DEPARTMENT OF
~~NATIONAL RESOURCES~~
NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1978/11

INTERIM REPORT ON THE BATCHELOR 1:100 000 SHEET (5171), N.T.

by

I.H. Crick

Record 1978/11

INTERIM REPORT ON THE BATCHELOR 1:100 000 SHEET (5171), N.T.

by

I.H. Crick

CONTENTS

TABLES

FIGURES

FOREWORD

This record describes the geology of the Batchelor 1:100 000 Sheet area as indicated by fieldwork by BMR geologists from 1972-5, and shown on the Batchelor 1:100 000 preliminary map. More recently, fieldwork in surrounding areas has resulted in substantial changes to the concepts of Lower Proterozoic stratigraphy in the Pine Creek Geosyncline, including the Batchelor Sheet area. The new concepts are described in the papers listed below, and the reader is referred to them where the text of this Record indicates that ideas have been modified since fieldwork in this Sheet area.

The 1:500 000-scale Solid geology of the Pine Creek Geosyncline, published by BMR in 1979, includes the Batchelor area and incorporates the new stratigraphic concepts. A second edition of the Batchelor 1:100 000 preliminary map is to be produced with a map commentary, and will show the new stratigraphy and the results of recent fieldwork.

CRICK, I.H., STUART-SMITH, P.G., and NEEDHAM, R.S., 1978 - Stratigraphic significance of a discovery of Lower Proterozoic tuff in the Pine Creek Geosyncline. BMR Journal 3, 163-165.

NEEDHAM, R.S., CRICK, I.H., and STUART-SMITH, P.G., in prep. - Regional geology of the Pine Creek Geosyncline. Proceedings of the International Uranium Symposium on the Pine Creek Geosyncline, Sydney June 4-8 1979. International Atomic Energy Agency, Vienna.

ABSTRACT

This Record describes the geology of the Batchelor 1:100 000 Sheet Preliminary Edition, published in 1978, and as then interpreted. The Sheet area is on the western side of the Pine Creek Geosyncline, N.T. There have been substantial advances in the understanding of the stratigraphy and environment of deposition of the Lower Proterozoic sequence in the Pine Creek Geosyncline in the short time since the sheet was published. As a result, this Record is an interim statement, essentially following that of earlier workers (summarised by Walpole & others, 1968). However, reference is made to the more recent work.

Archaean igneous and metasedimentary rocks are overlain by a thick sequence of Lower Proterozoic clastic and minor carbonate sediments. Recent work (post-dating this map) has shown that the geosynclinal model used by earlier workers to interpret the Lower Proterozoic sequence in the Pine Creek Geosyncline is fundamentally incorrect, and substantial stratigraphic changes have since been made. Pre-tectonic sills intruded the Lower Proterozoic sequence, which was then folded and intruded by a post-tectonic, diapiric granite at about 1800 m.y. Relatively thin and undeformed Adelaidean arenite-carbonate-lutite sediments unconformably overlie the Lower Proterozoic strata, and are in turn unconformably overlain by thin, gently-dipping Cambrian-Ordovician carbonates and lutites in the southwest. Mesozoic poorly consolidated conglomerate, arenites, and lutites form flat-lying mesas, mainly in the south.

Most mineralisation (Au, Ag, Cu, Pb, Zn, Fe, U) is contained within the Lower Proterozoic Goodparla Group.

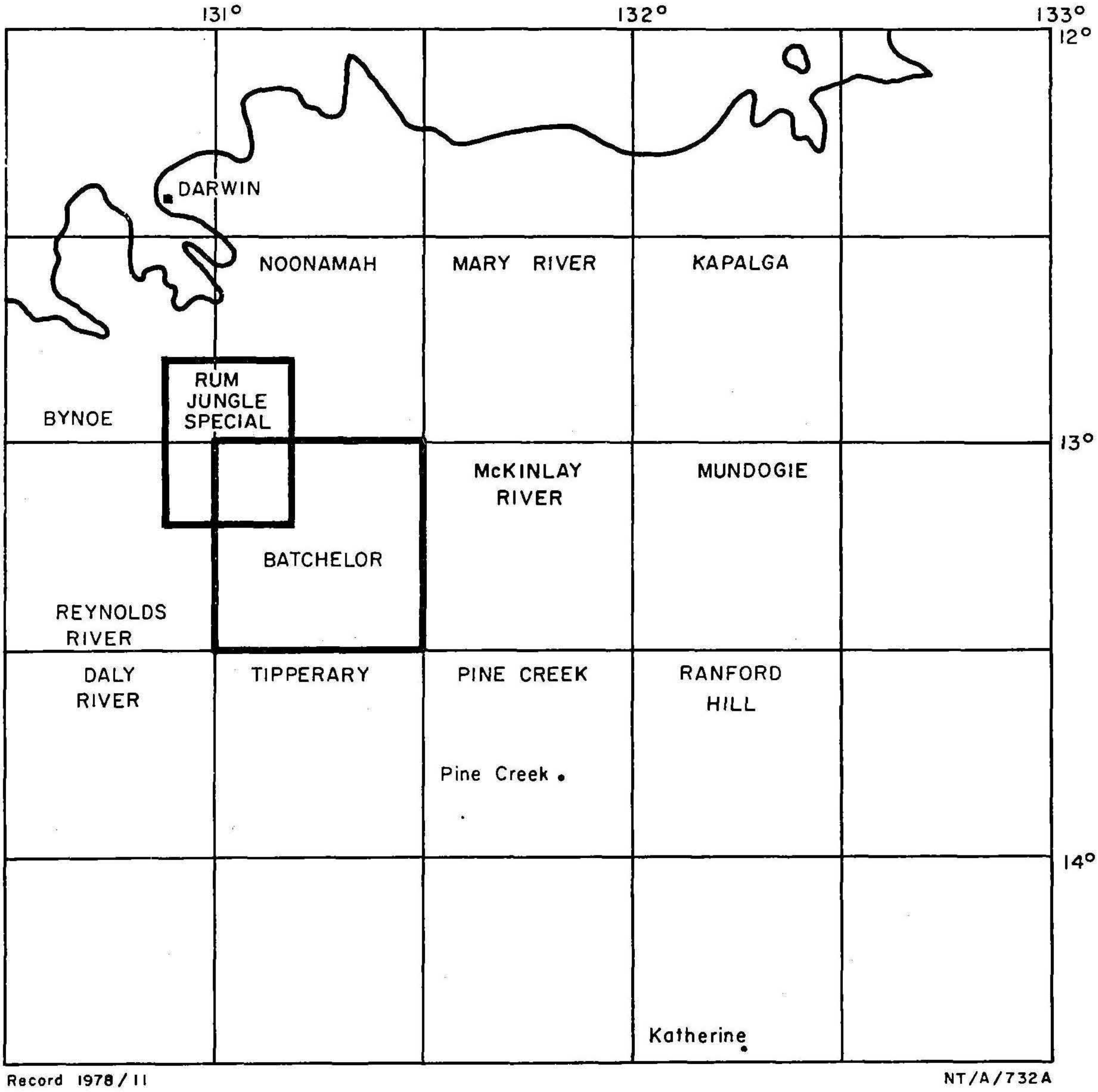

Fig. 1 Locality map of the Batchelor 1:100 000 Sheet area

INTRODUCTION

Recent discoveries of tuff in the Golden Dyke Formation (and its correlation with units in the South Alligator Group - Crick & others, 1978) and of evaporite-mineral pseudomorphs in the Celia Dolomite, Coomalie Dolomite, and Golden Dyke Formation (Crick & Muir, 1979) have substantially advanced understanding of the geology of the Batchelor 1:100 000 Preliminary Sheet area 3 since the map was published in early 1978. This Record is an interim commentary for the map, which will be superseded by a new Batchelor 1:100 000 Sheet and commentary.

The mapping which contributed to the preparation of the Sheet and this Record includes work done by BMR in the 1950s, summarised by Walpole & others (1968), and work done by K. Johnson, J. Ingram and the author from 1972 to 1975.

K. Johnson mapped most of the northeast part of the Sheet area and J. Ingram most of the southwest and northeast parts. I. Crick worked mainly in the southeast part around the Burnside Granite.

Location

The Batchelor 1:100 000 Sheet area (5171) is in the north of the Northern Territory between latitudes 13°00'S and 13°30'S, and longitudes 131°00'E and 131°30'E (Fig. 1). It forms part of the Pine Creek 1:250 000 Sheet area, SD 52-8. In the northeast corner of the Batchelor Sheet area is the small township of Batchelor, 100 km by road south of Darwin. Adelaide River, another small town, is in the central eastern part of the Sheet and is 114 km by road south of Darwin.

