century most of the major mineral deposits (other than uranium and iron ore) had been discovered and were being worked. These included gold at Pine Creek, Union Reefs, Brocks Creek, and Northern Hercules; tin at West Arm, Mount Finniss, Mount Wells, and Mount Shoobridge; silver-lead at the Evelyn mine; copper at Daly River; and copper-gold at Iron Blow. In the early years of this century, these deposits were supplemented by the discoveries of tin at Maranboy, Hayes Creek, and Horseshoe Creek, and wolfram at Wolfram Hill, but mining activity began to decline about 1920, and did not improve until the post-war development of the early 1950's began to take effect.

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* Only key references have been specifically quoted in the descriptive accounts of the various mines and mineral deposits, but numerous other relevant reports, both published and unpublished, are listed in the general bibliography. Information on old workings and production statistics, unless otherwise stated, has been largely obtained from Annual Reports of the Director of Mines, Wardens and Inspectors of Mines, Northern Territory, but it has not generally been possible to acknowledge the source of this information in detail in the text. K. R. Yates (BMR) collated much of the information which was derived from these references and is used in this account.

Since then, mineral production has been dominated by the discovery of the uranium-copper orebodies of the Rum Jungle area in 1949; the uranium ore-bodies of the South Alligator River area, discovered in 1953-54; and the Frances Creek iron orebodies, which came into production in 1966.

Owing to incomplete production records, especially before about 1890, the relative importance of many of the mines and mineral deposits is difficult to assess. When recorded production figures are converted to values at current prices, the Rum Jungle area (uranium, copper, and subordinate lead) and the South Alligator River area (uranium and minor gold) are estimated to have accounted for about three-quarters of the total recorded mineral production of the region (excluding construction materials). This is all the more striking since neither was a major producer before 1950. Of the remaining localities, the most productive have been the Spring Hill/Union Reefs/Pine Creek mineral belt (gold, tin, copper, and silver-lead), the Brocks Creek/Cosmopolitan Howley area (gold, copper), Mount Wells (tin), Wolfram Hill/Horseshoe Creek (tin, wolfram, gold, copper, lead), West Arm/Mount Finniss (tin, gold, tantalite), Maranboy-Yeuralba (tin, wolfram, copper), and Iron Blow/Yam Creek (copper, gold). Other significant producers have been the Northern Hercules area (gold, copper, silver-lead, tin), Daly River (copper), Mount Shoobridge (tin, copper), Umbrawarra (tin), Woolwonga (gold), and Hayes Creek (tin).

In terms of individual metals, uranium (including the estimated uranium content of stockpiled ore) is estimated to make up approximately two-thirds of the total value of the recorded mineral production of the region (excluding construction materials), although this cannot be computed exactly, since the selling price of uranium produced at Rum Jungle has not been made public. Of the remaining metals, copper has been the most important (26,000 tons of metal in concentrates and stockpiled ore at Rum Jungle, plus 29,600 tons of ore from other localities, estimated to average about 15 percent Cu). This is followed by gold (recorded production about 520,000 oz, which is known to be incomplete), and tin (recorded production about 7000 tons of concentrate, which is also known to be incomplete). Other significant contributions have been made by silver-lead (4100 tons of lead in Rum Jungle concentrates and 4000 tons of silver-lead ore from other localities), and wolfram (830 tons of concentrate). Tantalite (15 tons of concentrate) and manganese (450 tons of ore) have been minor contributors.

The total recorded production of gold and tin concentrates is greater than the figures obtained by adding up the known production from individual mines (see Table 14), because the source of some production is not recorded, especially in the case of alluvial workings before about 1890.

Excluding uranium and construction materials, the value of recorded production of the whole region would amount to about $52,000,000 at current (1966) prices.

TABLE 14. PRODUCTION FIGURES FROM MINES IN THE KATHERINE-DARWIN REGION (to end 1965)

	Gold (oz)	Tin Concentrate (tons)	Copper (tons)	Copper Ore (tons)	Lead Ore (tons)	Silver (oz)	Wolfram Concentrate (tons)	Tantalite Concentrate (tons)	U_3O_8 (tons)
Whites			13,100		(A)	64,000 (B)			1010
Dysons									520
Mount Burton			100						10
Rum Jungle Creek South									(C)
Intermediate			7230 (D)						
Rum Jungle	10								
Virginia	25								
	35		20,430			64,000			1540
El Sherana	)	(							210
El Sherana West	) 11,570	(							170
Rockhole + Teagues	)	(							150
Palette	)	(							120
Saddle Ridge	)	(							70
Coronation Hill	)	(							70
Other Prospects									30
Zamu Creek					20				
					20				820
Cosmo Howley	33,780								
Rest of Howley Line	32,450								
Zapopan	26,650								
Rest of Brocks Creek Area	6370								
Brittania	840								
Fountain Head	9870								
Mount Ellison				3250					
	109,960			3250					
Yam Creek	15,400								
Iron Blow				13,700					
Golden Dyke	1400								
	16,800			13,700					
Mount Shoobridge		145							
Barretts		115							
Other Prospects				360	2				
		260		360	2				
Northern Hercules	32,800								
Coronet Hill				250					
Mount Davis				990					
Mount Diamond				700					
Waldens				1220					
Evelyn					2206	89,000			
Other Prospects		45		15	580				
	32,800	45		3175	2780	89,000			
Spring Hill Area	21,170	300							
Elizabeth	3440								
Flora Belle					130				
McKinlay					750	40,000			
Union Reefs	54,700								
Union Extended	3500								
Pine Creek	94,000								
Caledonia	460								
Lucknow					150				
Mount Wigley					60				
Copperfield				2140					
Kellys		2							
	175,270	302		2140	1090	40,000			
Mount Wells		1530							
Mount Masson + Others		330							
		1860							
Wandie	6380								
Crest of the Wave		143							
Wolfram Hill				230	85		650		
Hidden Valley	30	50			25				
Emerald Creek		42							
Driffield	5300								
Horseshoe Creek		650							
Mount Todd	915	180							
Yenberrie							160		
Woolngi	4600								
	17,225	1065		230	110		810		
West Arm	620	585						15	
Blyth		75							
Fletchers Gully	2450	4							
Buldiva-Collia		45							
	3070	709						15	
Daly River				6000					
Wheal Danks				500					
Empire-Wallaby				175					
				6675					
Maranboy		1280							
Yeuralba		12		50			40		
		1292		50			40		
Mount Ringwood	2800								
Great Western Group	3600								
Woolwonga	9200								
Watts Creek Area	150								
Yemelba	250								
Hayes Creek		156							
Stray Creek		18							
Umbrawarra		269							
Douglas River, etc.		5							
Maude Creek	540								
Carpentaria				20					
Mount Gates	250				11				
Minglo									
Green Ant Creek									
	16,790	448		20					
Grand Total	373,520	5981	20,430	29,600	4000	193,000	850	15	2360
			See (D) above		See (A) above	See (B) above			See (C) above

(A) No production to date. Metal contents of stockpiled ore awaiting treatment is estimated at 4100 tons.
(B) Probably incomplete. Represents production recorded in Annual Reports, N.T. Administration, 1960-1962.
(C) Production figures not available for publication. U_3O_8 contents of mined ore, including stockpiled ore awaiting treatment, is estimated at 2600 tons.
(D) To June 1967. Does not include metal contents of stockpiled material awaiting treatment by heap leaching and cementation at that date.

GENESIS

The most important orebodies of the Katherine-Darwin Region, in terms of value of production, are the uranium-copper-lead deposits of the Rum Jungle area and the uranium-gold deposits of the South Alligator River area. Both these groups show pronounced stratigraphical or lithological control; most of the orebodies lie in carbonaceous or chloritic and in part pyritic shales and slates, which are assigned to the Golden Dyke Formation in the Rum Jungle area and to the Koolpin Formation in the South Alligator River area. Most of the deposits in the Rum Jungle area also lie within a few hundred feet of the contact of these slates with the underlying Coomalie Dolomite; in the South Alligator River area comparable dolomites occur, but their relation to the ore deposits is not as close. In both areas, the major deposits also occur close to the unconformity between Lower Proterozoic and Carpentarian or Adelaidean rocks, and in the South Alligator River area several of them actually transgress the unconformity. The major deposits in both areas also occur close to major faults or shear zones. However, in the South Alligator River area, at least one of the deposits occurs in a volcanic neck, apparently related to lavas within the Carpentarian succession, while at Rum Jungle the relation of the orebodies to the Rum Jungle Complex is obscure, since at least part of the complex antedates the deposition of the Lower Proterozoic sedimentary rocks.

Condon & Walpole (1955) interpreted most of the dolomite occurrences in the South Alligator River area and some in the Rum Jungle area as reef breccias, and concluded that the uranium mineralization is syngenetic because it is persistently associated with a particular sedimentary facies, although metal values may have been redistributed during subsequent folding and nearby igneous activity. More recently the origin of the deposits in the South Alligator River area has been attributed to the Carpentarian acid volcanics (Stewart, 1965), although Prichard (1965) still accepts the earlier interpretation; Spratt (1965) treats the reef hypothesis with some reservations for the Rum Jungle area.

The gold deposits of the Cosmopolitan Howley/Bridge Creek area and at the Golden Dyke mine also show strong stratigraphical control; economic mineralization is virtually restricted to the pyritic slates and schists which contain nodules and lenses of quartz. The beds are part of the Golden Dyke Formation, and although most of the disseminated pyrite was probably syngenetic, the gold mineralization was probably younger and controlled by the favourable physical and chemical characteristics of the beds.

Except for occurrences of iron ore and construction materials, most of the remaining mines and mineral deposits are of hydrothermal origin and comprise quartz veins, fissure lodes, greisens, and pegmatites, commonly located within the Lower Proterozoic sedimentary rocks near one or other of the major granitic intrusions. Several groups of deposits are clustered around the composite Cullen Granite batholith and the nearby (and probably related) Mount Shoobridge, Burnside, Margaret, Prices Springs, McKinlay, and Wolfram Hill Granites. They comprise the tin-copper-lead deposits of the Mount Shoobridge area; the Hayes

Creek tin field; the gold deposits of Brocks Creek, Woolwonga, and Yam Creek; the complex gold and base-metal sulphide lodes of Iron Blow and Mount Bonnie; the tin and tin-copper deposits of Mount Wells, Mount Masson, and Mount Harris; the lead occurrences of Minglo and Namoona, and the silver-lead-zinc lodes of the Evelyn and McCarthys mines; the Northern Hercules gold mine; the copper and copper-gold-arsenic lodes of Coronet Hill, Mount Davis, and Mount Diamond; the tin and wolfram lodes, in part with minor copper and lead, of Wolfram Hill, Hidden Valley, Emerald Creek, Horseshoe Creek, Mount Todd, and Yenberrie; and the gold deposits of Wandie, Driffield, Mount Todd, and Woolngi.

In addition, a major re-entrant of sediments within the Cullen batholith contains a highly productive group of deposits, most of which are localized on a large shear zone which closely follows the north-westerly axis of the re-entrant. The deposits include the gold, tin, and silver-lead occurrences of the Burrundie/Spring Hill/Flora Belle area, the auriferous lodes of the Union Reef and Pine Creek areas, and the copper deposits of Copperfield.

Many of the deposits associated with the Cullen Granite are characterized by complex mineral associations, such as gold-copper-lead-zinc at Iron Blow and Mount Bonnie, tin-copper at Mount Wells, tin-lead at Emerald Creek, and wolfram-copper-molybdenum at Yenberrie. A range of conditions from mesothermal to hypothermal appears to be represented by these associations.

Nearly all the deposits are associated with faults or shear zones, but some degree of stratigraphical or lithological control is evident; the more massive sulphide deposits, such as Iron Blow and Mount Ellison, and the silver-lead lodes, such as the Evelyn, are generally found in the black slate/chert/dolomite environment of the Golden Dyke Formation, whereas the bulk of the quartz-gangue gold and tin deposits occurs in the greywacke and slate of the Burrell Creek and Masson Formations.

In the south-east, the tin and tin-wolfram-copper deposits of Maranboy and Yeuralba are also closely associated with granitic intrusives, and show many similarities to some of the deposits near the Cullen Granite.

In the west, the tin-tantalite deposits of the West Arm/Mount Finniss/Mount Tolmer belt and the copper deposits of the Daly River area may be related to the Litchfield Complex; a southern extension of this belt includes the gold deposits of Fletchers Gully and the tin lodes of the Collia and Buldiva areas, which are closely associated with the Allia and Soldiers Creek Granites.

Supergene enrichment of iron-rich sediments in the Masson Formation is thought to have been responsible for the Frances Creek iron-ore deposits (mostly hematite); Pritchards Lode at Mount Bundey (magnetite and minor sulphides, oxidized to martite) is a product of magnetic segregation or contact metasomatic replacement resulting from the intrusion of the Mount Goyder Syenite.

Rum Jungle Area (Fig. 25)*

Rum Jungle Mines

Jensen (1915a); Condon & Walpole (1955); Rhodes (1965); Fitzgerald & Hartley (1965); Spratt (1965)

The Rum Jungle area is the outstanding mineral producer of the Katherine-Darwin Region, largely owing to the production of uranium since 1949. Base metals, notably copper and lead, are associated with several of the uranium orebodies and also form separate bodies in the same general geological setting. A number of phosphate rock occurrences are also known.

Before 1949, only small-scale production of copper is recorded from this area, including about 60 tons of 11 percent ore in 1907. Two diamond drill holes were put down to inclined depths of 300 and 320 feet in 1913, but significant copper values, between 1 and 5 percent, were only encountered in the secondarily enriched zone, between 35 and 67 feet inclined depth, in one of the holes (Jensen, 1915a). Since 1949, intensive exploration by the Bureau of Mineral Resources and Territory Enterprises Pty Ltd has resulted in the discovery and delineation of four uranium orebodies, two copper orebodies, one large low-grade lead occurrence, and a group of phosphate rock occurrences; several other promising uranium and base-metal prospects are still under investigation at the time of writing (June 1966).

Most of the known uranium and base-metal orebodies occur within a relatively small area, locally known as the 'Embayment', in which Lower Proterozoic sedimentary rocks occupy a re-entrant in the Rum Jungle Complex. The orebodies are restricted to pyritic black slate or chloritic schist of the Golden Dyke Formation, close to its contact with the underlying Coomalie Dolomite.

The sedimentary rocks dip off the Rum Jungle Complex in a broad dome-shaped structure, and the complex has been shown, at least in part, to antedate them (Rhodes, 1965). The 'Embayment', which is formed by the displacement of the complex for about 3 miles along the Giants Reef Fault, is occupied by a broad west-pitching synclinal structure, complicated by tight minor folding and intense shearing of many of the rocks. Orebodies appear generally to be related to these minor structures.

Most of the orebodies occur at a relatively constant depth, between 100 and 300 feet below the present surface. The present surface in many places also coincides fairly closely with the old erosion surface separating the Lower Proterozoic rocks from unconformably overlying sandstone and breccia of probable Adelaidean age.

* All available geological data on the Rum Jungle area are currently being reviewed and compiled by the Bureau of Mineral Resources, and it is hoped to undertake a similar review for the South Alligator area. For this reason, only summaries of the geology and economic geology of these two areas are given here, although the deposits are of outstanding importance.

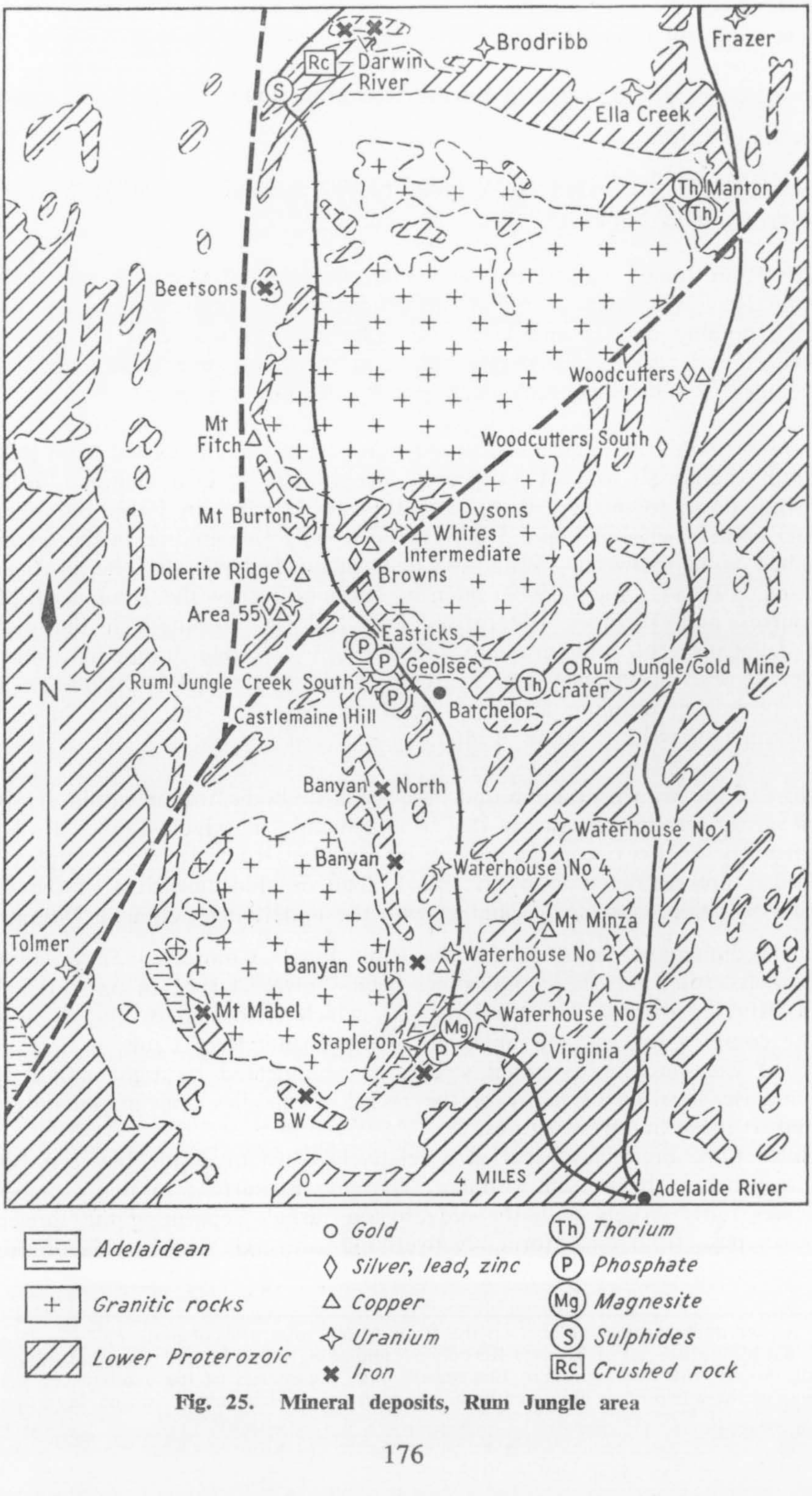

Fig. 25. Mineral deposits, Rum Jungle area

The orebodies are thus broadly controlled by stratigraphy — being confined to the lower portion of the Golden Dyke Formation — but the part played in ore localization by the Giants Reef Fault, the Rum Jungle Complex, minor structural features, the unconformity surface, and lithological changes within the Golden Dyke Formation itself, have not been completely assessed.

Within the Embayment, *Whites orebody,* which was the site of the original uranium discovery in the Rum Jungle area, consisted of disseminated uranium and copper mineralization in a steeply south-dipping zone, 50 to 80 feet wide and about 400 feet long, which has been mined by an open cut to a vertical depth of 350 feet. Uraninite, torbernite, chalcopyrite, bornite, and galena were the main ore minerals, and production amounted to 270,000 tons of ore averaging 0.33 percent U_3O_8 and 3.4 percent Cu, plus 40,000 tons averaging 0.28 percent U_3O_8 only (Spratt, 1965; Fitzgerald and Hartley, 1965). In addition, 287,000 tons of ore averaging 2.4 percent Cu and about 0.3 percent Co have been mined and treated, and 85,000 tons of ore averaging 5.1 percent Pb with minor copper and cobalt are stockpiled, awaiting treatment (information supplied by Territory Enterprises Pty Ltd, July 1967). Production of 64,000 oz of silver is also recorded (Annual Reports, N.T. Administration, 1960-1962).

At *Dysons,* about a mile east of Whites, another north-easterly-trending lens of mineralized material has been mined by open cut to a depth of 150 feet, yielding 154,000 tons of ore with an average content of 0.34 percent U_3O_8. Uraninite and saleeite were the main ore minerals.

Immediately south-west of Whites, the *Intermediate Deposit,* which was a copper orebody without associated uranium mineralization, has been mined by open cutting, resulting in a production of 373,000 tons of ore averaging 2.45 percent Cu, and of 360,000 tons of material suitable for heap leaching and cementation. The bulk of the leach ore, estimated to average 1.8 percent Cu, had been stockpiled and was still awaiting treatment in July 1967 (information supplied by Territory Enterprises Pty Ltd). The geological setting is similar to Whites Deposit.

Browns prospect, which is also within the Embayment area, 1 mile south-west of Whites, is a large low-grade lead deposit, and occurs in graphitic, sericitic, and talcose slate and schist comparable to those at Whites. The primary ore minerals are galena and minor chalcopyrite, sphalerite, and linnaeite; cerussite and malachite predominate in the oxidized zone, within about 50 feet of the surface. This deposit has been traced for about 3000 feet in length and 1200 feet in depth, and varies in width from about 40 to 160 feet; the average grade has not been disclosed. The body trends east-north-east and dips to the south; the dip is shallow near the surface, but steepens to about 85° at a depth of 150 feet (Thomas & Whitcher, 1965).

Outside the Embayment area, only two orebodies have been worked. At *Mount Burton,* 3 miles west of Whites, a small lenticular body containing disseminated torbernite, pitchblende, malachite, and chalcocite has been mined to produce 6000 tons of ore, averaging 0.21 percent U_3O_8 and 1.04 percent Cu, and 1400 tons averaging 2.66 percent Cu. The host rocks were pyritic black slate and minor quartzite, underlain by dolomite (Spratt, 1965).

At *Rum Jungle Creek South,* 4 miles south of Whites, uraninite was the main ore mineral, and production, some of which is still stock-piled, amounted to 653,000 tons of ore, averaging 0.4 percent U_3O_8. The host rock is chloritic schist, occupying a north-west-trending syncline between the Rum Jungle Complex and the Waterhouse Granite. The orebody occurred just below the present base of oxidation, at a depth of about 100 feet, and was about 750 feet long, 150 feet wide, and 130 feet thick, elongated parallel to the fold axis in the host rocks (Spratt, 1965).

Another small secondary copper orebody has recently been indicated by auger and waggon drilling at *Mount Fitch,* 5 miles north-west of Whites. The main ore minerals are malachite and chalcocite, and the deposit overlies low-grade pyrite-chalcopyrite mineralization in both the Golden Dyke Formation and the Coomalie Dolomite.

The known phosphate occurrences of the Rum Jungle area are largely concentrated near Castlemaine Hill, 1½ miles east of Batchelor township, and include the *Geolsec* and *Easticks* deposits. Similar occurrences have also been recorded from the *Waterhouse* and *Stapleton* areas, from 6 to 8 miles south of the township. All the deposits occur at or close to the Lower Proterozoic/Adelaidean unconformity, overlying weakly phosphatic dolomite and siltstone of the Coomalie Dolomite and Golden Dyke Formation, and are regarded as the products of sedimentation and supergene concentration in the period immediately preceding the deposition of the Adelaidean rocks. The phosphate rock occurrences range from a lilac or red apatite siltstone and sandstone to a quartz breccia with a phosphatic matrix. Fluorapatite is the dominant phosphate mineral, generally associated with finely divided hematite. Assays range up to 37 percent P_2O_5, with 4 to 18 percent Fe_2O_3 and from 1 to 33 percent Al_2O_3. Reserves are estimated at about 4,000,000 tons of phosphate rock, averaging 10 percent P_2O_5, of which about 1,000,000 tons are in the Geolsec deposit. The material is suitable for use as ground rock phosphate, but not for the manufacture of superphosphate, and there are at present no plans for its immediate utilization (Pritchard & Cook, 1965).

Of other prospects in the area, *Area 55,* 5 miles west-north-west of Batchelor township, appears to offer the best possibilities. Low-grade uranium, copper, and lead mineralization has been encountered in drill holes put down to test geophysical and geochemical anomalies in Golden Dyke and Coomalie Dolomite rocks, and appears to be related to minor structural features, including shear zones and steeply plunging fold axes. Further work is in progress.

Other prospects which offer possibilities for the occurrence of both uranium and base-metal deposits are *Dolerite Ridge,* between Area 55 and Mount Burton; the *Celia Creek* area, 12 miles north of Batchelor township; the *Rum Jungle East* area (*Woodcutters* prospects) between Manton Dam and the Batchelor turn-off on the Stuart Highway; and the *Gould Airfield* and Waterhouse areas, south of Batchelor township. Further geophysical and geochemical surveys, with provision for follow-up diamond drilling, are now being undertaken by the Bureau of Mineral Resources in the Rum Jungle East and Gould Airfield areas.

Since this was written, diamond drilling of a geochemical anomaly by the Bureau of Mineral Resources has disclosed a major zone of lead-zinc-silver mineralization at the site of the old Woodcutters Prospect in the Rum Jungle East area. Mineralization appears to be associated with a steeply dipping shear zone in dolomitic and carbonaceous pyritic slates of the Golden Dyke Formation close to its contact with the Coomalie Dolomite. Up to May 1967, five drill hole intersections of lode material, ranging from about 20 to nearly 80 feet in width (measured along the hole), had been obtained over a strike length of 1600 feet and to a maximum vertical depth of about 600 feet, and testing was continuing.

Outlying Prospects

Away from Rum Jungle, a number of other radioactive anomalies occur around the margin of the Rum Jungle Complex. They include the Brodribb, Ella Creek, Manton, and Crater prospects, but on the available information these are unlikely to have any potential for economic development.

The *Brodribb prospect,* 15 miles north of Rum Jungle, has been tested by extensive costeaning and six diamond drill holes totalling 1580 feet, but the radioactivity appears to be concentrated in superficial ferruginous deposits overlying pyritic slate of the Golden Dyke Formation, and no primary mineralization of economic grade has been located (Sullivan, 1953b, unpubl.; Matheson, 1953b, unpubl.). At Ella Creek, 3 miles to the east, and at *Frazer,* another 4 miles to the north-east, conditions appear to be similar (Smith, K., 1953, unpubl.; Sullivan, 1953b, unpubl.).

At the *Crater* prospect, 1 mile north-east of Batchelor township, mineralization occurs in beds of the Crater Formation, especially in a conglomerate, 90 feet thick, which strikes west-north-west and dips south at 40°. This prospect was tested by two diamond drill holes totalling 1140 feet, and the radioactivity was found to be due to detrital grains of thorianite in the conglomerate (MacKay, 1953c, unpubl.; Rhodes, 1960, unpubl.). The *Manton prospect,* 15 miles north-north-east of Batchelor, is also in beds of the Crater Formation, and may be of the same type.

Twelve miles south-west of Rum Jungle, the *Tolmer* uranium prospect occurs in rocks of the Burrell Creek Formation about half a mile north of the Giants Reef Fault. This prospect has been tested by Rio Tinto Exploration, but no orebodies of economic grade were discovered.

There are also four separate radioactive prospects, known as *Waterhouse No. 1, 2, 3,* and *4,* in the area between 4 and 8 miles south and south-east of Batchelor township. Some detailed geological and geophysical work has been done on all of them, and No. 2 has been tested by a shallow shaft put down by United Uranium N.L. and two diamond drill holes put down by the Bureau of Mineral Resources. However, results to date are regarded as inconclusive, and a further investigation by the Bureau of Mineral Resources is in progress at the time of writing (June 1966).

A number of quartz-tourmaline stringers, ranging from a few inches to several feet wide, occur in arkosic grit and quartz-pebble conglomerate of the Lower Proterozoic Crater Formation 3 miles east of Batchelor township. One of them at the *Batchelor* prospect was worked in 1943 and yielded 12 oz of gold from about 12 cwt. of ore. The stringer appears to have been almost completely removed in the course of this operation, and no other occurrences of auriferous material have been located in the area (Sullivan, 1946c, unpubl.; Crohn, 1965a, unpubl.).

At the *Virginia* mine, 1 mile east of Stapleton Siding, 24 oz of gold are reported to have been obtained before 1891, and workings are reported to have included a shaft 120 feet deep (Tenison Woods, 1886; Parkes, 1892).

At the Little Finniss River Crossing on the Stapleton/Mount Tolmer road, traces of copper have been reported from poorly exposed slate, probably of the Burrell Creek Formation.

Occurrences of iron ore are known from the Darwin River, Beetsons, Stapleton, and Mount Mabel areas, and magnesite from the Stapleton area. These are discussed on pp. 236 and 245.

South Alligator River Area (Fig. 26)

Condon & Walpole (1955); Prichard (1965)

The South Alligator River area consists of a north-westerly belt of Lower Proterozoic rocks centred on El Sherana, about 170 miles south-east of Darwin (Pl. 30). The Koolpin Formation, consisting of shale and siltstone, in part pyritic and carbonaceous, with minor chert, dolomite, and silicified dolomite, contained the bulk of the uranium mined from the area, and lithologically bears a striking resemblance to the Golden Dyke Formation, which is the predominant host rock for the uranium mineralization in the Rum Jungle area.

The Koolpin Formation is overlain with a strong angular unconformity by Carpentarian rhyolite flows and pyroclastics (Edith River Volcanics), and by sandstone and conglomerate with minor interbedded volcanics (Kombolgie Formation). It is also intruded by volcanic necks related to the Edith River Volcanics, by sills and dykes of dolerite, gabbro, and diorite (Zamu Complex), and by the Malone Creek Granite.

Economic mineralization in the area is restricted to relatively small, high-grade uranium deposits, some with subordinate gold, although minor occurrences of copper, lead, and phosphate rock have also been recorded.

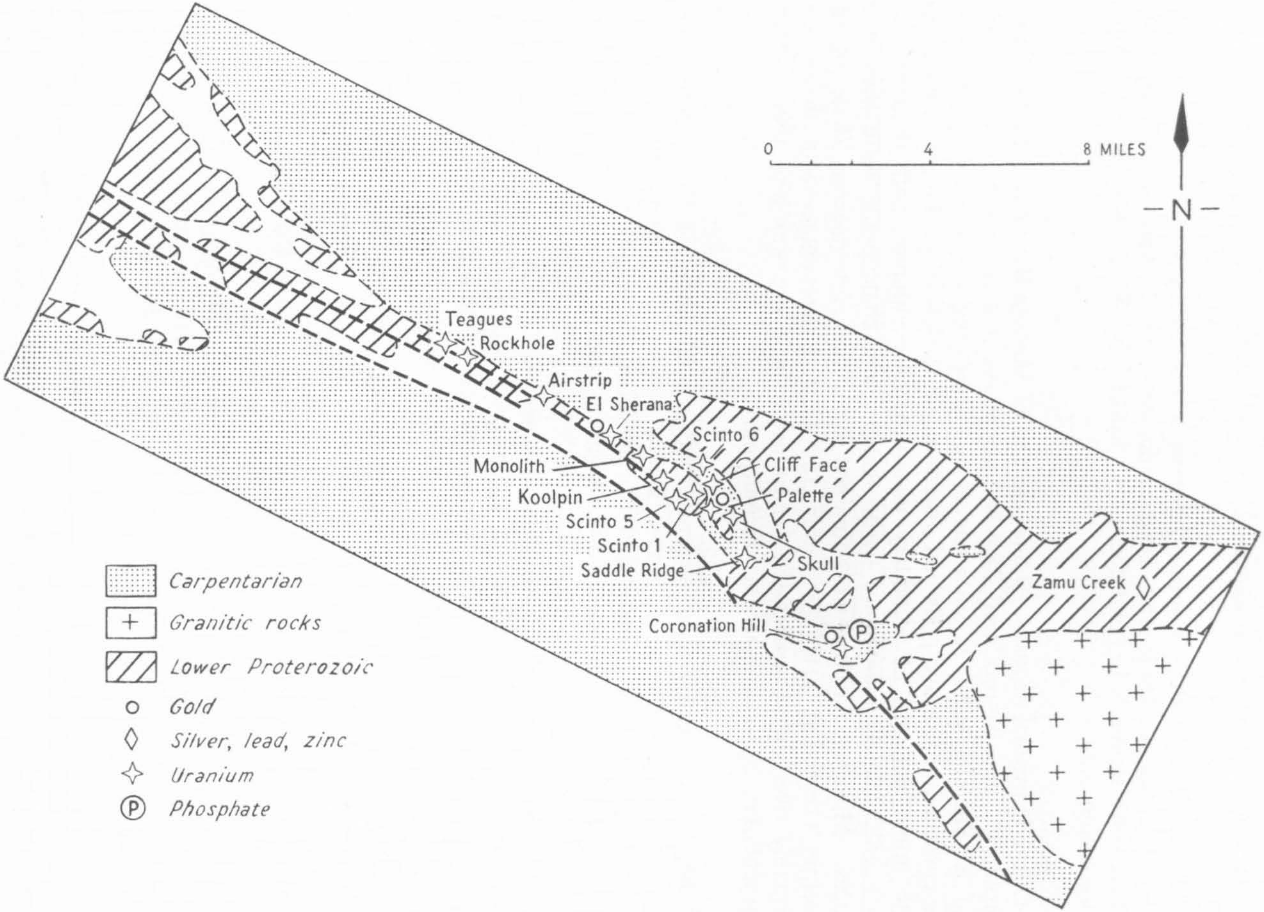

Fig. 26. Mineral deposits, South Alligator River area

The most important mineral deposits lie within the central part of the belt, covering an area of about 15 by 2 miles from Rockhole mine in the north-west to Coronation Hill in the south-east. However, related occurrences are also known at Coirwong Gorge on the north-western extension of the belt, and at Sleisbeck to the south-east, a total distance of about 60 miles.

All the deposits in this group have been worked by United Uranium N.L., except for the Rockhole and Teagues deposits, which were worked by South Alligator Uranium N.L., and Sleisbeck, worked by North Australian Uranium Corporation N.L.

Of the individual deposits, *El Sherana* and *El Sherana West* have had the largest output; El Sherana produced 38,400 tons of ore averaging 0.5 percent U_3O_8, and El Sherana West 21,300 tons of ore averaging 0.8 percent U_3O_8. The ore consisted of massive pods and disseminated veinlets of pitchblende, associated with minor amounts of secondary metatorbernite, autunite, and gummite, and some gold. Small amounts of pyrite, galena, and chalcopyrite were present in places. Most of the ore was obtained from the carbonaceous shale of the Koolpin Formation, generally within 150 feet of the contact with the unconformably overlying Carpentarian sandstone; a little ore was also found in the Carpentarian beds close to the unconformity.

The *Rockhole* and *Teagues* deposits, with a total output of 13,200 tons of ore averaging 1.1 percent U_3O_8, have a similar setting, although the proportions of ore in the Lower Proterozoic and Carpentarian formations varied in different parts of the deposits. Minor gold was again present.

Palette (4700 tons of ore averaging 2.5 percent U_3O_8), *Scinto* 5 (5700 tons, 0.4 percent U_3O_8), *Koolpin Creek* (2300 tons, 0.12 percent U_3O_8), and *Skull* 530 tons, 0.5 percent U_3O_8), also conformed to this pattern, although only Palette carried significant gold.

Sleisbeck (600 tons, 0.4 percent U_3O_8) also occurs in rocks of the Koolpin Formation, but the bulk of the ore was found in a quartz-hematite breccia which is regarded as a silicified dolomitic rock, and the deposit is associated with minor phosphate rock occurrences similar to those of the Rum Jungle area.

At *Saddle Ridge* (29,800 tons, 0.2 percent U_3O_8), only secondary uranium minerals were encountered, but they occurred both in shale of the Koolpin Formation and in Carpentarian tuff; they were also associated with minor occurrences of phosphate rock.

At *Coronation Hill* (25,700 tons, 0.3 percent U_3O_8), pitchblende with minor gold and some phosphatic material occurred in tuff, breccia, and altered rhyolite forming a volcanic neck associated with the Edith River Volcanics, and at *Scinto 6* (1700 tons, 0.15 percent U_3O_8), pitchblende occurred in altered dolerite of the Zamu Complex.

Minor occurrences from which no production has been recorded include the *Airstrip, Monolith, Scinto 1, Cliff Face,* and *Coirwong* uranium prospects.

In the *Zamu Creek* area, about 15 miles east-south-east of El Sherana mine, an isolated lead prospect occurs in basic intrusives of the Zamu Complex. Total recorded production is about 20 tons of silver-lead ore, mined between 1948 and 1950.

A small copper prospect occurs in chert and siltstone of the Gerowie Formation, associated with dykes and sills of dolerite and amphibolite, about 4 miles north-east of Coirwong Gorge. This was tested by Broken Hill Pty Co. Ltd by diamond drilling about 1958, but the results were disappointing.

Other Radioactive Prospects

Outside the Rum Jungle and South Alligator River areas, radioactive prospects are known from several parts of the region, but none is of major economic importance.

At the *Adelaide River mine,* 2½ miles south of Adelaide River township, 3800 tons of ore averaging 0.5 percent U_3O_8 have been mined from a shear zone in greywacke and siltstone of the Noltenius Formation. The shear zone trends north and dips steeply east; the main oreshoot pitches south at about 45°. The ore consisted of pitchblende with some pyrite and chalcopyrite, and occurred partly in small irregular quartz veins and partly as disseminations in the sedimentary rocks. Original exploration and development work involved 9 shafts, the deepest to 200 feet, and 14 diamond drill holes totalling 3989 feet; the ore was worked from two levels. In 1959-60 after the mine was abandoned the Bureau of Mineral Resources put down a further four drill holes totalling 2490 feet. After this later drilling, ore reserves in 1960 were calculated to be 1500 tons of broken ore, averaging 0.5 percent U_3O_8 and 5500 tons of possible ore, averaging 0.22 percent U_3O_8 (Plumb, 1960, unpubl.).

