DEPARTMENT OF
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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1974/41

PROGRESS REPORT : GEOLOGICAL REVIEW AND REVISION OF THE RUM JUNGLE AREA, NORTHERN TERRITORY, 1973

by

K. Johnson

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ERRATA SHEET TO ACCOMPANY RECORD 1974/41

Summary Page

2nd line	:	insert hyphen between "uranium" and "base", i.e. "uranium-base metal field".
8th line	:	make "high" plural, i.e. "highs".
12th line	:	incorrect spelling, should be "Finniss".

Page Three

14th line	:	delete the word "and" after Waterhouse "Granite".

Page Five

14th line	:	should read "...... and a deltaic environment respectively (Stanton, 1972), the Crater Formation was deposited in a near shore marine environment".
20th line	:	should be p.1 not p.2.
37th line	:	should read "......, beyond which basin conditions prevailed".

Page Six

3rd line	:	insert semi-colons around Granite, i.e. "Granite".

Page Eleven

21st line	:	insert the word "are" between "both" and "within", i.e. "......, and both are within the ......"

Page Thirteen

12th line	:	delete the word "in" between "folded" and "the F_1 axes" i.e. "......, have folded the F_1 axes ....."

Page Fourteen

7th line	:	insert the number "7", i.e. "(...... p. 7)".
12th line	:	insert "uranium" between "economic" and "and", i.e. "All the economic uranium and base metal ...... ".

Page Fifteen

15th line	:	should read "...... because it was closed dilution factors were a minimum, and the metals were concentrated.."

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SUMMARY

The area remapped lies within a 35 km radius of the Rum Jungle uranium base metal field. It is one of the few areas in the Northern Territory where the contact relationships between the Archaean and the Lower Proterozoic can be examined.

Changes of facies within Lower Proterozoic sediments reflect variations in depositional environments away from the Archaean basement high. Near-shore shelf-type sediments of the Batchelor Group were deposited on the basement highs; these grade into euxinic sediments of the Goodparla Group deposited on and around the Batchelor shelf, which in turn grade into greywackes of the Finnis River Group, deposited in geosynclinal troughs.

Locations most suitable for the deposition of syngenetic uranium and base metal protore were restricted basins, either on the edge of or within the Batchelor shelf, into which black shale of the Golden Dyke Formation was deposited.

INTRODUCTION

In 1949, Mr J.M. ('Jack') White discovered secondary uranium minerals 4.8 km northeast of Rum Jungle siding. The discovery was investigated by the Bureau of Mineral Resources (BMR). Since then BMR has mapped the Katherine-Darwin Region (Walpole et al., 1968), and has conducted a number of detailed geochemical and geophysical surveys in the Rum Jungle area.

The present investigation began in March 1972, and has involved 40 weeks' field work during 1972 and 1973. The program was originally to revise and update the existing Rum Jungle District Special Sheet (BMR, 1960), but was later expanded to include parts of the Batchelor, Marrakai, Tumbling Waters, and Mt Tolmer 1-mile Sheet areas (BMR, 1962). The remapping covers the area between latitudes 12°45'S and 13°15'S, and longitudes 130°50'E and 131°15'E, an area of 2465 km² (see Fig. 1); the original map covered an area of 1350 km² between latitudes 12°48'S and 13°12'S, and longitudes 130°53'E and 131°11'E. The revised map will be published at a scale of 1:100 000.

Concurrently with the mapping a detailed petrological, mineralogical, and geochemical study of the country rocks and mineral occurrences is being undertaken to determine the source of metals, and the factors involved in their concentration to ores.

Alterations and additions to the original map of the area are discussed in Appendix 1, and are shown on Plate 1. A revised map will be completed after further work during the 1974 field season.

STRATIGRAPHY

ARCHAEAN BASEMENT COMPLEXES

Sullivan & Matheson (1952) and Malone (1962b) believed that the Batchelor Group was intruded and domed by the Rum Jungle and Waterhouse Granites. Rhodes (1965) reported that B.P. Ruxton and J. Shields (BMR), had discovered an unconformity between the Rum Jungle 'Granite' and the overlying metasediments. Since then French (1970) has described several nonconformities between the granites and the overlying Batchelor Group, proving that these 'granites' in places formed crystalline basement. A detailed study of the Rum Jungle 'Granite' by Rhodes (1965) showed that it consists of schists, gneisses, and several varieties of granite, and he renamed it the Rum Jungle Complex. Isotopic dating (Richards et al., 1966) of this complex showed that at least part of it was Archaean, with an age of 2550 m.y. The Waterhouse 'Granite' has not been mapped in detail, but work by Lau (1971) and the author has shown it to be a complex of fine and coarse-grained granite and schist, and its name will formally be changed to Waterhouse Complex.

The nonconformities between the Rum Jungle Complex and either the Beestons or Crater Formations are exposed at five localities, (Plate 1, nos 45, 47, 94, 95, 96), French (1970) has described three (Figs 2,3), and the other two (Pl. 1, nos 47, 96; Figs 4,5) were found during the present remapping. Only one nonconformity (Pl. 1, no. 60) has been found between the Beestons Formation and the Waterhouse Granite (French, 1970). The nature and significance of the nonconformities will be discussed later.