Access

Access to most of this area is restricted to the winter months, May to October, when little rain falls. During the summer, monsoonal rains make large areas inaccessible. An all-weather bitumen-sealed road, the Stuart Highway, runs north-south through the eastern half of the Sheet area with sealed branches leading to Batchelor, to Fountain Head Siding in the southeast, and for about 15 km along the Daly River Mission road in the southwest. Numerous tracks and some graded dirt road provide good access in the northwest, while in the southwest few tracks exist and progress by four-wheel-drive vehicle is largely impeded by north-south trending ranges and steep mesas. A few rough tracks provide some access to the eastern half of the area but their condition varies greatly from year to year owing to the effects of heavy monsoonal rains and to the varying efforts made to maintain them.

The North Australian Railway, which closed in June, 1976, runs from the northwest to the southeast corners of the Sheet area.

Long grass impedes progress and observation of low-lying outcrops at the beginning of the dry season, but is progressively burned off as the season continues.

Climate

The climate is tropical with marked wet and dry seasons. The wet extends from November to March, the dry from May to September. April and October are transitional months. About 60 percent of the annual precipitation falls in the three months January, February, and March. Virtually no rain falls in the dry. The mean annual rainfall is approximately 1400 mm.

Temperatures remain high throughout the year. The range between mean monthly temperatures is in the order of $7^{o}C$. Temperatures are highest in November and coolest during June, July, and August. The mean maximum temperatures varies from 30 to 37^{o} and the mean minimum from 16 to $24^{o}C$. Relative humidity ranges from about 50 percent in July to 80 percent in January. In terms of human comfort, the months of June, July, and August are the most pleasant when mornings occasionally are cool enough for pullovers to be worn.

Vegetation

An account of the vegetation is given by Story (1969). His figures for the percentage areal distribution of the main types are modified below for the Batchelor 1:100 000 Sheet area.

Tall open forest (15%) is dominated by *Eucalyptus miniata* and *E. tetradonta*, together or separately, averaging over 12 m in height. Visibility at eye level is up to 30 m but varies greatly according to the density of non-eucalypts below the canopy; the non-eucalypts form a distinct 4-m layer of palms, small trees, and tall shrubs, comprising about 20 species. Small shrubs are uncommon, grasses are abundant.

Woodland (35%) is made up of a greater variety of eucalypts, many of them deciduous. The trees are more widely spaced than those of the tall open forest, and are smaller, ranging from 6 to 12 m. The same palms, non-eucalypt small trees, and tall shrubs are common below them.

Stunted woodland (25%) flora is similar to that of the woodland, but is characteristically dwarfed and crooked. It is found on stony low rounded hills.

Scrub (10%) is dense and low (about 8 m) and dominated by non-eucalypts, commonly <u>Melaleuca</u>, <u>Pandanus</u>, <u>Grevillea</u>, and <u>Acacia</u>.

Shrubs are common and the ground cover is patchy and variable, often of short grasses and sedges and other non-grasses. Scrub is found downslope from the woodland.

Paperbark forest (1%) occurs as a gallery forest along many of the creeks where it is mixed with other evergreen non-eucalypt trees.

Grassland and savannah (20%) forms a mosaic of communities in which the grasses on the whole are perennial mid-height (commonly <u>Themeda</u> and <u>Eriachne</u>), while the trees are widely scattered and consist of a characteristic collection of eucalypts, <u>Pandanus</u>, and <u>Melaleuca</u>

Water resources

High rainfall, generally low relief, and large areas of permeable Cainozoic cover all contribute to plentiful groundwater. Drilling on Cainzoic cover around the Burnside Granite area in the southeast (Crick, 1976) showed the water-table in July to be generally 10 to 20 m below surface. Malone (1962) states that usually a flow of about 1000 gallons/hour could be expected from any bore sunk in the area covered by the Pine Creek 1:250 000 Sheet area, provided it was not sited in granite or in a bad topographic position. J. Shields (pers. comm.) has had the most success from bore holes by siting them over the intersection of two or more faults interpreted from aerial photography.

Most small creeks dry up during the dry but may leave isolated waterholes. Several creeks and the Adelaide River are perennial, fed during the dry season by springs issuing from the base of the Mesozoic mesas or from limestone country in the northwest. There are several small springs in the Burnside Granite.

STRATIGRAPHY

ARCHAEAN

Rum Jungle Complex

Only the extreme southeastern corner of the Rum Jungle Complex extends into the Batchelor 1:100 000 Sheet area. The Rum Jungle Complex, previously thought to be intrusive and called the Rum Jungle Granite (Malone, 1962) contains a variety of igneous and metasedimentary rocks unconformably overlain by the Batchelor Group (Rhodes, 1965). Rhodes distinguished six major units, to which Johnson (1977) added a seventh (metasedimentary) unit containing banded iron formation ($ABgr_1$). Table 1 lists the lithology and relationships of each unit of the complex. The metadiorite ($ABgr_4$) is the only unit that does not occur in the Batchelor 1:100 000 Sheet area.

Waterhouse Complex

Previously called the Waterhouse Granite (Malone, 1962) the Waterhouse Complex is composed of similar igneous and metasedimentary rocks to the Rum Jungle Complex (Johnson, 1977). Only one unit ($ABgt_4$) crops out in the Batchelor Sheet area, along the northwestern edge. This unit has been described by Johnson as brecciated and veined fine to coarse granite, with amphibolite in places.

Age of the Rum Jungle and Waterhouse Complexes

Richards & others (1977) report that the late-stage leucogranite in the Rum Jungle Complex, ($ABgr_7$), postulated as Carpentarian by Stephansson & Johnson (1976), has a whole-rock Rb/Sr age of 2300-2400 m.y. This age is in good agreement with that determined by Page (1976). However, the mineral isochrons, determined mostly from the potassium feldspar/whole-rock tine lies, are much younger and give a mean of 1792 ± 49 m.y. Stephansson & Johnson consider this indicates a later period of enhanced mobility of Sr, during which the approximate uniformity in $^{87}Sr/^{86}Sr$ was re-established among coexisting mineral phases, but with a diffusion range smaller than hand-specimen diameter, whereby sample-to-sample differences at the whole-rock level were preserved. The mean resetting age for the minerals is remarkably close to the value of 1800 m.y. reported for the late intrusive granites elsewhere in the Geosyncline (Walpole & others, 1968) and to the age of the regional metamorphic event in the Alligator Rivers region further to the east (Page, 1975). The extrapolated zircon ages of rocks considered by Rhodes (1965) to be stratigraphically older, are at least 2500 m.y. (Richards & others, 1977).

Page (1976) reports that the coarse porphyritic granites and some microgranites from the Waterhouse Complex broadly conform to a 2400 m.y. isochron, whereas garnet gneisses, and a nearby foliated microgranite at one locality, give a whole-rock isochron of 1755 $\pm$ 26 m.y. but have a high initial $^{87}Sr/^{86}$ ratio of 0.780 $\pm$ 0.009, which indicates that these are Archaean rocks which have been reset at the younger age (Page, 1976).

LOWER PROTEROZOIC SEDIMENTS

Subdivision of these sediments follows that of Walpole & others (1968) and is as follows:

- Finniss River Group
  - Burrell Creek Formation
- Goodparla Group
  - Golden Dyke Formation
  - Masson Formation
    - Acacia Gap Tongue
- Batchelor Group
  - Coomalie Dolomite
  - Crater Formation
  - Celia Dolomite
  - Beestons Formation

The age of these groups is not precisely known, but as they unconformably overlie the Rum Jungle and Waterhouse Complexes and as the Goodparla Group is intruded by 1800 m.y. granites (Compston & Arriens, 1968) they were deposited sometime between 1800 to 2300 m.y.

Batchelor Group

Beestons Formation

Descriptions of this formation are given by Malone (1962), Walpole & others (1968), French (1970), and Lau (1971); Johnson (1977) subdivides the formation into two facies:

Ble_1 Quartzite, friable quartz sandstone, magnetitic sandstone.

Ble_2 Hematitic shale, banded ironstone, quartz-pebble conglomerate, containing arkose, arkosic conglomerate, siltstone and shale.

Ble_1 dips steeply and mainly forms strike ridges along the eastern margin of the Waterhouse Complex where it is less 30 m thick, whereas Ble_2 crops out mainly around the Rum Jungle Complex and near the northern margin of the Waterhouse Complex, is up to 200 m thick, and forms more subdued topography.

Celia Dolomite

The Celia Dolomite is generally contiguous with the Beestons Formation, south and east of the Rum Jungle Complex (French, 1970) and is markedly lenticular (Walpole & others, 1968).