At *George Creek,* 9 miles south of Adelaide River township, surface indications of torbernite occurred in similar host rocks; the primary ore again consisted of small concentrations of pitchblende, pyrite, and chalcopyrite in joints and minor shear zones. Exploratory work consisted of seven diamond drill holes totalling 1540 feet and a shaft of 126 feet deep, with 200 feet of drives and cross-cuts. One hundred and twenty tons of ore, averaging 0.26 percent U_3O_8, were extracted, and reserves in 1960 were estimated to be about 250 tons of comparable grade (Arkin & Walpole, 1960, unpubl.).

At the *ABC prospect,* 11 miles north-east of Katherine township, autunite and phosphuranylite occur in interbedded tuff and amygdaloidal basalt of the Carpentarian McAddens Creek Volcanics. This prospect has been tested by about 2000 feet of costeaning and 57 diamond drill holes totalling 2550 feet; ore reserves in 1955 were estimated at 1050 tons averaging 0.4 percent U_3O_8 (Matheson, 1953c, unpubl.; Gardner, Rade & Britten, 1955, unpubl.).

A group of prospects occurs in the southern part of the Cullen Granite; they include the *Fergusson River prospect;* the *YMCA* or *Edith River prospects,* from 1 mile east to 3 miles south-south-east of Edith River Siding; *Tennysons prospects,* from 2 to 4 miles west-south-west of Edith River Siding; *Hore and O'Connors prospect,* 5 miles west-north-west of Edith River Siding; and the *Yenberrie prospect,* 5 miles north of Edith River Siding. They all have a number of features in common: they consist of small quartz veins and disseminations containing predominantly secondary minerals such as torbernite and meta-autunite, in places in association with apatite and finely divided hematite or with limonitic gossanous material; and they are generally located on northerly or north-north-westerly steeply dipping shear zones associated with silicification and greisenization of the surrounding granite. Individual shoots are invariably small, and range from 12 to 18 inches wide and up to 25 feet long; the grade at the surface has been estimated as 0.1 to 0.2 percent U_3O_8 (Fisher, 1952, unpubl.; Gardner, 1953b,e, unpubl.).

The conglomerate and arkose of the Mount Partridge Formation are radioactive at Spring Peak and Mount Basedow near Jim Jim Creek. The radioactivity is attributed to thorium-bearing minerals, probably monazite, in the sediments. These rocks in the eastern part of the Pine Creek Geosyncline are in a similar stratigraphical position to the thorium-bearing Crater Formation near Rum Jungle.

Other radioactive prospects, which are located in areas of major base-metal occurrences or are themselves associated with base-metal deposits, are mentioned later. They include the *Fleur de Lys mine* (Brocks Creek area), the *Mount Shoobridge* uranium prospect (Mount Shoobridge area), *Madigans* prospect (Mount Finniss, West Arm area), and the *Burrundie* prospect (Iron Blow/Mount Bonnie area).

Brocks Creek Area (Fig. 27)

The Brocks Creek area was one of the earliest to be developed in the Katherine-Darwin Region; the main products were gold, with minor copper and some bismuth. The economic deposits include both sulphide lodes and zones of disseminated quartz-sulphide mineralization associated with favourable beds in the Lower Proterozoic Golden Dyke Formation, and especially with a number of distinctive beds containing nodules and lenses of quartz in a matrix of slate or schist. These beds have been referred to in the past as 'pressure conglomerates', 'nodular siltstone', 'silicified dolomites', and 'quartz-lens schists', and their origin is still incompletely understood.

Cosmopolitan Howley Group of Mines

Parkes (1892); Brown (1895); Brown & Basedow (1906); Jensen, Gray & Winters (1916); Hossfeld (1942, unpubl.); Sullivan & Iten (1952); McQueen (1959, unpubl.); Vanderplank (1965, unpubl.)

The *Cosmopolitan Howley* mine has been the largest single producer in the area. Gold is reported to have been discovered here in 1879, and mining continued with minor interruptions until 1904; from 1908 to 1915 some gold was obtained by cyaniding the tailings dumps. In 1938 a major programme of underground exploration was undertaken by Anglo-Queensland Mining Pty Ltd, and their shaft was reopened by Brocks Creek Uranium N.L. in 1955. Diamond drilling was undertaken by the Mines Branch, N.T. Administration, in 1948 and 1963, and by the Bureau of Mineral Resources in 1957-59.

Recorded production is 33,780 oz of gold from about 50,000 tons of ore, but this is almost certainly incomplete.

Workings consist of nine open cuts, up to 250 feet long, 40 feet wide, and 80 feet deep, together with a number of old shafts and stopes, mostly now inaccessible, and the Anglo-Queensland 1938 shaft, which is 175 feet deep, and has some 600 feet of drives and crosscuts at the 170-foot level.

The workings broadly follow the contact between a graphitic shale sequence, some 500 feet thick, and the underlying chloritic schist with minor mica schist and quartzite. The quartz-lens schists are best developed in the basal part of the graphitic shale sequence. The workings follow the contact around the nose of the north-west-pitching Howley Anticline, with a marked concentration near the axes of minor drag-folds, most of which appear to pitch at about 55°, parallel to the major fold. The lodes have probably been extensively leached to a depth of 20 feet below the present surface.

All major ore shoots above the water-table, i.e., within about 100 feet of the surface, have probably been worked out. The best prospects for reopening the mine lie in the discovery of extensions or repetitions of the known shoots in depth, which must be expected to be refractory ores, rich in pyrite and arsenopyrite.

The best intersections on the 170-foot level were 10.8 dwt Au per ton over 25 feet, 150 feet south-west of the shaft, and 8.1 dwt over 27 feet, 40 feet north of the shaft, but it appears that most of the workings on this level are in the footwall of the main mineralized zone (Sullivan & Iten, 1952).

The logs of the diamond drill holes show that core recovery was generally poor in the ore zones, and the core assays do not give a reliable indication of the grade of the ore. The sludge assays, which represent the softer more mineralized parts of the lodes, were appreciably higher than the assays of the cores. However, sludge assays are available for only one hole, which had 15-foot and 85-foot intersections averaging about 10 dwt per ton. The best core assays from 9 holes were 16 feet at 8.6 dwt per ton and 10 feet at 6.8 dwt per ton (McQueen, 1959, unpubl.; Vanderplank, 1965a, unpubl.).

North-west of the Cosmopolitan Howley mine, further gold occurrences have been worked at the Chinese Howley, Big Howley, Bridge Creek, and Mount Paqualin, all of which lie on or close to the crest of the Howley Anticline, and in or close to the graphitic shale horizon, which is the main host rock at the Cosmopolitan Howley mine. Recorded production from this group of mines (excluding the Cosmopolitan Howley) is 32,450 oz, of which at least 13,000 oz came from the Big Howley mine (Sullivan & Iten, 1952).

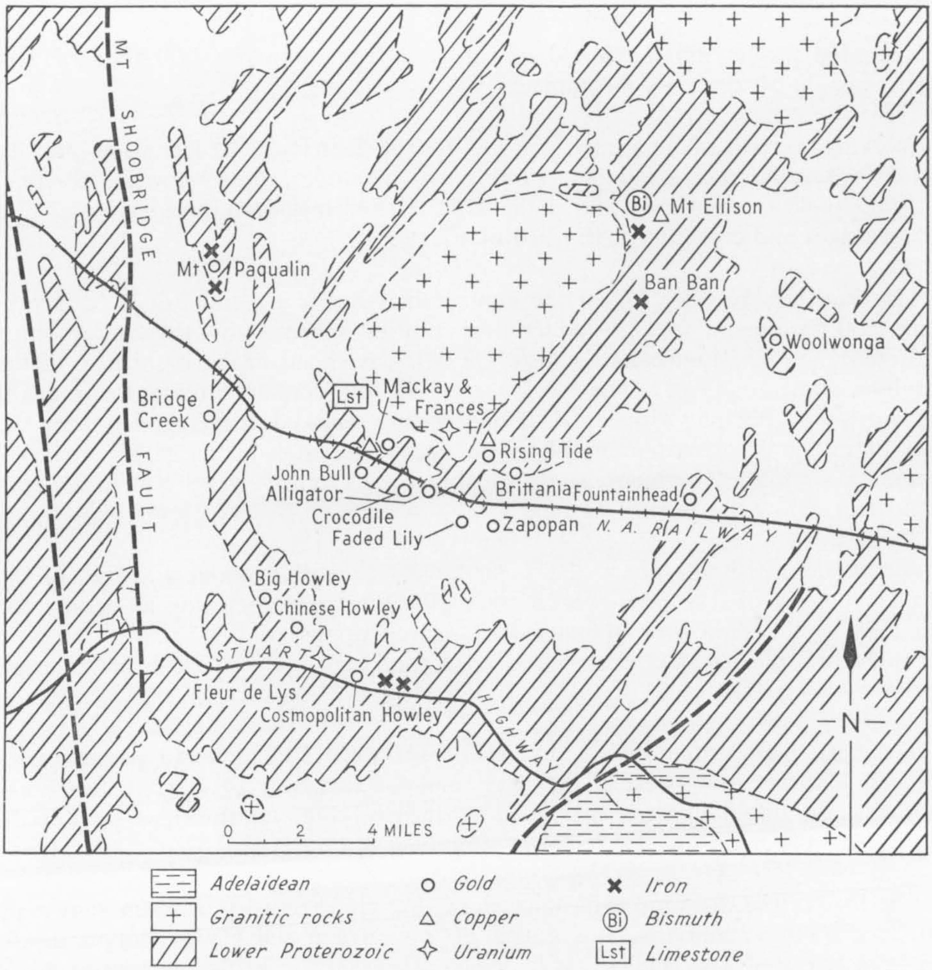

Fig. 27. Mineral deposits, Brocks Creek area

At the *Chinese Howley* mine, steeply dipping quartz reefs from 6 to 12 inches wide have been intermittently worked over a zone 3000 feet long, but the bulk of the production is believed to have come from associated alluvial deposits.

At the *Big Howley* mine, the main reef was a saddle-shaped body, 20 feet thick at the crest, which pitched to the north-west at 33°, parallel to the bedding of the surrounding sedimentary rocks. This was worked between 1882 and 1903 by means of an extensive system of open cuts, a 300-foot adit, and two shafts 171 and 190 feet deep. Tailings were cyanided intermittently until 1915, but no work has been done on the mine since then.

At *Bridge Creek,* a group of small but locally very rich leaders, ranging in width from 1 or 2 inches to about 18 inches, has been intermittently worked since 1873. Parkes (1892) records five shafts from 50 to 70 feet deep in this area, and workings were reported to have reached a depth of 110 feet in 1914. The area was re-examined in 1964 by a local syndicate, which costeaned the surface, but no follow-up work has been done as yet. Total recorded production is 1190 oz, but this is known to be incomplete.

At *Mount Paqualin,* a group of small workings is known, but the production has not been recorded.

Fleur de Lys Mine

Firman (1955b, unpubl., 1956, unpubl.); McAndrew (1954b)

The only prospect in this vicinity which has been worked for minerals other than gold is the Fleur de Lys mine, 1 mile north-west of the Cosmopolitan Howley; it contains torbernite, malachite, azurite, and cuprite in the oxidized zone, and uraninite, pyrite, chalcopyrite, and chalcocite in the primary zone. According to Firman (1956) the ore occurs in shear zones in thin-bedded siltstone and slate. Five shafts, up to 100 feet deep, were in existence in 1955, when the mine was being worked by Brocks Creek Uranium N.L., but the only recorded production is about 440 lb of U_3O_8 in 1954-55.

Zapopan/John Bull Group of Mines

AGGSNA (1940); Parkes (1892); Brown (1895); Brown & Basedow (1906); Jensen (1915); Jensen, Gray, & Winters (1916); Cottle (1937a); Rayner & Nye (1937); Sullivan & Iten (1952)

At Brocks Creek, a line of workings extends in a west-north-westerly direction for about 6 miles; the main mines, from east to west, are Zapopan, Faded Lily, Alligator, Crocodile, and John Bull. The line appears to be associated with a structure, possibly a major fault, which slightly transgresses the bedding of the host rocks (Cottle, 1937d).

The *Zapopan* has been the largest producer in this group, and was worked from 1885 to 1911. Tailings were treated intermittently until 1933. According to Brown & Basedow (1906), the main reef worked had an average width of 3 to 5 feet, and trended east with a dip of about 60° to the south. It was worked to a depth of 225 feet. Two other reefs and an irregular quartz body were also worked. Throughout the mine, the best values were found at the intersections of the major reefs with cross-reefs. Recorded production is 26,650 oz of gold from about 40,000 tons of ore. Two diamond drill holes are reported to have been put down in 1908 and three in 1915, but no payable shoots were intersected, although No. 4 bore intersected a heavily mineralized section assaying up to 10 percent Pb between 149 and 184 feet, and core from No. 5 bore between 479 and 484 feet assayed 5.9 dwt Au per ton (Jensen, 1915). The host rock, from the evidence of dump material, was mainly slate and hornfels, but Jensen, Gray & Winters (1916) also record quartzite, chert, sericite schist, and garnetiferous amphibolite from the immediate vicinity of the lodes.

Little is known about the *Victoria* and *Morning Star* mines, which are situated on the line of lode between Zapopan and the Faded Lily.

The *Faded Lily* has a shaft 212 feet deep, with 400 feet of drives on the bottom level. At this level, the lode was reported to be 8 to 13 feet wide, assaying 1 to 2 dwt Au per ton. The country rock was graphitic andalusite-sillimanite hornfels, cut by quartz-tourmaline veins. A diamond drill hole put down in 1914 to a depth of 504 feet failed to encounter any downward extension of the lode (Jensen, 1915).

The *Alligator* mine worked a system of small quartz leaders in amphibolite. At least three shafts are reported to have been sunk, the deepest to 90 feet. Some of the leaders were apparently extremely rich.

At the *Crocodile* mine, conditions apparently were very similar to those at the Alligator.

The *John Bull* mine included several shafts; the deepest was 135 feet, on a lode of 1 foot 8 inches wide, which was worked for a length of about 100 feet.

The *Homeward Bound* mine had workings extending to a depth of 100 feet over a length of 300 feet. Its exact location is in some doubt, but is most probably between the Zapopan and Faded Lily mines.

The total recorded production of the mines in this group, exclusive of the Zapopan, is 6370 oz, but this is certainly incomplete.

Another mine in this vicinity is the *Mackay and Francis,* which was described by Jensen, Gray, & Winters (1916) as working a 9-inch lode rich in chalcocite. Assays of up to 36 percent Cu and 13 dwt Au per ton were reported, but no production is recorded.

Brittania/Fountain Head Group of Mines

Parkes (1892); Brown (1895, 1908b); Jensen, Gray, & Winters (1916); AGGSNA (1937, 1940); Cottle (1937b, 1937d); Rayner & Nye (1937b, 1937f); Sullivan & Iten (1952)

To the east and north-east of Brocks Creek, another group of mines comprises the Brittania, Rising Tide, and Fountain Head mines.

The *Brittania* mine, 2 miles north-east of Brocks Creek Siding, was worked intermittently from 1875 to at least 1893. The main lode was at least 350 feet long and up to 1 foot 6 inches wide, and was thought by Cottle (1937d) to follow a major north-westerly fault zone. Several small rich leaders were also worked, and the workings included two open cuts 120 and 150 feet long, and several shafts, the deepest to 60 feet. Total recorded production (incomplete) is 840 oz of gold from 220 tons of ore.

The *Rising Tide* mine, 1½ miles north-north-east of Brocks Creek, consists of two shafts, 80 and 100 feet deep, on the flanks of a north-westerly quartz-filled fault, close to its intersection with an east-north-easterly zone of graphitic slate with abundant small discontinuous gossanous cappings. Some copper staining occurs in the gossanous zone, and a strong geochemical anomaly was obtained around the intersection of the fault and the gossanous zone by the Bureau of Mineral Resources in 1950 (Sullivan & Iten, 1952). However, only pyrite has been reported from the shaft, and there is no recorded production.

In 1959, a geophysical survey by the Bureau of Mineral Resources delineated four electromagnetic anomalies, of which one coincided with a small gossanous outcrop and two others appeared to be related to an amphibolite sill (Hays, 1959, unpubl.). In 1963, a diamond drill hole was put down to a depth of 295 feet by the Bureau to test one of the anomalies, but only pyritic mineralization was found (Shields, 1965, unpubl.). It appears that base metals, especially copper, have undergone surface enrichment in this area, and the surface concentrations have apparently been derived from very low-grade material in the primary sulphide zone.

The *Fountain Head* mines, 6 miles east of Brocks Creek, were intermittently worked from 1883 to 1951. The auriferous quartz veins range from a few inches to about 5 feet wide and up to 300 feet long. They generally trend north-west, parallel to the axis of a major anticline in the host greywacke and slate of the Lower Proterozoic Burrell Creek Formation. The workings consisted of numerous open cuts and at least three shafts, the deepest to about 100 feet. Two diamond drill holes were put down in 1908 to vertical depths of 520 and 490 feet, but no payable lodes were encountered.

Total recorded production is 9870 oz, of which a substantial proportion, especially in the early years of the mine, appears to have come from alluvial deposits.

Mount Ellison Mine

Brown & Basedow (1906); Jensen, Gray, & Winters (1916); Sullivan & Iten (1952)

The Mount Ellison mine, 10 miles north-north-east of Brocks Creek, lies in graphitic shale at the same stratigraphic horizon as the Cosmopolitan Howley mine. The mine was worked from 1891 to 1911 by means of a number of shafts, of which the deepest was 228 feet with workings at five levels (Brown & Basedow, 1906). The main lode strikes north-north-west, parallel to the enclosing sedimentary rocks, and dips steeply to the east. The thickness was reported to range from a few inches to about 3 feet, and numerous cross-fractures and subsidiary shears were encountered in the workings. The ore was oxidized to the 70-foot level, with a zone of secondary cuprite and chalcocite below, which passed into the primary quartz-chalcopyrite-pyrite ore. Bismuth minerals were present in both the primary and oxidized ore. Recorded production is about 3250 tons of copper ore, averaging about 20 percent Cu, most of which came from the oxidized and secondarily enriched zones. About 3 tons of bismuth was also produced. A diamond drill hole put down by the Australian Mining and Smelting Co. to a depth of 348 feet in 1955 encountered only disseminated pyrite mineralization; Murray (1955, unpubl.) has suggested that the lode was not intersected because it pitches north, parallel to the pitch of a tight anticlinal fold in the surrounding sedimentary rocks.

Iron Blow/Mount Bonnie/Golden Dyke Area (Fig. 28)

The Iron Blow/Mount Bonnie/Golden Dyke area contains a number of gold and base-metal mines within a belt of Golden Dyke sedimentary rocks extending from the Stuart Highway to the railway near Grove Hill.

The gold mines in the western portion of this belt, between Yam Creek and the Golden Dyke, have been collectively referred to as the Priscilla Line of Reef, but the various mines of this group appear to be associated with a number of separate geological features, and show partly structural and partly stratigraphic control.

Yam Creek Mines

Parkes (1892); Jensen, Gray, & Winters (1916); McDonald (1901); Rayner & Nye (1937c); Sullivan & Iten (1952)

In the Grove Hill area gold has been won from the *Yam Creek* workings, *Radfords Blow,* and the *Princess Louise* and *Temperance* mines, as well as numerous alluvial workings, such as *Neates Gully, Port Darwin Camp, Sandy Creek* and *Stuart Gully.* Most of the mines of this area were worked intermittently between 1872 and 1910 for a total recorded production of 15,400 oz; no records are available for the appreciable production from alluvial and eluvial deposits worked in the early years. Some copper mineralization is also recorded in the area, but no copper ore appears to have been produced.

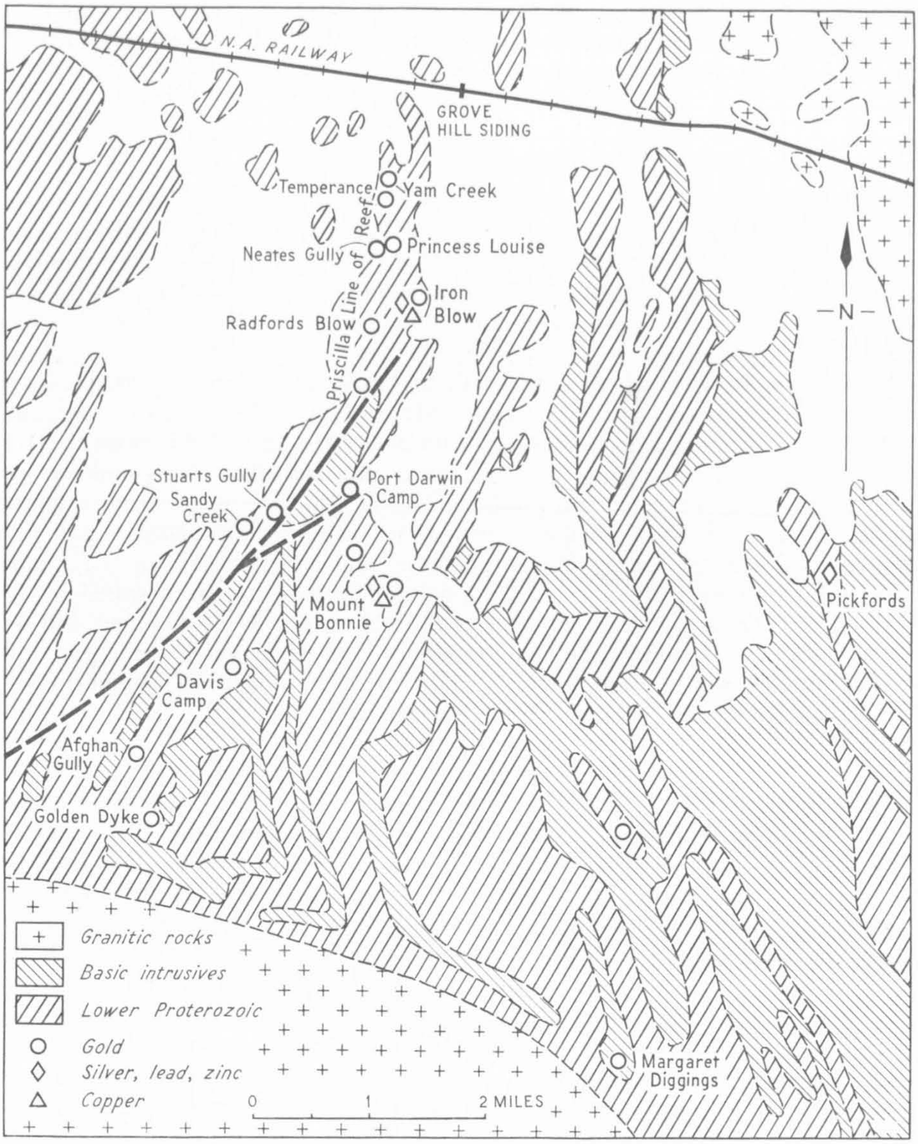

Fig. 28. Mineral deposits, Iron Blow/Mount Bonnie/Golden Dyke area

The workings were mostly on quartz leaders in interbedded slate and sandstone. Both the reefs and the surrounding sedimentary rocks generally have a northerly strike, but the reefs generally dip east at 50° to 75°, whereas the sedimentary rocks usually dip west. Workings include one shaft 186 feet deep and numerous other shafts between 50 and 150 feet deep, a 200-foot adit, and several hundred shallow pits, costeans, and small open cuts. A 600-foot cross-cut has been driven west from the 186-foot level of the main shaft. Reefs ranged in width from a few inches to about 6 feet and exceptionally to 12 feet, and carried up to 10 percent pyrite in the primary zone. The average grade of all the ore mined was apparently about 7 dwt per ton.

Iron Blow and Mount Bonnie Mines

Parkes (1892); Brown (1907); Brown & Basedow (1906); Jensen (1915); Jensen, Gray, & Winters (1916); Hossfeld (1937a); Rayner & Nye (1937e); Noakes (1949); Sullivan & Iten (1952); Dunn (1961, unpubl.); Rix (1964a, unpubl.)

At the Iron Blow mine, 2 miles south of Grove Hill Siding, a complex gold and base-metal lode was worked intermittently between 1873 and 1914. Workings consisted of a main shaft 215 feet deep with about 400 feet of drives on the 100-foot level and 200 feet on the 200-foot level, and five other shafts and an open cut 150 feet long. The recorded production is 13,700 tons of ore from a quartz-sulphide lode in a north-trending shear zone with a steep easterly dip. The country rock consists largely of carbonaceous and sericitic slate of the Golden Dyke Formation with minor quartzite bands. The lode has been tested by two diamond drill holes put down in 1906 and 1912 to depths of 444 feet and 467 feet, and by six diamond drill holes totalling 2333 feet, which were put down in 1963 by the Mines Branch, N.T. Administration, under an agreement with United Uranium N.L. This work has shown that the main lode, from which all past production has been obtained, thins considerably below the 200-foot level, and that the probable remaining ore reserves are only about 40,000 tons above the 200-foot level and 10,000 tons below this level. The grade ranges from 4 to 6 dwt Au per ton and 0.2 to 1.0 percent Cu, with 4 to 5 percent Pb, 6 to 14 percent Zn, and 10 to 20 oz Ag in places. The drilling has also disclosed that a second lode is present below the 200-foot level on a parallel shear zone which crops out 150 feet west of the main shear, and carries little or no mineralization at the surface. This lode is a pyrrhotite-rich body with 0.8 percent Cu and 4.0 percent Zn over a true width of 33 feet at a vertical depth of about 350 feet (Rix, 1964a, unpubl.). South of this intersection, a magnetic anomaly was located by a geophysical survey by the Bureau of Mineral Resources in 1960 (Skattebol, 1962, unpubl.), but the hole drilled to test the anomaly did not intersect any magnetic material. The magnetic anomaly may be caused by a southerly extension of the pyrrhotite lode at a greater depth than that calculated by the geophysicists; some further testing may be warranted.

South of Iron Blow, some minor workings lie on the line connecting Iron Blow and Mount Bonnie mines, but no details are available.

The *Mount Bonnie* mine, 2½ miles south of Iron Blow, consists of an adit 240 feet long, which is connected to the surface workings by a series of inclined shafts and intermediate levels. The lode exposed in the workings trends north-east and dips north-west at about 45°. A north-trending outcrop of gossanous material immediately east of the workings does not appear to have been tested at depth. The mine is reported to have been worked intermittently between 1903 and 1916, but no records of production are available (Jensen, Gray, & Winters, 1916). Two diamond drill holes were put down in 1916 to depths of 370 and 411 feet to test the downward extension of the lode, but the results are not available. The ore appears to be comparable to that mined at Iron Blow, with low gold and copper values, moderate lead and zinc, and locally high silver, but the available information is insufficient to assess the tonnage and grade of ore which may still remain in the mine.

Golden Dyke Group of Mines

Brown (1895); Jensen, Gray, & Winters (1916); Hossfeld (1936c); AGGSNA (1936, 1940); Noakes (1949); Sullivan & Iten (1952)

To the south-west of the Mount Bonnie mine, a group of small gold mines and prospects includes *Davis Camp, Afghan Gully,* and *Golden Dyke* (which is also known as the Shackle). The area has been worked intermittently since 1872; most of the work was done at the Golden Dyke mine, which has a main shaft 100 feet deep, with nearly 500 feet of drives at the 100-foot level. The lode consists of a zone of quartz and sulphide impregnation in slate and sandstone of the Golden Dyke Formation, with minor beds containing quartz nodules, possibly at the same stratigraphic horizon as the lodes of the Cosmopolitan Howley mine. The lode trends north-west and dips at about 70° to the south-west, parallel to the bedding of the surrounding sedimentary rocks; it is close to a group of large amphibolite sills.

Recorded production from the Golden Dyke mine is only 1400 oz of gold, but the main shoot at the 100-foot level is reported to have averaged 7 dwt per ton over a length of 360 feet and a width of up to 10 feet (Hossfeld, 1936c), so that some further testing may be warranted.

Four miles south-east of the Golden Dyke mine, a group of shallow workings, situated at least in part in amphibolite, is known as the *Margaret Diggings.* Both reef and alluvial gold are reported to have been won, but the production is not recorded.

At *Pickfords* mine, also known as the *Bonnie Jean,* 4 miles east of Mount Bonnie, some lead and copper mineralization is known in a group of quartz reefs and a graphitic shear zone, all of which trend a few degrees west of north. The host rock is slate of the Golden Dyke Formation, and the lodes are close to amphibolite sills. No production is recorded.

Burrundie Uranium Prospect

A uranium prospect has been recorded 4 miles west-south-west of Burrundie Siding, mainly in gossanous cappings overlying carbonaceous and probably pyritic slate of the Golden Dyke Formation; but it appears to offer no possibility of economic development (Stewart, 1954, unpubl.; Firman, 1955a, unpubl.)

Mount Shoobridge Area (Fig. 29)

Parkes (1892); Brown (1895); Brown & Basedow (1906); Jensen, Gray, & Winters (1916); AGGSNA (1940); Sullivan & Iten (1952); Corbett (1960, unpubl.)

In the Mount Shoobridge area a series of small tin mines and lead and copper prospects occurs in pegmatites, quartz veins, and mineralized shear zones in the Golden Dyke sedimentary rocks. Many of them are associated with major meridional structures, such as the Mount Shoobridge Fault, and they may be genetically related to the nearby Shoobridge Granite.

The most productive mine of the group has been the *Mount Shoobridge* or *Old Company* mine, 1½ miles south of the Stuart Highway, which has been worked intermittently since 1882. The main workings consist of four shafts, of which the deepest was 180 feet deep, and had about 400 feet of drives on three levels. The major workings were on a steeply dipping quartz-muscovite reef from 2 to 8 feet wide, trending north-north-west, which contained patchy cassiterite shoots over a length of 300 feet. Other workings were on groups of pegmatite and greisen stringers, which occur sporadically throughout a zone 1200 feet long and about 100 feet wide. Individual stringers are commonly only a few inches thick, but a few attain a thickness of several feet. The total recorded production from this group of workings is 145 tons of tin concentrate.

At *Barretts* mine, 1½ miles south of the Old Company workings, an irregular body of greisen and pegmatite, elongated in a north-westerly direction, has been exposed for a length of about 300 feet with a maximum width of about 90 feet. The body dips to the north-east at an average of only about 30°, and most of the workings, consisting of shallow shafts, costeans, and open cuts, are less than 20 feet deep. Recorded production is 115 tons of tin concentrate.

Other mines close to the old road from Mount Shoobridge to Barretts mine include the *Chinamans Hill* and *Halls Creek* prospects, both of which consist of shallow shafts and open cuts on greisen and pegmatite dykes, but no details of production are available.

Copper and lead occurrences are known from numerous prospects in this general area, but few of them are of economic importance.

At *Jacksons* mine, 1 mile north-west of the Old Company workings, narrow seams of galena and cerussite occur in feldspar porphyry and adjoining quartz-mica schist, and an average grade of 3 percent Pb has been estimated for a

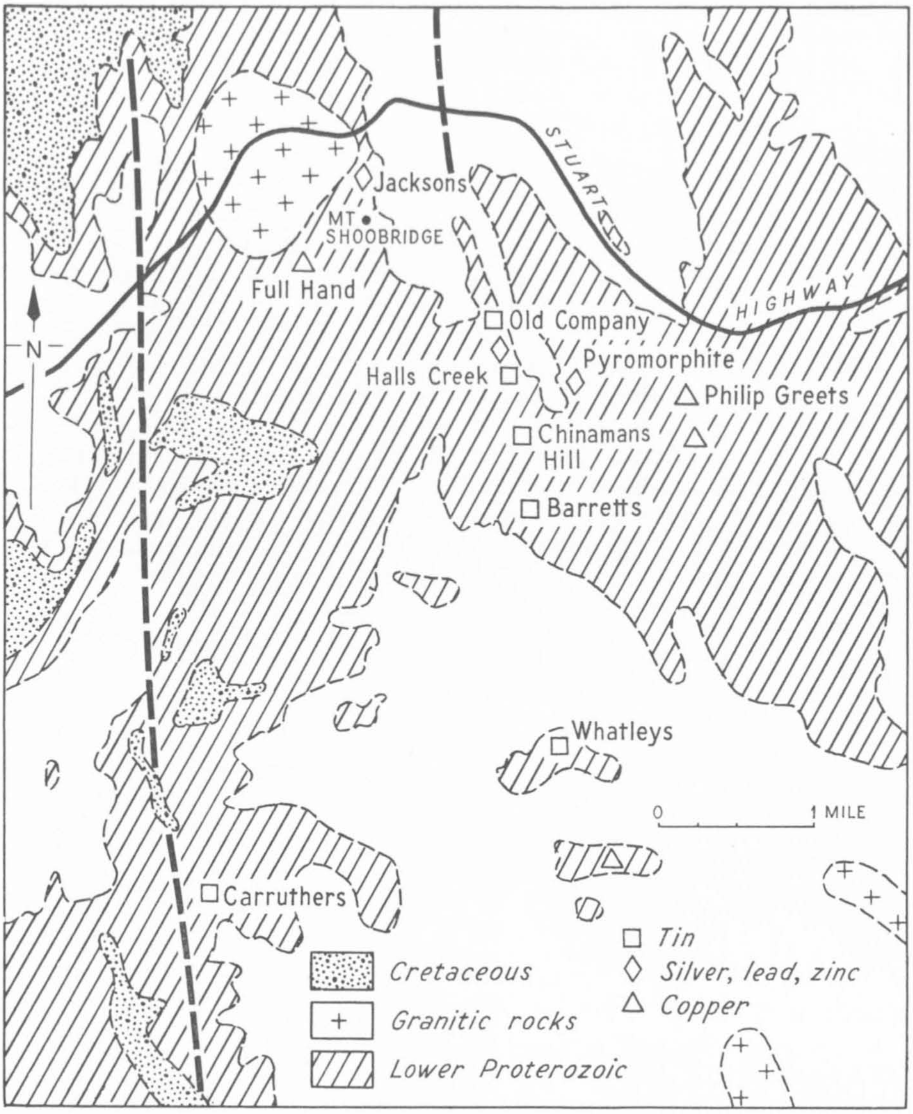

Fig. 29. Mineral deposits, Mount Shoobridge area

zone 300 feet long and about 50 feet wide (Patterson, 1958b, unpubl.). Recorded production is 2 tons of silver-lead ore.

At the *Full Hand* prospect, also known as the *Dead Finish,* half a mile south-west of Jacksons mine, two lodes are recorded. One, trending north-north-east, ranged from 1 to 3 feet thick, and is reported to have contained patches of very rich copper ore in the oxidized zone. The other, trending east-north-east, consists of a graphitic shear zone up to 9 feet wide; it contains disseminated copper and lead minerals and can be traced on the surface for over 1000 feet. This mine was worked intermittently from 1903 to 1909, and several shafts were sunk, the deepest being 120 feet. Recorded production is only 14 tons of copper ore. These lodes also carry minor amounts of radioactive minerals, but not in economic concentrations (Rosenhain & Mumme, 1953b, unpubl.).

At *Philip Greets* copper mine, 1½ miles south-east of the Old Company workings, an almost vertical lode, striking a few degrees east of north, is exposed for a length of about 900 feet with an average width of about 3 feet. It was worked between 1901 and 1912 from a large number of shafts, the deepest being 140 feet; recorded production is about 360 tons of ore, averaging 25 to 30 percent Cu.

Other prospects in this area, for which no details are available, include *Whatleys* and the *Pyromorphite* show (lead), and *Carruthers* prospect (tin).

During 1963, the area around the Old Company/Barretts mine mineralized zone was re-examined by United Uranium N.L., and a large number of waggon drill holes were put down. One diamond drill hole was also put down by the Mines Branch, N.T. Administration, under an agreement with the Company, but only low-grade tin and lead mineralization was found.

Northern Hercules/Coronet Hill Area (Fig. 30)

The Northern Hercules/Coronet Hill area is centred on Moline township, at the site of the old Northern Hercules mine, and contains a number of formerly highly productive mines which have been worked for gold, copper, and silver-lead-zinc.

Northern Hercules Mine

Parkes (1892); Brown (1895); Brown & Basedow (1906); Jensen (1919); Larsen (1957, unpubl.); Rayner & Nye (1937g); Sullivan (1940, unpubl.); Summers (1957a, unpubl.)

The Northern Hercules has been the main gold producer in this area, and has been worked intermittently between 1880 and 1908 and between 1954 and 1957. The mine was also referred to as the *Eureka* or *Houschildts Rush* in its early years and as *Hercules* in the 1930's. The old *Maybell* mine was later included in the Northern Hercules. Recorded production is 32,800 oz of gold and a small tonnage of copper concentrate, but this is known to be incomplete.