Highly deformed leucogneiss interlayered with feldspar-biotite schist crops out within the Rum Jungle Complex. These rocks are similar to those found in the lit-par-lit Gneiss Zone mapped by Needham et al. (1973) in the Nimbuwah and Nanambu Complexes in the Alligator Rivers region. Furthermore, medium-grained granite in contact with porphyritic granite within the Rum Jungle Complex is texturally similar to porphyritic diatexite in contact with granitoid diatexite mapped by Needham et al. (1973) in the Nimbuwah Complex. These textural and petrological similarities between the complexes, together with the results of recent isotopic dating by R.W. Page (pers. comm., 1974) of the Nanambu Complex (BMR, Alligator River 1:250 000 Sheet area) at 2520 ± 30 m.y. suggest that all three complexes could form parts of the same Archaean basement.

LOWER PROTEROZOIC SEDIMENTS

The Lower Proterozoic sediments reflect facies changes from shallow to deep-water environments.

The Batchelor and Goodparla Groups are shallow-water sediments, and are characterized by dolomite, shale, sub-greywacke, chert, ironstone, quartzite, sandstone, conglomerate, grit, and arkose. Among typical shallow-water depositional features found are cross bedding, floor and channel conglomerates, intraformational slumping within ironstones, and chemical and organic precipitation of limestone.

The deep-water sediments of the Finniss River Group are composed of greywacke, quartz-greywacke, shale, and minor conglomerate beds. Turbidite structures - graded bedding, sole markings, flame structures, and small-scale cross bedding - are common.

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Batchelor Group

The Batchelor Group consists of the Beestons Formation, Celia Dolomite, Crater Formation, and Coomalie Dolomite, which consist of alternating clastic and chemical sediments.

A littoral and neritic environment of deposition is indicated by:

1. Algal reef masses found in both the Coomalie and Celia Dolomites.

2. Variability of sediments within the Beestons and Crater Formations - e.g., arkose, arkosic grit, sandstone, hematitic sandstone, quartz greywacke, boulder conglomerate and siltstone. This variability also reflects the nearness of the Rum Jungle Complex and Waterhouse 'Granite', and the basement rocks from which the sediments were derived.

Beestons Formation

Spratt (1965) stated that the Beestons Formation 'is not known around the Waterhouse Granite'. However, French (1970) has shown that the Beestons Formation crops out as a series of strike ridges (commonly offset by minor faulting) of white, in places friable, quartz sandstone and quartzite east of the Waterhouse 'Granite'. These rocks differ markedly from the arkose, siltstone, conglomerate, grit, and sandstone cropping out around the Rum Jungle Complex; this suggests that around the Waterhouse 'Granite' the sediments have been more thoroughly reworked, so that sorting was more complete and labile components were winnowed out.

Several banded iron formations, mapped originally as part of the Beestons Formation (Pl. 1, nos 36, 49), are now recognized as rafts of Archaean sediments belonging to the Rum Jungle Complex, which survived digestion during Archaean migmatization.

Outcrops north of Mount Fitch (Pl. 1, nos 12, 19, 26, 33), thought by Pritchard & French (1965) to be Beestons Formation, are now considered to belong to the Crater Formation (see later). Consequently the 'Celia Embayment' area (Willis, 1969) 19 km north of Batchelor (Pl. 1, nos 15, 21), is Crater Formation and Coomalie Dolomite, rather than Beestons Formation and Celia Dolomite.

The Beestons Formation marks part of the old shoreline around both Archaean basement complexes. Later formations overlapped the Beestons Formation and Celia Dolomite, and consequently the present discontinuous outcrop pattern of these two formations may not represent a break in deposition, but may be an expression of the differing depths of erosion reached - e.g., southeast of the Rum Jungle Complex, the Batchelor Group is completely exposed, but at Mount Fitch only the Crater Formation and younger rocks are exposed.

Celia Dolomite

After the Beestons Formation the Celia Dolomite was deposited. The limit of this carbonate sedimentation southeast of the Rum Jungle Complex is marked by organic reefs, within which several types of algal mats are recognized (see Figs 6, 7). Williams (1963) suggested that algal mat type structures could have formed by folding. However, one particular 'cone-in-cone' type stromatolite was examined by Mobil Research and Development Corporation to determine its origin. The specimen was identified as Conophyton sp., a Precambrian alga known from the Proterozoic of Brazil and the Soviet Union.

Carbonate rocks do not crop out around the eastern side of the Waterhouse 'Granite'; but a BMR drill hole, R16 (Pl. 1), put down in 1973, intersected a pyritic, amphibolitic calcareous phyllite, which is thought to be equivalent to the Celia Dolomite.

Crohn et al. (1968) reported that outcropping Celia Dolomite was magnesitic and dolomitic; lower greenschist facies metamorphism converted the magnesite and dolomite to marble.

Crater Formation

Uplift and erosion of the source area (Malone, 1958) ended deposition and caused brecciation of the Celia Dolomite; brecciated Celia Dolomite crops out immediately north of Eva Valley homestead. The Crater Formation was deposited in response to this uplift, and overlaps the Beestons Formation and Celia Dolomite. This heterogeneous succession of rocks forms a series of ridges around both the Rum Jungle Complex and Waterhouse 'Granite'. It is predominantly arkosic, and most of the constituent minerals of the lower beds were derived from the underlying granitic rocks. The unit grades upwards from arkose into siltstone and then sandstone (Morlock & England, 1971).