The Celia Dolomite has been described by Malone (1962), Walpole & others (1968), and French (1970). Johnson (1977) has subdivided the formation into four facies around the Rum Jungle Complex (no relative age is implied):

Bll_1 dolomite, magnesitic marble, algal bioherms, and minor amphibolite interbeds.

Bll_2 silicified dolomite containing relict algal structures in places.

Bll_3 dolomitic carbonaceous sediments

Bll_4 calcareous amphibolite, micaceous quartz sandstone

Around the Waterhouse Complex, outcrop is very sparse and there is only one known exposure of a fresh calcareous amphibolite (para-amphibolite); however, very lateritised amphibolite exposed along breakaways may also be part of this unit (Johnson, 1975).

Extensive shallow stratigraphic drilling around the eastern margin of the Waterhouse Complex showed the Celia Dolomite to consist almost entirely of para-amphibolite, composed of coarse biotite, with phlogopite and tremolite, set in a fine-grained dolomite and quartz matrix (Johnson & others, in prep.).

Walpole & others (1968) comment that to the east of the Waterhouse Complex the Beestons Formation is overlain by silicified dolomite and dolomitic breccia of the Celia Dolomite, an interpretation not supported by Johnson (1975), who considers these rocks to be silicified brecciated sandstone of the Crater Formation.

Several types of algal mats are present in the Celia Dolomite (in facies Bll_1 and Bll_2) surrounding the Rum Jungle Complex. One particular cone-in-cone type stromatolite, 8 km northeast of Batchelor has been identified in Johnson (1974) as Conophyton sp., an identification subsequently confirmed by M.R. Walter (pers. comm.). In this area, the formation crops out as a number of small masses, 1 to 10 m high, and is partly silicified, the silicification being most prominent in beds rich in Conophyton (Prichard, 1976). The silicified Conophyton beds contain 24.1 - 33.1% magnesite while the unsilicified carbonate beds contained an average of 90% magnesite (Prichard, 1976).

Gypsum and halite pseudomorphs are common in this formation and were probably diagnetically emplaced from sediments originally deposited in inter-tidal to supratidal environment (Crick & Muir, 1979).

Morlock & England (1971) reported that dolomitic shales form the uppermost beds of the formation and underlie the Crater Formation 7 km east-northeast of Batchelor. Re-examination of this core showed that small grey cherty interbeds are present in the dolomitic shales, and are composed of fragments of quartz and rare K-feldspar (0.2 mm) in a cryptocrystalline matrix, suggesting that the cherty bands may be fine-grained tuffs.

The thickness of this formation appears variable - up to about 300 m in the area containing Conophyton and up to about 200 m around the Waterhouse Complex.

Crater Formation

This heterogeneous formation is also restricted to northwest of the Sheet area, and overlies the Celia Dolomite. It is made up of shale, sandstone, siltstone, arkose, grit and pebble beds, hematitised chert and quartzite, and quartz-hematite boulder conglomerate (Johnson, 1977).

Dodd (1953) and French (1970) describe a basal grit of varying thickness up to 30 m, overlain by a poorly sorted conglomerate made up of boulders of banded iron formation (BIF) and very rare pebbles of granite. The BIF boulders which are up to 60 cm long, are considered by Johnson (1974) to have been derived from Archaean BIF sediments of the Rum Jungle and Waterhouse Complexes. These BIFs are different to those elsewhere in the Pine Creek Geosyncline, which are confined mainly to the stratigraphically higher Koolpin Formation. The siliceous interbeds in the Archaean BIFs are fine-grained quartzite, unlike the chert bands common to the Lower Proterozoic BIFs.

French (1970) considers the formation was deposited in a fluviatile environment, while Johnson (1974) suggests that part of the formation was a transgressive beach deposit. The heterogeneous succession of rocks, their variable total thickness (300-600 m), and the poorly sorted conglomerates all point to a fluviatile origin.

Coomalie Dolomite

Overlying the Crater Formation is the Coomalie Dolomite, which is similar to the Celia Dolomite. Johnson (1977) subdivides the formation into three units (no relative age implied):

- Blo_1 Lateritised quartz sandstone and breccia
- Blo_2 Brecciated and silicified quartzite showing algal structures in places; chert, in places ferruginous.
- Blo_3 Dolomite, magnesite, and marble; algal in places.

Blo_1 and Blo_2 are most likely the result of recent silicification and weathering. Blo_3, which occurs mainly near the eastern flank of the Rum Jungle Complex, consists largely of gypsum pseudomorphs (Crick, 1979) which have been replaced predominately by magnesite (Prichard, 1977). The gypsum was probably emplaced diagenetically in sediments in a shallow-marine to supratidal environment (Crick & Muir, 1979). Conophyton sp. is also found in this formation and large algal mat structures are developed in places.

Goodparla Group

Golden Dyke Formation (Table 2)

Johnson (1977) describes the formation in the Rum Jungle area as mainly siltstone and shale (commonly carbonaceous and pyritic), with minor chert, ironstone, greywacke, and quartz sandstone. In the Burnside Granite area, fine-grained tuff (Crick & others, 1978) and thin beds of carbonate containing pseudomorphs after gypsum also occur.

The formation in the Rum Jungle area is subdivided into eight units (Johnson, 1977) and in the Burnside Granite area into five units (Table 2).

In the Rum Jungle area the formation has a maximum thickness of 3600 m southeast of Batchelor; it thins considerably and in places possibly lenses out, around the southern margin of the Waterhouse Complex. Around the Burnside Granite the formation has a relatively uniform thickness of about 100 m, considerably less than in the Rum Jungle area, owing to the absence of its lower units. Bld_5, in the Burnside Granite area, lenses out around the southeastern margin of the granite. Bld_7 contains fine-grained tuff in both the Rum Jungle and Burnside areas, and is considered by Crick & others (1978) to be equivalent to the Gerowie Tuff in the South Alligator Group. Regional correlations of the Golden Dyke Formation are discussed later and show that the Golden Dyke Formation is composed of five major units (Table 3) which can be traced to other parts of the geosyncline well outside the Batchelor Sheet area.

Masson Formation

Acacia Gap Tongue

This unit is characterised by the presence of quartz sandstone (pyritic in places), quartzite, and quartz greywacke. Poorly exposed pyritic carbonaceous siltstone and quartz siltstone, in places cropping out as thinly interbedded black quartz siltstone and white bleached carbonaceous siltstone (Malone, 1958), form interbeds with the quartz arenites. Interbedded pyritic quartzite, and feldspathic quartz greywacke and siltstone occur on the eastern flank of the Burnside Granite and are probably part of the Acacia Gap Tongue.

Walpole & others (1968) consider the tongue to be a western extension of the Masson Formation, protruding into the Golden Dyke Formation. In this Sheet area it is interbedded with unit Bld_5 of the Golden Dyke Formation east of Batchelor, and overlies unit Bld_4 in the Burnside Granite area, which suggests that it may be a time-transgressive unit. It reaches a maximum thickness of about 1200 m north of the Rum Jungle Complex, but in the west of the Sheet area it is generally less than 300 m thick, and apparently lenses out about 5 km southeast of Batchelor. On the eastern flank of the Burnside Granite it is about 300 m thick.

Recent field work has shown that the Acacia Gap Tongue can be traced from the Rum Jungle area eastwards for over 70 km (Crick, 1979). A regional unconformity between Bld_6 (equivalent to Koolpin Formation) and the underlying sediments (see Needham & others, 1979), which include the Acacia Gap Tongue, suggests that is is probably not a time-transgressive unit.

Finniss River Group

The Finniss River Group comprises the Burrell Creek Formation and the Noltenius Formation. The distinction between the two units, as described by Walpole & others (1968), 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. No clear-cut boundary exists between the two formations in the Sheet area, as the coarse greywacke were commonly found interbedded with siltstones and fine to medium-grained greywackes; besides, the coarser greywackes also appear to become finer to the east. Thus in the Batchelor 1:100 000 Sheet area the Noltenius Formation was not differentiated from the Burrell Creek Formation. Malone (1958) also considered the boundary between the two to be gradational, with some interfingering.

Burrell Creek Formation

Descriptions of the formation are given in Malone (1958, 1962a,b), Walpole & others (1968), and Johnson (1974, 1977). It conformably overlies the Golden Dyke Formation east of Batchelor, and in the Burnside Granite area the boundary is gradational and marked by the appearance of greywacke, commonly feldspathic. It overlaps the Golden Dyke Formation around the southern margin of the Waterhouse Complex (Malone, 1958), and exposures close to the Coomalie Dolomite (Johnson, 1977) indicate that its relationship with underlying strata may be locally unconformable.