The most recent and comprehensive accounts of the mine are by Summers (1957a, unpubl.) and Larsen (1957, unpubl.). The workings have opened up three parallel quartz-sulphide lodes in a north-north-westerly shear zone, of which the most easterly has been the most productive. Pyrite and arsenopyrite, with

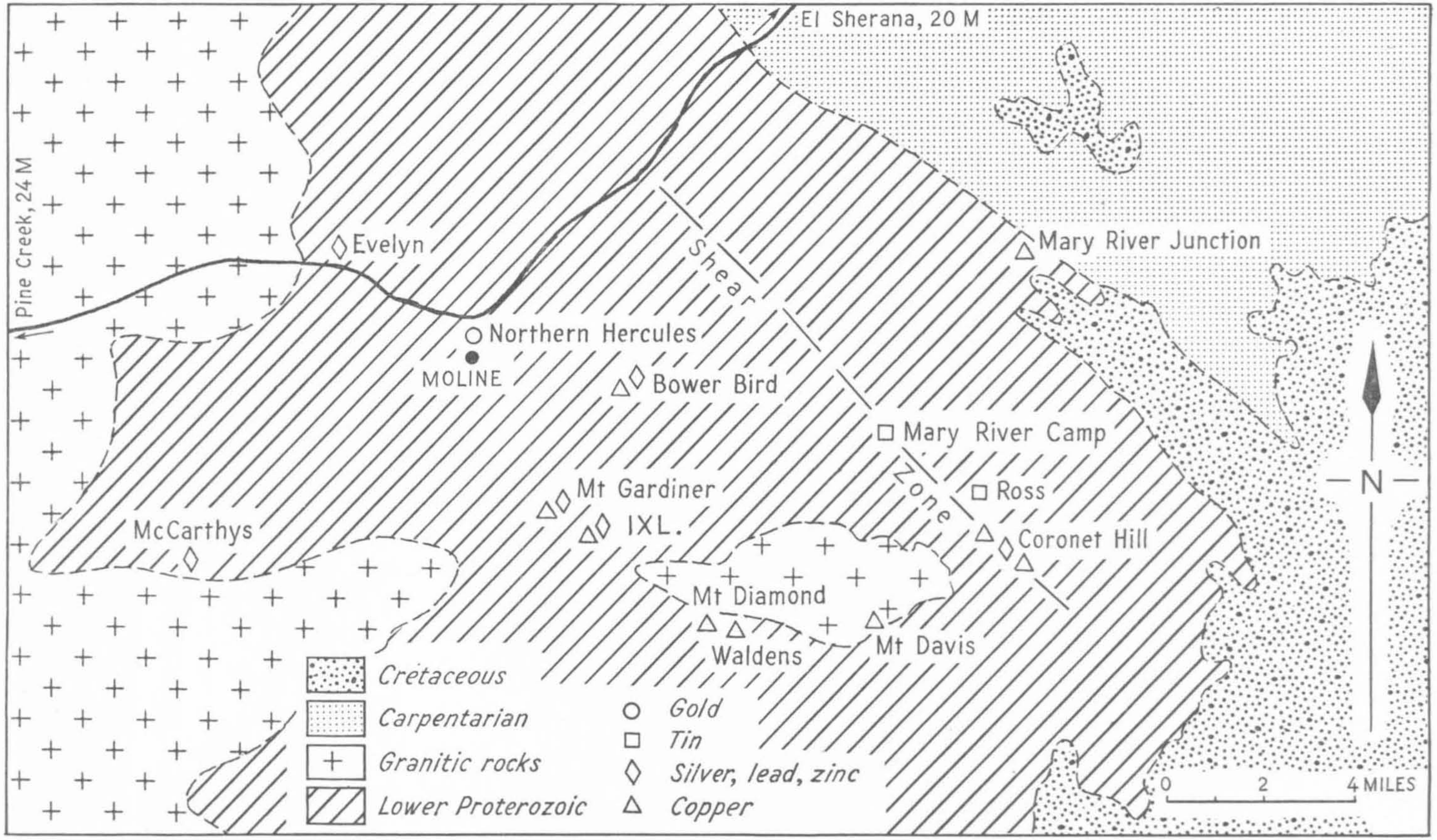

Fig. 30. Mineral deposits, Northern Hercules/Coronet Hill area

minor copper, lead, and zinc sulphides, are present in the unoxidized ore, but much of the early production was from the oxidized zone. The country rock consists of greywacke and slate of the Burrell Creek Formation.

The lodes dip to the west at 65° to 70°, and were originally worked from a number of shallow shafts and open cuts, but the main shaft was sunk to a depth of 440 feet in 1956, and a total of at least 4000 feet of driving and cross-cutting has been done on the 200, 300, and 400-foot levels.

At the 300-foot level, three separate shoots with a total length of about 400 feet were present in the eastern lode. They ranged from 3 feet 6 inches to 5 feet wide with from 12 to 22 dwt Au per ton, but both the width and the average grade are reported to have fallen off sharply at the 400-foot level. The central and western lodes have not been worked below the zone of oxidation. All the lodes have also been extensively tested by diamond drilling, and major extensions or repetitions of the known shoots are unlikely to be discovered within an economic depth from the surface.

Coronet Hill/Mount Davis/Mount Diamond Group of Mines

Parkes (1892); Brown & Basedow (1906); Brown (1908b); Jensen (1919); Ruxton & Shields (1962, unpubl.)

Among the copper mines of the area, the Coronet Hill, Mount Davis, Mount Diamond, Walden, IXL, and Mount Gardiner mines form a group which stretches from 6 to 12 miles south-east of Moline, close to an outlying lobe of the Cullen Granite batholith.

At *Coronet Hill,* a group of quartz-sulphide lodes occupy a major north-westerly shear zone, which in part forms the boundary between chert of the Golden Dyke Formation to the north-east and greywacke and siltstone of the Burrell Creek Formation to the south-west. All the lodes dip steeply to the south-west.

The workings extend intermittently over a total length of about 2½ miles, and consist of two adits from which about 1000 feet of drives and cross-cuts have been driven, and at least eight shafts, of which the deepest is about 120 feet. Most of the work appears to have been done between 1916 and 1918.

The lodes average 2 to 3 feet thick, with occasional bulges up to 10 feet, but assay values are very erratic. Of a group of 35 samples taken in 1961, 12 gave assays of over 5 percent Cu, 20 contained 8 to 30 oz Ag per ton, and 2 contained over 15 percent Pb (Ruxton & Shields, 1962, unpubl.). Pyrite and arsenopyrite are always present in the primary ore, and scorodite (iron arsenate) commonly occurs in the oxidized zone. Gold is generally low (less than 1 dwt per ton), but up to 0.7 percent Bi and traces of antimony may be present.

Recorded production is about 250 tons of ore, averaging 22 percent Cu. In 1961, six diamond drill sites were selected as a result of a survey by the Bureau of Mineral Resources (Ruxton & Shields, 1962, unpubl.), but no further work has been done as yet.

At *Mount Davis,* two steeply dipping northerly lodes were worked from a large number of shafts, the deepest of which was about 60 feet, and a total production of about 990 tons of copper ore is recorded for the period 1907-19. The mineralogy of the lodes appears to have been similar to that of the Coronet Hill lodes; the average width of the lodes was only from 1 foot to 18 inches, with occasional bulges to 4 feet. The locality is completely surrounded by granite, and the country rock of the lodes was described by Jensen (1919) as a quartz-mica-chlorite rock which may be a metamorphosed inlier of Lower Proterozoic sediments, or a product of metasomatic alteration of the granite, which is an offshoot of the Cullen Granite batholith.

At *Mount Diamond,* mining was carried out sporadically between 1898 and 1920, and nine shafts were sunk, the deepest to 216 feet, with levels at 60, 100, and 200 feet.

The workings were on a quartz-chalcopyrite lode which trended north-west and dipped steeply to the south-west. Some bornite and copper oxides and carbonates were also present. The country rocks are hornfels, derived from the sediments of the Burrell Creek Formation, and minor aplite and quartz porphyry dykes. The average width of the lode was 2 to 3 feet and the average grade of 33 samples from the 100-foot level was 6.8 percent Cu (Jensen, 1919). Total recorded production is about 700 tons of copper ore of unspecified grade, probably about 10 percent, most of which probably came from the oxidized zone.

At *Waldens* mine, a quarter of a mile north-east of Mount Diamond, a production of 1220 tons of ore is recorded, the grade probably being about 8 to 10 percent Cu. Mining was carried out intermittently between 1904 and 1919, and the workings consist of at least eight shafts, the deepest to about 100 feet. The lode trended north-west with a steep north-easterly dip, and the width is reported to have ranged up to 6 feet.

At *Mount Gardiner,* some work was done on two shear zones containing quartz, iron oxides, and copper oxides and carbonates. The country rock is hornfels. Fourteen tons of copper ore were produced in 1907, and 7 tons of silver-lead ore in 1929-30.

At the *IXL* mine, 1 mile east of Mount Gardiner, rich ore is reported to have been obtained from a vertical lode in a shear zone in hornfels, but no production records are available.

Evelyn Mine

Parkes (1892); Brown (1895); Brown & Basedow (1906); Jensen (1919); Hossfeld (1937e); Rayner & Nye (1937i); Rowston (1957, unpubl.)

At the Evelyn mine, 3 miles north-west of Moline, a group of small silver-lead-zinc lodes occurs in limestone and calcareous slate of the Golden Dyke Formation. The lodes were worked between 1886 and 1890; the original workings consisted of seven shafts, the deepest to 116 feet, and a number of open cuts and adits of which few details are available. The lodes have since been re-examined on several occasions, and United Uranium N.L. have now (June 1966) reopened the mine.

Nine separate lodes have been recognized in the area, mostly trending a few degrees west of north and dipping steeply to the east. The largest had an average width on the surface of 4 to 5 feet and has been traced for a length of about 250 feet. The lodes transgress the bedding of the host rocks, which trends west-north-west, and are associated with a zone of brecciation, silicification, and iron-impregnation marked by a prominent outcrop of quartz-hematite breccia at Pinnacle Hill, immediately south-east of the main workings. Galena and sphalerite are the main ore minerals in the primary zone, but hydrozincite, smithsonite, cerussite, anglesite, and secondary copper minerals occur in the oxidized zone.

Total recorded production is about 2200 tons of ore containing 600 tons of lead and 89,000 oz of silver, most of which was probably obtained from the oxidized zone.

Rowston (1957, unpubl.) reported that a diamond drill hole put down by Zinc Corporation in 1955 intersected 4 feet of ore assaying 20 percent Pb, 8 percent Zn, and 25 oz Ag per ton at a depth of about 250 feet below the outcrop of the main lode, but a shaft designed to test the occurrence was abandoned before reaching its target.

Three holes totalling about 500 feet were drilled to the north of the main workings by United Uranium N.L. in 1964, and met with disappointing results. In 1965 further exploration included the rehabilitation of the original main shaft to a depth of 100 feet, and underground driving and drilling which confirmed the continuity of the main lode to a depth of at least 265 feet and six subsidiary lodes to a depth of 100 feet or more.

Other Mines and Prospects

Among the smaller mines of this area, some information is available on the Mary River Junction, McCarthys, Bower Bird, and Ross mines.

At the *Mary River Junction* mine, 12 miles east of Moline, 69 tons of rich copper ore are reported to have been won from shallow workings in 1913 and 1917-18. The mine was re-examined in 1963 by United Uranium N.L., but no further mining was done (Rix, 1964c, unpubl.).

At *McCarthys* silver-lead mine, 7 miles south-west of Moline, a 3-foot lode was worked between 1912 and 1918 from several shafts, the deepest being 80 feet.

The lode strikes northerly, transgressing the bedding in the surrounding hornfels and andalusite-chiastolite schist derived from greywacke and slate of the Masson Formation by metamorphism by the nearby Cullen Granite (Jensen, 1919). Total recorded production is 570 tons of ore containing 70 percent Pb and 10 oz Ag per ton.

At the *Bower Bird* mine, 5 miles east-south-east of Moline, both silver-lead and copper ore have been mined on a small scale, but the only record of production is 8 tons of argentiferous galena in 1913.

The only known occurrences of tin in the area are at the *Mary River Camp* locality, 4 miles north-west of Coronet Hill, and at *Ross* prospect, about 1 mile north of Coronet Hill. Recorded production is 45 tons of tin concentrate from Mary River Camp, but none from the Ross prospect.

Spring Hill/Union Reefs/Pine Creek Area (Fig. 31)

In the Spring Hill/Union Reefs/Pine Creek area, a group of mines occupies a north-north-west belt about 25 miles long, which coincides partly with a major shear zone, and in the south with a major re-entrant in the Cullen Granite batholith. Gold is the main mineral mined, with subordinate tin, silver-lead-zinc, and copper.

Spring Hill Group of Mines

Parkes (1892); Brown & Basedow (1906); Jensen, Gray, & Winters (1916); Jensen (1919)

The most northerly group of mines consists of the tin and gold mines of the Spring Hill and Burrundie areas, which have been worked intermittently since 1882.

At *Deans Camp,* also known as *Jimmys Knob,* 2 miles south of Burrundie, narrow seams of rich tin ore occur in a feldspar porphyry intrusion and in adjoining black slate. Workings include several adits and a number of shafts, the deepest to 107 feet.

At the *Mundic* mine, half a mile east of Deans Camp, a number of shafts have been sunk on an east-west 2-foot quartz-pyrite-cassiterite reef. Workings extend over a length of about 500 feet, and the deepest shaft is reported to be 100 feet deep.

At the *Horseshoe* mine, west of Spring Hill Siding, both lode and alluvial tin are reported to have been won. At least one shaft was sunk on a kaolinized

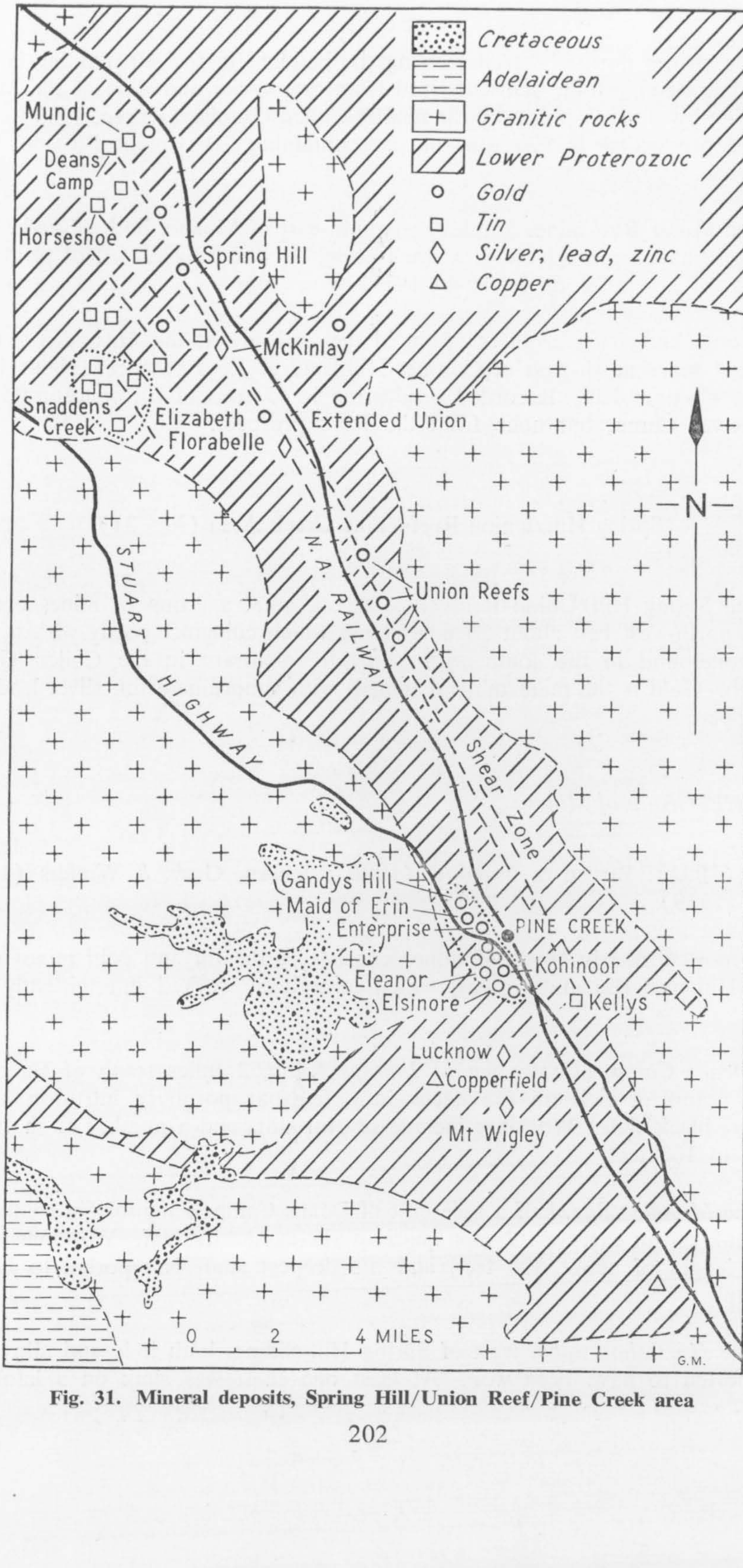

Fig. 31. Mineral deposits, Spring Hill/Union Reef/Pine Creek area

Fig. 1: Karst topography in massive and jointed Tindall Limestone, Daly River road, 10 miles west of Stuart Highway, Pine Creek Sheet.

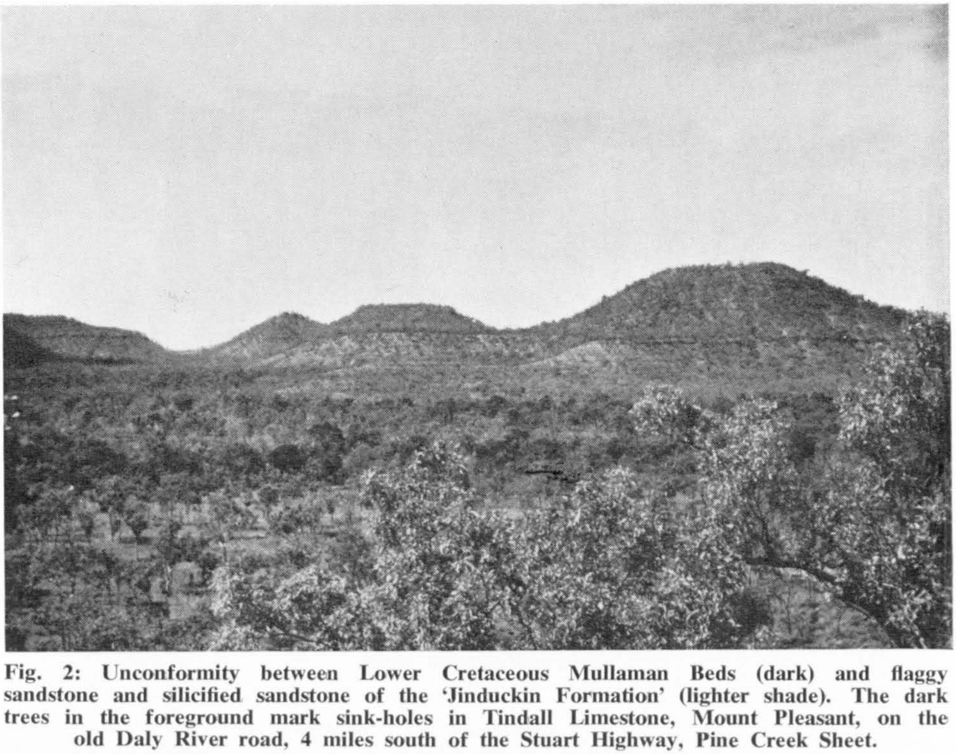

Fig. 2: Unconformity between Lower Cretaceous Mullaman Beds (dark) and flaggy sandstone and silicified sandstone of the 'Jinduckin Formation' (lighter shade). The dark trees in the foreground mark sink-holes in Tindall Limestone, Mount Pleasant, on the old Daly River road, 4 miles south of the Stuart Highway, Pine Creek Sheet.

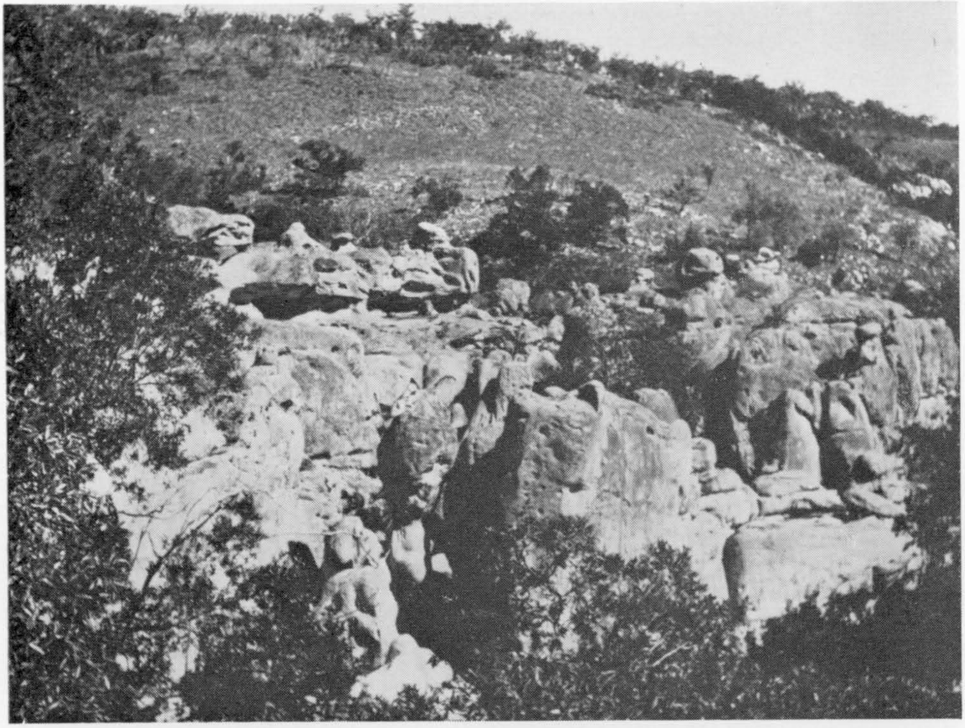

Fig. 1: Friable sandstone at the base of Mullaman Beds, headwaters of South Alligator River, Mount Evelyn Sheet. Sandstone fills a valley in Carpentarian Kombolgie Formation.

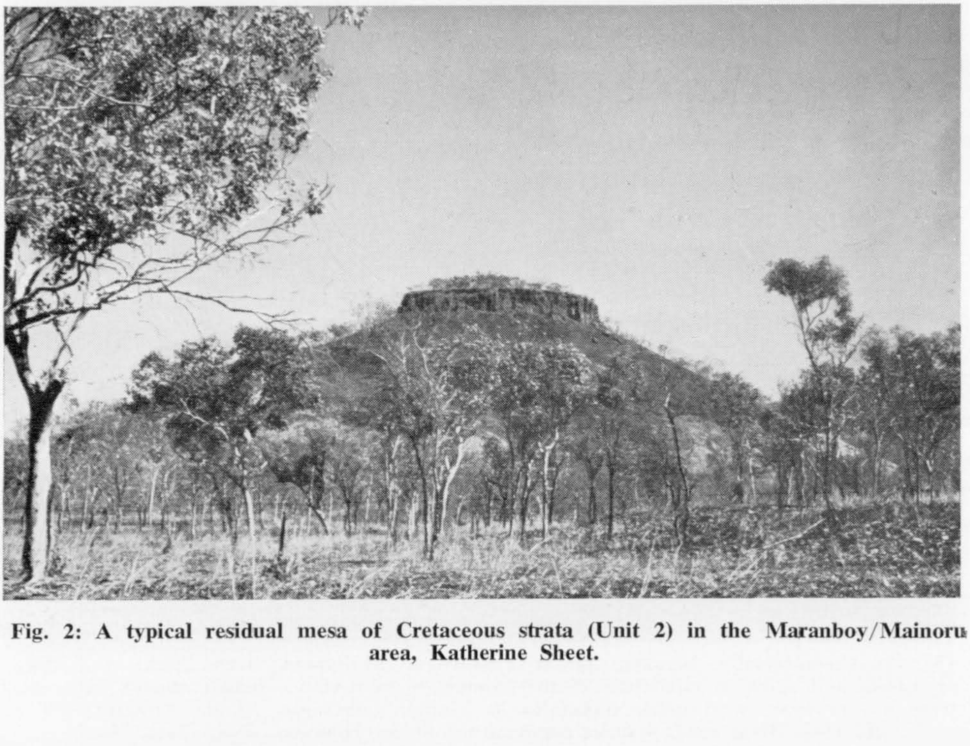

Fig. 2: A typical residual mesa of Cretaceous strata (Unit 2) in the Maranboy/Mainoru area, Katherine Sheet.

PLATE 23.

Fig. 1: Altered fine-grained dolerite consisting of laths of sericitized plagioclase (Pl), aggregates of chlorite (C), and laths of tremolite-actinolite (TA) after pyroxene. The texture is intergranular. Diameter 3.2 mm; ordinary light; T.S. 5616, Mundogie Hill DDH No. 1 on copper prospect, Coirwong Creek area.

Fig. 2: Altered hypersthene-diallage dolerite consisting of subhedral labradorite (L), diallage (D), hypersthene (Hy) partly altered to bastite, and biotite (B). Diameter 3.5 mm; crossed nicols; T.S. 5663, Zamu Creek area.

PLATE 24.

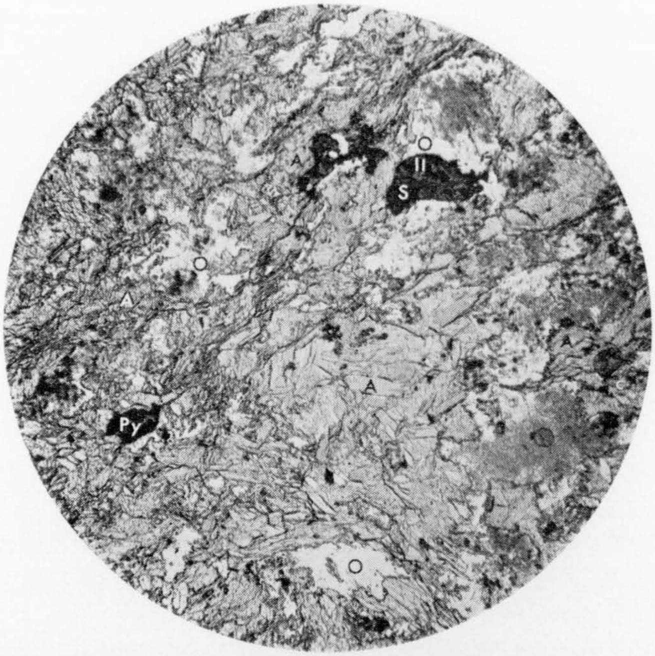

Fig. 1: Oligoclase-actinolite schist, consisting of euhedra and subhedra of actinolite (A) which form large aggregates, pools of metamorphic oligoclase (O), together with sphene (S) surrounding cores of ilmenite (Il) and pyrite (Py). Diameter 4 mm; ordinary light; T.S. 5629, Burrundie area.

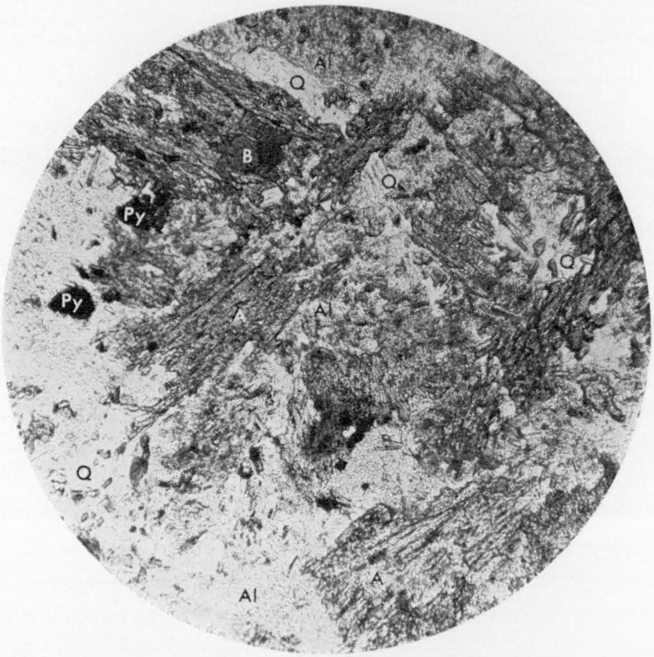

Fig. 2: Albite-actinolite rock consisting of poikiloblastic actinolite (A), albite (Al), quartz (Q), biotite (B), and pyrite (Py). Diameter 2 mm; ordinary light; T.S. 5590, Enterprise Exploration DDH No. 2 (115 feet), Brocks Creek area.

porphyry dyke, and others on a gossanous shear zone at the contact of an amphibolite intrusion; the deepest shaft is reported to have been 60 feet deep.

Other known tin occurrences include the *Snaddens Creek* alluvial tin field and a number of other workings for which no detailed information is available.

Production was about 300 tons of tin concentrate, mostly obtained before 1930; but the records do not generally indicate the production from individual mines, and the total is almost certainly incomplete. Production of about 15 tons of concentrate has also been recorded from the area since 1950.

Among the gold mines, *Spring Hill* was the most important. The main lode worked a ferruginous quartz reef, from 18 inches to 5 feet and in places up to 12 feet wide, which strikes north and dips to the east at about 55°. The country rock consists of well jointed black slate of the Burrell Creek Formation. Several shafts were sunk between 1882 and 1896, the deepest to 345 feet. In 1913, an adit was driven right through the hill without encountering any payable shoots, and in 1934-38 another adit was driven for 980 feet, but was abandoned 200 feet short of its target. The most recent attempt to reopen the mine was in 1951-55, but this was also abandoned as the results were not up to expectations. Total recorded production is 21,170 oz of gold.

About 2 miles south-east of Spring Hill, the *McKinlay* silver mine was worked from 1888 to 1893 by means of at least ten shafts, the deepest to 130 feet, and by an adit 230 feet long. The lode was reported to strike north and dip to the east at about 55°; it had an average width of 3 feet, and contained galena, cerussite, and pyrite. Total recorded production is 15 tons of lead, about 40,000 oz of silver, and 735 tons of silver-lead ore of unspecified grade. Assays of up to 30 percent Pb and 3700 oz Ag per ton were reported.

About 2 miles south-south-east of the McKinlay mine, the *Elizabeth* gold mine was worked between 1891 and 1897. It consisted of five shafts, from 50 to 80 feet deep, sunk on a 3-foot quartz reef which strikes north-north-west and dips 60° east, parallel to the bedding of the surrounding sedimentary rocks, which are locally altered to schist. Total recorded production is 3440 oz of gold.

In the *Flora Belle* mine, about half a mile south of the Elizabeth, a vertical 3-foot lode trending north-north-west contained galena, sphalerite, marcasite, and arsenopyrite in the primary zone. Seven shafts were sunk on the lode, the deepest to 250 feet. Recorded production is 133 tons of silver-lead ore, but this is probably incomplete.

Union Reefs Group of Mines

Parkes (1892); Brown (1895, 1907); Brown & Basedow (1906); Jensen (1915, 1919); Hossfeld (1936b); White et al. (1967)

In the Union Reefs area, two parallel north-north-west lines of lodes have been worked over a total length of about $2\frac{1}{2}$ miles. Most of the work was done between 1873 and 1906, with sporadic activity since.

Total recorded production from this group of mines is about 54,700 oz of gold, but returns from extensive tributing operations were only partly recorded.

The lodes include a large number of quartz reefs, commonly en echelon, in two subparallel north-north-west shear zones (*Union* line and *Lady Alice* line) which are part of a larger structure extending for at least 20 miles from near Pine Creek in the south to Spring Hill in the north. Within the Union Reefs area, individual reefs range up to about 15 feet wide and several hundred feet long. Pyrite and arsenopyrite with minor galena and copper sulphides are present in most of the lodes below the water-table, and some of the lodes also contain relatively abundant calcite, dolomite, and ankerite. The country rock consists of steeply dipping slate and greywacke of the Burrell Creek Formation, partly metamorphosed to low-grade hornfels.

Workings consist of a large number of shafts, open cuts, adits, and costeans, but few penetrate below the water-table, which is generally encountered at about 100 feet. The two deepest shafts, now inaccessible, were the Millars No. 10 (200 feet), and the South Union No. 1 (170 feet).

Two diamond drill holes were put down in 1903-04 to inclined depths of 861 and 1052 feet (531 and 746 feet vertical depths), and assay results of up to 19 dwt Au per ton were obtained, but the widths of the lode intersections were not recorded, and no follow-up work appears to have been done (Brown, 1906).

Four additional holes to inclined depths between 400 and 480 feet (350 to 400 feet vertical depths) were drilled in 1913-14, but no assay results of more than 3 dwt per ton were obtained, although the No. 3 hole recorded a 6-foot lode intersection which assayed 10.2 percent Pb at a vertical depth of about 380 feet (Jensen, 1915).

In 1963-4, the Bureau of Mineral Resources undertook a comprehensive re-examination of the entire field and drilled 13 holes totalling 6200 feet. Results confirm that the lode system extends below the level of the deepest existing workings, but the better values occur in relatively small shoots. One shoot is estimated to contain reserves of 23,000 tons of ore, averaging 21 dwt of gold per ton (White et al., 1967).

To the north of the Union Reefs field, the *Union Extended* mine was worked between 1875 and 1908 by means of a number of shafts up to 120 feet deep, and at least one large open cut. The lodes were generally irregular and discontinuous quartz stringers, commonly only a few inches wide, although there were a few larger reefs up to 15 feet wide. Some very rich concentrations of secondary gold were associated with irregular bands of dolomite, probably representing zones of replacement in the sheared sedimentary rocks. Total recorded production is 3500 oz of gold, including production from the nearby *Isabel* and *Penders Hill* leases, of which no other details are known.

Parkes (1892); Brown (1895, 1908b); Brown & Basedow (1906); Jensen (1915, 1919); Jensen & Oliver (1914); Hossfeld (1936a); Kleeman (1937); Rayner & Nye (1937h); Noakes (1949); Vanderplank (1965, unpubl.)

Pine Creek has been the largest producer of gold in the Katherine-Darwin Region, containing about 15 separate mines, of which the Enterprise, Eleanor, and Elsinore have been the most important. The field has been worked intermittently from the early 1870's, with the bulk of the work between about 1880 and 1914. The recorded production totals about 76,100 oz from 54,000 tons of ore (Hossfeld, 1936a). However, a total of at least 95,000 oz is thought to be a better approximation, although it cannot be apportioned accurately between the various mines.

The field extends over a north-north-westerly belt about 4 miles long and about half a mile wide. All the workings are on quartz reefs in slate and greywacke of the Burrell Creek Formation, in part altered to low-grade spotted hornfels by the nearby Cullen Granite. Pyrite and arsenopyrite are present in all the lodes below the zone of oxidation, and galena and chalcopyrite occur sporadically.

The reefs are of two main types. One group consists of steeply dipping bodies, many of them several hundred feet long, which strike parallel to the enclosing sedimentary rocks. In vertical section, they are commonly parallel to the bedding for part of their depth, although they may cut across the bedding where they cross a fold axis. Where two reefs are present on opposite limbs of a fold, a considerable thickness of quartz may be developed at the intersection near the fold axis, and the resultant formations have been described as saddle reefs. The vertical extent of the reefs is generally small compared to their strike length, and they generally pitch parallel to the nearby fold axes, at 10° to 30° to the south. The best examples of lodes of this type are in the Enterprise and Kohinoor workings.

The other type of lode consists of smaller leaders, from a few inches to about 2 feet wide, dipping to the south-east at an average of about 30°. The leaders are generally grouped one above the other. Such lodes were best developed at the Eleanor mine, where values of over 4 oz Au per ton have been recorded in places.

The most northerly workings are the *Gandys Hill, Maid of Erin,* and *International* mines, which consist of numerous shallow shafts and open cuts on small irregular quartz leaders in hornfels. The sedimentary rocks in this area are more intensely metamorphosed than those in the central and southern parts of the field, and this may account for the absence of the larger and better defined type of reef.

At the *Enterprise* and *North Enterprise* mines, half a mile west of Pine Creek township, a large south-pitching saddle reef and minor parallel reefs have been worked on both limbs of the anticline for a strike length of about half a mile.

The North Enterprise includes part of the old *Monarch, Newcastle,* and *Emperor* leases. Most of the workings are shallow shafts and open cuts, but a 260-foot shaft, the deepest on the field, has been sunk near the southern end of the line of workings, and a 400-foot adit has been driven on the North Enterprise lease. A 280-foot north drive from the shaft and extensive stopes from the adit are on the east limb of the saddle reef, but the reef is substantially intact over a length of 800 feet between the shaft and the adit. In this area, it has an estimated vertical extent of 100 to 150 feet and an average width of 3 to 4 feet.

The shaft was sunk before 1915 to follow up a diamond drill hole intersection of 4 feet of laminated quartz, assaying 4½ oz Au per ton, but in the drive the lode in the immediate vicinity of this intersection assayed only about 12 dwt, and little work was done until 1962, when the shaft was reopened by Messrs R. and M. Blake. A limited amount of driving has since been done, and a trial parcel of about 720 tons of ore has been extracted to investigate the treatment characteristics of the ore. This yielded 120 oz of gold plus about 32 tons of concentrate containing another 190 oz of gold, i.e. an average overall recovery of about 9 dwt per ton.

In 1964, two diamond drill holes were put down by the Mines Branch, N.T. Administration, under an agreement with the leaseholder. One of these, about 600 feet north of the shaft, obtained an intersection of 6 feet of lode material (inclined width), assaying 21 dwt per ton, which confirmed the continuity of the lode between the North Enterprise and Enterprise workings. The other hole, which was designed to intersect the lode about 100 feet down dip from the intersection of the 260-foot level of the main shaft, obtained only scattered low-grade intersections (Vanderplank, 1965, unpubl.).

South of the Enterprise, the gap in the main ridge through which the Stuart Highway passes may represent a transverse fault, since the main line of workings south of the gap appears to be displaced several hundred feet to the east.

South of the gap, on the *Sultana, Ophir, Bashi Bazook, Czarina,* and *Sagabiel* leases, only small irregular groups of leaders appear to have been worked, but records for this group of mines are incomplete. A diamond drill hole put down on the Sagabiel lease in 1913 obtained an intersection assaying 4 oz 11 dwt per ton from 559½ to 560½ feet inclined depth, but this has not been followed up.

At the *Southern Cross, Henry George, Christmas, New Year, New Thunderer, Kohinoor, North Australian,* and *Michaelmas* leases 1 mile south of Pine Creek township, another large saddle reef and associated spurs were worked from a number of open cuts and three adits, the longest being 700 feet. The reef system has a southerly pitch, and extensions of the known shoots might be expected underneath the southern part of the existing Kohinoor workings, but only low values were encountered in two diamond drill holes put down by the Mines Branch, N.T. Administration, in 1965.