Three quartz pebble conglomerate beds (French, 1970) form prominent strike ridges around the southern margins of the Rum Jungle Complex: this type of conglomerate, with its long strike and interlayered pelites, is commonly marine, and deposited on a transgressive beach over a surface of low relief (Pettijohn, 1957). Roberts (pers. comm., 1974) found that the radioactivity of the conglomerates was caused by detrital thorianite; Morlock & England (1971) determined the radioactivity of some of the conglomerates as due to an amorphous or metamict phosphate of Th, Ca and Fe within certain opaques. In contrast to the uraniferous conglomerate deposits of the Witwatersrand in South Africa, and the Blind River in Canada which were deposited in a closed terrestrial basin and a delta respectively (Stanton, 1972), from the open sea.

Near the base of the Crater Formation a hematite boulder conglomerate is a useful marker horizon. It crops out around the northern margins of the Waterhouse 'Granite' and the southern margins of the Rum Jungle Complex. The existing BMR 1-mile sheets (see list, p. 2) show this unit as a 'pytitic, carbonaceous dolomitic marl, in places slumped and brecciated and containing chert lenses, bands and nodules'. It is now recognized as a quartz and banded iron formation pebble conglomerate, the pebbles of which were derived from banded iron formations within the basement complex. On the western side of the Rum Jungle Complex, the hematite boulder conglomerate can be traced as far north as Mount Fitch, where it grades into arkose. Although the arkose has been mapped as the Beestons Formation, the lensing out probably represents either a lateral facies change or a local disconformity within the Crater Formation.

Coomalie Dolomite

Deposition of the Crater Formation ceased with a return to stable shallow marine conditions, which resulted in the formation of algal reefs, and the deposition of the Coomalie Dolomite. Distribution of this carbonate facies marks the limit of the Batchelor shelf, beyond which the basin was deeper.

Carbonate outcrop is sparse, and poorly preserved stromatolite structures are seen only in outcrops along Coomalie Creek, near Sundance homestead. In outcrop Coomalie Dolomite is commonly either heavily silicified or lateritized or both (Shatwell, 1965), or is thickly covered by ferruginous or kaolinitic quartz sand (Shatwell & Duckworth, 1966).

BMR drilling in 1973 showed that the Coomalie Dolomite does not extend as far east of the Waterhouse Granite as is shown on the existing maps (Pl. 1, nos 73, 72). Ridges on the southwestern edge of the Waterhouse 'Granite', mapped originally as quartz-veined Crater Formation (Pl. 1, nos 79, 80, and 81) were found to be dolomitic marble at depth. This marble is believed to represent either a thin lens of recrystallized Coomalie Dolomite, or a carbonate lens within the Golden Dyke Formation. The reduced thickness of the Batchelor Group southwest of the Waterhouse 'Granite' and at Mount Fitch reflects the asymmetry of the Batchelor shelf, which was narrower on the western margins of the complexes, wider on the eastern margins and widest between them.

Relationship between the Batchelor Group and the Basement Complexes

At least six localities show the nonconformable relationship between the basement complexes and the overlying Beestons and Crater Formations (Pl. 1, nos 45, 47, 60, 94, 95, 96). The common features of these nonconformities are:

1. The shearing of the contact between basement and sediment - e.g., at locality no 47 (Pl. 1) there is a 40-cm chloritic shear zone (see Fig. 4);

2. The absence of thermal metamorphic effects in the overlying sediments.

Shearing gives clear evidence of differential movement between the sediments and the basement, and both features indicate that the doming of the complexes was caused by tectonism rather than by later granitic intrusion. However, in places there are indications that the basement was reactivated, e.g.:

1. 4.8 to 5.6 km southwest of Woodcutter's South Prospect arkosic Beestons Formation sediments have been granitized;

2. Extensive boron metasomatism in the form of quartz-tourmaline veins and replacement of parts of the upper Crater Formation by quartz and tourmaline (e.g., immediately north of Eva Valley homestead) is found around both basement complexes. An excellent exposure (see Fig. 8) is found at locality No. 96 (Pl. 1), where quartz-tourmaline veins are seen to radiate from a fresh biotite granite that intrudes schist, gneiss, and granite of the Rum Jungle Complex, and the quartz tourmaline veins penetrate into the overlying Crater Formation sediments.

3. Chlorine-carbon dioxide metasomatism has occurred on the eastern margin of the Waterhouse Granite (Pl. 2, No. 78), where well developed scapolite crystals (see Fig. 9) replace plagioclase within the granite. On the western margin of the Rum Jungle Complex, in the Mount Fitch area, impure dolomitic shales of the Golden Dyke Formation have been scapolitized (Marjoribanks, 1967).

Although Williams (1963) states that the basement has been domed only as a result of tectonism, the thermal effects quoted above suggest some thermal reactivation of the complex. The possibility therefore exists that, to varying degrees, both tectonism and thermal reactivation of the complexes have caused doming of the basement and the overlying sediments.

Goodparla Group

The Goodparla Group is composed of sediments deposited in basins around or within the Batchelor shelf. The group consists of:

1. The <u>Golden Dyke Formation</u>, a siltstone-mudstone sequence, composed of black shale, siltstone, quartzite, and ironstone.

2. The <u>Acacia Gap Tongue</u>, a very distinctive pyritic, massive quartzite, which is correlated with Masson Formation farther east.