Reddish-brown to grey siltstone or shale, commonly exhibiting slaty cleavage, constitute a major proportion of the formation. The coarser sediments include fine to coarse quartz greywacke, locally feldspathic; tuffaceous parts display rare bedding, and are interbedded with calcareous lithic-feldspathic quartz greywacke containing minor amounts of volcanic clasts made up mainly of laths of alkali feldspar. The calcareous greywacke usually crops out as isolated scattered dark grey 'flattened' elongate boulders, and is informally called 'tombstone greywacke'. Minor quartz-pebble conglomerate, and in one place a dacitic boulder conglomerate, are found in this formation.

In the western portion of the Sheet area the formation forms high strike ridges and interbeds of siltstone and medium to coarse greywacke have been sculptured by weathering, whereas in the northeastern portion of the sheet low rounded hills with rare outcrop of coarse-grained greywacke are generally covered with a thin layer of rocky rubble. Grainsize generally decreases to the east.

The sedimentary structures present are characteristic of a flysch deposit, including graded bedding, scour marks, flute casts and flame structures; and irregular thickness of beds is a common feature. In places the complete turbidite sequence as defined by Bouma (1962) is present (Johnson, 1974).

ADELAIDEAN SEDIMENTS

Tolmer Group

Descriptions of the Tolmer Group which is an arenite-carbonate-lutite assemblage found mainly along the margins of the Daly River Basin south of this Sheet area, are given by Malone (1962) and Walpole & others (1968), who provide a concise account of the group's varied nomenclatural history. Subdivision of the group in this Sheet area follows that by Malone (1962a). The group was considered to be younger than the Victoria River Group (Randal, 1962; Walpole & others, 1968), but Sweet & others (1974) consider it to be a correlative of the Bullita Group, which contains glauconite dated by the Rb/Sr method at 1120 m.y.

Buldiva Sandstone

Depot Creek Sandstone Member

This member unconformably overlies folded and faulted Lower Proterozoic sediments of the Burrell Creek Formation in the southwest of the Sheet area, the Golden Dyke Formation east of the Waterhouse Complex, and the Coomalie Dolomite about 2 km west of Batchelor, at Castlemaine Hill.

The member consists mainly of ripple marked pink medium to coarse quartz sandstone, which in places is friable or silicified. It is generally well-sorted and bedded and contains rare lenses of conglomerate. Malone (1958) and Johnson (1974) report the presence of a basal breccia, probably a silicified regolith (Johnson, 1974) which mainly consists of angular fragments of chert or quartzite in a siliceous hematite-rich fine-grained sandy matrix. In places, especially over the Golden Dyke Formation, the breccia fragments are shale, whereas at Castlemaine Hill, quartz breccia fragments give way to carbonate fragments at depth (Spratt, 1965). Fluorapatite has been identified in parts of the sandstone and breccia, particularly where it overlies the Coomalie Dolomite (Pritchard & others, 1963).

Malone (1958) comments that outliers of this member were apparently deposited in irregularities in the Lower Proterozoic basement, which accounts for their present scattered distribution, and Stephansson & Johnson (1976) propose that the isolated outcrops of the member around the Waterhouse Complex were deposited within a rim-syncline which developed about 1800 m.y. ago. The thickness of the member in the Sheet area is not known, but is probably less than 150 m.

Stray Creek Sandstone Member

The member rests unconformably on the Depot Creek Sandstone Member within a triangular outcrop area of Adelaidean and younger sediments in the southwest of the Sheet area. It is faulted against the Burrell Creek Formation along its western edge. It consists mainly of well-bedded fine to medium-grained well-sorted quartz sandstone; the grains are subangular to well-rounded. Beds of commonly pink siliceous fine-grained rock which may be silicified dolomite occur towards the top of the member. The thickness of the unit is about 200 m.

Hinde Dolomite

This unit rests conformably on the Buldiva Sandstone, within the same triangular outcrop area of sediments in the southwestern part of the Sheet area, as several small isolated outcrops. It consists of flaggy grey to pink dolomite and stromatolitic carbonates identified by Walpole & others (1968) as 'Collenia' bioherms. Its thickness is not known.

Waterbag Creek Formation

The formation conformably overlies the Hinde Dolomite within the same wedge of sediments mentioned above, and is confined to an outcrop area of less than 5 km^2. It consists of interbedded ferruginous sandstone, varicoloured siltstone and silicified limestone and marl less than 100 m thick. The sandstone and siltstone contain pseudomorphs after halite.

PALAEOZOIC SEDIMENTS

Daly River Group

The Daly River Group was first defined by Noakes (1949) and includes all the Lower Palaeozoic sediments of the Daly River Basin mainly to the southeast of this Sheet. The group is subdivided by

Malone (1962a) and Randall (1962, 1963) into three formations of which two, the Tindall Limestone and the Jinduckin Formation, are present in the southwest corner of this Sheet. A summary of geological investigations of the group is given by Opik (1956), Walpole & others (1968), and Jones (1971).

Tindall Formation

The formation is early Middle Cambrian (Opik, 1956; Gatehouse, 1968). It forms scattered outcrops of horizontal mainly fine grey fossiliferous limestone, commonly containing nodular algal structures and bands and nodules of chert. Outcrops are commonly pillars of limestone boulders. Several sink-holes are present in the extreme southwest indicating the presence of the limestone under Cainozoic cover. Less than 5 m of section is exposed.

Jinduckin Formation

The formation is poorly exposed and less than 10 m of section is known. It consists mainly of siltstone and silty shale with minor interbedded sandstone and silicified carbonate. Outcrop is commonly lateritized or very ferruginous. The formation is Cambrian to early Ordovician; early Ordovician (Tremadocian) fossils are present in the uppermost part of the formation (Opik, 1968; Jones, 1971). It conformably overlies the Tindall Formation.

MESOZOIC SEDIMENTS

Mullaman Beds

The Mullaman Beds form isolated flat-lying residual mesas capped by laterite and unconformably overlie the Burrell Creek Formation, Tolmer Group, and the Daly River Group in the southwest of the Sheet area. Descriptions of the beds, which extend over large areas of northern Australia are given by Skwarko (1966, 1967, 1968) who assigns them to the Lower Cretaceous. Recently, Hughes (1978) has redefined these beds as the Early Jurassic to Neocomian Petrel Formation.

In the Sheet area, the beds consist of moderately to poorly sorted commonly poorly consolidated quartz sandstones and conglomerates with rounded to angular grains in a clayey or limonitic matrix. The pebbles in the conglomerates consist of generally well-rounded milky quartz. Micaceous, buff, clayey quartz sandstone and sandy claystone are also present. The finer-grained sediments are thinly bedded and commonly ferruginous; in places ironstone is found at the base of the beds.

The beds probably represent the most northerly occurrence of the Inland Belt of Skwarko (1966, 1967) which characteristically contains lacustrine sandstones and finer-grained marine sediments. The thickness of the beds is variable, but is up to about 30 m.

CAINOZOIC SEDIMENTS

Roughly half the Batchelor Sheet area is covered by Cainozoic sediments, which have been subdivided into four units:

Qa Alluvium consisting of sand, silt, clay and black soil, commonly found adjacent to, and in, drainage channels and flood plains which abound in the northeast of the Sheet.

Qs Talus and colluvial sand.

Czs Unconsolidated detritus of unknown origin is assigned to this unit.

Czl Massive and nodular laterites, developed in patches over all rock units. The Mullaman Beds are commonly capped with massive laterite.

GEOMORPHOLOGY

Since the deposition of the Mullaman Beds, the area has been subject to continuous erosion. At least three land surfaces, the products of three main erosional cycles, developed during the Cainozoic era in the Katherine-Darwin region (Hays, 1968). The oldest is the Tennant Creek Surface which has not been positively identified in this Sheet area.

The Wave Hill Surface is lower than and encroaches upon, the Tennant Creek Surface. Hays (1968) describes it in the Pine Creek area, southeast of the Batchelor Sheet, as a deeply dissected plateau which is gradually reduced to a string of residuals along interfluves northwards and north-eastwards to the coast. Some of the higher ridges of Lower Proterozoic sediments are flat-topped, indicating the presence of this surface in the Sheet area.

The Koolpinyah surface is considered by Hays to be developing at present in the coastal areas and in a few inland basins directly connected to the coastal plains. Little of this surface is represented in the Batchelor Sheet area, and Williams (1969) consider that it has been largely removed by recent erosion.