Immediately west of the Kohinoor lease, the *Eleanor* mine has been one of the most productive on the field, most of the gold being obtained from a group of relatively narrow, gently dipping leaders. The main shaft has a depth of 180 feet, and other workings include an adit 300 feet long, a large open cut, and several shallower shafts. A diamond drill hole was put down on this lease by the Mines Branch, N.T. Administration, in 1965, but no payable intersections were obtained.

In the most southerly part of the field, comprising the *Democrat, Republic, Chin Phillips, Rack-a-Rock, Rising Sun, Elsinore, Golden Gate, Sydney,* and *North Star* leases, workings are still more widely spaced, and records of past activity are poor. The deepest shaft was the Dashwood Shaft on the Elsinore lease, with a depth of 210 feet; no payable lodes were encountered and no stoping was done. A geophysical survey (Rayner & Nye, 1937h) indicated a number of possible occurrences of non-outcropping quartz reefs which might warrant testing, but no systematic follow-up work has been done.

Other Mines and Prospects

A number of other mines and prospects have been worked at various times in the Pine Creek district.

At the *Caledonia* mine, about 4 miles north-east of Pine Creek, a production of 460 oz of gold is recorded, and at *Lucknow,* 2 miles south of Pine Creek township, 150 tons of silver-lead ore was produced in 1907.

At *Mount Wigley,* 4 miles south of Pine Creek, a north-north-west galena-bearing quartz reef was worked in 1907 from a shaft at least 25 feet deep (Jensen, 1919). The lode is reported to have been 2½ feet wide, and the recorded production is 60 tons of silver-lead ore.

At *Copperfield,* 4 miles south-west of Pine Creek, mining was carried out intermittently between 1872 and 1917, and total recorded production is 2140 tons of ore averaging about 12 percent Cu. The main lode trends north-north-west and dips west at about 60°. It had an average width of 3 to 5 feet, and was worked from at least six shafts, the deepest being 130 feet. Most of the ore was obtained from the oxidized zone (Parkes, 1892; Brown & Basedow, 1906; Jensen, 1919).

Another small copper prospect occurs half a mile west of the railway, 10 miles south of Pine Creek township. Here, a 3-foot north-north-westerly quartz reef with cuprite and malachite occurs at the contact of a quartz-feldspar dyke with the surrounding slate and metagreywacke; it has been exposed in a 10-foot prospecting pit, but no production is recorded (Crohn, 1965d, unpubl.).

The only tin production in this area has come from *Kellys* mine, 3 miles south-east of Pine Creek township, where a series of small cassiterite-bearing ferruginous quartz veins occurs in a north-south zone of sheared slate and sandstone about three-quarters of a mile long (Brown, 1908b). Recorded production is 2 tons of tin concentrate from about 32 tons of ore, mined in 1908 and 1909.

Mount Wells/Mount Harris Area (Fig. 32)

All the tin appears to have been derived from fissure lodes of quartz and cassiterite with varying amounts of sulphides. Near the surface the sulphides are commonly oxidized to limonite and hematite, and the outcrops range from ironstained quartz to highly gossanous material in which it is difficult to identify the cassiterite.

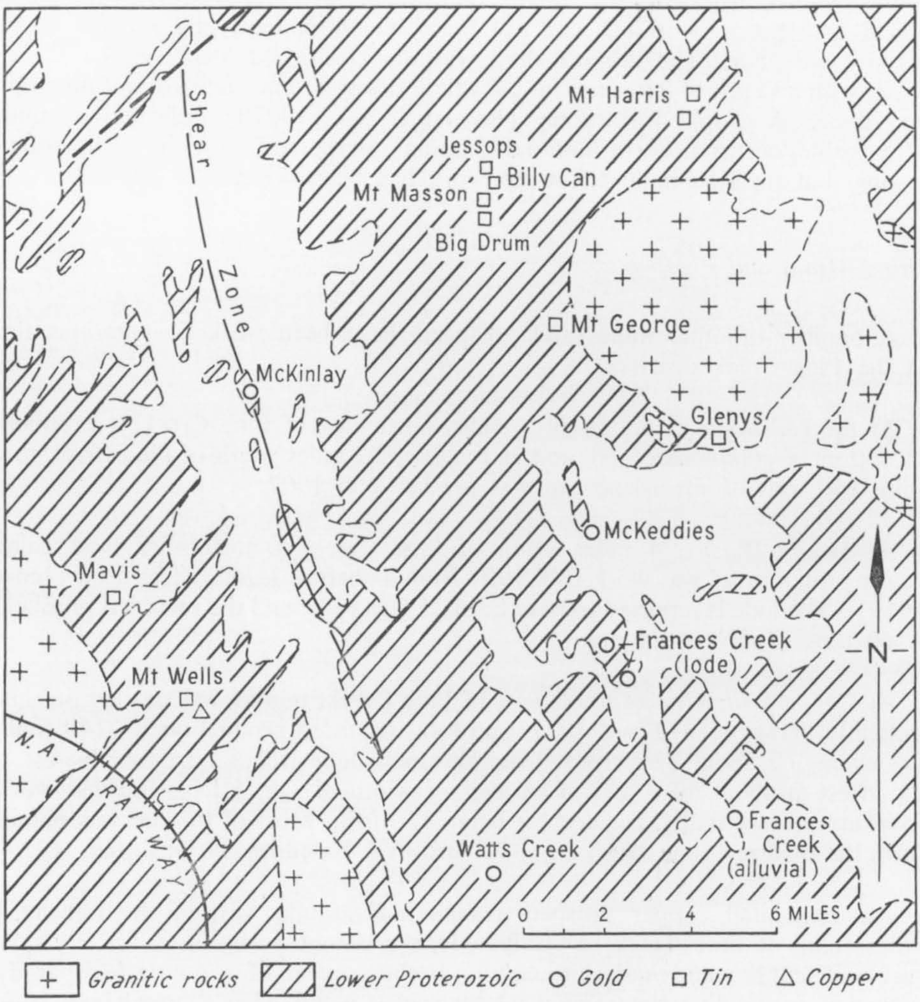

Fig. 32. Mineral deposits, Mount Wells/Mount Harris area

Mount Wells Mine

Parkes (1892); Brown (1895); Brown & Basedow (1906); Jensen, Gray, & Winters (1916); Rayner & Nye (1937); Noakes (1949); Smith (1958, unpubl.)

Mount Wells, 2½ miles north of Burrundie Siding, was the earliest of these mines to be worked, and was also by far the largest producer. The mine was worked intermittently from 1879 to 1929. Three main lodes and numerous minor lodes and groups of stringers crop out on the crest and upper slopes of the hill, which rises to 860 feet above sea level, or about 400 feet above the level of the surrounding valleys. The lodes are generally 1 to 4 feet wide, although stockworks and groups of stringers associated with the main lodes have locally been worked for widths of 20 feet or more. The lodes strike a few degrees east of north and dip east at about 80°. The country rock is micaceous slate and greywacke of the Burrell Creek Formation. Workings consist of numerous open cuts and shafts, the deepest being 160 feet, and of three major and several minor adit levels. At least 3600 feet of cross-cutting and driving was done on the three major adit levels, but most of the workings are no longer accessible. In 1957, The Broken Hill Proprietary Company Ltd drilled three holes, totalling 1540 feet, to test the persistence of the lodes below the existing workings, but no intersections of payable ore were obtained (Smith, 1958, unpubl.).

Recorded production is about 1530 tons of tin concentrate from about 100,000 tons of ore, with an average grade of just under 1 percent Sn. The most recent production was 5 tons of concentrate (from old battery sands) in 1963. The primary ore contained varying amounts of pyrite and chalcopyrite and traces of wolfram and scheelite, but the only recorded production other than tin was 7 tons of 37 percent copper ore in 1917.

A Government Battery for the treatment of ore from various small producers in the area was opened in 1962 at the site of the old Mount Wells plant.

Jessops Lode/Mount Masson Group of Mines

Hays (1958, unpubl.; 1960, unpubl.)

About 15 miles north-north-east of Mount Wells, a group of workings on a north-south fault zone comprises Jessops Lode and the Mount Masson and Big Drum mines. All these mines occur in greywacke and slate of the Masson Formation (Hays, 1960, unpubl.).

Jessops Lode, discovered in 1957, consists of an almost incoherent mass of angular quartz, slate, and iron oxide fragments in a matrix of fine quartz, iron oxide, and cassiterite. The upper part of the lode was probably formed by the collapse of the original sulphide-rich lode after a decrease in volume resulting from oxidation and leaching. The lode trends roughly north, and has been worked by an open cut about 160 feet long and 8 feet wide, and by an adit 60 feet long, which opens off the north end of the open cut. The dip is westerly at about 60° in the open cut, flattening to about 35° in the adit. The *Billy Can* lease covers a southern en echelon extension of Jessops Lode. To June 1965, recorded production of tin (in concentrates) from both leases is about 100 tons from about 10,000 tons of ore.

At *Mount Masson,* mining has been carried out intermittently since 1942, and the total recorded production to June 1965 is 31 tons of tin (in concentrates) from 2870 tons of ore. The main workings consist of an adit 240 feet long, and a water shaft 120 feet deep, on the same line of lode. In the adit, from which all the production has been obtained, the lode ranges from a few inches to about 3 feet thick, and dips almost vertically.

In 1963, a waggon-drilling programme was undertaken by United Uranium N.L. to search for repetitions or extensions of the known lodes at Jessops and Mount Masson mines, but the results were disappointing (Grenning, 1963, unpubl.).

At the *Big Drum,* just south of Mount Masson, an adit 105 feet long has been driven on an ironstained quartz reef from a few inches to about 3 feet wide, but only sparsely disseminated tin has been encountered, and total production is only 0.5 ton of tin concentrates (Crohn, 1963b, unpubl.).

Other Mines and Prospects

The *Mavis* mine, about 5 miles north-west of Mount Wells, was discovered in 1958, and had produced 3.5 tons of tin concentrate to the end of 1962. The lode consists of a cassiterite-bearing quartz reef with minor hematite and limonite, which has been partly exposed in a small adit and several open cuts over a total distance of about 600 feet. It is 6 inches to about 3 feet wide, and includes some extremely rich patches of coarse cassiterite. The reef appears to follow the bedding of the surrounding sedimentary rocks, which consist of Lower Proterozoic slate and greywacke folded into a series of large relatively open folds, plunging to the north at 30° to 40° (Dunn, 1960, unpubl.). This lode appears to offer good prospects of further small to medium-scale production.

At *Mount Harris,* 6 miles east-north-east of Jessops Lode, a group of leases of which the *Nelson, Buffalo,* and *Margaret* are the most important have been worked intermittently since 1956. The country rock consists of slate and greywacke of the Masson Formation. The area contains numerous lodes, ranging from networks of small leaders to reefs several feet thick, most of which appear to fill tension gashes associated with north-trending faults. Some but not all of the lodes are highly ferruginous, and several contain traces of gold as well as tin. To June 1965, recorded production of tin (in concentrates) is about 10 tons from 900 tons of ore, and further investigation of the area appears to be warranted (McQueen, 1956, unpubl.; Hays, 1958, unpubl., 1960, unpubl.).

At *Mount George,* 12 miles north-east of Mount Wells, a group of quartz veins and stockworks has been mined intermittently since 1926 by means of one large and several small open cuts for a total recorded production of 12 tons of tin concentrate. The workings are in contact-metamorphosed slate and greywacke of the Masson Formation within half a mile of the contact of the Cullen Granite.

Five miles south-east of Mount George, the *Glenys* leases, formerly known as *Lucys Diggings,* lie in a comparable position relative to the Cullen Granite. Small quartz-cassiterite stringers have been worked from a series of shallow shafts and small open cuts, but there is no record of production. A recent investigation has shown that this area may also contain some 10,000 cubic yards of eluvial material averaging between 5 and 15 lb of cassiterite per cubic yard (Hays, 1963a, unpubl.), but lack of water in the dry season and difficulty of access in the wet season have prevented systematic exploitation of the deposits, and the recorded production is only 0.2 ton of tin concentrate.

Wolfram Hill/Mount Todd Area (Fig. 33)

The Wolfram Hill/Mount Todd area covers a north-westerly belt, some 30 miles long and 8 to 10 miles wide, which stretches from near Ranford Hill to the Stuart Highway at Edith River. The belt contains a variety of mines, mostly small, from which gold, tin, wolfram, and lead have been obtained. The belt trends generally parallel to the south-eastern margin of the Cullen Granite, and many of the mines in the northern part of the belt are closely associated with the Wolfram Hill Granite. The mineralization is probably related to the intrusions.

Wandie, Crest of the Wave, and Wolfram Hill Mines

Brown & Basedow (1906); Brown (1908b); Jensen (1919); AGGSNA (1938); Kleeman (1938); Thyer, Rayner, & Nye (1938)

The most northerly workings in the Wolfram Hill/Mount Todd area are the mines of the *Wandie* goldfield, which extend over several square miles. Auriferous quartz reefs strike north-north-west and dip vertically or steeply to the west, approximately parallel to the enclosing sedimentary rock, which is mainly fissile slate of the Burrell Creek Formation. The field was worked between 1895 and 1905, and the recorded production is 6380 oz of gold. Numerous shafts are reported to have been sunk to water level, which was generally encountered at about 60 feet, but the bulk of the production appears to have been from alluvial workings.

Two other small mines, known as *Saunders Rush* and the *Brilliant* mine, are situated about 5 miles south-east of Wandie, but no details of their production are available.

The most northerly tin mine of the Wolfram Hill/Mount Todd area is the *Crest of the Wave,* 5 miles south of Wandie; it has been worked intermittently since 1907. The main lode was a quartz-cassiterite reef with minor arsenopyrite, which was worked from several shafts to a maximum depth of 150 feet over a strike length of about 450 feet. The lode strikes north-west and dips south-west at 60°; the strike is parallel to the trend of the enclosing rocks, which are mainly chlorite schist derived from argillites of the Burrell Creek Formation. The average width of the lode was only 8 inches, but the average grade was exceptionally high, and the total recorded production is 143 tons of tin concentrate. Minor parallel lodes are also known. The mine was re-examined in 1963 by United Uranium N.L., but no further work has been carried out.

In the immediate vicinity of the Wolfram Hill Granite, a group of mines has been worked for tin, wolfram, and lead.

Fig. 33. Mineral deposits, Wolfram Hill/Mount Todd area

At *Wolfram Hill* itself, two parallel lines of lode have been intermittently worked since 1900. The lines trend north-west to north-north-west, and dip steeply to the east, subparallel to the bedding of the indurated siltstone of the Burrell Creek Formation, and a prominent joint direction. The best ore occurred in steeply pitching pipes up to 50 feet in length and 10 feet in maximum width, the deepest of which was worked to 130 feet. The ore consists of wolfram and chalcopyrite with minor pyrite and arsenopyrite in a gangue of quartz and black mica. Recorded production is about 630 tons of wolfram concentrate, averaging 70 percent WO_3, and 230 tons of copper ore averaging 30 percent Cu.

At *Irwins* mine, a quarter of a mile west of Wolfram Hill, rich copper ore is reported to have been obtained from a north-westerly lode, from 4 to 10 feet wide, which was worked to a depth of 40 feet. No production figures are available.

At the *Silver Spray* mine, 4 miles east-north-east of Wolfram Hill, a series of quartz lenses with galena and sphalerite occur in a north-north-west zone over a total length of about 2000 feet. Individual shoots range up to 100 feet long and 2 feet wide. The only recorded production is 85 tons of galena, mined between 1905 and 1907. A prospect known as the *Tableland* is recorded about 1 mile north of the Silver Spray, but no details of its production are available.

At the *Last Hope* (or *Harveys*) mine, 2 miles north-west of Wolfram Hill, a number of shallow shafts have been sunk on a group of auriferous quartz reefs, most of which strike east, but the recorded production is only about 30 oz.

On the southern margin of the Wolfram Hill Granite, a series of small mines are collectively referred to as the *Hidden Valley* field; they include the Vulcan, Black Angel, and Bells tin mines, the Mountain View and Black Hill wolfram mines, Wests lead mine, and a group of unnamed lead prospects centred on Crocodile Billabong, 3 miles south-west of Wolfram Hill.

At the *Vulcan, Black Angel,* and *Bells* mines, disseminated cassiterite occurs in breccia zones in slate. Many of the zones dip at relatively low angles, and shoots of payable ore are small. Workings consist of open cuts, adits, and shafts, the deepest being about 60 feet; the total recorded production since 1905 is about 50 tons of tin concentrate.

At the *Mountain View* mine, wolfram has been won from a group of pegmatite veins which strike north-west to north-north-west and dip at about 30° to the north-east. Most of the veins ranged from an inch to about 6 inches in thickness, and were worked from short adits and underhand stopes. No separate production figures are available, and the production has been included with the figures for Wolfram Hill.

Small wolfram-bearing quartz veins are also known from *Black Hill,* 4½ miles south-west of Wolfram Hill, but production appears to have been negligible.

The only recorded production of silver-lead ore from this area is from *Wests* mine, 1½ miles west of Hidden Valley, where 25 tons of ore averaging 70 percent Pb and 34 oz Ag per ton was mined. In 1958, the Australian Mining and Smelting Company investigated this mine and a number of nearby prospects, but with generally disappointing results. The most encouraging indications were obtained at a prospect three-quarters of a mile south-west of *Crocodile Billabong,* where costeaning revealed a 33-foot zone of cerussite veinlets in siltstone; but four diamond drill holes failed to intersect payable ore at depth (Patterson, 1958a, unpubl.).

A number of small tin mines are also known within the Wolfram Hill Granite. At two of these, *Connells* and *Martins* claims, disseminated cassiterite occurred within the granite itself; at *Kellys* claim cassiterite and minor wolfram occurred in a lode containing quartz, iron oxides, and argillaceous material. No records of production are available, but the amount cannot have been large.

Emerald Creek and Driffield Mines

Brown (1895, 1908b); Brown & Basedow (1906); AGGSNA (1938); Hossfeld (1941); Rattigan & Clark (1955, unpubl.)

The *Emerald Creek* tin field, about 8 miles south-west of Wolfram Hill, consists of a group of small lodes, most of which are quartz reefs with cassiterite, iron oxides, and secondary lead minerals at the surface. The deepest workings are reported to be about 70 feet deep. Little work has been done below the water-table, and appreciable amounts of sulphides could be expected in the primary ore.

Recorded production between 1908 and 1913 is about 42 tons of tin concentrate, the greater part of which was probably from alluvial deposits. Only sporadic gouging has been undertaken since then.

The *Driffield* gold field, about 2 miles south-east of Emerald Creek, was one of the earliest fields in this belt to be worked. Between 1882 and 1912, *Creers, Lady Jane, Lady Mary, Gordon,* and *Parrys* mines were operated from numerous shafts and open cuts, the deepest to about 100 feet. The lodes consisted of quartz with minor iron oxides, and showed considerable variation in strike and dip. Many of the payable shoots were small and very irregular, which made systematic development almost impossible. The country rock consists of extensively faulted slate of the Burrell Creek Formation (Hossfeld, 1941). The total recorded production is about 5300 oz of gold from 10,700 tons of ore, but this is known to be incomplete.

Horseshoe Creek and Mount Todd Mines

Brown & Basedow (1906); Brown (1908b); Jensen (1919); AGGSNA (1937, 1938, 1939); Cottle (1937a); Hossfeld & Nye (1941); Rayner & Nye (1937a); Rattigan & Clark (1955, unpubl.)

Between Driffield Creek and the Edith River, some 8 miles to the south, another group of small tin and gold mines make up the Horseshoe Creek and Mount Todd fields. Most of the mines were discovered and worked between 1902 and 1914, with only sporadic small-scale activity in more recent years (Cottle, 1937a; Hossfeld & Nye, 1941).

The Horseshoe Creek field includes the *Scotchman, Boylings, Doris, Ethel, Marie,* and *Keenans* mines, in all of which cassiterite-bearing quartz-kaolin lodes with minor copper minerals were worked. The lodes generally occupy shear zones which trend north to north-west, subparallel to the strike of the surrounding slate and greywacke of the Burrell Creek Formation. Most of the lodes are irregular lenticular bodies, partly en echelon, with variable dips. The length of payable shoots ranged from 20 to 200 feet, and the width from a few inches to about 4 feet. All the payable shoots above the water-table appear to have been worked out, the deepest workings being about 150 feet. Recorded production is about 650 tons of tin concentrate, including some production from alluvial deposits.

In the Mount Todd field, both tin and gold have been produced. The main tin producers were the *Morris* and *Shamrock* mines, which resemble the Horseshoe Creek mines in the attitude and size of ore shoots and the type of lodes. Total recorded production is 180 tons of tin concentrate, including some from alluvial deposits. About 5 tons of the total amount have been won since 1958.

Among the gold mines of this area, the *Jones Brothers Reef* appears to have been the most extensively worked, and has a recorded production of 915 oz. It is a ferruginous quartz reef, which has been traced on the surface for about 2000 feet, striking a few degrees east of north and dipping steeply to the east. The country rock consists of tightly folded greywacke and slate of the Burrell Creek Formation. The width of the reef ranges from about 1 to 3 feet, with average values of about 16 dwt per ton in two shoots, totalling about 1200 feet in length. It has been worked from five shafts, the deepest to 150 feet, and from a number of open cuts. In 1938-39, five diamond drill holes were put down by Mount Todd Gold Mines N.L. to test the downward extension of the reef, but the results were disappointing. Below water level, the lode contains pyrite, arsenopyrite, and minor chalcopyrite and galena.

Tollis Reef, 1 mile south of Jones Brothers, has been worked on a small scale from a shaft 35 feet deep, but no details of production are recorded. The reef strikes north-west, and has been traced on the surface for 4000 feet with a width of 1 to 4 feet. Samples taken from the shaft in 1937 gave an average of 14 dwt Au per ton over a width of about 2 feet, and surface samples gave an average of 4.5 dwt (Cottle, 1937a).

Quigleys Reef (or New Mount Todd), 1½ miles north-east of Jones Brothers, has also been traced over a length of 3000 feet, and has a maximum width of 7 feet. It has been opened up by means of a 110-foot adit, numerous small open cuts, and several shafts, the deepest to 80 feet. Four samples taken in 1941 gave an average grade of 13 dwt Au per ton over a width of 20 inches in the adit, and surface samples averaged 8.7 dwt, but no production is recorded (Hossfeld & Nye, 1941).

Yenberrie Mines

Gray & Winters (1916); Jensen (1919); AGGSNA (1938); Rattigan & Clark (1955, unpubl.)

The Yenberrie wolfram field is situated about 2 miles west of Mount Todd. The lodes consist of greisenized quartz-aplite dykes and are confined to a stock of the Cullen Granite, about half a square mile in area, which is intruded into greywacke and slate of the Burrell Creek Formation. Within the granite, nine quartz-aplite dykes are known, of which the largest is over 1000 feet long and about 60 feet wide. The dykes strike consistently north-north-west and dip steeply to the west. Within the dykes, wolfram and minor molybdenite occur in quartz reefs, which commonly strike parallel to the trend of the dykes, and also as small disseminations, especially on joint planes and in small seams rich in mica.

Recorded production is about 160 tons of wolfram, 2½ cwt of molybdenite and a small quantity of bismuth. Most of the ore has been obtained from the quartz reefs, which average about 1 foot thick, and occasionally attain 2 or 3 feet. The reefs were worked from numerous shallow shafts and small open cuts, but none of the workings extends below water level, which mostly lies at a depth of 30 to 40 feet. Below this level, minor pyrite, arsenopyrite, copper sulphides, and bismuth minerals accompanied the wolfram and molybdenite. The grade of the disseminated occurrences does not appear to have been systematically investigated, and some further testing may be warranted (Gray & Winters, 1916).

Woolngi Mines

Jensen (1919); Rattigan & Clark (1955, unpubl.)

The Woolngi gold field, at the southern extremity of the area, occupies an isolated position in a deep re-entrant within the Cullen Granite, about 20 miles south-east of Pine Creek. The field was worked mainly between 1896 and 1908, with only sporadic small-scale activity in more recent years. The main lode worked was a quartz reef which trends east for part of its course, but swings to the north-north-west in the west. It has been worked from several shafts, at least one of which reached a depth of 90 feet, and from two adits, 160 feet and 90 feet long. The average width of the reef is reported to have been 3 feet, and recorded production, which is known to be incomplete, is about 4600 oz of gold.

West Arm/Mount Finniss/Fletchers Gully Area

The West Arm/Mount Finniss/Fletchers Gully area comprises a belt of country nearly 120 miles long and up to 10 miles wide, and contains a large number of tin and tantalite-bearing greisens and pegmatites, generally intruded into greywacke and slate of the Lower Proterozoic Noltenius and Burrell Creek Formations.

At least 90 separate mines and prospects are known in this belt, most of them in the northern section between West Arm and Bamboo Creek. The recorded production from individual mines is generally small.

West Arm/Mount Finniss/Bamboo Creek Group of Mines (Fig. 34)

Parkes (1892); Brown & Basedow (1906); Brown (1908b); Playford (1904); Noakes (1949); Summers (1957b, unpubl.)

The West Arm/Bamboo Creek portion of the belt trends north and extends over an area about 40 miles long and 6 miles wide. It consists mostly of gently undulating to moderately steep hills, rising about 200 feet above the surrounding alluvial flats. Tin was discovered in 1886, and total recorded production to 1957 (probably incomplete) is 585 tons of tin concentrate and 15 tons of tantalum concentrate (Summers, 1957b, unpubl.).

The pegmatites are generally small, and range up to some hundreds of feet long and tens of feet wide; they are elongated north or north-north-east, parallel to the dominant direction of shearing, and the regional trend of the fold axes in the surrounding sedimentary rocks. Many of the pegmatites are zoned, and in most of them the feldspars are kaolinized and chlorite is developed. Some of the eluvial deposits on the flanks of the hills have been worked on a small scale, but no true alluvial deposits of economic grade have been proved in the area, in spite of several extensive investigations by Australian and overseas companies.

The *Hang Gong Wheel of Fortune* is situated 1 mile north of Observation Hill, 71 miles by road from Darwin, and has a total recorded production of 189 tons of tin concentrate, mostly produced in 1904 and 1905. It was reopened in 1956, and the eluvial deposits have since been worked by Mr W. Farlow for a recorded production of 1.1 tons of concentrates.

Workings consist of one large open cut, 100 by 20 feet, and two smaller open cuts, all partly caved. There are also three shafts, to 15 feet deep, and numerous shallow pits and costeans. It appears that all the near-surface mineralized shoots within the pegmatite have been worked out, but substantial amounts of eluvial material, containing both tin and tantalite, still remain (Crohn, 1963a, unpubl.).

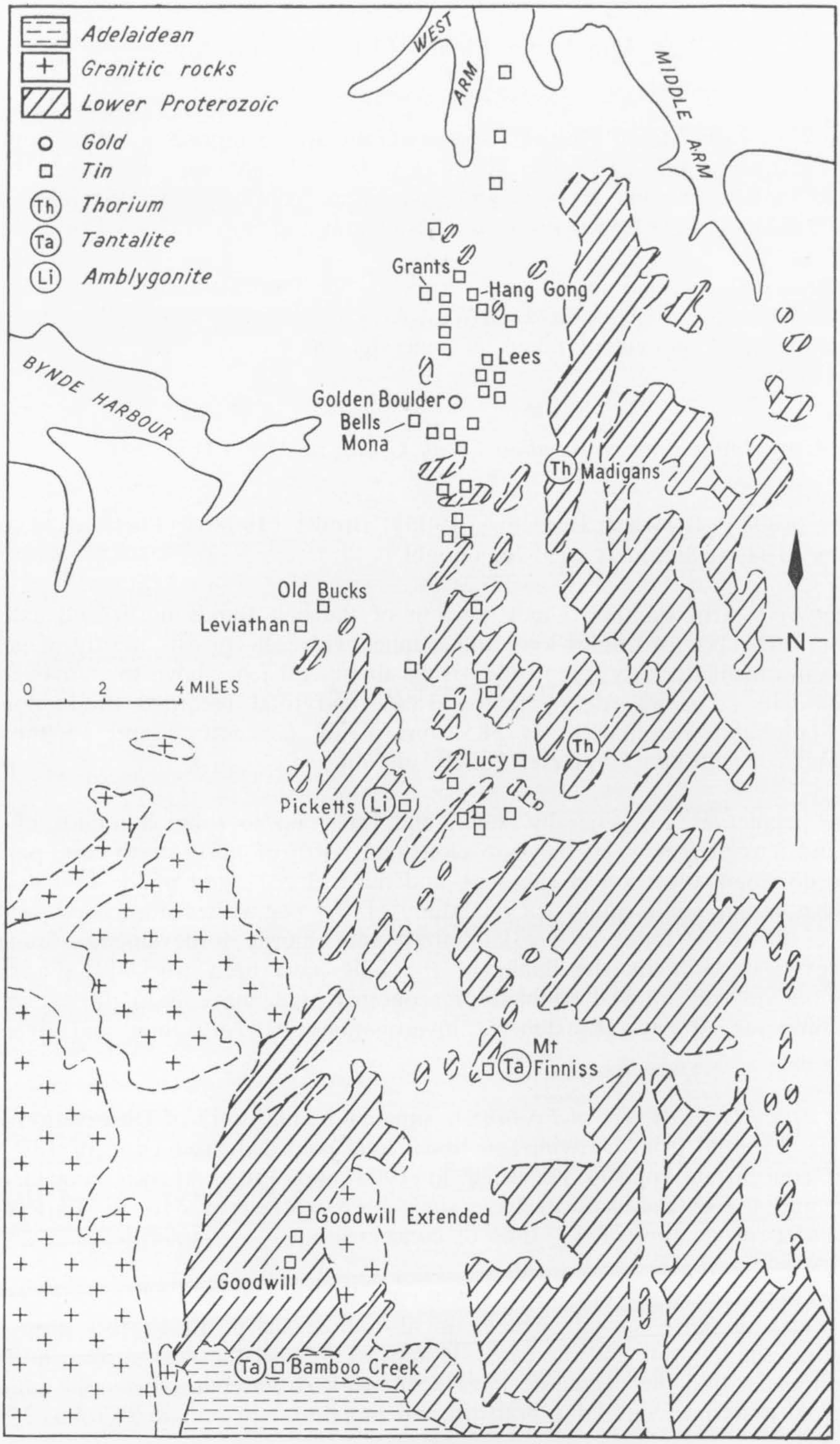

Fig. 34. Mineral deposits, West Arm area

Bells Mona mine is 3 miles south-west of Observation Hill, and has a total recorded production (probably incomplete) of 13.5 tons of tin concentrate. The main workings consist of two open cuts 280 by 70 feet, 10 feet deep, and 90 by 50 feet, 8 feet deep. There are also five shafts, of which two were reported in 1908 to be 42 and 62 feet deep. Some stoping was carried out from the 62-foot level, but two diamond drill holes, 405 and 126 feet long, put down in 1910, encountered only traces of tin (Summers, 1957b, unpubi.).

The *Leviathan* mine is on the east bank of Leviathan Creek, 9 miles south-south-west of Observation Hill, and has a total recorded production of 170 tons of tin concentrate, all of which was obtained before 1909. Workings consist of two open cuts, 150 by 20 feet, 20 feet deep, and 120 by 30 feet, 10 feet deep. Parkes (1892) reported that three shafts were being worked, but these can no longer be identified. The pegmatites were reported to be up to 15 feet wide and zoned, with most of the mineralization concentrated in the marginal quartz-mica zones. This mine now appears to be worked out (Summers, 1957b, unpubl.).

The *Mount Finniss* mine, 17 miles south-south-west of Darwin River Siding, and 1½ miles from the Finniss River, has a total recorded production of 19 tons of tin concentrate and 12 tons of tantalum concentrate. The workings consist of two 40-foot shafts, five small open cuts, and numerous shallow pits and costeans. The pegmatite has overall dimensions of 600 by 250 feet, and is strongly zoned, with a core of massive milky quartz, surrounded by zones of kaolinized feldspar, quartz-feldspar-mica, and quartz-mica. Cassiterite and tantalite are scattered throughout the pegmatite, with a slight concentration in the kaolinized feldspar zone. A survey of the associated eluvial deposits in 1944 indicated reserves of about 50,000 cubic yards containing 0.84 lb of tantalite per yard with subordinate tin. Two diamond drill holes put down in 1956 showed that the pegmatite bottoms at shallow depth (Hughes, 1944, unpubl.; Summers, 1957b, unpubl.).

The *Goodwill* mine, 15 miles due west of Rum Jungle Siding, has a recorded production (probably incomplete) of 7.6 tons of tin concentrate, mostly obtained between 1936 and 1950. The workings consist of an open cut, 190 feet long, 50 feet wide, and up to 35 feet deep; only minor remnants of pegmatite are now left in the walls of the open cut(Summers,1957b, unpubl.).

The *Goodwill Extended* mine lies 2 miles north of the Goodwill mine, on the east bank of Walkers Creek. No production records are available, but the mine is known to have been worked in 1956. Workings consist of four shafts, the deepest being 48 feet, and several open cuts. At least five small irregular pegmatites are present, most of them showing pronounced zoning. The mineralization is generally scattered throughout the pegmatites, with some local concentrations in the quartz-mica wall zones. Some further exploration may be warranted (Summers, 1957b, unpubl.).

The *Bamboo Creek* mine, 19 miles due west of Rum Jungle Siding, and 1½ miles south of the junction of Bamboo and Walkers Creeks, has a total recorded production of 46 tons of tin concentrate and 5 cwt of tantalite concentrate. Workings consist of three open cuts and an adit 250 feet long. All shoots above the adit level have been worked out, and some underhand stoping has also been done. The pegmatite is a lenticular body, about 250 by 60 feet in horizontal extent, which pitches steeply. The ore minerals appear to have been restricted to the footwall side of the pegmatite body, and a limited amount of further exploration may be warranted in search of downward extensions or repetitions of the known shoots (Reid, 1953, unpubl.; Owen, 1954b, unpubl.; Summers, 1957b, unpubl.).

Considerable shallow testing has been undertaken at *Grants* mine, 1½ miles north-west of Observation Hill; at *Lees* mine, three-quarters of a mile south of Observation Hill; at the *Old Bucks* mine, 8 miles south-west of Observation Hill; and at the *Lucy* mine, on the east bank of the Annie River, 10 miles west of Darwin River Siding. However, little or no production is recorded from these prospects, and no further work is thought to be warranted (Summers, 1957b, unpubl.).

Only one mine in this area has recorded a significant gold production. This is the *Golden Boulder,* 2 miles south-south-west of Observation Hill, which is reported to have produced 620 oz of gold.

Picketts mine, 3½ miles west-south-west of the Lucy mine, has attracted recent attention because of the occurrence of amblygonite, but attempts to reopen the mine have not been successful.

Two radioactive prospects occur in the Charlotte River area, one 12 miles north-west and the other 9 miles west of Darwin River Siding. The more northerly, known as *Madigans,* consists of thorium minerals in fracture zones of ferruginous sandstone, and has been tested by two diamond drill holes, totalling 290 feet, but economic development is not feasible (Hyde, 1956, unpubl.).

Mount Tolmer/Fletchers Gully/Buldiva Group of Mines

Parkes (1892); Brown (1895); Hossfeld (1937b, c); Noakes (1949)

South of the Tabletop Range (Tolmer Plateau) tin has been worked at *Mount Tolmer* (also known as Blyth), 25 miles due west of Adelaide River township. Most of the production came from a group of greisens or altered pegmatite dykes up to 30 feet wide. The dykes strike roughly north, and are intruded into greywacke and slate of the Noltenius Formation. Minor eluvial and alluvial deposits were also worked. Workings in 1889 were reported to include two shafts, 60 feet and 32 feet deep, and some shallow pits and open cuts, but the area was abandoned in 1894. Since then, the area has been worked on a small scale on several occasions, and total recorded production is 75 tons of tin concentrate, of which at least 45 tons were won before 1891.

A mica occurrence is recorded near *Prospect Hill,* about 8 miles south of Mount Tolmer. It is apparently associated with a pegmatite similar to those in other parts of this tin belt, but no production is recorded.

Another small group of workings occurs at *Fletchers Gully,* 25 miles south of Daly River police station; gold has been the main mineral won. Alluvial gold was discovered in 1905, and both lode and alluvial deposits were worked intermittently until 1940. According to Hossfeld (1937b), the auriferous lodes consisted of quartz veins in shale of the Noltenius Formation, close to the axis of an anticline trending north-west. Some of the veins were associated with subvertical shears; others occupied tension gashes dipping at low angles to the north-east or south-west. Veins were mostly only a few inches wide; the largest were 2 to 3 feet. The most consistent vein was Bigmouths Reef, with an average width of 3 inches, which was worked over a length of 200 feet and to a depth of 100 feet.

Tin was worked in a number of small pegmatite dykes in the same vicinity.

Total recorded production is 2450 oz of gold and 4.2 tons of tin concentrate.

The Muldiva and Buldiva tin fields, 10 miles south-east of Fletchers Gully, and the Collia tin field, another 12 miles to the south-south-east, are closely associated with the Soldiers Creek Granite, but still lie within the general meridional belt under discussion.

At *Buldiva,* tin has been won from numerous small pegmatite lenses intruded into the Soldiers Creek Granite and the nearby Noltenius Formation, from a basal conglomerate in the overlying Cretaceous Mullaman Formation, and from recent eluvial and alluvial deposits.

The pegmatites are concentrated in a zone embracing the margin of the Soldiers Creek Granite and the adjoining country rock, and are mostly low grade. Thirteen samples taken in 1937 over average widths of 30 inches averaged 0.63 percent Sn, with only 4 samples in excess of 1 percent (Hossfeld, 1937c). The payable pockets in the basal conglomerate of the Mullaman Formation are small (average thickness 12 inches) and irregularly distributed. The bulk of the production has come from the eluvial and alluvial deposits, and some further prospecting for additional deposits of this type appears to be warranted.