Golden Dyke Formation

The transition zone or interface between Coomalie Dolomite and overlying Golden Dyke Formation has long been recognized as the most favourable stratigraphic horizon for concentration of uranium and base metals (Ivanac & Langron, 1968; Walpole et al., 1965). In 1973, BMR drilling showed that, on the eastern side of the Waterhouse 'Granite', this zone consisted of weakly pyritic, calcareous pale green siltstone. This contrasts with the strongly graphitic, calcareous shale (Fig. 10) of the transition zone on the eastern and southeastern boundary of the Rum Jungle Complex (Shatwell, 1965; Willis, 1969; Semple, 1968).

West of the Rum Jungle Complex slate and siltstone of the Golden Dyke Formation grade into the overlying quartz greywacke and siltstone of the Burrell Creek Formation (Marjoribanks, 1967). To the south and southeast of the Waterhouse 'Granite' there is a lateral facies change between the Finniss River Group and the Golden Dyke Formation. North of the Rum Jungle Complex the Golden Dyke Formation persists, and to the east there is a gradual vertical facies change to the Burrell Creek Formation. The spatial distribution of Golden Dyke Formation suggests that sediments were shed from the northeast.

Three types of ironstone, which are important environmental indicators, provide marker beds within the Golden Dyke Formation. The three basic types are:-

Mount Deane ironstone: 8 km west of the Coomalie airfield (Pl. 1, no. 54), a 6 to 12-m ironstone band forms an outcrop which has a northerly strike length of about 5 km. It was originally mapped and described (Bryan, 1962) as a 'propylitized basic igneous rock'. However, a study of unweathered specimens showed it to be an oolitic, chamositic limestone (Roberts, pers. comm., 1973). This type of ironstone is similar to those described by Stanton (1972, p. 419) as being typical of deposition in a near-shore shallow-water marine environment.

Mount Minza ironstone: The Mount Minza ironstone, exposed for about 5 km north of Mount Minza (Pl. 1, No. 76), is a silicified carbonate breccia with a matrix of ferruginous siltstone. Its lateral extent suggests that it slumped in situ, (Marmont, 1972). A similar ironstone crops out south and northwest of Heathers Lagoons (Pl. 1, no. 37). This type of formation is believed to represent the carbonate facies type, as described by James (1954).

Darwin River Siding ironstone: 3-5 km northeast of Darwin River Siding (Pl. 1, no. 5), a banded quartzite-hematite ridge, up to 20 m wide, crops out. A similar type of ironstone, known as the BW prospect (Pl. 1, no. 85), occurs 11 km west of Stapleton Siding, where it forms a massive hematite ridge within the Golden Dyke Formation. Both are believed to be the oxidized portions of banded ironstones of the pyritic facies type (Stanton, 1971, p. 399), being deposited on the steeper shelf in reducing conditions.

Acacia Gap Tongue

The Acacia Gap Tongue is a very distinctive massive pyritic quartzite, interbedded with shale of the Golden Dyke Formation. It extends as far south as Batchelor, and forms prominent ridges on the eastern and western sides of the Rum Jungle Complex. It was deposited in the shallowest parts of the Goodparla Group basin which surrounded the Batchelor shelf, as indicated by the Mount Deane chamositic oolitic ironstone, which is in direct contact with Acacia Gap Tongue quartzite.

Finniss River Group

The Finniss River Group is divided into two formations, and consists of flysch-type greywacke and siltstone deposited in troughs around the Batchelor shelf and Goodparla basin. The Noltenuis Formation is predominantly greywacke, and the Burrell Creek Formation mainly siltstone.

The formations grade into each other, and are lateral facies equivalents. As discussed below, the range of rock types reflects the closeness of the sediments to the source area.

Between the Tolmer Plateau and Adelaide River township the Noltenius and Burrell Creek Formations present classical greywacke-siltstone assemblages. The greywackes are medium to coarse-grained, and show graded bedding. The siltstone interbeds show axial plane cleavage and the greywacke beds fracture cleavage (Fig. 11). These sediments are believed to represent proximal turbidite sequences.

West of the basement complexes the dominant rock types are well cleaved red siltstone and slate of the Burrell Creek Formation, which represent distal turbidite sequences. Interbedded with the siltstone are quartz greywacke and subgreywacke bands which form prominent strike ridges. The quartz greywacke has been mapped as the Noltenius Formation, but Marjoribanks (1967) considers that the interbeds represent variations from a lutite to an arenite facies within the Burrell Creek Formation. The quartz greywacke assemblages could represent sediments deposited in basement valleys which radiated from the source area to the south, and beyond which the finer sediments were deposited (Henderson, 1972). The lack of typical feldspar and mica suggests that the fan valley 'greywackes' were transported far enough for them to be completely decomposed. The absence of cross-bedding indicates that the sediments were not reworked by ocean currents (Walker, 1967).

Westward toward the Litchfield Complex an increasing degree of dynamic and thermal metamorphism is indicated by the formation of kink-banded and andalusite schist. Within this zone the Bynoe Harbour-Bamboo Creek tin-bearing pegmatites and greisens are found.

Outcrop is poor east of the complexes because of the blanketing effect of the Adelaide River flood plain. Where exposed the dominant rock type is siltstone of the Burrell Creek Formation.

Typical sedimentary structures found within the Finniss River Group are shown in Figs 12 and 13; in places the complete turbidite sequence, as defined by Bouma (1962), could be recognized in a single bed.