INTRUSIVE ROCKS

Zamu Dolerite

The Lower Proterozoic sediments of the Acacia Gap Tongue and the Golden Dyke Formation are intruded by highly altered doleritic sills. They occur as a series of roughly circular ridges around the Burnside Granite and in an anticline to the west of the granite. Although no basic intrusions crop out in the northwest corner of the Sheet area, drilling 3 km southeast of Batchelor (Johnson, 1977) intersected amphibolites within units Eld_1 and Eld_2 of the Golden Dyke Formation in BMR drill holes 23, 26, and 27 (shown on the map). The amphibolites consist mainly of fine to coarse fibrous actinolite and recrystallised polygonal quartz; relict doloritic textures are also present.

Eight kilometres east of Batchelor a rock which has an iron-rich gossanous appearance, and which directly overlies the Acacia Gap Tongue, has been referred to by Malone (1958), Bryan (1962), and Walpole & others (1968) as a highly altered basic sill.

Descriptions of the basic intrusives in the Burnside Granite area are given by Bryan (1962) and Walpole & others (1968). These authors agree with Noakes (1949), Sullivan & Iten (1952), and Malone (1962), who considered that these basic rocks were emplaced as sills before folding. They are generally concordant but are slightly transgressive near the southeastern boundary of the granite. Thicknesses vary considerably from less than 1 m to up to 30 m, but within one sill the thickness may be remarkably uniform over a distance of several kilometres or more. No sills occur in or above unit Eld_7 of the Golden Dyke Formation, and the major sills appear to have been emplaced near or on the boundary between the different lithological units, i.e. between Eld_7 and Eld_6, Eld_6 and Eld_5, Eld_5 and Eld_4, and Eld_4 and the Acacia Gap Tongue.

The intrusives consist mainly of fine to medium-grained actinolite-feldspar rock, in places coarser grained. Bryan (1962) considers that the rocks were originally fine to medium-grained dolerites containing coarser segregations richer in pyroxene, and that the pyroxenes were subsequently uralitised due to the combined effects of autometamorphism and regional metamorphism. On the other hand, Ferguson & Needham (1978) consider that contact metamorphism to amphibolite grade up to 1 km away from the granite contact has been responsible for the alteration. However, amphibolite from BMR drill hole B7 (plotted on the map) 200 m from the granite contact, contains cores of actinolite in green hornblende (Crick, 1976) indicating that uralitisation had in fact occurred before contact metamorphism.

All the amphibolites in the western part of the Pine Creek Geosyncline are included in the Zamu Dolerite, a new term replacing 'Zamu Complex' and including intrusions of that name in the South Alligator River area (Ferguson & Needham, 1978). The amphibolites are generally ortho-pyroxene-normative and their major and trace-element chemistry indicates they are continental tholeiites (Ferguson & Needham, 1978).

Burnside Granite

The Burnside granite has diapirically intruded and domed Lower Proterozoic sediments, which form an incomplete rim-syncline around the granite's southwestern margin. It is a fairly homogeneous fine to coarse biotite adamellite, in places porphyritic and containing rare xenoliths. Aplite, pegmatite, and quartz veins are common, especially near its southern margin, and in places the granite is sheared. A large north-trending vertical quartz vein about 1.5 m wide, bisects the granite and is probably associated with faulting observed near its southern margin.

A Rb-Sr age of 1760 m.y. has been determined by Leggo (in Walpole & others, 1968) for this and other granites in the Pine Creek Geosyncline, and a K/Ar age of 1520 m.y. for biotite in this granite was determined by Hurley & others (1961). Compston & Arriens (1968) report a preliminary figure of 1830 m.y. based on two whole-rock Rb/Sr analyses from the Burnside Granite, from unpublished work by P.J. Leggo and G.H. Riley. The younger K/Ar age probably reflects argon loss caused by a later episode of heating. Stephansson & Johnson (1975) suggest it could possibly reflect retrograde metamorphism of the granite at the time of intrusion in a solid-state, following its formation about 300 m.y. earlier. However, there is no evidence to suggest that granites are emplaced in a solid-state (Dr B.W. Chappell, pers. comm.).

Subsurface granitic bodies

Stephansson & Johnson (1975) propose that granite diapirism in the Pine Creek Geosyncline occurred after formation of a regional granitic layer at depth, and that the diapirs were formed at an average distance of 24.2 km between the domes, which they suggest is a valid figure for the central part of the geosyncline. However, it is difficult to reconcile this figure with the character of the Cullen Granite, which is made up of a number of coalescing granitic plutons. Using their figure, they postulate a hidden granitic body half-way between the Waterhouse Complex and the Burnside Granite, and point to a weak gravity anomaly as indicating the presence of that body.

Structural and metamorphic evidence strongly suggests the Waterhouse and Rum Jungle Complexes have been diapirically intruded (Stephansson & Johnson, 1975), but the late-stage leucogranite granites in the complexes, which coincide with mass deficiencies, are not, as they suggest, much younger than the surrounding granites. All the granite in the complexes are in the order of 2300-2500 m.y. old (Page, 1976; Richards & others, 1977).

STRUCTURE

ARCHAEAN

The schist, gneiss, and granite gneiss in the Rum Jungle and Waterhouse Complexes are strongly contorted. Rhodes (1965) reports that in the Rum Jungle Complex the general foliation strike is easterly. A local conspicuous foliation strike at about 140° can be found throughout the complex; this is subparallel to the axes of the north-westerly folds of the surrounding metasediments. Walpole & others (1968) state that the trends of the foliation and banding in the older rocks of the complex range from 090° to 180°, but the most prominent direction is 110°.

LOWER PROTEROZOIC

Folding

Substantial deformation (D_1) of the lower Proterozoic sediments has resulted in tight to isoclinal folding (F_1) with north-trending fold axes. In the Burnside Granite area the folds in places are overturned, possibly as a result of the granite's intrusion. The large Howley Anticline, which includes sediments of the Golden Dyke Formation west of the Burnside Granite (Sullivan & Iten, 1952), is in places, doubly-plunging. Stephansson & Johnson (1975) report that polyphase folding structures die out away from the Rum Jungle and Waterhouse Complexes, and cite this fact amongst others as evidence that the complexes were diapirically intruded by a younger granite. Stephansson & Johnson (1975) believe that the F_1 folds were refolded (as, for example, in the Howley Anticline) as a result of forces generated by granite intrusions and that such folds were not caused by any major orogeny involving crustal shortening or metamorphism.

The strike of the F_1 fold axes varies in places around the margin of the Burnside Granite. South of the granite the fold axes trend more easterly, probably influenced by the development of a rim-syncline in that area. Walpole & others (1968) suggest that the Rum Jungle, Waterhouse, and Burnside Domes existed before the final folding of the sediments. They suggested that the sediments were folded around rigid blocks which were probably moved vertically relative to the neighbouring sediments, thus producing the steep dips on the flanks of the domes. Dips around the margin of the Burnside Granite vary from shallow to steep, and as it is transgressive in places and is the same age as the Cullen Granite (which has intruded tightly to isoclinally folded sediments of the Masson Formation in the Mundogie 1:100 000 Sheet area, resulting in overturning of the folds in places (Needham & others, 1978), there is no evidence to suggest that the Burnside Dome existed before the final folding of the Lower Proterozoic sediments. However, the contention of Walpole & others (1968) the Waterhouse and Rum Jungle Complexes have moved vertically is supported by the structural analysis by Stephansson & Johnson (1975), who suggest that diapiric intrusion of Carpentarian granites into both complexes domed the Batchelor and lower Goodparla Group sediments, and was accompanied locally by the formation of major D_2 structures. Berkman (1965) and Rhodes (1965) considered that polyphase folding uplifted the Rum Jungle Complex and domed the overlying sediments; Stephansson & Johnson (1975) noted that the polyphase folds die out radially away from the Rum Jungle Complex, and considered diapirism a more likely mechanism for uplift of the complex with the attendant focus of intensity of polyphase folding.

Faulting

The Burrell Creek Formation in the centre of the Batchelor 1:100 000 Sheet area is cut by meridional faults. They include both high-angle normal and reverse faults. The Mount Shobridge Fault is the longest (30 km) and has a net vertical displacement of west block down. Walpole & others (1968) consider these to have been basement faults antedating the deposition of the Burrell Creek Formation.

Younger meridional and northeast-trending faults intersect Lower Proterozoic, Adelaidean, and Palaeozoic sediments in the southwest of the Sheet area. These include high-angle and vertical normal faults, and wrench faults. The longest, the Adelaide River Fault, over 20 km long, has a net horizontal displacement (dextral) of about 500 m.

Minor strike-slip, vertical to low-angle, normal and reverse dip faults cut the Lower Proterozoic metasediments near the margin of the Burnside Granite.