At *Muldiva,* some production has come from quartz-mica-tourmaline-cassiterite lodes intruded into schist and granulite. The largest lode ranged from 1 to 2 feet wide, and has been traced for about 150 feet, but the bulk of the production was from alluvial deposits.

At *Collia,* alluvial tin was discovered in 1922, and the field has been worked intermittently since then. Most of the production has come from shallow pockets in small watercourses, and additional deposits of this type, and of eluvial material, may still remain to be discovered. Quartz-tourmaline veins are abundant in the

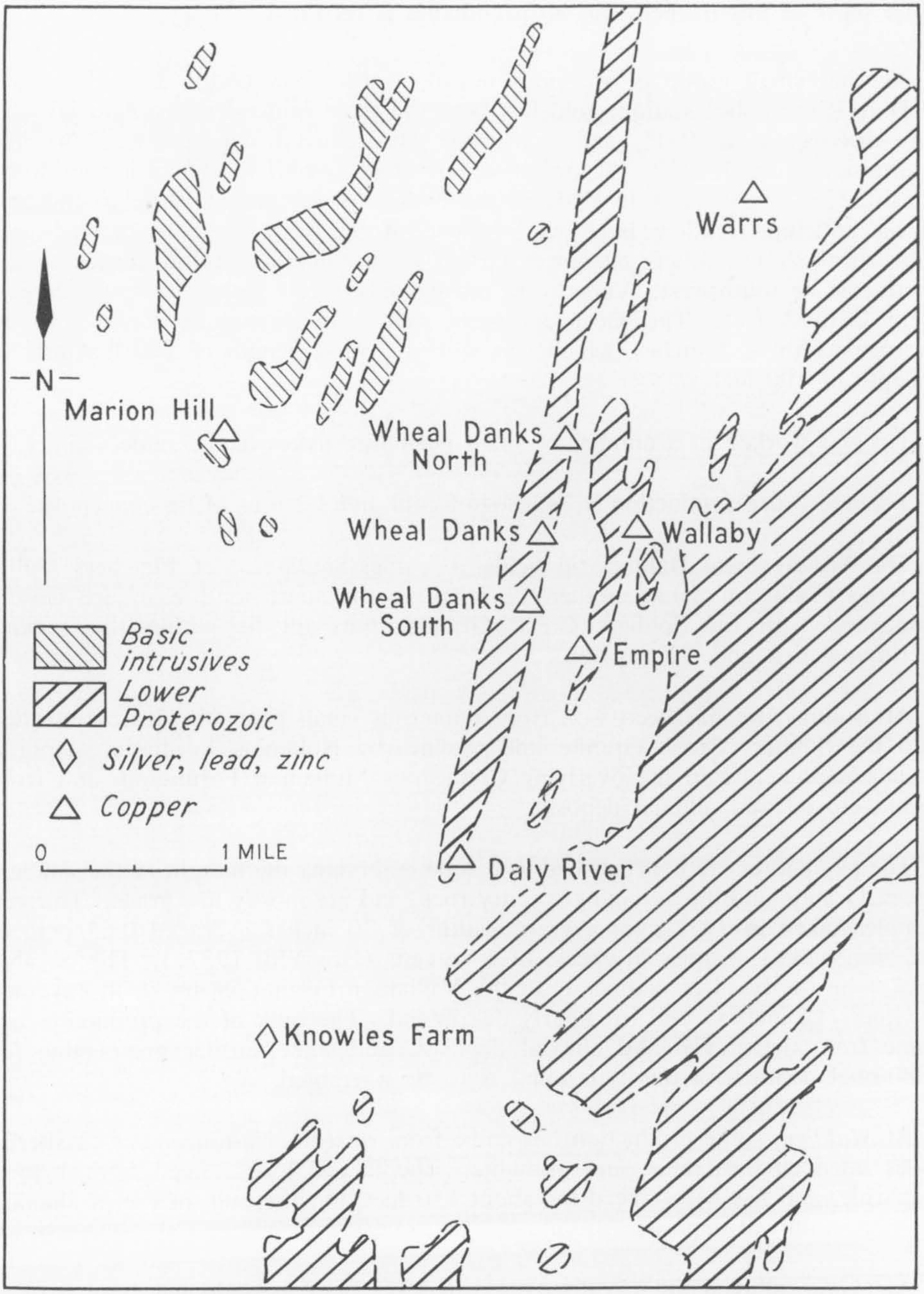

Fig. 35. Mineral deposits, Daly River area

Soldiers Creek Granite in this vicinity, but no tin-bearing lodes, which could have provided the source of the alluvial deposits, have been found.

Total recorded production from Buldiva, Muldiva, and Collia is 45 tons of tin concentrate.

Daly River Area (Fig. 35)

Parkes (1892); Brown (1895, 1908b); Brown & Basedow (1906); Hossfeld (1937d, 1938); Noakes (1949)

The Daly River area includes a group of copper and silver-lead deposits, most of which are situated on two subparallel shear zones; the shear zones trend a few degrees east of north, and each can be traced for about 5 miles.

The largest producer has been the *Daly River* copper mine, near the southern end of the western shear zone, about 8 miles north of the Daly River police station. The mine was worked intermittently from 1884 to 1918; the workings consist of a large open cut, some 250 feet long, about 30 feet wide, and up to 100 feet deep, and five shafts up to 120 feet deep. In the open cut, nearly all the lode material has been removed; it is reported to have consisted largely of malachite, azurite, and chalcocite, with quartz and limonite gangue, and to have occurred as bunches and stringers in a shear zone in slate of the Burrell Creek Formation. Sulphides, including minor amounts of chalcopyrite, are visible in the waste rock from several of the shafts, but it appears that little ore was extracted from any of the shafts, and a diamond drill hole put down by Zinc Corporation Ltd failed to intersect any significant ore occurrences under the open cut.

Recorded production is about 6000 tons of ore, averaging 20 percent Cu, practically all of which was obtained from the oxidized zone. No zone of secondary enrichment has been recorded, and the primary ore, consisting largely of disseminated chalcopyrite, was apparently too low-grade for economic extraction (Hossfeld, 1937d). However, some further testing of the lodes near the existing shafts may be warranted, especially in view of the possibility that the ore shoot in the open cut may have a shallow pitch and may therefore have been missed by the Zinc Corporation drill hole.

To the north of the Daly River mine, the main workings on the western shear are the *Wheal Danks* group of mines, which were worked intermittently from 1887 to 1904.

At Wheal Danks South, three shafts up to 35 feet deep were sunk on a cellular ironstone gossan with quartz and malachite. At Wheal Danks itself, workings consist of two shafts 95 feet deep, a 200-foot tunnel, and a winze 125 feet deep from the tunnel. At Wheal Danks North, the main workings are two open cuts.

At both localities, assays of lode and dump material average about 2 to 4 percent Cu and 1 to 3 dwt Au per ton(Hossfeld, 1937d), but recorded production is about 500 tons of ore averaging 28 percent Cu, which probably represented hand-picked material.

On the eastern shear zone, the most southerly workings are at the *Empire* mine, where two shafts were sunk to depths of 20 feet and 40 feet. A north-trending shear zone with copper staining over a width of up to 4 feet can be traced for 150 feet on the surface. In the shafts, chalcopyrite and arsenopyrite are recorded. Recorded production is 5 tons of high-grade ore (probably over 25 percent Cu) and 138 tons of low-grade ore (probably less than 10 percent Cu).

About 1 mile north of the Empire mine, the *Wallaby* mine has workings on both copper and silver-lead lodes. The copper lode has a shaft 40 feet deep, from which 30 tons of ore, averaging 35 percent Cu, have been produced, but the remaining portions of the lode are reported to be of very low grade (less than 1 percent Cu).

The silver-lead lodes have been opened up by two shafts, the deeper to 35 feet, and by several costeans. The lodes consist of a number of small quartz reefs in a zone 300 feet long and about 20 feet wide, and contain cerussite, anglesite, mimetite, and pyromorphite. Assays range up to 5 percent Pb, 2 dwt Au, and 4 oz Ag per ton, but no production has been recorded (Hossfeld, 1937d, 1938).

At *Warrs* mine, another 2 miles to the north, a group of copper-stained quartz reefs and shear zones in slate has been exposed in shallow shafts and prospecting pits over a total strike length of about 500 feet, but no production is recorded.

Two isolated occurrences of silver-lead minerals are also known from the *Knowles Farm* prospect, 2 miles south-west of the Daly River copper mine. No production is recorded, but several costeans have been dug, and selected samples of gossan are reported to have given high silver and lead assays, with minor copper and gold (Hossfeld, 1937d).

A copper prospect is also known in an extensive area of dolerite in the *Marion Hill* area, 3 miles north-west of the Daly River copper mine, but no production is recorded.

Altogether, although the recorded production from the belt is small, some further prospecting of the two main shear zones by geophysical surveys and diamond drilling may be warranted.

Maranboy Mines (Fig. 36)

Gray & Jensen (1915); Thyer, Rayner, & Nye (1937, unpubl.); Lewis (1937, unpubl.); Noakes (1949); Iten (1950, unpubl.); Walpole (1952, unpubl., 1958a); Mackay (1960, unpubl.)

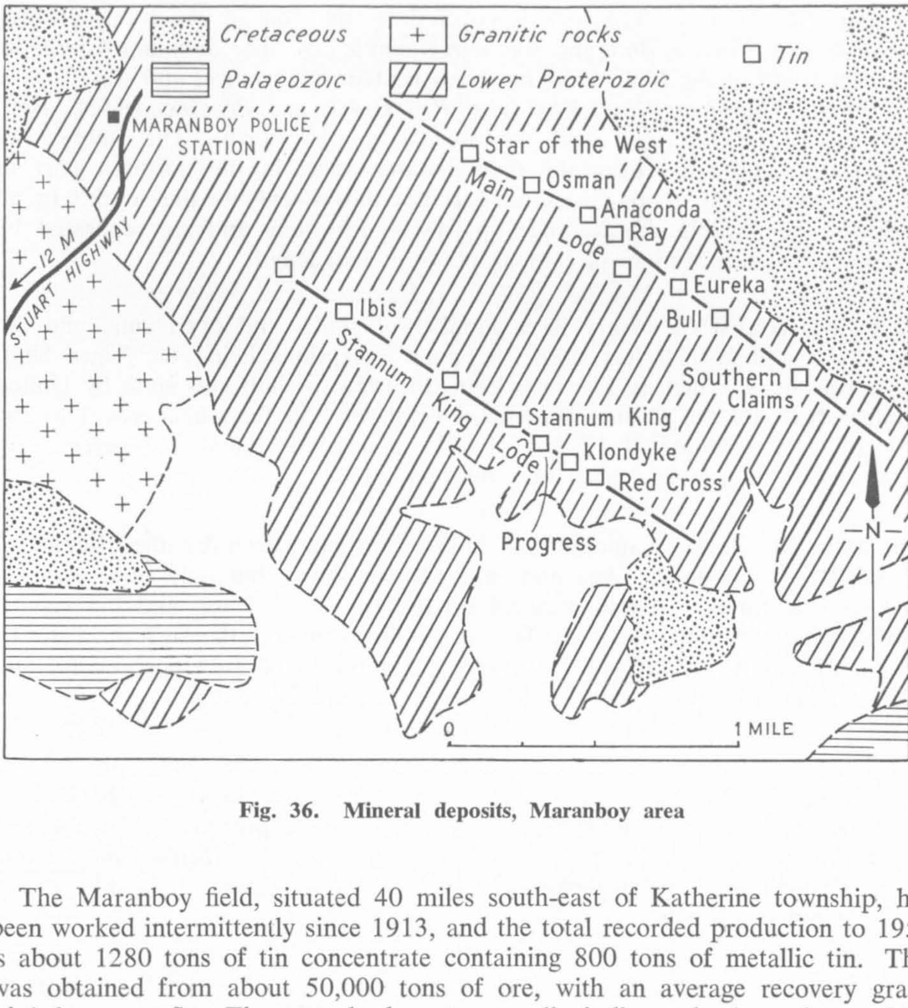

Fig. 36. Mineral deposits, Maranboy area

The Maranboy field, situated 40 miles south-east of Katherine township, has been worked intermittently since 1913, and the total recorded production to 1952 is about 1280 tons of tin concentrate containing 800 tons of metallic tin. This was obtained from about 50,000 tons of ore, with an average recovery grade of 1.6 percent Sn. The records do not generally indicate the lease from which individual crushings were obtained. Only about 3 tons of tin concentrate have been produced since 1952.

The main source of production has been from stanniferous quartz-tourmaline lodes trending east-south-east or south-south-east, the east-south-easterly set being the more important of the two. The cassiterite occurs in places as finely disseminated crystals, but more commonly as groups of small stringers in joints and brecciated zones. Minor production has also been obtained from greisens, especially in the northern part of the field. The country rock consists of greywacke, siltstone, and shale of the Burrell Creek Formation, which has been folded into a major south-east-pitching anticline with minor tight crenulations in the axial zone.

The *Main* lode, with a total length of 13,000 feet, has been the most important producer, especially in its central 4000-foot zone, which has an average width of about 8 to 25 feet. The lode is covered by the *Star of the West, Osman, Anaconda, Ray, Eureka, Bull,* and *Southern Claim* leases. The *Stannum King* lode, 3500 feet south of the Main lode, has been next in importance, and was worked from the *Ibis, Stannum King, Klondyke, Red Cross,* and *Progress* leases. Both lodes strike east-south-east and dip steeply to the north. The only other important producer has been the *Cosmopolitan* lode, in the northern part of the field, which also trends east-south-east but dips steeply to the south. In all the lodes, the payable shoots range up to 400 feet long and are separated by barren or low-grade sections of comparable or greater length.

Workings consist of a very large number of shafts and open cuts, and are generally less than 120 feet deep, the main exceptions being the Tiger Shaft on the Ray lease, which is 140 feet deep. In 1958, a shaft was sunk by United Uranium N.L. on the Osman lease to a depth of 250 feet; a cross-cut at the 125-foot level encountered 17 feet of lode material averaging 1.7 percent Sn, but results on the 250-foot level were disappointing.

In 1958-59, eleven diamond drill holes were put down by the Bureau of Mineral Resources on the Anaconda and Osman leases, but only three encountered payable tin ore. These were all on the Anaconda lease, and the results, from vertical depths between 350 feet and 600 feet below the surface, were 12 feet 6 inches (true width) of 1.51 percent Sn, 6 feet of 1.47 percent Sn, and 7 feet 3 inches of 1.56 percent Sn(Mackay, 1960, unpubl.).

Walpole (1958a) estimated that 170,000 tons of ore, averaging 1.06 percent Sn, remained in the lodes to the level of the deepest workings in each block; a smaller tonnage of somewhat higher average grade could presumably be obtained by selective mining. At the time of writing (June 1966), a further programme of deep test-drilling is being undertaken by Metals Exploration N.L. and a group of associated companies.

The *King River* mine is about 10 miles north-west of Maranboy. Gray & Jensen (1915) report some activity in this area in 1913, but Walpole (1958a) reports most production taking place after 1929. The lode is in a quartz-tourmaline vein striking north-west and dipping steeply to the south-east. The ore consists of stringers of coarse cassiterite ranging from 1/16 inch to 3 inches in width. An open cut and two shallow shafts have produced about 111 tons of ore containing about 4.7 tons of tin concentrate.

Yeuralba Mines

AGGSNA (1937, 1938, 1939); Hossfeld (1939, unpubl.); Noakes (1949); Ward (1950, unpubl.); Walpole & Drew (1953, unpubl.); Walpole (1958a)

At Yeuralba, 20 miles north of Maranboy, a number of hydrothermal tourmaline and topaz-bearing lodes have been worked intermittently for tin, tungsten, and copper since about 1924. They include *The Gates, O'Sullivans Camp,* and *Yeuralba King* mines. Recorded production is about 40 tons of wolfram concentrate, 12 tons of tin concentrate, and 50 tons of copper ore averaging 24 percent Cu.

Except for the Yeuralba King mine, which lies some distance to the east of the remaining mines of the group, the lodes are located in and immediately around the Yeuralba Granite, which crops out over an area of about 20 square miles; it is intruded into greywacke and shale of the Burrell Creek Formation, which are extensively altered by contact metamorphism. The granite is hydrothermally altered along major fracture zones trending north-east and north-north-west; the greisen, quartz-tourmaline, and quartz-topaz-tourmaline lodes are closely associated with the fracture zones, especially the north-north-west set. In addition to wolfram and cassiterite, the lodes contain some scheelite, fluorite, apatite, and bismuth and copper minerals.

All the existing workings are shallow, and little systematic testing has been done. Walpole & Drew (1953, unpubl.) list 17 separate greisen and lode formations, ranging from 200 to over 2000 feet long and from 50 to 400 feet wide, which they consider warrant further testing. Grab samples of eight of these occurrences gave assays ranging from a trace to 0.95 percent WO_3 and up to 0.59 percent Sn.

Extensive alluvial and eluvial deposits are present around some of the lodes, but sampling by a local syndicate in 1963 showed that only relatively small areas are payable (Hays, 1963b, unpubl.).

At the *Ludan* prospect, 8 miles east of Yeuralba, Hossfeld (1939, unpubl.) reports some gold values in a major north-north-westerly shear zone. Some copper also occurs within this zone, and in small en echelon shear zones in an amphibolite dyke to the east of the major shear, but no production is recorded.

Miscellaneous Mines and Prospects

A number of isolated and generally small mines and prospects do not fit readily into any of the groups discussed previously. Most of them have been worked for gold, a few for tin, copper, or lead, and one for manganese.

Adelaide River/McKinlay River area

Parkes (1892); Brown (1895); Jensen, Gray, & Winters (1916); AGGSNA (1936, 1937)

A number of gold mines occur in the Burrell Creek Formation between the Adelaide and McKinlay Rivers, north of the railway.

The *Mount Ringwood* mines are 25 miles north-east of Brocks Creek, and were worked between 1894 and 1902 for a total recorded production of about 2800 oz of gold. Workings consisted of numerous shafts to depths of 50 or 60 feet, and the auriferous lodes ranged in width from 4 to 15 feet. The country rock consists of greywacke and siltstone of the Burrell Creek Formation.

The *Great Western, Great Northern,* and *Star of the North* mines, 20 miles north of Brocks Creek, have a broadly similar setting. Recorded production between 1896 and 1920 is about 3600 oz of gold. The deepest shaft in 1904 was reported to be 120 feet deep. One large quartz reef, 14 feet wide, was worked, but some rich crushings also appear to have been obtained from other smaller lodes.

At *Mount Tymn,* 18 miles north-west of Brocks Creek, work appears to have been carried out intermittently between 1891 and 1897 on a group of auriferous quartz reefs from 1 to 3 feet wide, but recorded production is only 6 oz of gold.

The *McKinlay* gold mine, also known as *Hardys,* is situated 20 miles east-north-east of Brocks Creek, near the McKinlay River crossing on the present Mount Wells/Mount Harris road. A series of auriferous quartz reefs, with limonite, clay, and minor pyrite and arsenopyrite, appears to be associated with a major north-north-west shear zone in sandstone, slate, and chlorite schist of the Burrell Creek Formation. Assays of up to 13 dwt Au per ton over a width of 4 feet 8 inches are recorded, and a zone over 40 feet wide is reported to average 2.7 dwt per ton (Hossfeld, 1940), but the recorded production is only 7 oz of gold. This shear zone may warrant some further prospecting.

The *Woolwonga* gold mines, 10 miles north-east of Brocks Creek, were worked intermittently between 1871 and 1908 for a total recorded production of over 9200 oz of gold. Production was from a series of reefs up to 2 feet wide and 300 feet long, most of which occurred in a major north-westerly shear zone, with minor reefs in tension openings at right angles to this. The country rock consists of sandstone and slate of the Burrell Creek Formation. Most of the workings are in the oxidized zone; the deepest shaft, to 170 feet, encountered primary ore consisting of quartz, pyrite, and arsenopyrite, but this was low grade — of the order of 2 dwt per ton — and could not be treated economically (Voisey, 1937; Rayner & Nye, 1937d).

Maude Creek/Watts Creek/Frances Creek Area (Fig. 32)

Brown & Basedow (1906); Jensen (1919)

The Maude Creek/Watts Creek/Frances Creek area, from 10 to 15 miles north-east, east, and south-east of the Burrundie Siding, contains several groups of small gold mines and alluvial workings. The main centres of alluvial production were *Frances Creek,* near the junction of its two main tributaries, *McKeddies* diggings on Maude Creek, and the *Watts Creek* diggings, which are actually situated in the headwater region of Frances Creek. The only recorded production is 130 oz from Frances Creek and 21 oz from the Watts Creek diggings.

A group of quartz reefs 4 miles north-west of the Frances Creek gorge was opened up before 1936 by several shallow shafts and small open cuts, but no records of production are available. Another attempt to work the reefs was made by a local syndicate in 1962, but only a trial parcel, which yielded 8 oz of gold, has been produced (Crohn, 1963c, unpubl.).

Before 1940, some prospecting for gold had also been done on the ironstone outcrops in the Frances Creek area, which are now being developed as a source of iron ore. Assays of around 2 dwt Au per ton were reported from parts of the Ochre Hill occurrences, but no production is recorded.

Spring Peak/Mundogie Hill Area

At *Yemelba,* 40 miles north-north-east of Moline township, a group of auriferous quartz reefs was worked intermittently between 1933 and 1939. The reefs contain iron oxides, minor pyrite, and locally some copper minerals, and occur in siltstone, sandstone and conglomerate of the Lower Proterozoic Mount Partridge Formation, associated with north-north-westerly shear zones. Recorded production is about 250 oz of gold.

About 12 miles north-west of Yemelba, some gold has been won from the *Mundogie Hill* locality, mostly from small eluvial and alluvial deposits, but no records of production are available.

About 10 miles north-east of Mundogie Hill, near *Spring Peak,* a number of small tin-bearing quartz reefs in sandstone of the Mount Partridge Formation were discovered in 1955. Costeaning and diamond drilling of the prospect did not locate occurrences of economic importance.

Namoona/Minglo Area

Debnam (1955b, unpubl., 1955d, unpubl.)

Two lead occurrences are recorded from the area north-west of Goodparla homestead.

At *Namoona,* 15 miles north-west of Goodparla homestead, small bunches and disseminated grains of galena and cerussite, in part associated with veinlets and irregular blows of quartz, are widespread in a north-westerly zone in greywacke, siltstone and shale of the Lower Proterozoic Masson Formation. Geochemical testing by the Bureau of Mineral Resources has shown a lead anomaly over a strike length of about a mile and a width of several hundred feet, but costeaning and diamond drilling by Australian Mining and Smelting Co. Ltd in 1955 showed that the average grade near the surface was low. However, the costeans did reveal several seams of massive galena up to 2 feet wide, some bedded and some in small shear zones; some of them might be suitable for selective mining by prospectors or small syndicates.

The *Minglo* occurrence, 6 miles west of Namoona, has not been tested to the same extent, but appears to be associated with a more sharply defined shear zone, and the host rocks in this area show evidence of contact metamorphism by the nearby Cullen Granite. The ore consists of galena and anglesite; the anglesite occurs in bands surrounding cores of galena. At present the prospect is being selectively mined, and small parcels of hand-picked ore are being produced. In the period 1964-65 18.4 tons of ore containing about 58 percent Pb and 4.5 oz Ag per ton were produced.

Hayes Creek Area

Jensen, Gray, & Winters (1916); AGGSNA (1940); Sullivan & Iten (1952); Dunn (1963, unpubl.)

The Hayes Creek area contains a group of small tin mines and prospects, situated a few hundred yards north of the Stuart Highway, about 8 miles south-east of Brocks Creek Siding.

The lodes consist of quartz-cassiterite veins with minor iron oxides, and are concentrated in the intensely fractured axial portion of a north-north-easterly anticline. Most of the lodes, which range from a few inches to about 6 feet in width, trend parallel to the axis of this fold, but the dips range from about 30° to vertical. The country rock consists of greywacke and slate of the Burrell Creek Formation (Dunn, 1963, unpubl.). Workings include several adits, the longest about 300 feet, and numerous small open cuts and stopes from the surface. The lodes have been worked intermittently since 1915, and the total recorded production is 156 tons of tin concentrate, including a small amount from alluvial deposits in Hayes Creek itself. The most recent attempt to reopen the workings was in 1962, but only about 0.75 ton of tin concentrate, mostly from old dumps, was obtained before the attempt was abandoned.

Umbrawarra/Stray Creek Area

Jensen (1919)

The Umbrawarra/Stray Creek area, from 10 to 15 miles south-west of Pine Creek, contains the only known substantial tin occurrences within the Cullen

Granite. Both the Umbrawarra and Stray Creek fields have been worked intermittently from about 1909, and the total recorded production is 269 tons of tin concentrate from Umbrawarra and 18 tons from Stray Creek, with the bulk of the production in each case coming from alluvial deposits. The alluvial deposits consisted mainly of small relatively rich pockets in flat-bottomed creek valleys, commonly controlled by small rock bars; other occurrences of this type may still be present. The primary deposits appear to have been mainly small zones of disseminated cassiterite in chloritized granite; these also may warrant further investigation to determine whether any extensive low-grade deposits, suitable for large-scale development, are present.

Minor deposits of alluvial tin have been recorded from *Nellie Creek,* about 15 miles north-east of Pine Creek, and from the headwater region of the *Douglas River,* 10 to 15 miles north-west of Pine Creek. Recorded production from the two areas is only 3 tons and 2 tons of concentrates respectively, but they may warrant further prospecting by individuals or small syndicates.

Myra Falls Area

A small tin occurrence has been recorded from the Myra Falls area, which is situated in an embayment of the Arnhem Land Plateau, about 20 miles south-east of Oenpelli mission (Gray, 1915). Minor cassiterite-bearing quartz veins and traces of apatite, beryl, and copper minerals have been noted in schist and gneiss of the Archaean Myra Falls Metamorphics, but the only recorded production is a few hundredweights of tin concentrate from alluvial deposits.

Katherine River Area

Parkes (1892); Brown (1895); Rattigan & Clark (1955, unpubl.)

The Katherine River area contains several small gold and copper occurrences, of which the *Maude Creek* field, 15 miles east of Katherine, has been the most important. Leases include *Cemetery, Dalhouzie, Golden Creek, Golden Tree, Hibernia, Lady Maud, Maud Hill,* and *Mystery*. In this field, a group of ferruginous quartz reefs occurs in basic lava and tuff of the Lower Proterozoic Dorothy Volcanics and in altered basic intrusives. The reefs range up to 7 feet in width, and show variable dips and strikes. Workings consist mainly of shallow shafts and open cuts, and total recorded production is about 540 oz of gold, won mostly in 1890-92 and 1932-40. Minor copper mineralization is associated with many of the reefs, but no production of copper is recorded (Cottle, 1937e).

About 250 oz of gold are also reported to have been obtained from the *Mount Gates* area, about 6 miles north-west of Maude Creek. The area was worked mainly between 1890 and 1895; the workings consisted of several shafts up to 30 feet deep, and most of the gold came from three narrow quartz reefs in metamorphosed sandstone and slate intruded by altered dolerite and granite dykes.

At the *Carpentaria* mine, 3 miles north of the Maude Creek workings, copper mineralization occurs sporadically for about a mile in a north-north-westerly zone in basic lava, tuff, and altered intrusives similar to those in the Maude Creek area. Most of the mineralization consists of azurite and malachite in minor shear zones, and none of the workings has exposed the primary ore. The workings consist mainly of shallow shafts and short adits, most of which were probably developed between 1902 and 1919. Total recorded production is only 20 tons of copper ore of unspecified grade.

Green Ant Creek Area

Owen (1954b, unpubl.); Dunn (1955, unpubl.)

In the Green Ant Creek area, a number of small manganese prospects occur a few hundred yards south of the Stuart Highway, almost exactly 100 miles from Darwin. The occurrences consist of irregular bodies of low-grade manganese ore at the unconformity between steeply dipping greywacke and siltstone of the Burrell Creek Formation and overlying subhorizontal beds of the Cretaceous Mullaman Beds. Some of the ore may have been deposited on the eroded surface of the Burrell Creek beds, but most of it appears to have been formed by replacement of siltstone below the unconformity, presumably by solutions circulating before the Cretaceous beds were laid down. Recorded production is about 450 tons of ore in 1954-56 and 90 tons in 1964. The ore was used in the treatment plant at Rum Jungle, but the prospects of further production are not encouraging because of the low grade and the patchy distribution of the ore.

Other Mines and Prospects

The *Pig Hole* mine, 10 miles south-east of Marrakai homestead, is thought to have been a small gold producer in the early years of this century, but no details are available. It is reported to have produced 15 oz of gold in 1940.

At *Mount Tolmer South,* 10 miles north-north-east of Litchfield homestead, a copper occurrence is recorded in phyllite and schist of the Noltenius Formation, but there was probably no production.

At the *Daly River Gorge,* upstream from Daly River police station, some shallow workings in Adelaidean sandstone are thought to have been put down for gold, possibly localized in a major fault zone, but no records of production are available.

Iron Ore Deposits

Occurrences of iron ore are known from several widely separated localities in the Katherine-Darwin Region. They do not fit into the groupings adopted for the hydrothermal types of deposit and are therefore discussed separately.

The three main potential sources of iron ore in the area, in order of importance, are Frances Creek near Burrundie, Pritchards Lode at Mount Bundey, and the Darwin River/Batchelor/Waterhouse area.

Frances Creek Area (Fig. 37)

Crohn (1961a, unpubl.; 1965b, unpubl.)

In the Frances Creek area, about 10 miles east of Burrundie Siding and 120 miles south-east of Darwin, a group of iron ore deposits has been under investigation since 1961 by Northern Iron Mining Corporation Ltd, assisted by the Mines Branch, N.T. Administration. Considerable work has also been done on the deposits by New Consolidated Goldfields (A'sia) Pty Ltd under a former option agreement, and by MacDonald Construction Co. under a current working agreement with the leaseholders. Altogether, some 220 wagon drill holes and 6 diamond drill holes have been put down on the deposits to the end of 1964, supplemented by numerous costeans and surface samples. An agreement to export 3 million tons of ore to Japanese buyers was announced early in 1965. Average grade of the material to be mined is estimated at 63 to 64 percent Fe.

The deposits crop out intermittently over a strike length of about 15 miles, closely following the bedding of the Lower Proterozoic Masson Formation, which consists of greywacke, siltstone, and slate, folded into open folds of varying amplitude, generally with moderate to steep northerly pitches. The deposits have been individually named, the most important, from north to south, being *Saddle Extended, Saddle, Ochre Hill, Thelma Frances,* and *Helene;* others are *Elizabeth Marion, Jasmine,* and *Rosemary*. The most prominent outcrops are those associated with the Thelma Frances deposit, which consists of a tabular body about 1500 feet long and up to 40 feet wide, which is locally exposed in almost vertical cliffs up to 50 feet high. The largest tonnages, however, are contained in the Helene No. 7 and 8 leases, where a group of lenticular bodies appears to result from the thickening of one or more ore horizons on minor fold axes, which pitch north at moderate angles.

The orebodies appear to have resulted from supergene enrichment of a group of ferruginous beds in the Masson Formation. No pyrite or other sulphides have been encountered in any of the deposits, and the results of diamond drilling at Ochre Hill suggest that the primary material consisted of sheared and brecciated greywacke and slate with disseminated iron oxides, and some concentrations in joints, bedding planes, and other openings. The proportion of hematite to limonite increases from north to south towards the contact of the Cullen Granite, but it is not possible to show conclusively that this is the direct result of the granitic intrusion. It is clear, however, that the supergene enrichment is pre-Cretaceous, as the Thelma Frances deposit is in part overlain by flat-lying deposits of the Cretaceous Mullaman Beds.

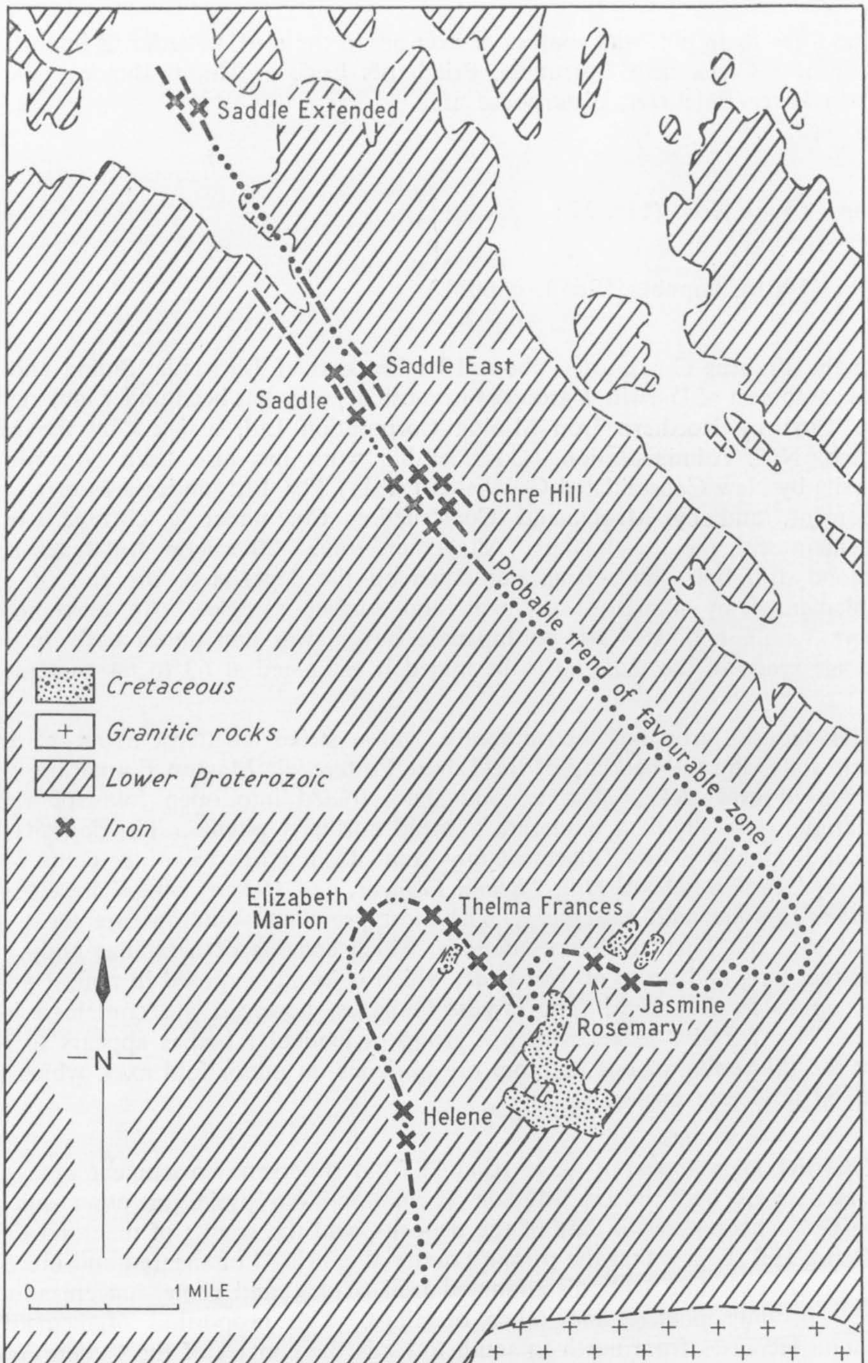

Fig. 37. Mineral deposits, Frances Creek area

PLATE 25.

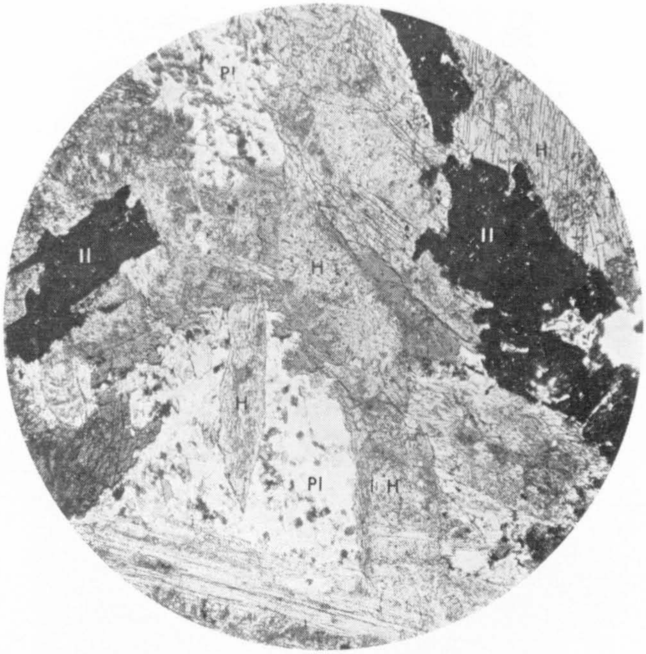

Fig. 1: Ortho-amphibolite, consisting of hornblende (H) displaying strongly pleochroic rims and weakly coloured centres, large anhedra of ilmenite (Il) partly made over to leucoxene, fine untwinned sodic plagioclase (Pl) and minor amounts of quartz and apatite. Diameter 4 mm; ordinary light; T.S. 5202B, Territory Enterprise DDH No. 337, Rum Jungle Creek South.