UPPER PROTEROZOIC SEDIMENTS

Tolmer Group

Buldiva Sandstone: Depot Creek Sandstone Member

After the Finniss River Group was deposited, the Lower Proterozoic sediments were folded, faulted, and eroded. The Depot Creek Sandstone Member was deposited on a very irregular erosion surface, whose irregularity is reflected by the erratic change in primary dips of the sandstone beds on the southwestern margin of the Waterhouse 'Granite'.

The basal unit of the member is a hematite-quartzite breccia (H.Q.B.) (Fig. 14), which is regarded as a silicified regolith, as it was formed over the Crater Formation, Coomalie Dolomite, and Golden Dyke, Noltenius, and Burrell Creek Formations.

In some places breccia fragments are of shale (especially over the Golden Dyke Formation) cemented mainly with iron oxide and secondary quartz.

Overlying the H.Q.B. is a sandstone, commonly ripple-marked, which, in contrast to the Lower Proterozoic units, has quartz grains that have not been extensively recrystallized, but retain their original rounded shape.

Some parts of the sandstone and breccia contain fluorapatite (Pritchard et al., 1963), particularly over Coomalie Dolomite; this is thought to be the result of supergene enrichment of fluorapatite over phosphatic dolomite (Pritchard et al., 1963; Walpole et al., 1965).

At Castlemaine Hill, 2 km west of Batchelor, H.Q.B. crops out, and drill cores show that the quartz breccia fragments give way to carbonate fragments of similar shape and size at depth (Spratt, 1965) - apparently a solution breccia formed by a process similar to that outlined by Holliday & Cutbill (1972) i.e., collapse and brecciation of silicified carbonate following solution of carbonate of the Coomalie Dolomite.

The existing map shows, in the Stapleton homestead area, a slump breccia within the Golden Dyke Formation (Pl. 1, no. 88). This breccia is now identified as H.Q.B. unconformably overlying the Golden Dyke Formation.

CAINOZOIC

Most of the area is covered by Cainozoic sand, laterite, black soil, and alluvium.

A laterite peneplain is well developed on the western and northern margins of the map area, where ferruginous and vesicular laterite, typically containing angular fragments of vein quartz and siltstone, overlies the Golden Dyke and Burrell Creek Formations. Alluvial soils occupy the drainage channels which dissect the peneplain. A surface zone of silicification is commonly developed on slate of the Burrell Creek Formation (Fig. 15).

The southern and eastern sides of the map area are largely covered by black soil and alluvium, although lateritic gravels are found along some creek beds. On the Batchelor 1-mile sheet, 8 km west of Stapleton homestead, a large outcrop of Depot Creek Sandstone is shown. However, much of this 'outcrop' is a remnant lateritized land surface which appears to have formed during an earlier period of easterly drainage. The dominant drainage pattern is now to the north, and dissects the older land surface.

INTRUSIVES

Basic intrusives crop out at Dolerite Ridge and Darwin River Siding, and both within the Golden Dyke Formation. Shatwell (1965) states that the Dolerite Ridge dolerite is unmetamorphosed; but Bryan (1962) describes the dolerite as being uralitized, and regionally metamorphosed to epidiorite. Dolerite in other outcrops is also extensively uralitized, and though this alteration could date from a late-magmatic (deuteric) event it is believed to have resulted from low-grade (greenschist) metamorphism.

Many non-outcropping amphibolites, interbedded within the Golden Dyke Formation, have been located by BMR auger drilling; for example, Shatwell & Duckworth (1966) describe the Gould area (Fig. 16) as being 'extensively intruded by amphibolites'; Gardener (1971) describes non-magnetic amphibolites in the Manton Dam area giving excellent slingram anomalies, and Willis (1969) states that they are intrusive; Semple (1968) and Duckworth (1968) describe amphibolites interbedded with shale of the Golden Dyke Formation in the Acacia Area (Fig. 16). The magnetic and chemical characteristics of these amphibolites are quite variable (Browne-Cooper & Gerdes, 1970). Rhodes (1965) considers that the amphibolites were originally 'tholeiitic dolerite sills' emplaced in the sediments before folding and metamorphism. Similar amphibolites surrounding the Burnside Granite are described by Sullivan & Iten (1952) and Bryan (1962). They are mostly concordant with the Golden Dyke Formation, and are believed to be sills folded with the sediments. The apparent abundance of amphibolites within the Golden Dyke Formation may be due to the fact that it is the most extensively explored unit.

Bryan (1962) considers amphibolites from drill cores taken at the Waterhouse Number 2 prospect to be igneous - i.e., ortho-amphibolites - because of an aureole of albite-epidote amphibolite facies metamorphism within 6 m of their contact with the country rock. He also describes amphibolites at Rum Jungle Creek South as being igneous, and those at Browns prospect as being both igneous and sedimentary.

Para-amphibolites have been found in other areas; for example, an actinolite-tremolite schist at Waterhouse No. 1 (Pl. 1, No. 74) is a metamorphosed impure dolomitic rock. A similar rock is found within the Celia Dolomite, 3.2 km southwest of Rum Jungle Creek South (Pl. 1, No. 59). Marjoribanks (1967) described amphibolites within the Golden Dyke Formation, in the Mount Fitch area, consisting of tremolite and intersitial plagioclase, quartz, and clinozoisite. He believes these to be altered dolomitic argillites. Williams (1970) described a non-magnetic amphibolite, on the eastern side of the Rum Jungle Complex, which surrounds an outcrop of Beestons Formation sandstone and greywacke. It probably formed by regional metamorphism of sediments, rather than from a basic intrusive. During 1973, BMR drilling 5 km southwest of Stapleton homestead (Pl. 1, R 15) located an amphibolite body below the Crater Formation; it is believed to be a para-amphibolite formed during regional metamorphism of an impure dolomitic rock of the Celia Dolomite.