METAMORPHISM

Rhodes (1965) states that the schists and gneisses of the Rum Jungle Complex ($ABgr_2$) formed in the almandine-amphibolite facies (Turner & Verhoogen, 1960). Minor retrograde metamorphism has occurred in the granite gneiss ($ABgr_3$), and metadiorite ($ABgr_4$), where small grains of secondary epidote are present in oligoclase. Along the southern margin of the complex, where shearing has been most intense, the plagioclase in the coarse granite ($ABgr_5$) has been almost completely sericitised, and veinlets of quartz cut the fractured mineral grains (Rhodes, 1965). Many of the plagioclase crystals in the large-feldspar granite ($ABgr_6$) have also been extensively replaced by sericite, which appears to be closely associated with veins of quartz-microcline pegmatite.

The Lower Proterozoic sediments were regionally metamorphosed to the lower greenschist facies at about 1800 m.y., whereas the Adelaidean and Palaeozoic sediments have only undergone diagenesis.

Contact metamorphism around the Burnside Granite produced chiastolite schists in the Golden Dyke Formation (Bld_4) to about 200 m from the contact. Spotted and knotted schists and phyllites occur up to about 1 km away from the outcrop of the granite's margin.

The presence of contact metamorphic affects around the Rum Jungle and Waterhouse Complexes is less certain. W.M.B. Roberts (pers. comm.) has described specimens from the Celia Dolomite around the eastern flank of the Waterhouse Complex, consisting of coarsely crystalline biotite with some phlogopite and tremolite, set in a matrix of fine-grained dolomite and quartz; he consideres the are hydrothermal assemblages rather than metamorphic. Malone (1962a) states that in the Rum Jungle open cuts, the rocks include tremolite schist, andalusite-mica schist, chiastolite schist, talc schist, and phyllite. Rhodes (1965) states that andalusite in these rocks is confined to mineralised shear zones.

Stephansson & Johnson (1975) report that in the Waterhouse Complex, near its eastern margin, scapolite crystals are found in brecciated diorite and granodiorite, and Marjoribanks (1967) states that scapolitisation of impure dolomitic rocks at Mount Fitch, 14.5 km northwest of Batchelor, is associated with quartz-tourmaline veins. The particular nature of both these occurrences suggests that localised hydrothermal effects have produced the scapolite. Stephansson & Johnson (1975) consider the apparently higher grade of metamorphism of the Celia Dolomite on the eastern side of the Waterhouse Complex, and the presence of scapolite, have originated from an 'igneous reactivation' of the Archaean basement. Certainly, if these metamorphic effects were due to high-temperature hydrothermal solutions, then a concealed granite intrusion could account for the high temperatures. However, there are no clear-cut contact metamorphic effects in Lower Proterozoic sediments in the Rum Jungle area which can be ascribed to a nearby identifiable granitic intrusion.

Stephansson & Johnson (1974) suggest that rare quartz-tourmaline veins that cut mainly the Crater Formation on the east of the Archaean complexes may have resulted from late hydrothermal activity associated with their 'igneous reactivation'.

Contact metamorphism associated with the intrusion of the Zamu Dolerite is extremely localised; it has been described by Bryan (1962) as occurring up to 5 ft (c. 1.5 m) away from the contact in the Rum Jungle area and up to 10 ft (c. 3 m) in the Burnside Granite area.

MINERALISATION

Comprehensive descriptions of mineralisation in the Batchelor 1:100 000 Sheet area are given in P.W. Crohn's account of mineralisation in the Katherine-Darwin region (in Walpole & others, 1968), and by Sullivan & Iten (1952) for the Burnside Granite area (Brocks Creek District).

No mining was taking place in this area (apart from the quarrying of aggregate) at the time of writing (July 1978). Gold (about 110 000 oz) and uranium (about 46 tonnes U_3O_8) have been produced from this Sheet area.

The Golden Dyke Formation is the most mineralised unit (Au, Ag, Cu, Pb, Zn, Fe, U). Minor mineralisation occurs in the Burrell Creek Formation (Au, U), at the base of the Depot Creek Sandstone Member in the Rum Jungle area (P), in the Crater Formation (Th, Au), and in the Coomalie and Celia Dolomites (Mg).

Mineralisation in the Burnside Granite area (Au, Cu, Fe, U) is mainly in units Bld_4, Bld_5 and Bld_6 of the Golden Dyke Formation. Minor mineralisation (Cu, U) also occurs in these units in the Rum Jungle area southeast of Batchlor, while the major deposits in the Rum Jungle area occur at the base of the Golden Dyke Formation (Bld, and Bld_2) near its boundary with the underlying Coomalie Dolomite.

Sullivan & Iten (1952) consider the gold mineralisation in the Burnside Granite area 'most intense' in the vicinity of drag folds and some small cross-faults, although they comment that it does show strong stratigraphic control (mainly Bld_6).

Sullivan & Iten (1952) consider the granites, e.g. the Burnside Granite, to have been significant in localising orebodies. The intrusion of the granites would have created a large groundwater circulatory system which may have been responsible for the leaching of metals from suitable source rocks, for example the tuff unit, Bld_7, or the basic sills. Subsequent redeposition took place in geochemically favourable carbonaceous-carbonate units of the Golden Dyke Formation.

Mineralisation within the basal units of the Golden Dyke Formation in the Rum Jungle area appears to be contained within an analagous carbonaceous-carbonate association to that in the Burnside Granite area. The mineralisation is commonly thought to be primarily syngenetic, with minor remobilisation and redeposition within fractures and shears (e.g. Walpole & Condon, 1955; Roberts, 1973). Stable-siotope studies by T.H. Donnelly (pers. comm.), of the Woodcutters Pb-Zn deposit 12 km northeast of Batchelor and of Browns Pb-Zn-Cu deposit 6 km northwest of Batchelor, suggest the presence of sulphides that have a magmatic component; the larger spread of the $\delta^{34}S$ values when compared to results from the Mount Bonnie deposit (southeast of the Batchelor Sheet area) indicates that some of the sulphur was derived from other sources.

The presence of andalusite, mentioned before, in shears, breccias, or associated with quartz-tourmaline veins, points to the presence at one time of high-temperature solutions. The intrusion of a younger granite, not yet exposed in the Rum Jungle and Waterhouse Complexes as proposed by Stephansson & Johnson (1975) may have initiated connate or a groundwater circulatory system in the Rum Jungle area also.

Density contrasts between the evaporites of the Celia and Coomalie Dolomites and adjacent pelitic rocks would be sufficient to produce diapirs. Many of the uranium and base-metal deposits in the Rum Jungle area appear to be located near carbonate anticlinal cores which may in fact be diapirs (Crick & Muir, 1979). In addition, brines produced during diagenesis and replacement of the evaporites (mainly by magnesite) would have greatly facilitated leaching of uranium and other metals from adjacent sediments and from the nearby Archaean basement (Crick & Muir, 1979).

Uranium mineralisation occurs in a shear zone cutting greywackes and siltstones of the Burrell Creek Formation at the Adelaide River mine 4 km south of Adelaide River (Plumb, 1960) and in joints and minor shear zones at the George Creek Prospect 14 km south of Adelaide River (Arkin & Walpole, 1960). Minor gold mineralisation (commonly associated with quartz veining) also occurs in fractures and shears in the Burrell Creek Formation. Such occurrences suggest a low-temperature hydrothermal origin. The presence of the Lower Proterozoic-Adelaidean unconformity within a few kilometres of the George Creek and Adelaide River prospects may be significant, similar to the association of the Lower Proterozoic-Carpentarian unconformity with uranium deposits in the South Alligator River valley (see Crick & others, 1979).

REGIONAL STRATIGRAPHIC CORRELATIONS

The similarity of the chert-banded and nodular shale siltstones in the Golden Dyke Formation (Bld_6) to those in the Koolpin Formation is commented on by Walpole & others (1968). However, they considered that the Koolpin Formation, which crops out in the South Alligator River valley, 100 km to the east, was deposited at a later time in a separate basin. Foy & Miezitis (1977) and Needham & others (1978), however, show that the basis for a separate basin does not exist. Furthermore the Gerowie Chert, which was thought by Walpole & others (1968) to be possibly a diagenetically altered dolomite, is composed mostly of tuff and does not interfinger with the Koolpin Formation as suggested by Walpole & others (1968), but overlies it (Crick & others, 1978a). Sedimentation in the Pine Creek Geosyncline probably took place during the Lower Proterozoic in a single basin.

The similarity of the Koolpin Formation to unit Bld_6 in the Golden Dyke Formation, and the fact that both are immediately overlain by a tuffaceous unit, strongly suggest that they are equivalent (Crick & others, 1978a). Overall, substantial changes have been made to the stratigraphy of the Golden Dyke Formation which is now subdivided into a number of formations (See Needham & others, 1979).