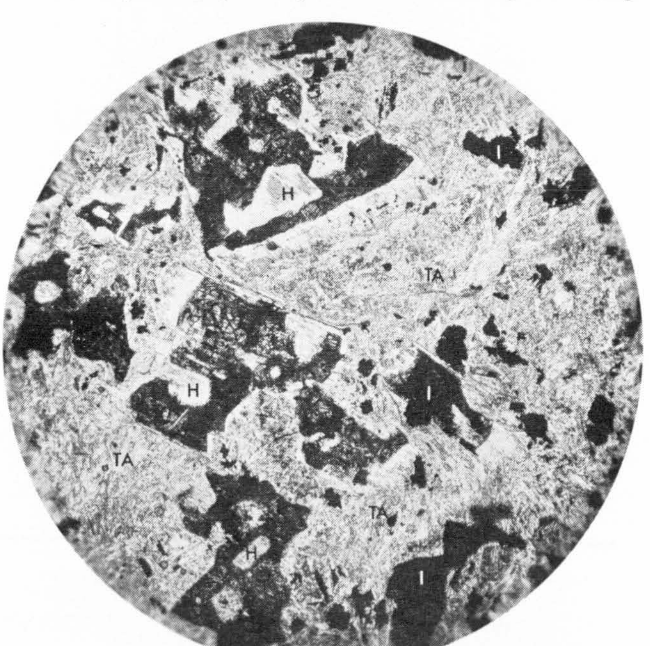

Fig. 2: Amphibolite consisting of tremolite-actinolite fibres (TA), brown hornblende (H) partly replaced and veined by iron oxide, and iron oxide anhedra (J). Diameter 4 mm; crossed nicols; T.S. 6880, BMR, DDH No. 4 (239 feet), Waterhouse No. 2 prospect, Rum Jungle area.

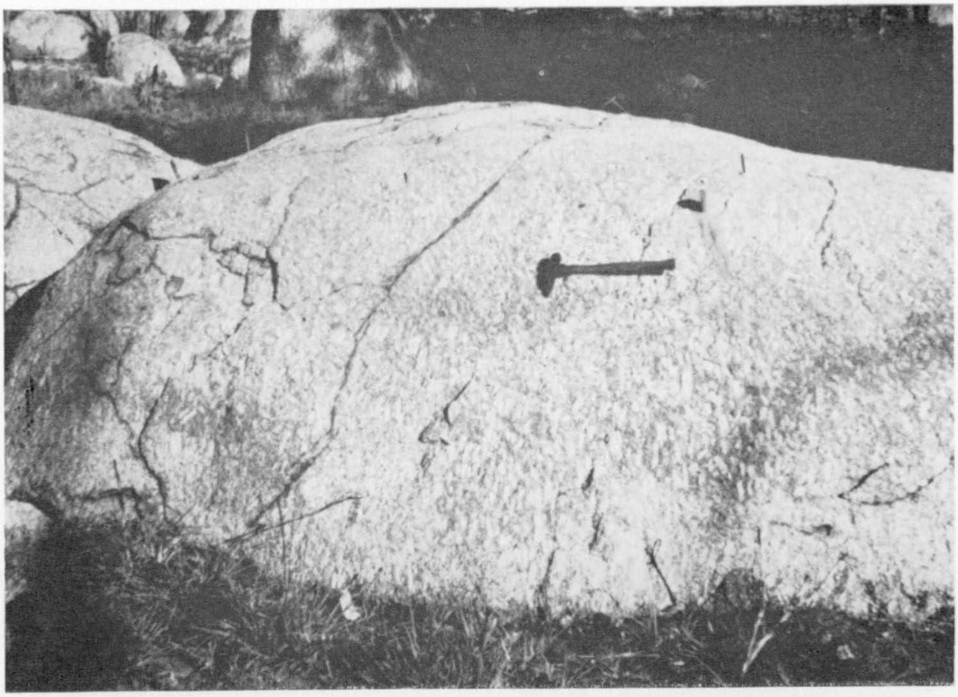

Fig. 1: Platy flow structure in Allia Creek Granite, Allia Creek, Fergusson River Sheet.

Fig. 2: Residual of Tennant Creek Surface above Koolpinyah Surface, 95-mile peg, Stuart Highway, Pine Creek Sheet.

PLATE 27.

Fig. 1: Tennant Creek Surface residuals standing above Wave Hill Surface looking north from Maranboy, Katherine 1 : 250,000 Sheet.

Fig. 2: Lateritic profile on Tertiary clay in hollow on Cretaceous sediments, Nightcliff near Darwin, Darwin Sheet.

Pritchards Lode, Mount Bundey Area

Dow & Pritchard (1958, unpubl.); Dunn (1964, unpubl.)

In the Mount Bundey area, 60 miles south-east of Darwin, a bold ironstone outcrop, known as Pritchards Lode, can be traced on the surface for about 2000 feet, with an average width of about 40 feet, and several smaller, less well exposed bodies occur within a few hundred yards. These lodes were noted by the Bureau of Mineral Resources in 1956, but a diamond drill hole put down by the Bureau in 1958 passed under the main outcrop at a vertical depth of about 300 feet without intersecting any lode material. Subsequently leases were taken up over the area by Nevsam Mining Company Pty. Ltd and in 1962, 16 diamond drill holes, totalling about 2000 feet, were put down by the Mines Branch, N.T. Administration, under an agreement with the leaseholders to evaluate the deposit as a source of iron ore. A contract has been made for the export of about 1.4 million tons of ore from this deposit to Japan.

The main lode trends north-east and dips almost vertically; most of the associated minor bodies lie in a north-south zone which diverges from the main lode near its southern extremity. The only rocks exposed near the lodes are a coarse-grained slightly foliated syenite, of the Mount Goyder/Mount Bundey igneous complex, and a few aplite dykes cutting the syenite. However, in several of the drill holes, remnants of metamorphosed and metasomatically altered sedimentary rocks were encountered, and the lodes may have been formed by magmatic segregation or by partial replacement of a large sedimentary inclusion in the syenite, or of a combination of both (Dunn, 1964, unpubl.).

To an average depth of about 80 feet below the outcrop, the lodes average about 64 percent Fe, and consist essentially of martite (hematite after magnetite) which is strongly magnetic and locally shows minor boxworks. Below about 80 feet, the lode material is mainly magnetite, with occasional remnants of partly replaced country rock and blebs and veinlets of pyrite and minor chalcopyrite. Sulphur in this section ranges from 1 to about 5 percent, and copper from 0.1 to 0.5 percent.

On the flanks of the lodes, there are also extensive deposits of boulder and scree ore, which are locally more than 6 feet thick, and which could probably be upgraded by a relatively simple sink-float process.

Both ground and airborne magnetometer surveys have been carried out over the area surrounding the known lodes, but although the lodes give rise to pronounced and easily recognized magnetic anomalies, there are no indications of comparable non-outcropping bodies in the immediate vicinity.

Darwin River/Batchelor/Waterhouse Area

Dunn (1962a, b, unpubl.)

In the Darwin River/Batchelor/Waterhouse area, small ironstone bodies are developed by enrichment of Lower Proterozoic ferruginous beds which, in part, resemble a banded iron formation; and by enrichment of ferruginous sandstone in the unconformably overlying Adelaidean succession, and of quartz-hematite breccias, some of which are probably tectonic in origin, and some are basal deposits of the Adelaidean succession. Some of the ironstone bodies in this area may have been derived from primary sulphide lodes by oxidation.

Several of the deposits have recently been investigated by Nevsam Mining Co. Pty Ltd; individual deposits generally appear to be small, but in many cases the deposits of rubble or scree ore on the flanks of the ironstones are likely to be of greater economic importance than the bodies themselves.

The most northerly group of deposits occurs from 2 to 3 miles north-east of *Darwin River* Siding, where gossanous ironstones several hundred feet long crop out intermittently on east-trending strike ridges of the Golden Dyke Formation. Apparent outcrop widths of the ironstone range up to 75 feet; no estimate of their vertical extent has been made, but they are probably oxidation products of pyritic bodies.

At *Beetsons* deposit, about 1 mile west of the railway, 5 miles south of Darwin River Siding, comparable outcrops occur on a strike ridge about half a mile long, trending a few degrees east of north. Several costeans and a shallow shaft show that the lode consists of irregularly alternating bands of dense hematite, cavernous hematite and goethite, and some low-grade ferruginous material. A considerable quantity of boulder and scree ore occurs on the eastern flank of the ridge.

Another group of prospects, including the *BW* prospect, occurs about 7 miles west of Stapleton Siding, where bands and lenses of massive hematite occur in a steeply dipping ferruginous slate, about 200 yards south of the southern margin of the Waterhouse Granite. The area has been tested by means of a number of costeans and shallow prospecting shafts, which show that the individual hematite bodies are very small; but they are surrounded by a considerable area of hematite rubble, which may be suitable for upgrading.

At *Mount Mabel,* near the western margin of the Waterhouse Granite, ironstone has been formed by superficial enrichment of ferruginous sandstone in the Adelaidean Depot Creek Sandstone Member; bands and lenses also occur in brecciated Lower Proterozoic banded iron formation, but the individual bodies appear to be small. The area also contains a few outcrops of a magnetite schist, estimated to contain between 10 and 30 percent magnetite, but this has not yet been systematically investigated.

Other localities in which ironstone occurrences have been recorded include *Banyan* homestead, *Castlemaine Hill,* and the East Finniss River railway bridge, but none of them have been investigated.

Other Occurrences

Numerous other localities in the Katherine-Darwin Region contain occurrences of ironstone, gossan, or other ferruginous material, and many of these have recently been examined as possible sources of iron ore, but the results have generally not been encouraging.

In the *Brocks Creek* area, several of the ferruginous outcrops described by Sullivan & Iten (1952) contain sections of massive hematite-goethite ore, especially to the east of the Cosmopolitan Howley mine, at Mount Paqualin, and to the west of Ban Ban homestead, but the individual shoots of high-grade material are too small for economic exploitation (Crohn, 1961b, unpubl.).

In the *Black Jungle Range* area, 100 miles east-south-east of Darwin and 50 miles due north of Moline, similar ferruginous outcrops are developed on rocks of the Lower Proterozoic Koolpin Formation, comprising carbonaceous siltstone with minor dolomite and limestone. None of the ferruginous material in this area is of ore grade, except possibly in rare small pods of no economic significance, and the underlying rocks are thought to contain disseminated pyrite rather than hematite or magnetite.

Other areas from which superficially enriched occurrences have been recorded are near Berry Springs, Marrakai Crossing on the Adelaide River, and the junction of the Mary and McKinlay Rivers, all in rocks of the Golden Dyke Formation (Barclay, 1964a, unpubl.), and in the Koolpin Formation near Coirwong Gorge.

At *Mount Tolmer,* 30 miles south-west of Rum Jungle, a steeply dipping tabular or lenticular ironstone occurs in siltstone and slate of the Lower Proterozoic Noltenius Formation, close to the contact with the unconformably overlying sub-horizontal ferruginous Adelaidean Depot Creek Sandstone Member. Towards the top, this steeply dipping lode merges into a flat-lying body which follows the unconformity. Several smaller isolated bodies occur in the Adelaidean rocks, probably in minor shear zones. All the occurrences consist partly of dense fine-grained hematite, and partly of a mixture of cellular hematite and limonite which bears some resemblance to a gossan. The full dimensions of the deposit cannot be determined without further exploration, as both the steeply dipping body in the Noltenius Formation and the flat-lying body at the unconformity pass under the Depot Creek Sandstone Member (Crohn, 1964, unpubl.).

Minor ironstone occurrences are found in the Depot Creek Sandstone in the Tabletop Range, the Florence Creek headwater area, 15 to 20 miles south-west of Rum Jungle, and in the George Creek area, about 10 miles south of Adelaide River township. None show any indications of the presence of economic deposits.

Ironstone occurrences are also known from the *Flora River* area, about 50 miles south-west of Katherine, where they appear to have been formed by surface enrichment of ferruginous sandstone beds in the Palaeozoic 'Jinduckin Formation' and the Adelaidean Waterbag Creek Formation. It seems that occurrences of ore grade are restricted to small widely scattered pods, probably developed in favourable structural locations, such as minor shear zones (Crohn, 1964b, unpubl.).

A distinctive occurrence of ferruginous material has also been recorded from the *Kapalga* area, between the estuaries of the South Alligator and West Alligator Rivers (Dunn, 1957, unpubl.). It consists of a steeply dipping lens of ferruginous siltstone in the Lower Proterozoic Mount Partridge Formation. The lens is estimated to have a maximum width of about 100 feet and a possible strike length of 5000 feet; two samples of the richest exposed material assayed 47.9 and 51.8 percent Fe_2O_3 and 7.3 and 22.6 percent TiO_2. The iron and titanium minerals are thought to be detrital in origin and to comprise hematite and ilmenite and/or rutile. The occurrence does not appear to be of economic importance as a source of iron ore, but the titanium content may warrant further investigation.

Oolitic ironstones also occur in the McMinn Formation of the Roper Group in the extreme south-eastern corner of the Katherine-Darwin Region. The occurrences are a westerly extension of the thicker and more extensive deposits in the Roper Bar area, which have been tested by The Broken Hill Proprietary Company Ltd (Cochrane & Edwards, 1960). On present indications they are not of immediate economic interest.

In the headwaters of Nourlangie Creek a quartz-hematite body crops out in Lower Proterozoic sediments near the contact with the Jim Jim Granite. The Broken Hill Proprietary Company Ltd drilled the body in 1958 without apparent success.

Disseminated Sulphide Occurrences

In this section, some of the major known occurrences of disseminated sulphides and their oxidation products are reviewed as a group, although many of them have already been referred to previously, especially in the discussions on the Rum Jungle and Brocks Creek areas and the various iron ore occurrences.

Most of the occurrences are associated with carbonaceous slate and siltstone of the Golden Dyke and Koolpin Formations, or with sills and dykes of dolerite and amphibolite. The occurrences in sedimentary rocks are apparently of syngenetic origin. They do not show any obvious association with quartz-sulphide lodes of the fissure-filling types.

The most northerly occurrence is a pyritic carbonaceous slate, probably of the Golden Dyke Formation, encountered in a waterbore 13 miles south of

Darwin; similar rock types have probably been responsible for the development of ferruginous outcrops in the Berry Springs area. In the Darwin River area, test-drilling for a proposed dam site has encountered highly pyritic bands in both Golden Dyke and Acacia Gap Tongue rocks; traces of copper sulphides are associated with some of these occurrences, but not, as far is known, in economic concentrations. Some of the nearby iron ore occurrences, such as Beetsons deposit, may also have been derived from similar material.

In the Rum Jungle area, disseminated pyrite mineralization is widespread, both in carbonaceous, and, in places, in chloritic sedimentary rocks, and in dolerite and amphibolite dykes and sills. The pyrite mineralization occurs in barren areas as well as in association with the uranium and base-metal mineralization. The association of the known orebodies with widespread pyrite mineralization has been known for many years, but its genetic significance is not yet fully understood.

In the Brocks Creek area, disseminated pyrite mineralization and associated ferruginous outcrops have been traced for many miles in carbonaceous beds of the Golden Dyke Formation. The gold mineralization at Cosmopolitan Howley and the copper at Mount Ellison, as well as numerous smaller mines and prospects, are intimately associated with these rocks, but the genetic relationship, if any, between the pyrite and the economic mineral occurrences is not clear. In several instances, base metals, especially copper and zinc, are concentrated in the ferruginous gossan-like outcrops, but are not associated with better or even comparable grades at depth.

In the Black Jungle Range and Coirwong Gorge areas, comparable ferruginous outcrops are developed on rocks of the Koolpin Formation, and the results of a limited diamond drilling programme by The Broken Hill Proprietary Company Ltd indicate that pyritic beds provided the source for the iron. No economic mineral deposits have so far been found, but by analogy with the adjoining South Alligator area and the Brocks Creek and Rum Jungle areas, some further investigation of the ferruginous outcrops of the Black Jungle Range and Coirwong areas is warranted.

The ferruginous outcrops near Marrakai Crossing and the junction of the Mary and McKinlay Rivers referred to on page 237 have not been systematically investigated for base metals; some testing is warranted.

Non-Metallic Minerals (Fig. 38)

Sand, Gravel, and Crushed Rock

In terms of past production, sand, gravel, and crushed rock are the most important non-metallic minerals of the Katherine-Darwin Region, but details of production from individual deposits are generally incomplete.

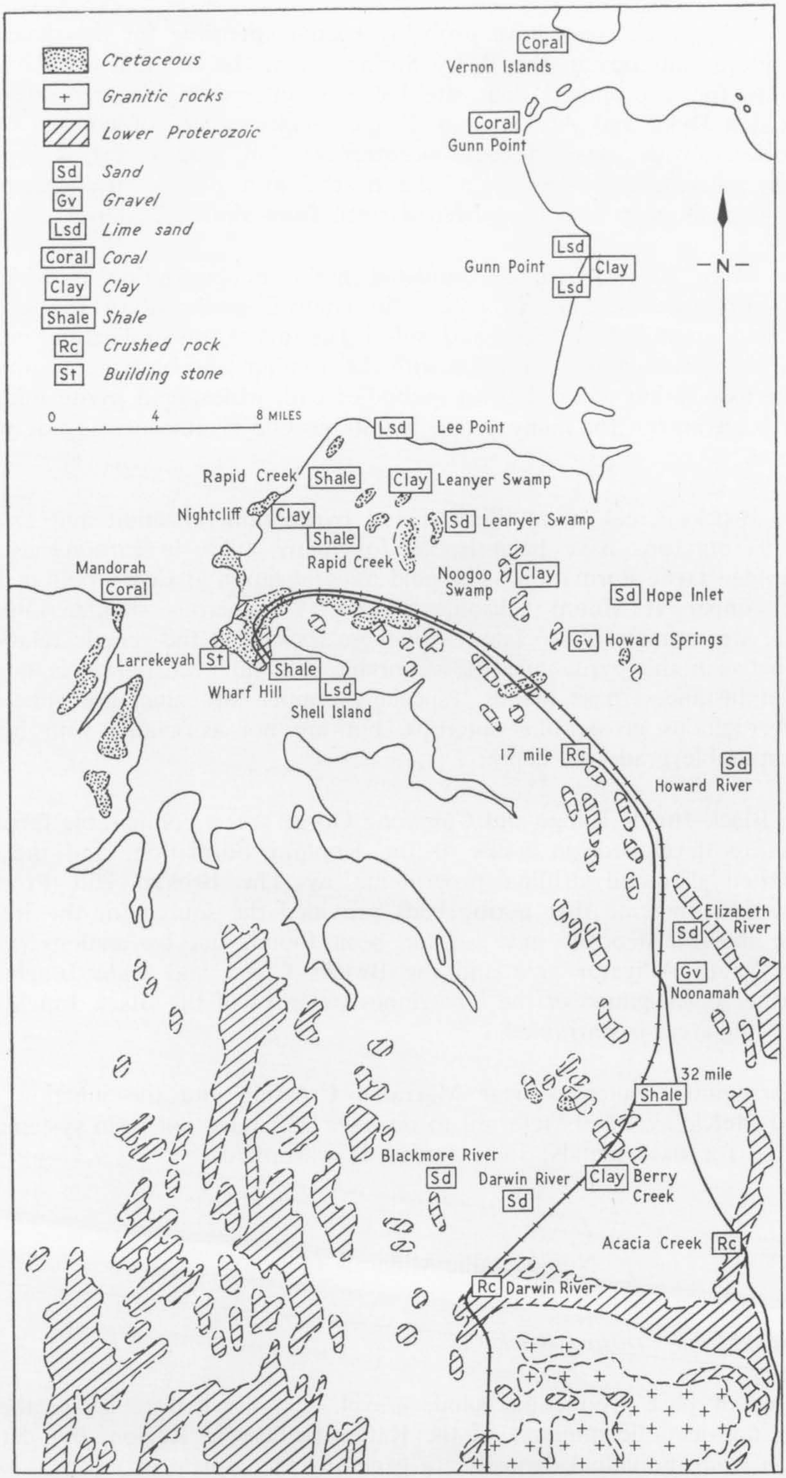

Fig. 38. Mineral deposits, Darwin area

At present, the main sources of crushed rock for construction purposes in the Darwin area are the quartzite and silicified sandstone of the Acacia Gap Tongue. In 1963-64 recorded production was about 45,000 tons, mainly from the 17-mile and Acacia Gap quarries. In previous years, considerable production has also come from the Darwin River quarry, a few hundred yards east of Darwin River Siding, in rocks of the same formation. This was mostly used in the construction of Darwin aerodrome.

In 1965, quarrying of flat-lying basaltic lavas of the Antrim Plateau Volcanics, 8 miles east of Katherine township, was started for use in the construction of Tindal Air Base.

Small tonnages have also been won from numerous other localities for use in local construction projects and for road construction. The rock types used include granite, acid and basaltic lavas, amphibolite, sandstone, and limestone.

Sand and gravel are widely available throughout the area, although individual deposits are generally small. Near Darwin, sand and gravel have been obtained from Leanyer Swamp and Hope Inlet, from the Adelaide, Howard, Elizabeth, Darwin, and Blackmore Rivers, and from some local beach deposits. Lateritic gravels have also been worked in the Howard Springs and Noonamah areas. Elsewhere, small tonnages have been won from many separate deposits for local use.

In 1963-64, recorded production of the area, mostly for use at Darwin, was about 26,000 tons of gravel and 13,000 tons of sand.

Building Stone

McQueen (1957a, unpubl.)

The only systematic quarrying of stone for building purposes has been undertaken at the Larrakeyah quarry, Darwin, in flat-lying leached Cretaceous shale from the pallid zone of the laterite profile. The leached shale is about 35 feet thick, and is overlain by about 15 feet of ironstained silicified shale; the leached material has an attractive appearance, and can be readily sawn when fresh, but hardens on exposure.

Limestone

Large quantities of limestone occur in several parts of the Katherine-Darwin Region, but both the physical and chemical characteristics are very variable, and they have not been used on a large scale.

The largest occurrences are in the gently dipping Lower Palaeozoic 'Daly River Group', especially the Tindal Limestone, which crops out over many square miles in the Fenton Airstrip, Katherine, and Tindal areas. The limestone commonly contains zones of silicification, and in places the magnesia content is too high for use in the manufacture of lime or cement. Analyses of grab samples from various localities commonly range from 75 to over 95 percent $CaCO_3$, and from less than 1 to over 20 percent $MgCO_3$, and a detailed test programme would be required to delineate areas suitable for economic development. Lime was manufactured on a small scale for some years at Katherine, the most recent recorded production being 350 tons in 1960-61, but there is no production at present.

Carbonate rocks are also widespread in the Lower Proterozoic succession, especially in the Celia, Coomalie, Golden Dyke and Koolpin Formations, e.g. at Rum Jungle, the Evelyn mine, and in the South Alligator area, but these rocks are generally too siliceous or too dolomitic for economic exploitation.

Some better-quality lenses of crystalline limestone are reported to be associated with amphibolites in the Brocks Creek area; they are probably of hydrothermal origin. Two occurrences of this type, 4 miles north-west of Brocks Creek and 4 miles west of Burrundie, have been quarried in the past for use in cyanidation and probably as flux for the smelting of metallic ores, but no records of production are available (Jensen, Gray, & Winters, 1916).

Lime Sand

Gardner & Rix (in prep.)

Large tonnages of lime sand are known from beaches in the Lee Point and Gunn Point areas and from parts of Darwin Harbour and, in spite of a rather high magnesia content, they may be suitable for the manufacture of cement.

In the Lee Point area, deposits aggregate about three-quarters of a mile in length, with widths of at least 600 feet and thicknesses of 3 to 8 feet, and in the Gunn Point area deposits of comparable width and somewhat smaller average thickness occur over a length of about 2½ miles. The deposits average between 60 and 68 percent $CaCO_3$ and 4 to 6 percent $MgCO_3$, but preliminary testing at Australian Mineral Development Laboratories has shown that they may be upgraded to 75 to 80 percent $CaCO_3$ by screening or selective flotation. Of the deposits in Darwin Harbour, only the occurrence on Shell Island has been tested. This is of better quality than the other deposits tested (78 percent $CaCO_3$, 2.5 percent $MgCO_3$), but contains only a relatively small tonnage (probably about 100,000 tons).

Material of comparable composition may also be available from some of the coral reefs, e.g. at Gunn Point and the Vernon Islands, but the physical difficulties of working these deposits are likely to prevent their exploitation in the foreseeable future.

Clay

McQueen (1957b, unpubl.); Gardner & Rix (1963, unpubl.); Rix (1964, unpubl.)

Deposits of clay suitable for the manufacture of both bricks and ceramics are known in the Darwin area.

Brick clays are of two types — sedimentary clays associated with swamps, as at Leanyer Swamp, Noogoo Swamp, and Berry Creek, and weathering products of Lower Proterozoic shales, as at Wharf Hill, Rapid Creek, and the 32-mile locality. In general, the swamp deposits are more plastic, but some of them, such as the Leanyer Swamp occurrence, carry deleterious amounts of salt and gypsum, and the shrinkage on drying is generally high.

On present indications, the deposits at the 32-mile locality, derived from shale of the Noltenius Formation, are most likely to be of immediate economic interest. At this locality, auger drilling has encountered clay and weathered shale which appear to be suitable for brick manufacture to an average depth of more than 30 feet over an area of about 400 by 1200 feet, immediately adjoining the railway (Vanderplank, 1964, unpubl.). Further work would probably increase these reserves.

Clay suitable for the manufacture of ceramics is only known from a coastal exposure about 4 miles south of Gunn Point, where Cretaceous kaolinitic and montmorillonitic clays are exposed in the beach and cliff sections. The clays are overlain by 20 to 30 feet of laterite, which forms an extensive plateau from 50 to 100 feet above sea level, bounded by an abrupt scarp on the seaward side. Neither the horizontal nor the vertical extent of the deposits can be determined from existing exposures since they pass under the laterite cover to landward and under beach deposits of calcareous sand to seaward. However, from the mode of occurrence, as bedded members of the flat-lying Cretaceous Mullaman Beds, it appears likely that the deposits will be of large horizontal extent. and the presence of clay in landslip material below the laterite scarp suggests a total vertical extent of not less than 30 or 40 feet (Rix, 1964b, unpubl.). A programme of testing by diamond drilling through the laterite cover on the landward side is being carried out by the Mines Branch, N.T. Administration.

Minor occurrences of sedimentary clays are also known from the Nightcliff area, but are not likely to be available for exploitation because of their position within an area zoned for residential purposes.

Graphite

Many of the black shales and slates in the Lower Proterozoic rocks of the Katherine-Darwin Region contain minor amounts of graphite, but there seem to be few occurrences of potentially economic size and grade. The only recorded production is from the vicinity of the Golden Dyke mine in the Burrundie district, from which 2 tons of graphite were won in 1924 for use as a pigment in paint manufacture.

Good-quality graphite has also been reported from the Finniss River area, but no production has been recorded.

Bauxite

No deposits of bauxite have so far been discovered in the Katherine-Darwin Region. Laterite is widespread, mostly developed on flat-lying rocks of the Cretaceous Mullaman Beds, and to a lesser extent on Carpentarian, Adelaidean, and Cambrian rocks. It generally appears to be ferruginous or siliceous, but no systematic testing has been undertaken. The nearest known occurrences of possible economic interest are on Croker Island and Cobourg Peninsula, about 150 miles north-east of Darwin. These were partly delineated by Reynolds Metal Company in 1960, and are currently being re-examined by United Uranium N.L.

Barite

A group of lodes composed largely of barite with traces of galena has been recorded from a locality 10 miles west of Dorisvale homestead, 150 miles south of Darwin. There are at least four separate lodes, ranging up to 20 feet wide and 200 feet long, which occur within ferruginous sandstone, siltstone, and sandy limestone of the Adelaidean Waterbag Creek Formation, and are overlain by lateritized Cretaceous sandstone. Most of the surface material appears to be stained and low-grade, and the isolation of the occurrence would be a major obstacle to any economic development, but further testing may be warranted to determine the full extent and average grade of the lodes and to investigate the possible improvement of grade below the zone of weathering (Hays, 1965, unpubl.).

Another occurrence of barite has been recorded within the Soldiers Creek Granite, 5 miles north-west of Collia Waterhole. A sample was reported by Hossfeld (1937c) to assay 58 percent BaO and 4.2 percent SrO, but no details of the extent of the occurrence are available.

Barite also occurs in limestone of the Golden Dyke Formation about 5 miles south-west of the Evelyn mine.

Magnesite

Magnesite nodules have been noted from several localities in the Katherine-Darwin Region, including Rum Jungle, Stapleton, Brocks Creek, and Katherine.

The occurrences appear to be variously derived from intrusive amphibolite and dolerite, from basic lava of the Antrim Plateau Volcanics, from dolomite in the Lower Proterozoic Celia, Coomalie, and Golden Dyke Formations, and from magnesian limestone in the Cambrian 'Daly River Group'. None have been investigated in sufficient detail to establish the available reserves and average grades, but the Stapleton occurrence, probably derived from dolomitic limestone in the Golden Dyke Formation, may be of sufficient size to warrant further investigation, especially in view of its proximity to the existing railway.

Amblygonite

Brown & Basedow (1906); Noakes (1949); Summers (1957b, unpubl.)

The occurrence of amblygonite at Picketts mine in the Finniss River area, 30 miles south-south-west of Darwin, has already been mentioned in connexion with the tin deposits of that area. An analysis of the mineral, quoted by Brown & Basedow (1906), showed 47 percent P_2O_5, 35 percent Al_2O_3, and 7.9 percent Li. Total recorded production from this locality amounts to about 64 tons of hand-picked ore, mostly obtained in 1906 and 1924-25. Recent attempts to resume mining of the deposit have not been successful.

Salt

Tidal salt pans in Shoal Bay just to the north-east of Darwin are harvested to produce most of the local requirements of coarse salt. The average annual production is 750 tons.

Mineral Sands

Beach sand near Point Blaze contains about 60 percent heavy minerals (by weight), and reserves are calculated at about 4000 tons of heavy minerals (Ward, 1957, unpubl.). The heavy minerals average 4.0 percent rutile, 16.2 percent zircon, 41.3 percent magnetite, and 31.0 percent hematite. They are not economically attractive because of the low total rutile content and isolation of the deposit.

Coarse rutile crystals occur in a creekbed north-east of Oenpelli mission (Dunn, 1962), and fine tabular crystals of rutile have also been found in Myra Creek to the south of Oenpelli. These occurrences may be the source of possible rutile-rich beach sands in Van Diemen Gulf.

Coal

Because of the presence of what he believed were Carboniferous fossils on the west coast, especially at Fossil Head, H. Y. L. Brown (1895) recommended boring for coal. Between 1905 and 1911 nine bores were drilled at Port Keats (just to the west of the Katherine-Darwin Region), Cliff Head, Cape Ford, and near Anson Bay between Cliff Head and Cape Ford. Only three of the bores reached their target depth (about 1500 feet), one (at Cliff Head) reached granite basement at 720 feet, and the others were abandoned for various reasons.

The only coal intersected was a number of seams of lignite, from 1 to 3 inches thick, and some carbonaceous sandstone. Two of the bores near Cape Ford produced artesian water at 600 and 1600 gallons per hour.

Phosphate

The phosphate deposits at Rum Jungle and the occurrences in the South Alligator River area have been dscribed on pages 178 and 182.

During 1965 phosphatic beach rock was found at Lee Point near Darwin. The phosphate in the beach rock is thought to be derived from a Cretaceous bed which contains phosphate nodules. The nodular bed is about 30 feet above the base of the Cretaceous at Nightcliff near Darwin, and has been found at a similar stratigraphic position in a drill hole at Gunn Point about 20 miles north-east of Darwin.

Although the nodules contain up to 27.0 percent P_2O_5 they only occur in 2 or 3-inch layers and do not appear to be of commercial value. Further investigation is being undertaken.

Underground Water

Noakes (1949) has summarized the information available from waterbores in existence to 1946. Most of the bores were drilled by the Army during World War II. Water was generally obtained at depths of less than 300 feet, and flowed at rates between 500 and 2000 gallons per hour. Very few of the bores put down into Lower Proterozoic and Cambrian sediments failed to produce water, which in general had a standing water level of 20 to 50 feet below the surface. One bore in Cambrian sediments at Manbulloo, south-west of Katherine, produced artesian water at a rate of 800 gallons per hour. Bores sited in granitic rocks were not as successful as those in sediments unless they intersected joints, fractures, or weathered zones in the granite. Bores in the Darwin area are generally sited on Cretaceous Mullaman Beds, but water was drawn from the underlying Lower Proterozoic sediments.

Between World War II and about 1960 very few bores were sunk in the Katherine-Darwin Region. The pastoral industry was mainly dependent on surface water for homesteads and stock. The municipal supply for Darwin township from the Manton reservoir was adequate. However, since about 1960 an improvement in the state of the cattle industry in the region and a need to augment the Darwin water supply has focussed more attention on the underground water potential.

Stock bores have been drilled in the Daly and Roper River basins, and homestead and service bores throughout much of the rest of the Katherine-Darwin Region. These in general have supported Noakes' (1949) previous observations about the water potential of the various major regions and rock types.

The most outstanding discovery in recent years has been the finding of a major aquifer in the McMinns Lagoon area about 20 miles south-east of Darwin. Officers of the Water Resources Branch recognized sinkholes under the cover of Cretaceous sediments in the McMinns Lagoon area. Subsequent drilling showed that the Cretaceous sediments rest on cavernous Lower Proterozoic dolomite, probably belonging to the Golden Dyke Formation. Tests have produced from 20,000 to 40,000 gallons per hour from some of the bores and it is intended to connect one of the bores to the Darwin water supply and test the drawdown effect of a long-term withdrawal of about 40,000 gallons per hour.

The Water Resources Branch of the Northern Territory Administration collates all available information on both surface and underground water in the Northern Territory, and is at present engaged in detailed studies of a number of areas within the Katherine-Darwin Region.