In conclusion, therefore, there is evidence of both para-and ortho-amphibolites in the Rum Jungle area.

STRUCTURE

Williams (1963) examined in detail the structure of the area, and deduced that there were three or possibly four periods of deformation, which were responsible for doming of the basement complex. As mentioned earlier, however, igneous reactivation of the basement complexes during the Lower Proterozoic could also have contributed towards the doming.

The major period of deformation, the F1 fold phase, produced isoclinal folding about north-trending axes, and is best exemplified in the Finniss River Group. In general the shales of the Golden Dyke and Burrell Creek

Formations have developed a strong slaty cleavage coincident with the bedding directions, whereas coarse greywackes and quartz-rich sediments of the Noltenius, Crater, and Beestons Formations, and the dolomites of the Celia and Coomalie Dolomites have remained massive, though some fracture cleavage has developed in them. The strike direction of the Finniss and Goodparla Groups has been determined by the dominant fold direction, but the strike of the Batchelor Group reflects the original depositional strike, which parallels the margins of the basement complexes.

The east-trending fold axes of the second folding phase, the F2 phase, have folded in the F1 axes. Later tectonic events resulted in flexuring of both sets.

A major structural feature, the Late Proterozoic to Early Cambrian (Berkman, 1968) Giants Reef Fault, strikes northeast across the map area; its horizontal displacement is 5 km, west side north, and the northwest block rotated vertically relative to the southeast block. If the complexes are restored to the position they occupied before horizontal movement, some idea of the vertical movement may be obtained by calculating the displacement of the hematitic boulder conglomerate near Area 55: about 1500 m southeast block down. The Crater Formation/Coomalie Dolomite boundary south of Manton Dam (southeast block) and east of Manton Dam (northwest block) indicates a vertical movement of about 620 m southeast block up.

The existing 1 mile-sheets show the Mount Fitch fault zone extending along the western boundary of the Rum Jungle Complex from Tumbling Waters to Area 55. At Mount Fitch there is evidence of minor faulting, and apart from colour differences in outcropping shales there is no justification for naming beds west of the mapped fault zone as the Burrell Creek Formation. There appears to be little evidence for the existence of the Mount Fitch fault zone over such a great length.

METAMORPHISM

Archaean metamorphism within the basement complexes reached almandine-amphibolite facies (Rhodes, 1965). Maximum metamorphic grade reached during Lower Proterozoic metamorphism of the Batchelor, Goodparla, and Finniss River Groups was quartz-albite-muscovite-chlorite greenschist subfacies (Turner & Verhoogen, 1960).

All the Lower Proterozoic sediments are silicified and their quartz recrystallized. There appears to be close relationship between metamorphism and deformation, with a preferred orientation of quartz grains developing during their metamorphic recrystallization. The alignment of the long axes of quartz grains in the greywackes of the Finniss River Group is north-south, paralleling the F1 fold axis. Within the Crater and Beestons Formations of the Batchelor Group the preferred orientation of quartz grains parallels the complex-sediment contact.

Boron and chlorine metasomatism (described above, p.) is believed to indicate renewed igneous activity within the basement complexes during the Early Proterozoic.

ECONOMIC GEOLOGY

References to ore deposits and mineralized areas are shown in Table 1. Individual mineral deposits will not be described.

Structural Control

All the economic and base-metal orebodies are found within the inter-basement syncline between the two complexes. The syncline was displaced by the Giant's Reef Fault, forming the Embayment syncline which embays the western margin of the Rum Jungle Complex and contains Browns Prospect and the Intermediate, Whites, and Dysons mines. The orebodies are localized within or close to minor structures such as shear zones, faults, or tight fold closures.

The structural zones are believed to represent dilatant zones of low pressure into which mineralized solutions have migrated.

Stratigraphic Control

The major stratigraphic controls are:

Coomalie Dolomite/Golden Dyke Formation contact. The contact can be either sheared, as it is in the Embayment area (this is thought to be tectonic shearing at formation boundaries which occurred during folding), or gradational, as at Woodcutters L5 prospect.

Siliceous beds (chert, quartzite, or siliceous ironstone - e.g., Waterhouse 1 & 2, Mt Burton, and Dysons). Siliceous beds acted as competent units which possibly acted as impenetrable barriers to mineralizing solutions. Prospects associated with this type of stratigraphic control are only small.

Superficial Control

Uranium or thorium prospects such as Brodribb, Ella Creek, Frazer, Woodcutters, and Woodcutters South have been formed by the selective concentration of uranium or thorium in a lateritic soil profile over black shale of the Golden Dyke Formation. These concentrations do not continue below the zone of weathering.

If the geology before the Giants Reef faulting is reconstructed the economic mineral deposits discovered so far - Dysons, Whites, Intermediate, Browns, and Rum Jungle Creek South - all occur along the arcuate line marking the keel of a major synclinal depression between the two basement complexes (Berkman, 1968). It represents a topographic low within the Batchelor shelf, and in it uraniferous and base-metal rich shales were deposited, and because it was closed it was only slightly diluted, and the metals could be concentrated into syngenetic protore.