GEOLOGICAL HISTORY

1. During the Archaean, continental crust consisting of high-grade metamorphic rocks intruded by granites was formed and subsequently eroded to form probably a mature surface with possibly the Rum Jungle and Waterhouse Complexes remaining as topographic highs.

2. Initial phases of sedimentation in the Lower Proterozoic (Batchelor Group and Golden Dyke Formation) occurred mainly in an intertidal to supratidal environment which resulted in evaporites forming in the Celia and Coomalie Dolomites.

3. Volcanism, which produced the fine-grained tuffs in the upper section of the Golden Dyke Formation, preceded a deepening of the basin and the introduction, in increasing quantities, of turbidites commonly containing volcanic clasts (Burrell Creek Formation).

4. Continental tholeiitic sills (Zamu Dolerite) intruded the undeformed sediments of the Masson and Golden Dyke Formations. The Lower Proterozoic sediments were subsequently metamorphosed to greenschist facies at 1800 m.y., and folded. The intrusion of the Burnside Granite into the folded metasediments, and the doming of the Rum Jungle and Waterhouse Complexes and surrounding metasediments by a granite batholith that has not yet been exposed by erosion completed this phase of igneous and tectonic activity at the end of the Lower Proterozoic and in the early Carpentarian.

5. Shallow-marine sediments were deposited at infrequent intervals in the Adelaidean, Palaeozoic, and Mesozoic eras, ending with deposition of the Lower Cretaceous Mullaman Beds. Little tectonic activity apart from faulting took place during this period.

6. Since the Cretaceous, this area has remained above sea level. At least three erosional cycles have occurred, delineated by the three land surfaces apparent in the present-day extremely mature surface.

REFERENCES

ARKIN, J., & WALPOLE, B.P., - Results of developmental work, George Creek uranium prospect, Northern Territory. Bureau Mineral Resources Australia Record 1960/10.

BAJORUNAS, L., & DUANE, D.B., 1967 - Shifting offshore bars and harbor shoaling. Journal Geophysical Research 72, No. 24, 6195-6210.

BOUMA, A.H., 1962 - SEDIMENTOLOGY OF SOME FLYSCH DEPOSITS, Amsterdam, Elsevier.

BRYAN, R., 1962 - Lower Proterozoic basic intrusive rocks of the Katherine-Darwin Area N.T. Bureau Mineral Resources Australia Record 1962/7.

COMPSTON, W., & ARRIENS, P., 1968 - The Precambrian geochronology of Australia, Canadian Journal of Earth Science 5

CONDON, M.A., & WALPOLE, B.P., 1955 - Sedimentary environment as a control of uranium mineralisation in the Katherine-Darwin region, Northern Territory. Bureau of Mineral Resources Australia Report 24.

CRICK, I.H., 1976 - Shallow stratigraphic drilling in the Burnside Granite area, Batchelor 1:100 000 Sheet, Northern Territory, 1975. Bureau Mineral Resources Australia Record 1976/101

CRICK, I.H., & MUIR, M.D., 1979 - Evaporites and uranium mineralisation in the Pine Creek Geosyncline. Proceedings of the International Uranium Symposium on the Pine Creek Geosyncline, Sydney June 4-8 1979 (in press).

CRICK, I.H., MUIR, M.D., NEEDHAM, R.S., & ROARTY, M.J., 1979 - The geology and mineralisation of the South Alligator Uranium Field. Proceedings of the International Uranium Symposium on the Pine Creek Geosyncline, Sydney June 4-8 1979 (in press).

CRICK, I.H., STUART-SMITH, P.G., & NEEDHAM, R.S., 1978a - Stratigraphic significance of a discovery of Lower Proterozoic tuff in the Pine creek Geosyncline. Bureau of Mineral Resources Journal of Australian Geology & Geophysics 3, 1978 pp. 163-165

CRICK, I.H., STUART-SMITH, P.E., & NEEDHAM, R.S., 1978b - Advance in the understanding of the stratigraphy of the Pine Creek Geosyncline, Northern Territory. Abstracts. 7th BMR Symposium, 1978 Bureau of Mineral Resources Record 1978/21.

DODD, P.H., 1953 - Crater line investigations. Bureau of Mineral Resources Australia Record 1953/29.

EVANS, O.F., 1942 - The origin of spits, bars, and related structures. University of Chicago Press. Reprinted in 'Spits and Bars' ed. M.L. Schwartz, Benchmark Papers in Geology, Dowden, Hutchison & Ross, Inc., 1972.

FERGUSON, J., CHAPPELL, B.W., & GOLEBY, A.B., in prep. - Granitoids in the Pine Creek Geosyncline. International Uranium Symposium on the Pine Creek Geosyncline, Sydney June 4-8 1979. Abstracts.

FERGUSON, J., & NEEDHAM, R.S., 1978 - The Zamu Dolerite - a Lower Proterozoic pre-orogenic continental suite from the Northern Territory, Australia. Journal of the Geological Society of Australia, 25, 309-322.

FOY, M.F., & MIEZITIS, Y., 1977 - Uranium mineralisation at Anomaly 2J, South Alligator Valley, Northern Territory, and its significance concerning regional structure and stratigraphy. Proceedings Australian Institute of Mining and Metallurgy, 261, 1-11.

FRENCH, D.J., 1970 - Crater Formation investigation, Rum Jungle district, Northern Territory, 1969, Bureau of Mineral Resources Australia Record 1970/65

GATEHOUSE, C.G., 1968 - Early Middle trilobites from the Litchfield area, Northern Territory. Bureau of Mineral Resources Australia Bulletin 80, 45-63.

HAYS, J., 1968 - Notes on Geomorphology, in Walpole and others, 1968 - Geology of the Katherine-Darwin region, Northern Territory. Bureau of Mineral Resources Australia Bulletin 82, p.161-170

HUGHES, R.J., 1978 - The geology and mineral occurrences of Bathurst Island, Melville Island and Cobourg Peninsula, Northern Territory. Bureau of Mineral Resources Australia Bulletin 177, 72 p.

HURLEY, P.M., FISHER, N.H., PINSON, W.H. Jr, & FAIRBAIRN, H.W., 1961 - Geochronology of Proterozoic granites in the Northern Territory, Australia; part 1. K-Ar and Rb-Sr age determinations. Bulletin of the Geological Society of America, 72(5) 653-662

JOHNSON, K., 1974 - Progress Report: Geological Review and Revision of the Rum Jungle area, Northern Territory, 1973. Bureau of Mineral Resources Australia Record 1974/41

JOHNSON, K., 1977 - Geology of Rum Jungle 1:100 000 Special map, Preliminary Edition. Bureau of Mineral Resources Australia

JOHNSON, K., HONE, I.G., & INGRAM, J.A., (in prep.) - Stratigraphic drilling in the Rum Jungle area, 1973-4. Bureau of Mineral Resources Australia Record.

JONES, P.J., 1971 - Lower Ordovician Conodonts from the Bonaparte Gulf Basin and the Daly River Basin, Northwestern Australia. Bureau of Mineral Resources Australia Bulletin 117

LAU, G.C., 1971 - Geochemical and radiometric investigation, Stapleton area, Rum Jungle district, N.T. Bureau of Mineral Resources Australia Record 1971/98

MACKAY, N.J., 1953 - Crater Prospect (1951), Rum Jungle. Bureau of Mineral Resources Australia Record 1953/28

MALONE, E.J., 1958 - Geology of the Darwin-Adelaide River Area, N.T. Bureau of Mineral Resources Australia Record 1958/96.

MALONE, E.J., 1962a - Pine Creek, N.T. - 1:250 000 Geological Series. Bureau of Mineral Resources Australia explanatory Notes SD/52-8.

MALONE, E.J., 1962b - Darwin, N.T. - 1:250 000 Geological Series. Bureau of Mineral Resources Australia explanatory Notes SD/52-4.

MARJORIBANKS, R.W., 1967 - A geological and radiometric survey of the Western Part of the Hundred of Goyder, N.T. Territory Enterprises Pty Ltd Report

MATHESON, R.S., 1950 - Report of the geology of the Rum Jungle uranium-bearing area, Northern Territory. Bureau of Mineral Resources Australia Record 1950/47

MORLOCK, J.S., & ENGLAND, R.N., 1971 - Results of the Crater Formation drilling, Rum Jungle district, N.T. Bureau of Mineral Resources Australia Record 1971/65

NEEDHAM, R.S., STUART-SMITH, P.G., CRICK, I.H., & ROARTY, M.J., 1978 - Mundogie 1:100 000 Sheet area data record. Bureau of Mineral Resources Australia Record 1978/103.

NEEDHAM, R.S., FERGUSON, J., & PRICHARD, C.E., 1979 - Excursion Guide. International Uranium Symposium on the Pine Creek Geosyncline, Sydney June 4-8 1979.