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INDEX TO MINES AND PROSPECTS

Name	Mine, Prospect, Field, Etc.	Metals	Location Lat. S.	Location Long. E.	Reference
ABC	prospect	U	14°15′50″	132°21′10″	Pl. 32
Adelaide River	mine	U	13°16′20″	131°06′15″	Pl. 32
Afghan Gully	prospect	Au	13°33′50″	131°30′45″	Fig. 28
Airstrip	prospect	U	13°29′40″	132°29′45″	Fig. 26
Alligator	mine	Au	13°28′10″	131°24′40″	Fig. 27
Anaconda	mine	Sn	14°31′55″	132°48′15″	Fig. 36
Area 55	prospect	U,Pb,Zn,Cu	13°01′20″	130°57′40″	Fig. 25
Bamboo Creek	field, mine	Sn,Ta	13°04′20″	130°42′40″	Fig. 34
Banyan	prospect	Fe	13°05′20″	131°00′00″	Fig. 25
Barretts	mine	Sn	13°33′10″	131°17′45″	Fig. 29
Bashi Bazook	mine	Au	13°49′55″	131°49′55″	
Batchelor	prospect	Au	13°02′20″	131°03′55″	Fig. 25
Beetsons	prospect	Fe	12°53′00″	130°58′00″	Fig. 25
Bells	mine	Sn,monazite	13°59′35″	132°16′35″	Fig. 33
Bells Mona	mine	Sn	12°42′45″	130°45′50″	Fig. 34
Big Drum	mine	Sn	13°21′00″	131°48′40″	Fig. 32
Big Howley	mine	Au	13°29′00″	131°19′40″	Fig. 27
Billy Can	mine	Sn	13°19′25″	131°49′05″	Fig. 32
Black Angel	mine	Sn	13°59′40″	132°16′10″	Fig. 33
Black Hill	prospect	W,Sn	13°58′40″	132°11′30″	Fig. 33
Black Jungle Range ..	prospect	Fe	13°05′00″	132″11′00″	Pl. 32
Blyth (see Mount Tolmer)					
Bonnie Jean (see Pickfords)					
Bowerbird	mine	Cu,Pb	13°40′00″	132°12′00″	Fig. 30
Boylings	mine	Sn,Cu	14°05′40″	132°07′30″	Fig. 33
Bridge Creek	mine	Au	13°26′10″	131°18′50″	Fig. 27
Brilliant	mine	Au	13°52′10″	132°14′30″	Fig. 33
Brittania	mine	Au	13°27′30″	131°26′30″	Fig. 27
Brocks Creek	field	Au,Cu	13°28′00″	131°25′00″	Fig. 27
Brocks (see Wolfram Hill)					
Brodribb	prospect	U	12°48′40″	131°02′15″	Fig. 25
Browns	prospect	Pb,Cu,Zn	12°59′40″	130°59′45″	Fig. 25
Buffalo	prospect	Sn	13°18′10″	131°52′45″	
Buldiva	mine	Sn	14°12′15″	130°48′40″	Pl. 32
Bull	mine	Sn	14°32′15″	132°48′40″	Fig. 36
Burrundie	prospect	U	13°34′00″	131°39′20″	Fig. 28
B W	prospect	Fe	13°12′00″	130°58′00″	Fig. 25
Bynoe Harbour	field	Sn,Ta	12°44′00″	130°46′00″	Fig. 34

Name	Mine, Prospect, Field, Etc.	Metals	Location Lat. S.	Location Long. E.	Reference
Caledonia	mine	Au	13°48′20″	131°50′20″	
Carpentaria	mine	Cu	14°23′50″	132°28′10″	Pl. 32
Carruthers	prospect	Sn	13°35′25″	131°16′00″	Fig. 29
Castlemaine Hill	prospect	P,Fe	13°03′30″	131°00′25″	Fig. 25
Celia Creek	prospect	U,Cu,Pb	12°53′00″	131°00′00″	
Cemetery	mine	Au	14°26′40″	132°27′35″	
Chin Phillips	mine	Au	13°50′30″	131°50′30″	
Chinamans Hill	prospect	Sn	13°32′40″	131°17′40″	Fig. 29
Chinese Howley	mine	Au	13°30′40″	131°21′00″	Fig. 27
Christmas	mine	Au	13°50′10″	131°50′20″	
Cliff Face	prospect	U	13°32′10″	132°33′30″	Fig. 26
Coirwong	prospect	Cu	13°12′00″	132°12′30″	Pl. 32
Coirwong Gorge	prospect	U	13°13′55″	132°09′50″	Pl. 32
Collia	mine (alluvial)	Sn	14°22′00″	130°54′00″	Pl. 32
Connells	prospect	Sn	13°57′40″	132°16′00″	
Copperfield	mine	Cu	13°52′35″	131°48′30″	Fig. 31
Coronation Hill	mine	U,Au,P	13°35′20″	132°35′25″	Fig. 26
Coronet Hill	mine	Cu,Pb,Zn,As,Ag	13°44′30″	132°20′00″	Fig. 30
Cosmopolitan	lode, mine	Sn	14°28′45″	132°48′00″	Pl. 32
Cosmopolitan Howley ..	mine	Au	13°32′20″	131°22′30″	Fig. 27
Crater	prospect	Th	13°02′40″	131°02′25″	Fig. 25
Creers	mine	Au	14°03′00″	132°11′00″	
Crest of the Wave ..	mine	Sn	13°53′10″	132°12′45″	Fig. 33
Crocodile	mine	Au	13°28′00″	131°24′30″	Fig. 27
Crocodile Billabong .. .	prospect	Pb	13°59′20″	132°12′50″	Fig. 33
Czarina	mine	Au	13°50′00″	131°50′00″	
Dalhouzie	mine	Au	14°26′40″	132°27′25″	
Daly River	mine	Cu	13°40′30″	130°41′30″	Fig. 35
Davis Camp	prospect	Au	13°33′20″	131°31′30″	Fig. 28
Darwin River	prospect	Fe	12°47′00″	130°59′00″	Fig. 25
Davis and Burns (see Crest of the Wave)					
Dead Finish (see Full Hand)					
Deans Camp	mine	Sn	13°34′00″	131°41′30″	Fig. 31
Democrat	mine	Au	13°50′25″	131°50′30″	
Dolerite Ridge	prospect	U,Pb,Cu,Zn	12°59′40″	130°58′10″	Fig. 25
Doris	mine	Sn	14°05′25″	132°07′30″	
Dorisvale	prospect	Ba	14°30′00″	131°15′00″	Pl. 32
Douglas River	mine (alluvial)	Sn	13°44′00″	131°36′00″	Pl. 32
Driffield	field	Au	14°03′00″	132°11′00″	Fig. 33
Dysons	mine	U	12°59′15″	131°00′50″	Fig. 25

Name	Mine, Prospect, Field, Etc.	Metals	Location Lat. S.	Location Long. E.	Reference
Easticks	prospect	P	13°02′20″	130°59′40″	Fig. 25
Edith River	prospect	U	14°12′00″	132°03′00″	Fig. 33
El Sherana	mine	U,Au	13°30′45″	132°31′10″	Fig. 26
El Sherana West	mine	U,Au	13°30′40″	132°31′05″	
Eleanor	mine	Au	13°50′20″	131°50′25″	Fig. 31
Elizabeth	mine	Au	13°39′40″	131°45′00″	Fig. 31
Elizabeth Marion	prospect	Fe	13°34′40″	131°51′00″	Fig. 37
Ella Creek	prospect	U	12°49′35″	131°05′35″	Fig. 25
Elsinore	mine	Au	13°50′40″	131°50′40″	Fig. 31
Emerald Creek	field, mine	Sn	14°01′00″	132°10′00″	Fig. 33
Emperor	mine	Au	13°49′30″	131°49′20″	
Empire	mine	Cu	13°39′35″	130°42′15″	Fig. 35
Enterprise	mine	Au	13°49′45″	131°49′45″	Fig. 31
Ethel	mine	Sn	14°05′00″	132°07′00″	
Eureka (see Northern Hercules)					
Eureka	mine	Sn	14°32′10″	132°48′35″	Fig. 36
Evelyn	mine	Pb,Ag,Zn	13°38′50″	132°07′15″	Fig. 30
Extended Union	mine	Au	13°38′00″	131°46′00″	Fig. 31
Faded Lily	mine	Au	13°28′35″	131°25′10″	Fig. 27
Fergusson River	prospect	U	14°04′00″	131°58′30″	Fig. 33
Fletchers Gully	mine	Au	14°06′40″	130°40′40″	Pl. 32
Fleur de Lys	mine	U,Cu	13°31′40″	131°22′00″	Fig. 27
Flora Belle	mine	Pb,Zn,Ag	13°39′20″	131°45′00″	Fig. 31
Flora River	prospect	Fe	14°55′00″	131°38′00″	Pl. 32
Fords (see Old Bucks)					
Fountain Head	mine	Au	13°28′00″	131°30′30″	Fig. 27
Frances Creek	mine	Au	13°30′05″	131°51′30″	Fig. 32
Frances Creek	mine (alluvial)	Au	13°32′30″	131°54′00″	Fig. 32
Frances Creek	prospect	Fe	13°34′00″	131°51′00″	Fig. 37
Frazer	prospect	U	12°47′40″	131°08′20″	Fig. 35
Full Hand	mine	Cu,Pb,U	13°31′50″	131°16′30″	Fig. 29
Gandys Hill	lode	Au	13°49′05″	131°49′00″	Fig. 31
Gates	mine	W,Bi	14°15′20″	132°43′00″	Pl. 32
Geolsec	prospect	P	13°02′20″	130°59′40″	Fig. 25
George Creek	mine	U	13°20′15″	131°08′00″	Pl. 32
Glenys	mine (alluvial)	Sn	13°25′00″	131°54′20″	Fig. 32
Golden Boulder	mine	Au	12°42′25″	130°46′50″	Fig. 34
Golden Creek	lease	Au	14°26′40″	132°27′15″	
Golden Dyke	mine	Au	13°34′20″	131°30′55″	Fig. 28
Golden Gate	mine (alluvial)	Au	13°50′50″	131°50′40″	

NAME	MINE, PROSPECT, FIELD, ETC.	METALS	LOCATION Lat. S.	Long. E.	REFERENCE
Golden Tree	mine	Au	14°26′40″	132°27′30″	
Goodwill	mine	Sn	13°02′00″	130°42′30″	Fig. 34
Goodwill Extended	mine	Sn	13°01′00″	130°42′50″	Fig. 34
Gordon	mine	Sn	14°03′00″	132°11′00″	
Gould airfield	prospect	U,Cu,Pb,Ni	13°06′00″	131°02′30″	
Grants	mine	Sn	12°40′05″	130°46′30″	Fig. 34
Great Northern	mine	Au	13°11′00″	131°23′35″	Pl. 32
Great Western	mine	Au	13°11′00″	131°23′35″	Pl. 32
Green Ant Creek	mine	Mn	13°33′00″	131°15′20″	Pl. 32
Halls Creek	prospect	Sn	13°32′30″	131°17′40″	Fig. 29
Hang Gong Wheal of Fortune	mine	Sn	12°40′20″	130°47′30″	Fig. 34
Hardies (see McKinlay (Au))					
Harveys (see Last Hope)					
Hayes Creek	mine	Sn	13°34′00″	131°28′00″	Pl. 32
Helene	prospect	Fe	13°35′50″	131°51′10″	Fig. 37
Henry George	lease	Au	13°50′00″	131°50′20″	
Hercules (see Northern Hercules)					
Hibernia	mine	Au	14°26′30″	132°27′25″	
Hidden Valley	field	Sn,W,Pb,Ag	13°59′30″	132°16′00″	Fig. 33
Homeward Bound	mine	Au	13°28′00″	131°25′00″	
Hore and O'Connors	prospect	U	14°09′40″	131°58′10″	Fig. 33
Horseshoe	mine	Sn	13°34′40″	131°41′30″	Fig. 31
Horseshoe Creek	field	Sn	14°05′00″	132°07′00″	Fig. 33
Houschildts Rush (see Northern Hercules)					
Howley Line	lode	Au	13°30′00″	131°20′00″	Fig. 27
Ibis	mine	Sn	14°32′10″	132°47′50″	Fig. 36
Intermediate	mine	Cu	12°59′30″	131°00′05″	Fig. 25
International	mine	Au	13°49′00″	131°49′10″	
Iron Blow	mine	Cu,Pb,Zn,Au,Ag	13°30′30″	131°33′00″	Fig. 28
Irwins	mine	Cu	13°56′30″	132°14′30″	Fig. 33
Isabel	mine	Au	13°38′00″	131°46′00″	
IXL	mine	Cu	13°44′30″	132°11′30″	Fig. 30
Jack Davis Shackle (see Golden Dyke)					
Jacksons	mine	Pb,Ag	13°31′20″	131°16′45″	Fig. 29
Jasmine	prospect	Fe	13°34′40″	131°51′00″	Fig. 37

NAME	MINE, PROSPECT, FIELD, ETC.	METALS	LOCATION Lat. S.	Long. E.	REFERENCE
Jessops	mine	Sn	13°19′15″	131°49′00″	Fig. 32
Jimmys Knob (see Deans Camp)					
John Bull	mine	Au,Cu	13°27′40″	131°23′40″	Fig. 27
Jones Brothers	mine	Au	14°07′30″	132°06′45″	Fig. 33
Jubilee Hill (see Cosmopolitan Howley)					
Kapalga	prospect	Fe,Ti	12°33′30″	132°18′15″	Pl. 32
Keenans	mine	Sn	14°05′00″	132°07′00″	
Kellys	mine	Sn	13°51′00″	131°51′20″	Fig. 31
Kellys	prospect	Sn,W	13°58′30″	132°16′15″	
King River	mine	Sn	14°25′30″	132°41′20″	Pl. 32
Klondyke	mine	Sn	14°32′40″	132°48′20″	Fig. 36
Knowles Farm	prospect	Pb,Zn,Cu,Au	13°41′25″	130°40′40″	Fig. 35
Kohinoor	mine	Au	13°50′20″	131°50′30″	Fig. 31
Koolpin Creek	mine	U	13°31′40″	132°32′40″	Fig. 26
Lady Alice	reef, group of mines	Au	13°42′30″	131°47′00″	
Lady Jane	mine	Au	14°03′00″	132°11′00″	
Lady Mary	mine	Au	14°03′00″	132°11′00″	
Lady Maud	mine	Au	14°26′35″	132°27′50″	
Last Hope	mine	Au	13°55′30″	132°13′30″	Fig. 33
Lees	mine	Sn	12°41′40″	130°47′30″	Fig. 34
Leviathan	mine	Sn	12°47′25″	130°43′00″	Fig. 34
Lucknow	mine	Pb,Ag	13°52′10″	131°50′05″	Fig. 31
Lucy	mine	Sn	12°50′25″	130°40′30″	Fig. 34
Lucys (see Glenys)					
Ludan	prospect	Au	14°14′00″	132°49′00″	Pl. 32
McCarthys	mine	Pb,Ag	13°45′00″	132°05′00″	Fig. 30
Mackay and Frances	mine	Cu,Au	13°27′20″	131°22′45″	Fig. 27
McKeddies Diggings	prospect	Au	13°27′00″	131°51′25″	Fig. 32
McKinlay	mine	Au	13°24′05″	131°44′10″	Fig. 32
McKinlay	mine	Ag,Pb	13°38′00″	131°44′00″	Fig. 31
Madigans	prospect	monazite	12°43′40″	130°49′25″	Fig. 34
Maid of Erin	mine	Au	13°49′15″	131°49′20″	Fig. 31
Manton	prospect	Th	12°52′00″	131°07′00″	Fig. 25
Maranboy	field	Sn	14°32′00″	132°48′00″	Fig. 36
Margaret	prospect	Sn	13°18′30″	131°53′00″	
Margaret Diggings	mine (alluvial)	Au	13°36′10″	131°34′30″	Fig. 28
Marie	mine	Sn	14°05′25″	132°07′40″	
Marion Hill	prospect	Cu	13°38′30″	130°40′25″	Fig. 35
Martins	prospect	Sn	13°57′00″	132°15′30″	

Name	Mine, Prospect, Field, Etc.	Metals	Location Lat. S.	Location Long. E.	Reference
Mary River Camp	mine (alluvial)	Sn	13°42′00″	132°20′00″	Fig. 30
Mary River Junction . .	mine	Cu	13°39′00″	132°20′00″	Fig. 30
Maud Hill	mine	Au	14°26′35″	132°27′25″	
Maude Creek	field	Au	14°27′00″	132°28′00″	Pl. 32
Mavis	mine	Sn	13°28′00″	131°41′30″	Fig. 32
Maybell (see Northern Hercules)					
Michaelmas	lease	Au	13°50′15″	131°50′35″	
Minglo	mine	Pb,Ag	13°20′45″	132°00′40″	Pl. 32
Monarch	lease	Au	13°49′35″	131°49′35″	
Monolith	prospect	U	13°31′10″	132°32′25″	Fig. 26
Morning Star	mine	Au	13°28′35″	131°25′30″	
Morris	mine	Sn	14°08′05″	132°08′20″	Fig. 33
Mount Bonnie	mine	Cu,Pb,Zn,Au,Ag	13°32′40″	131°32′45″	Fig. 28
Mount Bundey (see Pritchards Lode)					
Mount Burton	mine	U,Cu	12°58′50″	130°57′50″	Fig. 25
Mount Davis	mine	Cu	13°45′30″	132°17′05″	Fig. 30
Mount Diamond	mine	Cu	13°45′45″	132°14′15″	Fig. 30
Mount Ellison	mine	Cu,Bi	13°21′30″	131°30′20″	Fig. 27
Mount Finniss	mine	Sn,Ta	12°57′20″	130°47′20″	Fig. 34
Mount Fitch	prospect	U,Cu	12°57′00″	130°57′00″	Fig. 25
Mount Gardiner	mine	Cu,Pb,Ag	13°45′00″	132°10′00″	Fig. 30
Mount Gates	mine	Au	14°24′00″	132°22′00″	Pl. 32
Mount George	mine	Sn	13°22′20″	131°50′40″	Fig. 32
Mount Harris	field	Sn	13°18′00″	131°53′00″	Fig. 32
Mount Mabel	prospect	Fe	13°10′00″	130°56′00″	Fig. 25
Mount Masson	mine	Sn	13°20′00″	131°49′00″	Fig. 32
Mount Minza	prospect	Cu,Pb,Zn	13°08′00″	131°03′00″	Fig. 25
Mount Pacqualin	prospect	Au	13°23′00″	131°19′00″	Fig. 27
Mount Ringwood	mine	Au	13°10′00″	131°37′30″	Pl. 32
Mount Shoobridge	mine	Sn	13°32′10″	131°17′30″	Fig. 29
Mount Todd	field	Au,Sn	14°07′00″	132°07′00″	Fig. 33
Mount Tolmer	mine	Sn(Fe)	13°14′00″	130°43′25″	Pl. 32
Mount Tolmer South . .	prospect	Cu	13°22′10″	130°46′30″	Pl. 32
Mount Tymn	mine	Au	13°18′25″	131°13′00″	Pl. 32
Mount Wells	mine	Sn,Cu	13°30′20″	131°42′40″	Fig. 32
Mount Wigley	mine	Pb,Ag	13°53′00″	131°50′00″	Fig. 31
Mountain View	mine	W	13°58′50″	132°15′10″	Fig. 33
Muldiva	mine	Sn	14°11′50″	130°48′30″	Pl. 32
Mundic	mine	Sn	13°33′45″	131°42′10″	Fig. 31
Mundogie Hill	prospect	Au	13°03′50″	132°20′00″	Pl. 32
Myra Falls	prospect	Sn	12°27′00″	133°19′40″	Pl. 32
Mystery	mine	Au	14°26′45″	132°27′35″	

Name	Mine, Prospect, Field, Etc.	Metals	Location Lat. S.	Location Long. E.	Reference
Namoona	prospect	Pb	13°20′00″	132°05′30″	Pl. 32
Neates Gully	mine (alluvial)	Au	13°30′05″	131°32′50″	Fig. 28
Nellie Creek	mine (alluvial)	Sn	13°39′00″	131°55′00″	Pl. 32
Nelson	prospect	Sn	13°17′40″	131°53′00″	
New Mount Todd (see Quigleys Reef)					
New Thunderer	mine	Au	13°50′10″	131°50′10″	
New Year	lease	Au	13°50′15″	131°50′25″	
Newcastle	lease	Au	13°49′25″	131°49′25″	
North Australian	mine (alluvial)	Au	13°50′20″	131°50′15″	
North Enterprise	mine	Au	13°49′40″	131°49′40″	
North Star	mine	Au	13°50′45″	131°50′45″	
Northern Hercules	mine	Au,Pb,Cu	13°40′15″	132°09′10″	Fig. 30
Nourlangie Creek	prospect	Fe	13°13′30″	132°49′00″	Pl. 32
O'Sullivans Camp . .	mine	W,Sn	14°15′20″	132°44′00″	Pl. 32
Ochre Hill	prospect	Fe	13°32′00″	132°51′25″	Fig. 37
Old Bucks	mine	Sn	12°46′50″	130°43′30″	Fig. 34
Old Company (see Mount Shoobridge)					
Ophir	mine	Au	13°49′55″	131°50′10″	
Osman	mine	Sn	14°31′50″	132°48′05″	Fig. 36
Palette	mine	U,Au	13°32′20″	132°33′50″	Fig. 26
Parrys	mine	Au	14°03′00″	132°11′00″	
Penders Hill	mine	Au	13°38′00″	131°46′00″	
Philips Greets	mine	Cu	13°32′30″	131°18′40″	Fig. 29
Picketts	mine	amblygonite	12°51′15″	130°45′30″	Fig. 34
Pickfords	prospect	Pb,Ag	13°32′35″	131°36′10″	Fig. 28
Pighole	mine	Au	12°55′15″	131°28′45″	Pl. 32
Pine Creek	field	Au	13°50′00″	131°50′00″	Fig. 31
Port Darwin Camp . . .	mine (alluvial)	Au	13°31′50″	131°32′30″	Fig. 28
Princess Louise	mine	Au	13°30′05″	131°32′50″	Fig. 28
Priscilla Line	line of lode	Au	13°30′00″	131°32′30″	Fig. 28
Pritchards Lode	prospect	Fe	12°51′10″	131°35′30″	Pl. 32
Progress	mine	Sn	14°32′35″	132°48′15″	Fig. 36
Pyromorphite Show . . .	prospect	Pb	13°32′20″	131°17′40″	Fig. 29
Quigleys Reef	mine	Au	14°06′25″	132°07′30″	Fig. 33
Rack-a-Rock	mine (alluvial)	Au	13°50′30″	131°50′20″	
Radfords Blow	mine	Au	13°30′45″	131°32′40″	Fig. 28
Ransfords (see Mary River Junction)					

NAME	MINE, PROSPECT, FIELD, ETC.	METALS	LOCATION Lat. S.	Long. E.	REFERENCE
Ray	mine	Sn	14°32′00″	132°48′25″	Fig. 36
Red Cross	mine	Sn	14°32′45″	132°48′25″	Fig. 36
Republic	mine	Au	13°50′25″	131°50′35″	
Rising Sun	mine (alluvial)	Au	13°50′40″	131°50′30″	
Rising Tide	prospect	Cu	13°27′05″	131°25′40″	Fig. 27
Rockhole	mine	U,Au	13°28′30″	132°27′40″	Fig. 26
Rosemary	prospect	Fe	13°34′40″	131°52′20″	Fig. 37
Ross	prospect	Sn	13°43′45″	132°19′30″	Fig. 30
Rum Jungle	field	U,Cu,Pb,P	13°00′00″	131°00′00″	Fig. 25
Rum Jungle Creek South	mine	U	13°02′30″	130°59′40″	Fig. 25
Saddle	prospect	Fe	13°31′10″	131°50′45″	Fig. 37
Saddle Extended	prospect	Fe	13°29′40″	131°49′50″	Fig. 37
Saddle Ridge	mine	U	13°33′10″	132°34′05″	Fig. 26
Sagabiel	mine	Au	13°50′00″	131°50′10″	
Sandy Creek	mine (alluvial)	Au	13°32′10″	131°32′00″	Fig. 28
Sandy Creek	prospect	Sn	14°15′00″	132°46′00″	Pl. 32
Saunders Rush	mine	Au	13°50′40″	132°15′50″	Fig. 33
Scinto 1	prospect	U	13°32′20″	132°33′30″	Fig. 26
Scinto 5	mine	U	13°32′00″	132°33′00″	Fig. 26
Scinto 6	mine	U	13°31′30″	132°33′45″	Fig. 26
Scotchman	mine	Sn,Cu	14°05′00″	132°07′25″	Fig. 33
Shackle (see Golden Dyke)					
Shamrock	mine	Sn	14°09′15″	132°06′25″	Fig. 33
Silver Spray	mine	Pb,Zn,Ag	13°54′50″	132°18′05″	Fig. 33
Skull	mine	U	13°32′35″	132°39′00″	Fig. 26
Sleisbeck	mine	U	13°47′00″	132°49′00″	Pl. 32
Snaddens Creek	mine (alluvial)	Sn	13°38′00″	131°43′00″	Fig. 31
South Alligator River . .	field	U,Au	13°30′00″	132°30′00″	Fig. 26
Southern Claims	mines	Sn	14°32′20″	132°48′50″	Fig. 36
Southern Cross	mine	Au	13°50′00″	131°50′15″	Fig. 36
Spring Hill	mine	Au	13°36′15″	131°43′10″	Fig. 31
Spring Peak	prospect	Sn	12°59′00″	132°29′00″	Pl. 32
Stannum King	lode, mine	Sn	14°32′30″	132°48′10″	Fig. 36
Stapleton	prospect	magnesite,P	13°10′00″	131°00′01″	Fig. 25
Stapleton (see Virginia)					
Star of the North . .	mine	Au	13°07′50″	131°20′30″	Pl. 32
Star of the West	mine	Sn	14°31′45″	132°48′00″	Fig. 36
Stray Creek	mine (alluvial)	Sn	13°52′00″	131°41′00″	Pl. 32
Stuarts Gully	mine (alluvial)	Au	13°32′10″	131°32′00″	Fig. 28
Sultana	mine	Au	13°49′45″	131°49′55″	
Sydney	mine (alluvial)	Au	13°50′50″	131°50′50″	

NAME	MINE, PROSPECT, FIELD, ETC.	METALS	LOCATION Lat. S.	Long. E.	REFERENCE
Tableland	prospect	Pb,Zn	13°54′05″	132°18′30″	Fig. 33
Teagues	mine	U,Au	13°28′25″	132°27′35″	Fig. 26
Temperance	mine	Au	13°29′15″	131°32′50″	Fig. 28
Tennysons	prospect	U	14°13′00″	132°00′00″	Fig. 33
Thelma Frances	prospect	Fe	13°34′30″	131°51′30″	Fig. 37
Tollis	mine	Au	14°07′50″	132°06′35″	Fig. 33
Tolmer	prospect	U	13°09′00″	130°53′00″	Fig. 25
Twelve-mile (see Snaddens Creek)					
Umbrawarra	mine (alluvial)	Sn	13°57′00″	131°44′00″	Pl. 32
Union Reefs	field	Au	13°43′00″	131°47′00″	Fig. 31
Union	reef, group of mines	Au	13°42′45″	131°47′20″	Fig. 31
Victoria	mine	Au	13°28′35″	131°25′30″	
Virginia	mine	Au	13°10′40″	131°03′20″	Fig. 25
Vulcan	mine	Sn	13°59′45″	132°15′30″	Fig. 33
Waldens	mine	Cu	13°45′35″	132°14′20″	Fig. 30
Waldens	mine	Sn	13°45′00″	132°01′00″	Pl. 32
Wallaby	prospect	Cu,Pb,Zn	13°39′00″	130°42′30″	Fig. 35
Wandie	mine	Au	13°48′30″	132°11′30″	Fig. 33
Warrs	mine	Cu	13°37′20″	130°43′00″	Fig. 35
Waterhouse No. 1	prospect	U,Cu	13°06′00″	131°03′45″	Fig. 25
Waterhouse No. 2	prospect	Cu,U	13°08′30″	131°01′40″	Fig. 25
Waterhouse No. 3	prospect	U	13°09′40″	131°02′30″	Fig. 25
Waterhouse No. 4	prospect	U	13°06′40″	131°01′30″	Fig. 25
Watts Creek	mine (alluvial)	Au	13°33′30″	131°49′30″	Fig. 32
West Arm	field	Sn,Ta	12°40′00″	130°48′00″	Fig. 34
Wests	mine	Pb	13°59′50″	132°15′15″	Fig. 33
Whatleys	prospect	Pb	13°34′30″	131°18′00″	Fig. 29
Wheal Danks	mine	Cu	13°39′00″	130°42′00″	Fig. 35
Whites	mine	U,Cu,Pb,Co,Ni	12°59′25″	131°00′25″	Fig. 25
Wolfram Hill	mine	W,Cu	13°56′40″	132°14′50″	Fig. 33
Woodcutters	prospect	U,Pb,Zn,Cu	12°55′45″	131°07′20″	Fig. 25
Woodcutters South	prospect	Pb,Zn	12°57′40″	131°06′35″	Fig. 25
Woolgni	field	Au	14°05′00″	131°58′00″	Fig. 33
Woolwonga	mine	Au	13°24′30″	131°33′00″	Fig. 27
Yam Creek	mine, field	Au	13°29′40″	131°32′50″	Fig. 28
Yemelba	mine	Au	13°09′30″	132°28′30″	Pl. 32
Yenberrie	field	W,Mo,Bi	14°08′00″	132°04′00″	Fig. 33

Name	Mine, Prospect, Field, Etc.	Metals	Location Lat. S.	Location Long. E.	Reference
Yenberrie	prospect	U	14°07′20″	132°02′30″	Fig. 33
Yeuralba	field	W,Sn,Cu,Bi	14°17′00″	132°43′00″	Pl. 32
Yeuralba King	mine	Sn	14°16′10″	132°48′00″	Pl. 32
Y.M.C.A. (see Edith River)					
Zamu Creek	mine	Pb,Zn	13°34′20″	132°43′15″	Fig. 26
Zapopan	mine	Au,Pb	13°28′40″	131°25′50″	Fig. 27

APPENDIX 1

PERSONNEL ENGAGED IN REGIONAL MAPPING OF THE KATHERINE-DARWIN REGION, 1951-58

Field Party	Year	Area	Type of Investigation	Personnel (*Party Leader)
Rum Jungle	1951-52	Rum Jungle	Mainly detailed mapping of the Rum Jungle embayment area; some reconnaissance of surrounding area	R. S. Matheson (Senior Geologist), H. J. Ward, E. K. Carter, N. J. Mackay
Maranboy	1951-52	Maranboy	Detailed mapping of Maranboy tinfield, reconnaissance of Black Cap, Waterhouse, Maranboy, and Katherine R. 1-mile Sheets	B. P. Walpole,* G. Sleis (1951), N. J. Mackay (1951), B. J. Drew (1952)
Fergusson River	1951	Lewis Spring 1-mile Sheet	Detailed reconnaissance at 1-mile scale of part of Lewin Springs 1-mile Sheet	E. K. Carter
Brodribb	1953	Rum Jungle district	Reconnaissance of Marrakai and part of Tumbling Waters 1-mile Sheets	B. P. Walpole,* K. G. Smith, D. Catley
Mount Evelyn	1953	Mt Evelyn 1:250,000 Sheet	Reconnaissance	B. P. Walpole,* B. J. Drew, R. A. Britten, D. A. White
Edith River	1953	Lewin Springs, Katherine, and Mt Todd 1-mile Sheets	Detailed reconnaissance	J. H. Rattigan,* A. B. Clark
Waterhouse	1953	Rum Jungle district	Reconnaissance	F. J. Frankovich* (USAEC), G. F. Joklik, J. B. Firman.
Ban Ban	1954	Ban Ban, Burrundie, and Table Top 1-mile Sheets	1-mile reconnaissance mapping	B. P. Walpole (Senior Geologist), D. A. White*, P. R. Dunn, H. G. Quinlan, L. Fordon-Bellgrove
Tipperary	1954	Tipperary, Burnside, Mt. Stow, and part of Mt Evelyn 1-mile Sheets	1-mile reconnaissance mapping	K. G. Smith,* E. J. Malone, J. R. Stewart

Field Party	Year	Area	Type of Investigation	Personnel (*Party Leader)
Goodparla	1955	Goodparla N., Goodparla S., and Mundogie Hill 1-mile Sheets	1-mile detailed reconnaissance	B. P. Walpole (Senior Geologist), W. C. White,* P. R. Dunn, F. de Keyser, J. E. Johnson
Daly River	1955	Burnside, Reynolds R., Mt Hayward, Daly R., and Muldiva Ck 1-mile Sheets	1-mile detailed reconnaissance	D. A. White,* E. J. Malone, M. A. Randal, O. N. Warin, J. C. Foweraker
Ranford	1955	Mt. Evelyn and Ranford Hill 1-mile Sheets	1-mile detailed reconnaissance	C. E. Prichard,* J. R. Stewart, K. K. Hughes, J. Barrie, D. B. Dow
Woolwonga	1956	Woolwonga, Mt Bundey, and part of Humpty Doo and Marrakai 1-mile Sheets. Parts of Darwin, Pine Ck, Fergusson R., Alligator R., Katherine, and Mt Evelyn 1:250,000 Sheets	Detailed reconnaissance of 1-mile Sheets and reconnaissance mapping of E. part of Darwin, W. part of Alligator R., and parts of Pine Ck, Fergusson R.. Katherine, and Mt Evelyn 1:250,000 Sheets	P. R. Dunn,* D. B. Dow, P. W. Pritchard, M. A. Randal
Marrakai	1956	Adelaide R., Darwin area.	Marrakai W., Humpty Doo W., Mt Tolmer, Batchelor, Tumbling Waters and Southport 1-mile Sheets in detailed reconnaissance. Reconnaissance mapping of other parts of Darwin 1:250,000 Sheet	E. J. Malone,* O. N. Warin, H. L. Davies, W. A. Robertson, S. M. Hasan
Fergusson River	1957	Fergusson R., and part of Port Keats 1:250,000 Sheets	Ground and helicopter reconnaissance mapping	M. A. Randal*
Alligator River	1957	E. part of Alligator R. 1:250,000 Sheet	Reconnaissance mapping	P. R. Dunn* (6 weeks only), J. H. Herlihy
Urapunga	1958	E. half of Katherine 1:250,000 Sheet	Detailed reconnaissance of Waterhouse, Black Cap, and Diljin Hill 1-mile Sheets	P. R. Dunn,* R. A. Ruker, R. Bryan

The following also contributed to mapping of the Katherine-Darwin Region: P. H. Dodd (USAEC) 1953-54, K. W. A. Summers, 1956

APPENDIX 2

AGE DETERMINATIONS, KATHERINE-DARWIN REGION

Tables A, B, C, and D summarize the published and unpublished results of age determination work carried out on samples from the Katherine-Darwin Region. Leggo's results (Table A) most probably represent the true age of the samples. The scatter of potassium-argon ages (Table B) presented by Hurley et al. (1961) suggests that there has been some argon loss from most of the samples, thus giving an age too young. J. R. Richards (ANU, pers. comm.) now doubts the significance of many of the model lead ages he had previously determined (Table C), and suggests that they all represent a younger age than the age of formation of the galena; he also considers the lead-alpha age on zircon (Table C), and the uranium-lead and lead-lead ages on disseminated pitchblende and uraninite (Tables C and D) are no longer (1965) reliable indicators of the age of formation of the respective minerals.

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TABLE A: Rb/Sr AGES ON TOTAL ROCK SAMPLES

(Leggo, pers. comm.)

Sample No.		*Rock Unit*	*Locality*		*Age†*
ANU	*BMR*		*Lat S.*	*Long. E.*	
GA1182	D53/5/4	Edith River Volcanics	13°41′	132°40′	
GA1183	D53/5/5	Edith River Volcanics	13°40′	132°39′	
GA1184	D53/9/2	Edith River Volcanics	14°12′	132°11′	
GA25	D52/8/5	Cullen Granite*	13°46′	131°37′	
GA1228	D53/9/10	Cullen Granite	14°11′	132°01′	
GA1381	D52/8/20	Prices Springs Granite	13°29′	131°36′	
GA1382	D52/8/21	Prices Springs Granite	13°29′	131°37′	All fit the
GA16	D52/8/8	Litchfield Complex*	13°30′	130°42′	1760-m.y.
GA19	D52/4/5	Mount Bundey Granite*	12°54′	131°34′	isochron
GA13	D52/8/7	Allia Creek Granite*	13°57′	130°40′	
GA1226	D52/8/25	Burnside Granite	13°26′	131°25′	
GA1227	D52/8/26	Burnside Granite	13°25′	131°21′	
GA1232	D53/5/6	Malone Creek Granite	13°36′	132°39′	
GA1233	D53/5/7	Malone Creek Granite	13°36′	132°39′	
GA1234	D53/9/11	Grace Creek Granite	(A number of random)		
GA1235	D53/9/12	Grace Creek Granite	(samples from the)		All fit the
GA1236	D53/9/13	Grace Creek Granite	(southern part of)		1470-m.y.
GA1237	D53/9/14	Grace Creek Granite	(the granite)		isochron

† $\lambda = 1.39 \times 10^{-11}$ per year.

* Material from sample used by Hurley et al. (1961) for K/Ar work (Table B)

NOTE: Compston (pers. comm.) has made a preliminary re-assessment of Leggo's data and has obtained an isochron of a little over 1800 m.y. for most of these granites. Data from three of the four Grace Creek samples also fit an 1800+ m.y. isochron. The fourth sample appears to be anomalous and was responsible for the younger isochron (1470 m.y.) obtained by Leggo for all the Grace Creek Granite samples.

TABLE B: K/Ar (and one Rb/Sr) AGES ON MINERAL SEPARATIONS

(Hurley et al., 1961; Walpole & Smith, 1961)

Sample No.		*Rock Unit*	*Locality*		*Age**
MIT	*BMR*		*Lat. S.*	*Long. E.*	*(m.y.)*
3327	D52/8/4	Fenton Granite	13°37′	131°24′	1720 (biotite)
3328	(?)	Litchfield Complex	14°02′	130°33′	1560 (biotite)
3330	D52/8/7	Allia Creek Granite	13°57′	130°40′	1650 (biotite) 1640 (muscovite)
3331	D52/4/4	Litchfield Complex	12°56′	130°40′	1630 (biotite)
3332	D52/8/8	Litchfield Complex	13°30′	130°42′	1595 (biotite) 1605 (muscovite)
3334	D52/8/1	Burnside Granite	13°25′	131°24′	1520 (biotite)
3335	D53/9/1	Cullen Granite	14°12′	132°02′	1695 (biotite)
3336	D52/4/5	Mount Bundey Granite	12°54′	131°34′	1650 (biotite)
3337	D52/8/3	Prices Springs Granite	13°30′	131°37′	1695 (biotite)
3340	D52/8/5	Cullen Granite	13°46′	131°51′	1695 (biotite)

* λ e = 0.585 x 10^{-10} per year; λ = 5.30 x 10^{-10} per year.

A check Rb/Sr determination was made by Hurley et al. on sample No. 3335; it gave an age of 1765±90 m.y.

TABLE C: MODEL LEAD AGES

(Richards, 1963)

Sample No.	Locality	Model Ages (m.y.)			
		(a)	(b)	(c)	(d)
Pb- 7	Namoona prospect	(1580)	(1610)	(1579)	(1691)
- 8	Rum Jungle, Whites open cut ..	(1298)	(1317)	(1295)	(1418)
-10	Minglo prospect	(1630)	(1544)	(1637)	(1747)
-22a)	Whites mine, Rum Jungle	(1037)	(1428)	(1052)	(1185)
-22b)	.. ..	(1092)	(1382)	(1119)	(1249)
-22c)	.. ..	(1146)	(1447)	(1142)	(1271)
-23	Whites mine, Rum Jungle	(1256)	(1425)	(1267)	(1290)
-24	Whites mine, Rum Jungle	1535	1425	1542	1656
-26	Browns camp, Rum Jungle	1504	1382	1516	1630
-27	Browns camp, Rum Jungle	1525	1452	1529	1642
-54)	.. ..	(971)	(1436)	(970)	(1106)
-55)	.. ..	(1428)	(1447)	(1424)	(1541)
-56)	.. ..	1525	1452	1531	1644
-57)	.. ..	1514	1506	1508	1622
-58)	.. ..	1504	1512	1498	1609
-59)	From drillholes on	1525	1463	1513	1627
-60)	Whites-Browns line of	1525	1539	1513	1627
-61)	mineralization	1525	1501	1527	1641
-62)	.. ..	1514	1528	1513	1627
-63)	.. ..	1525	1441	1529	1642
-64)	.. ..	1535	1490	1527	1641
-65)	.. ..	1525	1458	1517	1631

(a) Russell-Farquhar (1960) model t_{6-7}
(b) Russell-Farquhar (1960) model t_{8-4}
(c) Holmes-Houtermans (Moorbath, 1962) model — $t_0 = 4.55 \times 10^9$ year
(d) Holmes-Houtermans (Moorbath, 1962) model — $t_0 = 4.51 \times 10^9$ year

Ages in brackets regarded as anomalous. Richards considers ages calculated by method (a) as most reliable. Richards quotes U/Pb determinations on a sample of pitchblende from Whites mine. It gives the following ages:

$t_{206/238} = 560$ m.y.; $t_{207/235} = 658$ m.y.; $t_{207/206} = 1015$ m.y.; $t_{208/232} > 6 \times 10^9$y.

Richards also quotes a Pb/α determination on zircon from the Rum Jungle Complex giving an age of 1889 m.y. and a K/Ar age on a sample from the same complex of 1610 m.y.

TABLE D: U/Pb AGE DETERMINATIONS ON URANINITE

(Greenhalgh & Jeffery, 1959)

Locality	*206/238*	*Age (m.y.) 207/235*	*207/206*
Adelaide River mine	1450 ± 30	1110 ± 75	470 ± 250
Fleur de Lys mine	576 ± 17	627 ± 80	816 ± 400
Sleisbeck	305 ± 3	370 ± 25	816 ± 150
El Sherana 1	605 ± 1	743 ± 5	1196 ± 18
El Sherana 2	388 ± 1	447 ± 2	766 ± 12
Palette lode 1	683	695	729 ± 2
Palette lode 2	612 ± 2	635 ± 7	719 ± 30
Palette lode 3	500 ± 1	507 ± 3	533 ± 20
Palette lode 4	509 ± 1	506 ± 3	494 ± 18
Palette lode 5	476 ± 1	542 ± 1	830 ± 20

APPENDIX 3

PETROGRAPHY AND MINERAGRAPHY OF A SPECIMEN FROM THE KOOLPIN FORMATION

(DDH No. 1, 60 feet vertical depth, Rockhole mine, South Alligator River, Mount Evelyn 1 : 250,000 Sheet)

by R. D. Stevens (Petrography) and W. M. B. Roberts (Mineragraphy)

The hand specimen is a dark to black very fine-grained thinly bedded rock containing light grey nodules and bands of chert parallel to the bedding. Veins of quartz and calcite cut the rock parallel and normal to the bedding. Pyrite is scattered through all but the chert nodules; it is concentrated in the quartz veins and around the edges of the chert nodules.