Later tectonic events, mainly shearing and faulting, associated with igneous reactivation of the basement complexes, provided the energy for concentrating the protore into mineral deposits.

The Mount Fitch, Mount Burton, Area 55, and Waterhouse No. 2 prospects all lie on the edge of the Batchelor shelf, flanking both basement complexes. It is suggested that along these flanks the basin was not restricted enough to prevent dilution of the metal-rich black shales which were deposited above the Coomalie Dolomite. This caused a weak development of syngenetic protore, subsequent remobilization of which was inadequate to produce an orebody.

At the Woodcutters L5 Pb-Zn prospect (Pl. 1, no. 38) the highly dolomitic nature of the country rock suggests that 'the Woodcutters dolomite was formed in a restricted basin type environment which developed during deposition of the Golden Dyke sediments' (Roberts, 1973). It appears that the basin was sufficiently restricted to prevent a dilution of the metal-bearing calcareous shales which were deposited. Later structural events mobilized the protore into several near-vertical fissure fillings within the core of a tight anticlinal structure.

In summary, the most productive period of syngenetic protore deposition took place in restricted basins, either on the edge of or within the Batchelor shelf. It was here that metalliferous shale of the basal Golden Dyke Formation accumulated and dilution was at a minimum. Later tectonic, and possibly igneous, events concentred these syngenetic protore deposits into orebodies.

Heier & Rhodes (1966) showed that the Rum Jungle Complex is anomalously high in uranium, and possibly weathering of this complex released uranium, which was concentrated as syngenetic protore in the black shales of the Golden Dyke Formation.

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APPENDIX 1

Plate 1 shows places where the most important changes to geological and planimetric detail will be made on the new 1:100 000 Rum Jungle Special map. The numbering corresponds to notations on the map.

(1) Outcrop of extensively quartz-veined siltstone belonging to the Golden Dyke Formation.

(2) Outcrop of weathered purple shale of the Golden Dyke Formation - not Cainozoic cover as shown on the existing map.

(3) Outcrop of ferruginous quartz greywacke belonging to the Golden Dyke Formation.

(4) Not Crater Formation or Coomalie Dolomite, but ferruginized shale with chert interbands belonging to the Golden Dyke Formation.

(5) Oxidized outcrop of a pyritic ironstone with carbonaceous shale of the Golden Dyke Formation.

(6) No outcropping Golden Dyke Formation as is suggested by the existing map, simply alluvial cover.

(7) This is the position of the new Darwin River Dam. Also shown on the new map will be the water storage area, and the fence (about 75 km long) which has been constructed around the Darwin River and Manton Dam catchment areas.

(8) Shows the correct position of the Ella Creek thorium prospect.

(9) Outcrop of heavily chloritized siltstone of the Golden Dyke Formation.

(10) The construction of the Darwin River Dam has meant that about 16 km of the old railway has had to be re-routed around the catchment area.

(11), (14), (24), (25), (30), (37) An outcropping ironstone within the Golden Dyke Formation. The nature of these ironstones change from massive hematite (e.g., 24) to banded, and in placed brecciated, hematite-chert (e.g., 37).

(12), (15), (19), (21), (26), (33) These outcrops belong to the Crater Formation, and not Beestons Formation or Celia Dolomite. They are heavily recrystallized, and in some cases tourmalinized, arkose and subarkose. Their arkosic nature reflects their proximity to the Rum Jungle Complex.

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(13) This outcrop is believed to be part of the sheared margin of the Rum Jungle Complex, and is similar to the mylonitic zone found in the embayment area between Crater Formation sediments and granite of the Rum Jungle Complex.

(16), (17) The Beestons Formation and Celia Dolomite, as shown on the map are in fact graphic pegmatite, schist, and gneiss of the Rum Jungle Complex.

(20) This outcrop is not Celia Dolomite, but a banded iron formation belonging to the Rum Jungle Complex.

(18), (22) These outcrops belong to the Crater Formation. The outcrop, originally mapped as Beestons Formation, consists of strongly recrystallized subarkose and buff feldspathic greywacke of the lower Crater Formation. The so-called Celia Dolomite outcrop consists of recrystallized, very pure sandstone.

(23) These small siliceous outcrops possibly represent carbonate phases within Coomalie Dolomite, which have since been extensively recrystallized and brecciated.

(27) The original map implies more outcrop of rocks of the Rum Jungle Complex than actually exists. The new map will indicate actual outcrop.

(28) Outcrop of banded iron formation of the Rum Jungle Complex.

(29) Not Coomalie Dolomite, but silicified shale of the Golden Dyke Formation.

(31) Not Golden Dyke Formation, but a recrystallized quartz sandstone of the Acacia Gap Tongue.

(32) Not Coomalie Dolomite, but silicified black shale of the Golden Dyke Formation.

(34) Apart from a minor quartz blow there is no other surface evidence which could be taken as indicating the possible presence of the Mt Fitch fault-zone, which will therefore not be shown on the new map.

(35) Highly weathered siltstone of the Golden Dyke Formation, not Burrell Creek Formation.

(36) Not Beestons Formation, but a banded iron formation of the Rum Jungle Complex.

(38) Woodcutters L5 lead-zinc prospect.