NOAKES, L.C., 1949 - A geological reconnaissance of the Katherine-Darwin Region, Northern Territory. Bureau of Mineral Resources Australia Bulletin 16

ÖPIK, A.A., 1956 - Cambrian Geology of the Northern Territory. In El sistimo cambrico, su paleogeogratia y el problema de su base. 20th International Geological Congress, Mexico, 2.

PAGE, R.W., 1975 - Geological Branch: Summary of Activities, 1975. Bureau of Mineral Resources Australia Report 194

PAGE, R.W., 1976 - Geological Branch: Summary of Activities, 1976. Bureau of Mineral Resources Australia Report 196

PLUMB, K.A., 1960 - Results of diamond drilling at Adelaide River uranium mine, 1959-60. Bureau of Mineral Resources Australia Record 1960/90.

PRICHARD, C.E., 1976 - Magnesite - Northern Territory. Economic Geology of Australia and Papua New Guinea. 4. Industrial Minerals and Rocks. Australian Institute of Mining and Metallurgy.

PRITCHARD, P.W., & FRENCH, D.J., 1965 - Rum Jungle geochemical survey 1963, Mt Burton Mine - North Mt Fitch Prospect area. Bureau of Mineral Resources Australia Record 1965/6

RANDAL, M.A., 1962 - Fergusson River, N.T. - 1:250 000 Geological Series. Bureau of Mineral Resources Australia explanatory Notes SD/52-12.

RHODES, J.M., 1965 - The geological relationships of the Rum Jungle Complex, N.T. Bureau of Mineral Resources Australia Report 89.

RICHARDS, J.R., RUXTON, B.P., & RHODES, J.M., 1977 - Isotopic dating of the leucocratic granite, Rum Jungle, Australia. Proceedings of the Australasian Institute of Mining and Metallurgy 264, p.33-43

ROBERTS, W.M.B., 1973 - Dolomitisation and the genesis of the Woodcutters lead-zinc prospect, Northern Territory, Australia. Mineralium Deposita 8, 35-36.

SKWARKO, S.K., 1966 - Cretaceous stratigraphy and palaeontology of the Northern Territory. Bureau of Mineral Resources Australia Bulletin 73

SKWARKO, S.K., 1968 - in Walpole and others, 1968 - Geology of the Katherine-Darwin region, Northern Territory. Bureau of Mineral Resources Australia Bulletin 82.

SPRATT, R.N., 1965 - Uranium ore deposits of Rum Jungle; in GEOLOGY OF AUSTRALIAN ORE DEPOSITS. 8th Commonwealth Mining and Metallurgy Congress, Melbourne, 1, 201-6.

STANTON, R.L., 1972 - ORE PETROLOGY. New York, McGraw-Hill.

STORY, R., 1969 - Vegetation of the Adelaide - Alligator Rivers Area in Lands of the Adelaide-Alligator Area, Northern Territory. Commonwealth Scientific and Industrial Research Organisation, Australia Land Research Series 25, 114-130.

STEPHANSSON, O., & JOHNSON, K., 1975 - Granite Diapirism in the Rum Jungle Area, Northern Australia. Precambrian Research, 3, 159-185.

SULLIVAN, C.J., & ITEN, K.W.B., 1952 - The geology and mineral resources of the Brocks Creek district, Northern Territory. Bureau of Mineral Resources Australia Bulletin 12.

SWEET, I.P., MENDUM, J.R., MORGAN, C.M., & PONTIFEX, I.R., 1974 - The geology of the Northern Victoria River Region, Northern Territory. Bureau of Mineral Resources Report 166.

TURNER, F.J., & VERHOOGEN, J., 1960 - IGNEOUS AND METAMORPHIC PETROLOGY 2nd edn. N.Y. McGraw-Hill.

WALPOLE, B.P., CROHN, P.W., DUNN, P.R., & RANDAL, M.A., 1968 - Geology of the Katherine-Darwin region, Northern Territory. Bureau of Mineral Resources Australia Bulletin 82.

WILLIAMS, M.A.J., 1969 - Geomorphology of the Adelaide-Alligator area in Lands of the Adelaide-Alligator area, Northern Territory. Commonwealth Scientific and Industrial Research Organisation, Australia. Land Research Series 25, 71-94.

TABLE 1. LITHOLOGY AND RELATIONSHIPS OF ROCK UNITS IN THE RUM JUNGLE COMPLEX, AFTER RHODES (1965) AND JOHNSON (1977)

Unit	Description	Relationships
$ABgr_7$	Leucocratic granite; fine to medium, even grained, pink or grey adamellite, aplitic and pegmatitic in places	Youngest rock in the Complex
$ABgr_6$	Large-feldspar granite; adamellite with large tabular or ovoid feldspars up to 6 cm	Intruded and veined by pegmatites and leucogranite granite. Contains inclusions of schist, gneiss, and diorite
$ABgr_5$	Coarse granite; pink, leucocratic, massive, coarse, equigranular adamellite.	Appears to grade into large-feldspar granite; contains xenoliths of schist and is cut by veins of leucocratic granite
$ABgr_4$	Metadiorite; dark, fine-grained; massive, except where locally sheared	Intruded and veined by leucocratic granite; forms inclusions in large-feldspar granite, and appears to grade laterally into it. Does not crop out in the Sheet area.
$ABgr_3$	Granite gneiss, medium-grained, equigranular; well-banded granite gneiss, to streaky nebulitic granite gneiss, to homogeneous gneissic granite	Cut by leucocratic granite and pegmatites; contains inclusions of schist and gneiss. Appears to grade into large-feldspar granite
$ABgr_2$	Schists and gneisses; includes biotite gneiss, biotite-muscovite gneiss, biotite granofels, thinly banded feldspathic gneiss, quartz-muscovite schist, minor phyllite, chlorite schist, actinolite schist	Small, poorly exposed area on eastern side of Complex; also inclusions and remnants within the younger rocks of Complex
$ABgr_1$	Metasediments containing banded iron formation	Originally considered by Rhodes (1965) to be downfolded or down-faulted younger sediment, but considered by Johnson (1977) to be part of the Complex. Found as xenoliths within the granites.

TABLE 2. UNITS OF THE GOLDEN DYKE FORMATION

Unit	Rum Jungle area	Burnside Granite area
Bld_8	Red siltstone and shale with rare chert nodules; chert; contorted quartz-hematite beds; minor quartz-mica greywacke	Red to grey siltstone and shale with rare chert nodules; minor quartz-hematite beds (BIF) and greywacke
Bld_7	Siliceous black shale; purple and green siltstone; chert; calcareous amphibolite; minor ironstone and greywacke; rare chert-nodular siltstone	Fine tuff commonly altered to dark grey chert with a white weathered surface; siliceous shale and siltstone, possibly tuffaceous
Bld_6	Ironstone in places, massively hematitic, oolitic or stromatolitic; chert, hematitised chert. Unit contains the Mount Minza and Darwin River Siding-type ironstones of Johnson (1974)	Ironstone; gossanous and botryoidal limonite-stained ironstone; chert-banded and nodular ferruginous carbonaceous shale and siltstone
Bld_5	Pyritic sandstone, siltstone, chert; intraformational slumping; minor chamositic oolitic ironstone (Mount Deane-type ironstone of Johnson, 1974).	Interbedded carbonates (containing gypsum pseudomorphs) and siltstone or shale
Bld_4	Pyritic, siliceous, ferruginous siltstone, sericitic siltstone	Pyritic carbonaceous shale; carbonaceous chiastolite schist
Bld_3	Black pyritic shale	
Bld_2	Siliceous black shale, quartz-veined and brecciated; chert; quartz sandstone, pyritic and tourmalinised in places	
Bld_1	Carbonaceous, pyritic, calcareous shale	

TABLE 3. NEW REGIONAL STRATIGRAPHY (NEEDHAM & OTHERS, 1979) AND CORRELATIONS WITH THE GOLDEN DYKE FORMATION (Bld) IN THE BATCHELOR 1:100 000 SHEET AREA

	New regional stratigraphy	Rum Jungle Area	Burnside Granite Area
FINNISS RIVER GP.	Burrell Creek Fm	same	same
SOUTH ALLIGATOR GP.	Kapalga Fm Gerowie Tuff Koolpin Fm	Bld_8 Bld_7 Bld_6	Bld_8 Bld_7 Bld_6
MOUNT PARTRIDGE GP.	Wildman Siltstone Acacia Gap Sst Member	Bld_5 Acacia Gap Member	Bld_{4-5} Acacia Gap Member
NAMOONA GP.	Masson Fm	Bld_{1-4}	not present