The rock mainly consists of silt-sized lenticular to subspherical particles of cloudy dolomite set in matrix of very fine dense graphite or non-crystalline dolomite with some cryptocrystalline silica. A distinctive banding is produced by alternating laminae with a dolomitic or graphitic matrix. The rock is mainly a pyritic carbonaceous marl.

The nodules and bands of chert are confined to the bands with a dolomitic matrix. In places, the matrix has been partly replaced by cryptocrystalline silica to produce incipient chert nodules containing numerous dolomite lenticles. The nodules were apparently formed by a complete diagenetic replacement by chert of some of the material in the dolomite bands. The banding in the unreplaced marl is arched around the nodules, which suggests that the nodules were formed before the rock was consolidated.

The quartz veins range from less than 0.05 to 0.6 mm in width; the wider veins are generally normal to the bedding and the thinner ones parallel to the bedding. The veins transect both the marl and chert nodules. The calcite veins are generally less than 0.2 mm wide and are parallel to the bedding; they are cut by the quartz veins in places.

The pyrite is largely associated with the quartz veins and forms irregular masses up to 8 mm long within the vein. The amount of pyrite present is roughly proportional to the amount of quartz; this suggests that the pyrite was introduced at the same time as the quartz veins.

The graphite, which is crystalline, is in places also associated with the quartz, in which it forms irregular aggregates up to 0.25 mm long. It was probably derived from the sediment and redeposited in the quartz.

A little chalcopyrite is scattered through the rock, and in places it is associated with the calcite. It forms rounded grains up to 0.04 mm across.

APPENDIX 4

LIST OF CRETACEOUS FOSSILS, KATHERINE-DARWIN REGION

The following are lists of Lower Cretaceous macrofossils collected by Skwarko (1966) in the Katherine-Darwin Region between 1960 and 1962. They are listed under localities. The determinations of most of the plant remains are those of M. E. White; the naming of Mollusca is almost entirely by Skwarko. Most of the non-molluscan invertebrates such as corals, bryozoans, and brachiopods still await identification and description.

TT1: Larrakeyah Quarry, Darwin (Darwin Sheet). Lat. 12°28'S., long. 130°50'E. Upper Albian or lower Cenomanian.
Ammonite indet.
Belemnites (Dimitobelidae) indet.

TT2: Myilly Point, Darwin (Darwin Sheet). Lat. 12°27'S., long. 130°49'E. Upper Albian or lower Cenomanian.
Belemnites (Dimitobelidae) indet.

TT3: 4.8 miles N. of Pine Creek, 30 feet below top of mesa to W. of Stuart Highway (Pine Creek Sheet). Lat. 13°47'S., long. 131°47'E. Unit B (Aptian).
Plant remains indet.

TT4: 7.0 miles N. of Pine Creek, 25 feet below top of mesa to W. of Stuart Highway (Pine Creek Sheet). Lat. 13°47'30"S., long. 131°44'30"E. Unit B (Aptian).
Plant remains indet.

TT9: 7 miles N. of Beswick homestead, 0.25 miles at 125° from Baker Creek crossing (Baker Creek is a tributary of the Waterhouse River) (Katherine Sheet). Lat. 14°28'S., long. 133°08'E. Unit 2 (late Neocomian).
Maccoyella sp. cf. *M. corbiensis* (Moore, 1870).
Belemnites indet.
Crinoid spines.
Roots indet.

TT10: 7 miles N.W. of Maranboy-Mainoru road, W. bank of Bukalorkmi Creek (Katherine Sheet). Lat. 14°23'30"S., long. 133°26'30"E. Unit 2 (late Neocomian).
Pseudavicula dickinsi Skwarko, 1966.
Syncyclonema territorianum Skwarko, 1966.
Camptonectes magnificus Skwarko, 1966.
Trigonia sp. indet.
Eriphyla(?) bauhiniana Skwarko, 1966.
Dosiniopsis(?) sp.
Pelecypods indet.
Brachiopods indet.
Belemnites indet.

TT11: 2 miles N. of locality TT10 (Katherine Sheet. Lat. 14°22'30"S., long. 133°25'30"E. Unit A (?Neocomian, Aptian).
(?)*Ptilophyllum oligoneurum* Tenison Woods, 1883.
(?)*Otozamites feistmanteli* Zigno, 1881.

TT12: 1.5 miles N. of Maranboy-Mainoru road, about 17 miles from Sugarbag Waterhole (Katherine Sheet). Lat. 14°26'S., long. 133°28'E. Unit 2 (late Neocomian).
Worm borings.

TT13: Yeuralba, 28 miles N. of Maranboy police station (Katherine Sheet). Lat. 14°17'S., long. 132°49'E. Unit 2 (late Neocomian).
Brachiopods indet.
Worm borings indet.
Root remains indet.

TT14: 13 miles E. of Beswick homestead, just E.S.E. of Sugarbag Waterhole (Katherine Sheet). Lat. 14°33'S., long. 133°17'E. Unit 2 (late Neocomian).
Ammonite fragments indet.
Belemnite fragments indet.

TT15: Shoal Bay, about 6 miles S. of Gunn Point (Darwin Sheet). Lat. 12°15'S., long. 131°01'E. Upper Albian.
Ammonites.
Gastropods.
Pelecypods.
Crustaceans.

TT16: 6 miles E. of Beswick homestead, about 3 miles S. of Maranboy-Mainoru road (Katherine Sheet). Lat. 14°35'S., long. 133°13'30"E. Unit 2 (late Neocomian).
Ammonite fragments indet.
Belemnite fragments indet.

TT17: About 2 miles E.S.E. of locality TT16 (Katherine Sheet). Lat. 14° 36'S., long. 133°15'E. Unit 2 (late Neocomian).
Australiceras sp. nov. aff. *A. jacki* (Etheridge Jnr, 1880).
Ammonite fragments indet.

TT18: 10 miles E. of Beswick homestead, 5.5 miles S. of Maranboy-Mainoru road (Katherine Sheet). Lat. 14° 38'S., long. 133°14'30"E. Unit A (?Neocomian, Aptian).
Ptilophyllum pecten (Phillips, 1829).
Ptilophyllum oligoneurum Zigno, 1881.
Otozamites bengalensis (Oldham & Morris, 1862).
Taeniopteris spatulata McClelland, 1850.
Elatocladus sp.
Equisetalean stem indet.

TT19: Halfway between TT10 and TT11 (Katherine Sheet). Lat. 14°23'30" S., long. 133°26'E. Unit 2 (late Neocomian).
Wood fragments indet.
Worm borings indet.

TT40: About 5 miles S.E. of Coronet Hill mine, 2 miles E. of S. tip of Little Mary Waterhole (Mount Evelyn Sheet). Lat. 13°46'S., long. 132°24'E.
Syncyclonema territorianum Skwarko, 1966.
Pelecypods indet.

TT49: 1.2 miles N. of edge of plateau in cliffs facing Katherine River across main Yeuralba mine road (Katherine Sheet). Lat. 14°17'S., long. 132°43'E. Unit 2 (late Neocomian).
Maccoyella sp. cf. *M. corbiensis* (Moore, 1870).
Pseudavicula dickinsi Skwarko, 1966.
Syncyclonema territorianum Skwarko, 1966.
Camptonectes magnificus Skwarko, 1966.
Neithea sp. cf. *N. occidentalis* (Conrad, 1855).
Lima sp.
Pterotrigonia (Rinetrigonia) capricornia Skwarko, 1963.
Nototrigonia yeuralba Skwarko, 1963.
Crinoid spines.
Corals.

TT54: About 9 miles S.W. of Daly River crossing on road to Dorisvale homestead (Fergusson River Sheet). Lat. 14°26'S., long. 131° 27'E. Unit A (?Neocomian, Aptian).
Plants indet.

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APPENDIX 5

CHEMICAL ANALYSES OF KATHERINE-DARWIN GRANITES*

(i) ARCHAEAN-PROTEROZOIC GRANITES

	1	2	3	4	5	6	7	8	9	10
SiO_2	62.2	71.0	72.5	70.4	56.6	57.3	73.24	75.2	74.5	74.8
Al_2O_3	14.1	14.4	14.1	14.6	18.4	17.4	13.96	12.0	12.4	12.3
Fe_2O_3	3.7	0.84	0.41	0.89	2.0	2.7	0.88	0.8	0.4	0.55
FeO	3.8	1.53	1.25	1.56	5.4	4.5	0.71	1.08	1.22	0.97
MgO	2.55	1.52	0.49	0.91	2.4	2.5	0.68	0.47	0.69	0.79
CaO	3.1	1.37	1.39	2.55	4.9	5.05	0.7	0.88	0.81	0.44
Na_2O	3.65	3.45	3.55	3.9	4.9	4.0	3.23	2.8	2.85	0.92
K_2O	3.9	4.4	5.25	3.45	2.5	2.75	4.9	5.05	5.4	7.5
H_2O+	0.78	0.63	0.47	0.84	1.42	1.53	0.37	0.74	0.73	0.87
H_2O-	0.11	0.13	0.07	0.09	0.08	0.1	0.05	0.12	0.12	0.09
CO_2	0.15	0.12	0.21	0.08	0.3	0.48	—	0.18	0.38	0.31
TiO_2	1.32	0.24	0.20	0.32	1.08	0.88	0.2	0.27	0.25	0.15
P_2O_5	0.64	0.1	0.09	0.14	0.33	0.41	0.45	0.1	0.09	0.1
MnO	0.11	0.05	0.03	0.06	0.11	0.1	0.08	0.02	0.02	0.02
Total	100.1	99.8	100.0	99.8	99.9	99.7	99.45	99.7	99.9	99.8

Rum Jungle Complex

1. Gneiss; E. of Mt Fitch. Analyst, C. R. Edmond (AMDL). D52/4/24
2. Gneiss; lat. 12°57′S., long. 131°03′E. Analyst, C. R. Edmond. D52/4/15
3. Granite gneiss; lat. 12°59′S., long. 131°02′E. Analyst, C. R. Edmond. D52/4/32.
4. Granite gneiss; lat. 12°57′S., long. 131°03′E. Analyst, C. R. Edmond. D52/4/14
5. Diorite; lat. 12°58′S., long. 131°03′E. Analyst, C. R. Edmond. D52/4/11
6. Diorite; lat. 12°59′S., long. 131°03′E. Analyst, H. W. Sears (AMDL). D52/4/16
7. Coarse granite; on railway, S. margin of complex. Analyst, S. Baker (BMR). D52/4/3
8. Coarse granite; lat. 12°58′S., long. 130°59′E. Analyst, C. R. Edmond. D52/4/22
9. Coarse granite; lat. 12°59′S., long. 130°59′E. Analyst, C. R. Edmond. D52/4/27
10. Coarse granite; lat. 13°02′S., long. 131°01′E. Analyst, C. R. Edmond. D52/8/13

* Analyses by G. A. Joplin and S. Baker have been published by Joplin (1957, 1963).

(i) ARCHAEAN-PROTEROZOIC GRANITES (cont.)

	11	12	13	14	15	16	17	18	19	20
SiO_2	75.2	73.8	69.62	68.5	70.1	72.4	69.6	60.4	58.0	69.0
Al_2O_3	12.4	12.8	14.35	14.5	13.4	13.2	13.8	16.8	17.1	13.9
Fe_2O_3	0.51	0.66	1.09	1.22	1.28	1.23	1.89	2.45	2.2	0.74
FeO	0.86	1.08	2.2	2.1	1.75	1.14	1.57	2.85	4.5	2.35
MgO	0.44	0.47	1.4	0.92	1.04	0.75	1.13	1.43	2.75	1.48
CaO	0.44	1.06	0.8	1.78	1.69	1.33	1.73	4.75	3.6	1.3
Na_2O	1.89	3.20	2.67	3.75	2.95	3.05	3.35	4.2	4.75	2.95
K_2O	6.80	5.40	6.19	5.05	5.50	5.2	4.9	3.75	3.05	5.85
H_2O+	0.85	0.66	0.23	0.72	0.67	0.57	0.63	0.87	1.59	1.12
H_2O-	0.09	0.06	0.04	0.06	0.08	0.09	0.13	0.1	0.11	0.11
CO_2	0.19	0.42	—	0.25	0.5	0.24	0.2	0.67	0.27	0.31
TiO_2	0.16	0.27	0.61	0.62	0.49	0.33	0.5	1.15	1.15	0.43
P_2O_5	0.05	0.09	0.25	0.2	0.21	0.11	0.24	0.5	0.51	0.24
MnO	0.02	0.02	0.04	0.06	0.04	0.05	0.04	0.1	0.1	0.05
Total	99.9	100.0	99.49	99.7	99.7	99.7	99.7	100.0	99.7	99.8

Rum Jungle Complex (cont.)

11. Coarse granite; lat. 13°01′S., long. 131°01′E. Analyst, C. R. Edmond. D52/8/18
12. Coarse granite; lat. 13°01′S., long. 131°01′E. Analyst, C. R. Edmond. D52/8/19
13. Large feldspar granite; on railway, ¾ m. S. of Mt Fitch track. Analyst, S. Baker. D52/4/1
14. Large feldspar granite; lat. 12°54′S., long. 131°06′E. Analyst, C. R. Edmond. D52/4/13
15. Large feldspar granite; lat. 12°59′S., long. 131°02′E. Analyst, C. R. Edmond. D52/4/17
16. Large feldspar granite; lat. 12°58′S., long. 131°00′E. Analyst, C. R. Edmond. D52/4/19
17. Large feldspar granite; lat. 12°58′S., long. 130°59′E. Analyst, C. R. Edmond. D52/4/20
18. Large feldspar granite; lat. 12°50′S., long. 130°58′E. Analyst, C. R. Edmond. D52/4/25
19. Large feldspar granite; lat. 12°59′S., long. 131°03′E. Analyst, H. W. Sears. D52/4/29
20. Large feldspar granite; lat. 13°00′S., long. 131°01′E. Analyst, C. R. Edmond. D52/8/9

(i) ARCHAEAN-PROTEROZOIC GRANITES (cont.)

	21	22	23	24	25	26	27	28	29	30
SiO_2	71.2	75.0	73.6	73.0	74.6	74.0	73.1	76.9	73.2	77.4
Al_2O_3	13.9	13.0	13.2	13.6	12.8	12.9	13.5	12.8	13.2	13.7
Fe_2O_3	0.47	0.37	0.68	0.63	0.64	0.77	0.35	0.26	0.33	0.27
FeO	1.79	0.78	1.01	1.65	0.86	1.31	1.61	0.46	1.47	0.72
MgO	1.25	0.3	0.38	0.55	0.35	0.41	0.62	0.11	0.60	0.3
CaO	0.71	0.57	0.61	0.89	0.91	0.63	0.54	0.54	0.71	0.51
Na_2O	2.55	3.2	3.25	2.80	3.55	3.3	2.55	4.00	3.20	3.65
K_2O	5.8	5.9	5.75	5.55	5.00	5.3	5.95	4.1	5.60	5.3
H_2O+	0.92	0.31	0.76	0.71	0.49	0.86	0.79	0.37	0.87	0.6
H_2O-	0.06	0.08	0.11	0.08	0.09	0.1	0.08	0.07	0.07	0.08
CO_2	0.35	0.26	0.21	0.13	0.15	0.16	0.37	0.16	0.23	0.17
TiO_2	0.47	0.09	0.13	0.31	0.50	0.21	0.18	0.04	0.35	0.09
P_2O_5	0.18	0.02	0.05	0.10	0.06	0.08	0.05	0.02	0.10	0.03
MnO	0.03	0.03	0.02	0.03	0.04	0.03	0.02	0.01	0.02	0.02
Total	99.7	99.9	99.8	100.0	100.0	100.1	99.7	99.8	99.7	99.8

Rum Jungle Complex (cont.)

21. Large feldspar granite; lat. 13°01′S., long. 131°03′E. Analyst, C. R. Edmond. D52/8/12
22. Leucocratic granite; lat. 12°53′S., long. 131°05′E. Analyst, C. R. Edmond. D52/4/12
23. Leucocratic granite; lat. 12°59′S., long. 130°59′E. Analyst, C. R. Edmond. D52/4/21
24. Leucocratic granite; E.S.E. of Dysons open-cut. Analyst, C. R. Edmond. D52/4/28
25. Leucocratic granite; lat. 12°55′S., long. 131°04′E. Analyst, C. R. Edmond. D52/4/31
26. Leucocratic granite; lat. 13°00′S., long. 131°01′E. Analyst, C. R. Edmond. D52/8/10
27. Leucocratic granite; lat. 13°01′S., long. 131°03′E. Analyst, C. R. Edmond. D52/8/11
28. Leucocratic granite; lat. 13°01′S., long. 131°01′E. Analyst, C. R. Edmond. D52/8/14
29. Leucocratic granite (Mt Fitch type); lat. 12°58′S., long. 130°57′E. Analyst, C. R. Edmond. D52/4/33
30. Pegmatite; lat. 12°59′S., long. 131°01′E. Analyst, C. R. Edmond. D52/4/18

(i) ARCHAEAN-PROTEROZOIC GRANITES (cont.)

	31	32	33	34	35	36	37	38	39
SiO_2	60.42	76.86	69.00	71.58	73.51	75.00	74.00	73.58	68.20
Al_2O_3	18.20	12.39	16.05	15.48	14.49	13.71	14.06	14.16	16.53
Fe_2O_3	2.10	0.96	0.78	0.39	0.53	0.87	1.28	0.76	1.27
FeO	2.50	0.36	1.09	1.49	0.96	0.37	1.29	0.98	3.10
MgO	1.65	0.13	0.94	0.92	1.05	0.27	0.41	0.73	1.47
CaO	4.51	0.79	1.25	1.78	1.17	0.64	2.28	0.82	2.12
Na_2O	3.80	2.44	3.66	4.03	2.97	2.23	4.35	3.29	2.01
K_2O	6.96	5.43	6.32	3.66	3.98	5.81	1.26	4.42	4.11
H_2O+	0.30	0.50	0.32	0.86	0.53	0.68	0.35	0.88	0.66
H_2O-	nil	nil	nil	nil	nil	nil	nil	0.03	0.01
CO_2	—	—	—	—	—	—	—	—	—
TiO_2	0.10	0.07	0.20	0.10	0.21	0.10	0.22	0.05	0.47
P_2O_5	0.05	0.02	0.10	0.07	0.04	0.03	0.03	0.09	0.01
MnO	0.07	0.02	0.03	0.03	0.02	0.04	0.03	0.02	0.07
Total	100.66	99.97	99.74	100.39	99.46	99.75	99.56	99.81	100.03

Nimbuwah Complex

31. Hornblende-biotite granodiorite; N.E. of Oenpelli, nr Cooper Ck. Analyst, S. Baker. D53/1/1

Nanambu Granite

32. Biotite granite; Nanambu Ck. Analyst, S. Baker. B3915
33. Garnetiferous biotite granite; Nanambu Ck. Analyst, S. Baker. B1135

Litchfield Complex

34. Gneissic granodiorite; 5 m. W. of Finniss R. crossing. Analyst, S. Baker. D52/4/4
35. Granodiorite; Fog Bay area. Analyst, S. Baker. B4621
36. Garnetiferous granite; Mt Litchfield. Analyst, S. Baker. D52/8/8
37. Biotite granodiorite; S. of Mt Litchfield. Analyst, S. Baker. B2973
38. Muscovite-biotite granite; on track, 30 m. S.W. of Daly R. Analyst, S. Baker. D52/8/6
39. Biotite granodiorite; S.W. Muldiva Ck area. Analyst, S. Baker. B2997

(ii) EARLY CARPENTARIAN GRANITES

	1	2	3	4	5	6	7	8	9	10
SiO_2	75.26	68.41	72.94	65.0	71.30	67.72	67.04	69.92	67.90	72.10
Al_2O_3	12.05	17.26	13.70	14.70	14.57	15.51	16.42	15.08	15.81	14.00
Fe_2O_3	1.40	1.32	0.51	0.96	1.19	0.96	0.29	0.91	0.63	0.20
FeO	1.18	2.15	2.10	4.15	1.43	2.58	2.61	2.20	3.20	1.89
MgO	0.20	0.96	1.08	1.25	0.69	1.09	0.96	1.14	0.86	0.53
CaO	0.58	0.56	0.66	3.00	0.76	1.51	1.91	1.64	1.78	1.60
Na_2O	2.97	3.31	2.54	3.00	3.13	3.05	3.07	2.65	3.16	3.15
K_2O	5.31	4.37	4.93	4.95	5.68	5.37	5.31	5.18	4.19	4.90
H_2O+	0.48	0.85	0.90	1.25	0.87	1.08	1.40	0.77	0.91	0.69
H_2O-	nil	nil	0.04	0.16	nil	0.03	0.02	nil	0.02	0.06
CO_2	—	—	—	0.22	—	—	—	—	—	0.11
TiO_2	0.07	0.33	0.03	0.77	0.08	0.48	0.50	0.45	0.40	0.29
P_2O_5	0.04	0.09	0.09	0.28	0.08	0.19	0.22	0.18	0.16	0.08
MnO	0.02	0.05	0.04	0.06	0.06	0.09	0.10	0.05	0.08	0.04
Total	99.56	99.66	99.56	99.80	99.84	99.66	99.85	100.17	99.10	99.6

Malone Creek Granite

1. Biotite microgranite; where Malone Ck leaves granite. Analyst, S. Baker. D53/5/1

Wolfram Hill Granite

2. Porphyritic adamellite; nr Wolfram Hill. Analyst, S. Baker. B4009

Cullen Granite

3. Biotite granite; nr Edith R. crossing. Analyst, S. Baker. D53/9/1*
4. Hornblende-biotite adamellite; nr Edith R. crossing. Analyst, C. R. Edmond. D53/9/1*
5. Biotite granite; 2 m. E. of Pine Creek. Analyst, S. Baker. D52/8/5

McKinlay Granite

6. Biotite granodiorite; N. end of granite. Analyst, S. Baker. B3970
7. Biotite granodiorite; N. end of granite. Analyst, S. Baker. B3968

Prices Springs Granite

8. Biotite adamellite; nr Prices Spring hstd. Analyst, S. Baker. B3975.
9. Biotite adamellite; 3 m. E. of Grove Hill. Analyst, S. Baker. D52/8/3
10. Biotite adamellite; lat. 13°29′54″S., long. 131°37′24″E. Analyst, R. L. Bruce (AMDL). D52/8/21

* Both specimens from one 250-lb. sample

(ii) Early Carpentarian Granites (cont.)

	11	12	13	14	15	16	17	18	19	20
SiO_2	69.30	71.96	74.50	73.4	72.82	54.23	57.00	64.50	70.7	70.88
Al_2O_3	14.30	13.87	13.20	13.3	14.03	27.80	16.00	15.20	14.6	15.00
Fe_2O_3	0.55	0.41	0.18	0.57	0.91	0.42	0.98	1.01	0.49	1.80
FeO	2.65	1.35	1.41	1.51	1.83	0.23	5.85	3.30	1.75	0.89
MgO	0.80	0.68	0.25	0.32	0.79	0.09	4.05	2.25	0.85	0.74
CaO	1.95	1.07	0.80	0.92	0.87	8.94	5.20	2.40	1.71	1.27
Na_2O	2.95	3.50	3.35	3.50	2.76	6.48	2.80	3.25	3.80	3.29
K_2O	5.45	5.68	5.05	5.05	5.18	0.37	4.50	5.40	4.50	4.48
H_2O+	0.81	0.61	0.58	0.58	0.71	0.28	1.70	1.41	0.97	0.75
H_2O-	0.08	nil	0.04	0.04	nil	0.30	0.10	0.07	0.06	nil
CO_2	0.05	—	0.14	0.10	—	—	0.30	0.33	0.28	—
TiO_2	0.41	0.30	0.16	0.19	0.30	0.03	0.70	0.49	0.25	0.26
P_2O_5	0.14	0.07	0.03	0.03	0.07	0.49	0.40	0.29	0.10	0.03
MnO	0.06	0.05	0.03	0.05	0.05	Tr	0.12	0.07	0.02	0.03
Total	99.5	99.55	99.70	99.60	100.32	99.66	99.7	100.0	100.1	99.42

Prices Springs Granite (cont.)

11. Hornblende-biotite adamellite; lat. 13°29′37″S., long. 131°36′24″E. Analyst, R. L. Bruce. D52/8/20

Burnside Granite

12. Biotite adamellite; 2½ m. N.N.W. of Brocks Ck. Analyst, S. Baker. D52/8/1
13. Biotite adamellite; 2 m. N.N.W. of Rising Tide. Analyst, R. L. Bruce. D52/8/26
14. Biotite adamellite; 15 m. N.W. of Rising Tide. Analyst, R. L. Bruce. D52/8/25

Fenton Granite

15. Biotite granite; 2½ m. E. of Fenton airstrip. Analyst, S. Baker. D52/8/4
16. Contaminated albitite; 2 m. S. of Long airstrip. Analyst, G. A. Joplin

Shoobridge Granite

17. Marginal phase; E. edge of granite. Analyst, C. R. Edmond. D52/8/23
18. Porphyritic phase; on Bridge Ck. Analyst, C. R. Edmond. D52/8/24
19. Leucocratic variety; centre of granite. Analyst, C. R. Edmond. D52/8/22
20. Leucocratic variety; on Stuart Highway. Analyst, S. Baker. B3999

(ii) EARLY CARPENTARIAN GRANITES (cont.)

	21	22	23	24	25	26	27	28	29	30
SiO_2	70.42	70.40	73.4	71.16	59.76	60.40	70.14	72.61	73.00	73.00
Al_2O_3	14.02	15.18	13.0	13.82	16.56	17.21	15.70	14.20	13.50	12.80
Fe_2O_3	0.73	1.57	0.94	1.59	5.38	1.99	1.27	0.56	0.45	0.26
FeO	1.55	1.36	1.29	1.09	1.52	2.84	1.24	0.93	1.29	1.22
MgO	1.29	1.16	0.47	1.23	2.44	3.60	1.26	1.00	0.51	0.90
CaO	1.63	1.53	1.66	1.45	2.14	4.02	0.90	0.42	0.96	1.46
Na_2O	3.34	3.39	3.50	3.71	4.98	3.24	3.28	3.29	3.10	3.30
K_2O	6.06	3.84	4.65	5.05	5.52	4.70	4.20	5.43	5.75	5.10
H_2O+	0.98	0.63	0.51	0.58	0.94	0.92	0.92	0.84	0.66	0.70
H_2O-	0.02	0.03	0.06	nil	nil	0.04	0.02	nil	0.09	0.07
CO_2	—	—	0.10	—	—	—	—	—	0.32	1.00
TiO_2	0.25	0.34	0.26	0.09	0.15	0.35	0.25	0.15	0.10	0.12
P_2O_5	0.10	0.16	0.14	0.07	0.10	0.08	0.20	0.05	0.08	0.08
MnO	0.08	0.05	0.03	0.03	0.09	0.04	0.05	0.03	0.03	0.03
Total	100.47	99.64	100.0	99.87	99.58	99.43	99.43	99.51	99.80	100.00

Shoobridge Granite (cont.)

21. Leucocratic adamellite; on Stuart Highway. Analyst, S. Baker. B4325

Mount Bundey Granite

22. Hornblende-biotite adamellite; 3¼ m. E.N.E. old battery on Mt Bundey Ck. Analyst, S. Baker. D52/4/5*
23. Hornblende-biotite adamellite; 3¼ m. E.N.E. old battery on Mt Bundey Ck. Analyst, C. R. Edmond. D52/4/5*
24. Hornblende granite; 3 m. N.E. old battery on Mt Bundey Ck. Analyst, S. Baker. B3290

Mount Goyder Syenite

25. Quartz syenite; 2 m. S.S.E. of old Mt Bundey hstd. Analyst, S. Baker. B4220.
26. Quartz syenite; ½ m. E. of Mt Goyder. Analyst, S. Baker. B3285

Waterhouse Granite

27. Sheared adamellite; on track 4 m. from Stapleton hstd. Analyst, S. Baker. B3277.
28. Metamorphosed adamellite; 3 m. S.W. of Stapleton hstd. Analyst, S. Baker. B4324
29. Feldspathized granite. Analyst, C. R. Edmond. D52/8/17
30 Granitized actinolite-biotite schist. Analyst, C. R. Edmond. D52/8/15

* Both specimens from one 250-lb sample

(ii) EARLY CARPENTARIAN GRANITES (cont.)

	31	32	33	34
SiO_2	72.60	74.68	74.5	60.30
Al_2O_3	13.40	14.56	13.5	19.27
Fe_2O_3	0.87	1.58	0.31	0.73
FeO	1.32	0.37	1.04	5.66
MgO	0.82	0.33	0.24	1.61
CaO	1.04	0.48	0.91	3.54
Na_2O	3.15	4.77	3.15	2.33
K_2O	5.10	2.30	4.80	3.73
H_2O+	0.74	0.39	0.79	1.30
$H_2O—$	0.06	nil	0.08	0.03
CO_2	0.32	—	0.26	—
TiO_2	0.22	0.05	0.12	0.85
P_2O_5	0.13	0.05	0.11	0.12
MnO	0.03	0.04	0.02	0.07
Total	99.80	99.60	99.8	99.54

Waterhouse Granite (cont.)

31. Muscovite-biotite granite; lat. 13°12'S., long. 130°0.9'E. Analyst, C. R. Edmond. D52/8/16

Roberts Creek Granite

32. Sodaclase tonalite; E. of Goodwill mine. Analyst, S. Baker. B3289

Allia Creek Granite

33. Biotite-muscovite adamellite. Analyst, C. R. Edmond. D52/8/7*
34. Biotite tonalite. Analyst, S. Baker. D52/8/7*

* Both specimens from one 250-lb sample

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APPENDIX 6

MODAL ANALYSES OF KATHERINE-DARWIN GRANITES*

(i) Archaean-Proterozoic Granites

	1	2	3	4	5
Quartz	25	36	27	27	34
K-Feldspar	46	5	9	24	17
Plagioclase	20	43	53	37	42
Biotite		14	9		7
Muscovite		1		12	tr.
Hornblende	9		1.3		—
Non-opaque acc.		1			tr.
Opaque acc.			tr.		—

* Carried out on thin section (T.S.), or stained slab (slab)

Rum Jungle Complex

1. Coarse granite phase, 1 m. N. of Whites open-cut. Petrologist, R. Bryan (BMR). R9245 (slab)

Litchfield Complex

2. Biotite granodiorite, Fog Bay area. Petrologist, G. Joplin (ANU). B4626
3. Biotite granodiorite, N.W. of Goodwill mine. Petrologist, G. Joplin. B4611
4. Biotite adamellite, on track ½ m. W. of Kilfoyle Ck. Petrologist, R. Bryan. R9230 (slab)
5. Fine biotite adamellite, on track 2½ m. S.E. of Mt Litchfield. Petrologist, R. Bryan. R9229 (T.S.)

(ii) Early Carpentarian Granites

	1	2	3	4	5	6	7	8	9	10
Quartz	30	31	20	21	24	16	37	19	20	32
K-feldspar	66	65	45	36	40	23	33	43	57	32
Plagioclase			24	26	27	38	26	29	16	28
Biotite . . .		4	11	17	9	23	2	9	7	8
Muscovite .	3	tr.					0.5		—	—
Hornblende									—	—
Non-opaque acc. . . .	1	0.2					tr.		tr.	tr.
Opaque acc. .							1(pyrite)			

Malone Creek Granite

1. Altered fine granite, Malone Ck at edge of granite. Petrologist, R. Bryan. R9242 (T.S.)
2. Altered fine granite, Malone Ck at edge of granite. Petrologist, R. Bryan. R9242 (T.S.)

Cullen Granite

3. Pink coarse granite, Stuart Highway, 1 m. N. of Edith R. Petrologist, R. Bryan. R9239 (slab)
4. Pink and green coarse adamellite, 124-m. peg, Stuart Highway. Petrologist, R. Bryan. R9232 (slab)
5. Grey coarse granite, 25 m. E. of Pine Ck. Petrologist, R. Bryan. R9237 (slab)
6. Grey fine porphyritic granodiorite, old Lewin Springs hstd. Petrologist, R. Bryan. R9240 (slab)
7. Grey fine adamellite, Mt Davis area. Petrologist, R. Bryan. R9236 (T.S.)
8. Hybrid granite, Stuart Highway, S. of Edith R. Petrologist, R. Bryan. R9238 (slab)

McKinlay Granite

9. Biotite granite, 3 m. E.S.E. of Burrundie. Petrologist, R. Bryan. R9222 (T.S.)

Prices Springs Granite

10. Muscovite-biotite adamellite, 3 m. E. of Grove Hill. Petrologist, R. Bryan. B3237 (T.S.)

(ii) EARLY CARPENTARIAN GRANITES (cont.)

<table>
<tr><th></th><th>11</th><th>12</th><th>13</th><th>14</th><th>15</th><th>16</th><th>17</th><th>18</th><th>19</th><th>20</th></tr>
<tr><td>Quartz . . . .</td><td>30</td><td>42</td><td>20</td><td>35</td><td>32</td><td>30</td><td>20</td><td>34</td><td>21</td><td>25</td></tr>
<tr><td>K-feldspar . .</td><td>38</td><td>24</td><td>37</td><td>31</td><td>32</td><td>35</td><td>54</td><td>36</td><td>35</td><td>22</td></tr>
<tr><td>Plagioclase .</td><td>25</td><td>20</td><td>27</td><td>27</td><td>27</td><td>29</td><td>21</td><td>11</td><td>23</td><td>36</td></tr>
<tr><td>Biotite . . .</td><td>7</td><td>12</td><td>12</td><td>7</td><td>9</td><td>5</td><td>4</td><td rowspan="5">19</td><td rowspan="5">21</td><td rowspan="5">17</td></tr>
<tr><td>Muscovite .</td><td>tr.</td><td>—</td><td>—</td><td></td><td></td><td>0.3</td><td rowspan="4">1</td></tr>
<tr><td>Hornblende</td><td>—</td><td>—</td><td>3</td><td></td><td></td><td></td></tr>
<tr><td>Non-opaque acc. . . .</td><td>tr.</td><td>1</td><td>2</td><td>tr.</td><td>tr.</td><td>tr.</td></tr>
<tr><td>Opaque acc.</td><td></td><td>tr.</td><td>tr.</td><td></td><td></td><td></td></tr>
</table>

Prices Springs Granite (cont.)

11. Biotite granite 1 m. N. of railway, 3 m. E. of Grove Hill. Petrologist, R. Bryan. R9220 (T.S.)
12. Biotite adamellite. Prices Springs hstd. Petrologist, R. Bryan. B3975 (T.S.)
13. Hornblende-biotite adamellite, 2 m. W. of Burrundie. Petrologist, R. Bryan. R9221 (slab)

Burnside Granite

14. Biotite adamellite, 2 m. N. of Brocks Ck. Petrologist, R. Bryan. R9217 (T.S.)
15. Biotite adamellite, 1 m. W. of Ban Ban Springs. Petrologist, R. Bryan. R9218 (T.S.)
16. Biotite adamellite, N. of Brocks Ck. Petrologist, R. Bryan. B3275 (T.S.)

Fenton Granite

17. Red biotite granite, 2½ m. E. of Fenton airstrip. Petrologist, G. Joplin. B3278 (T.S.)
18. Grey muscovite-biotite granite, 1 m. N.W. of Fenton airstrip. Petrologist, R. Bryan. R9226 (slab)
19. Red hornblende-biotite granite, junction of Fenton and Douglas tracks. Petrologist, R. Bryan. R9225 (slab)

Margaret Granite

20. Biotite adamellite, 8 m. N.E. of Ban Ban Springs. Petrologist, R. Bryan. R9219 (slab)

(ii) EARLY CARPENTARIAN GRANITES (cont.)

	21	22	23	24	25	26	27	28
Quartz	23	35	4	33	28	44	22	33
K-feldspar . .	48	53	65	29	24	tr.	0.22	21
Plagioclase . .	20	15	20	28	31	39	41	29
Biotite		2		4		0.2	27	
Muscovite .				5		16		
Hornblende	9	3	7		17		9	17
Non-opaque acc. . . .		1	1			1		
Opaque acc. .		1	3	1		tr.	1	

Mount Bundey Granite

21. Hornblende-biotite granite, 3¼ m. E.N.E. of battery in Mt Bundey Ck. Petrologist, R. Bryan. B3286 (slab)
22. Hornblende granite, 3 m. N.E. of battery in Mt Bundey Ck. Petrologist, G. Joplin. B3290 (T.S.)

Mount Goyder Syenite

23. Quartz-hornblende syenite, 2 m. S.S.E. of Mt Bundey hstd. Petrologist, G. Joplin. B4220 (T.S.)

Waterhouse Granite

24. Metamorphosed adamellite, 4 m. W. of Stapleton hstd. Petrologist, G. Joplin. B3277 (T.S.)
25. Metamorphosed porphyritic adamellite, on track 1 m. W. of Little Finniss R. Petrologist, R. Bryan. R9243 (slab)

Roberts Creek Granite

26. Muscovite tonalite, nr Goodwill mine. Petrologist, W. Dallwitz (BMR). B3289 (T.S.)

Allia Creek Granite

27. Biotite tonalite. Petrologist, S. Hasan (BMR). B3272 (T.S.)
28. Muscovite-biotite adamellite. Petrologist, R. Bryan. R1101 (slab)