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(39) Contact between Acacia Gap Tongue quartzite and Golden Dyke Formation shale, marked by an ironstone which is identical in weathering texture to that at Mt Deane.

(40) Not Acacia Gap Tongue, but an ironstone within the Golden Dyke Formation.

(41) Massive quartzite of Acacia Gap Tongue, not shale of the Golden Dyke Formation.

(42) Not the Crater Formation as mapped, but a fractured quartz blow along a splinter fault of the Giant's Reef Fault.

(43) Extension of the Mt Deane chamositic iron formation.

(44) Ferruginized shale of the Golden Dyke Formation.

(45) An unconformity is exposed here between sheared and recrystallized arkose of the Beestons Formation, and granite of the Rum Jungle Complex.

(46) This outcrop is part of the sheared margin (mylonitic) of the Rum Jungle Complex, and not the Beestons Formation.

(47) An unconformity is exposed here between Beestons Formation and the Rum Jungle Complex.

(48) The outcrop mapped as Beestons Formation is too wide, half of the outcrop actually being granite of the Rum Jungle Complex.

(49) This outcrop is not part of Beestons Formation, but a banded iron formation belonging to the Rum Jungle Complex.

(50) This outcrop is a sheared quartz plug, and not Celia Dolomite.

(51) Hematitic sandstone and quartz-injected siltstone belonging to Beestons Formation, and not the Celia Dolomite.

(52) This is the hematitic boulder conglomerate, the banded iron formation boulders being derived from the Archaean basement. It is not a 'pyritic, carbonaceous dolomitic marl, in places slumped and brecciated, and containing chert lenses, bands and nodules,' as originally mapped.

(53) Not Coomalie Dolomite, but silicified carbonaceous shale of the Golden Dyke Formation.

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(54) No dolerite was found in the outcrop. The only crystalline rock found was an oolitic chamositic limestone which has a cellular limonitic crust on the weathered surface. This outcrop is believed to represent a sedimentary ironstone formation.

(55) Outcrop of laterite and ironstone breccia over Coomalie Dolomite.

(56) Outcrop of graphitic, pyritic, calcareous shale belonging to the basal member of the Golden Dyke Formation.

(57) Outcrop of amphibolite within the Golden Dyke Formation.

(58) Outcrop of 'quartzite' belonging to the Coomalie Dolomite.

(59) Outcrop of tremolite schist, which is believed to represent a metamorphosed impure magnesian limestone belonging to Celia Dolomite.

(60) An unconformity is exposed here between a quartz-sericite feldspar schist of the Waterhouse 'Complex' and a basal conglomerate and sandstone of the Beestons Formation.

(61) Ferruginized sandstone of the Beestons Formation.

(62) Not Beestons Formation, but a quartz blow.

(63) Orthoquartzite of the Beestons Formation, not the Crater Formation, as mapped.

(64) Not Crater Formation, but a sheared quartz blow.

(65) Not Coomalie Dolomite, but calcareous black shale of the Golden Dyke Formation.

(66) No evidence of Golden Dyke-Burrell Creek Formation contact. Outcrop appears to be weathered Golden Dyke Formation siltstone.

(67) An outcrop of siltstone (in places showing sole markings) belonging to the Burrell Creek Formation not shown on the existing map.

(68) Outcrop of quartz pebble conglomerate within the Golden Dyke Formation.

(69) Lateritic and silicified capping over Coomalie Dolomite not previously mapped.

(70), (71) Quartz blows not on existing map.

(72) Not silicified Coomalie Dolomite, but quartzite belonging to the Golden Dyke Formation.

(73) Not Coomalie Dolomite but silicified quartz sandstone, in places brecciated, belonging to the Golden Dyke Formation.

(74) Calcareous greenschist believed to represent altered dolomitic sediments interbedded with shale and siltstone of the Golden Dyke Formation.

(75) Outcrop of the Waterhouse Granite is very poor, and the existing map implies more outcrop than actually exists. The new map will indicate actual outcrop.

(76) A more extensive outcrop of the Mt Minza type ironstone exists in this area.

(77) Outcrop of Mt Minza type ironstone.

(78) Scapolitization of the Waterhouse Granite has occurred in this area.

(79), (80), (81) Not the Crater Formation, but silicified carbonate lenses which possibly represent an intertonguing of Coomalie Dolomite in slate of the Golden Dyke Formation, or a carbonate lens within the Golden Dyke Formation.

(82) Not Crater Formation, but ferruginous and carbonaceous shale of the Golden Dyke Formation.

(83) Outcrop of the Depot Creek Sandstone Member is not as extensive as shown on the present map.

(84) Correct position of the Virginia gold mine.

(85) B.W. prospect, an ironstone within the Golden Dyke Formation.

(86) A major fault-zone is evident here.

(87) Quartz conglomerate and siltstone of the Crater Formation.

(88) Hematite-quartzite-breccia crops out, and is the basal member of the Depot Creek Sandstone Member, and is not a breccia within the Golden Dyke Formation.

(89) Outcrop of coarse greywacke belonging to the Noltenius Formation is not shown on the existing map.

(90) Not outcropping Noltenius Formation, but siltstone of the Burrell Creek Formation.

(91) Red siltstone of the Burrell Creek Formation.

(92) There is no field evidence for a quartz-injected contact between the Noltenius and Burrell Creek Formations, as is shown on the existing map.

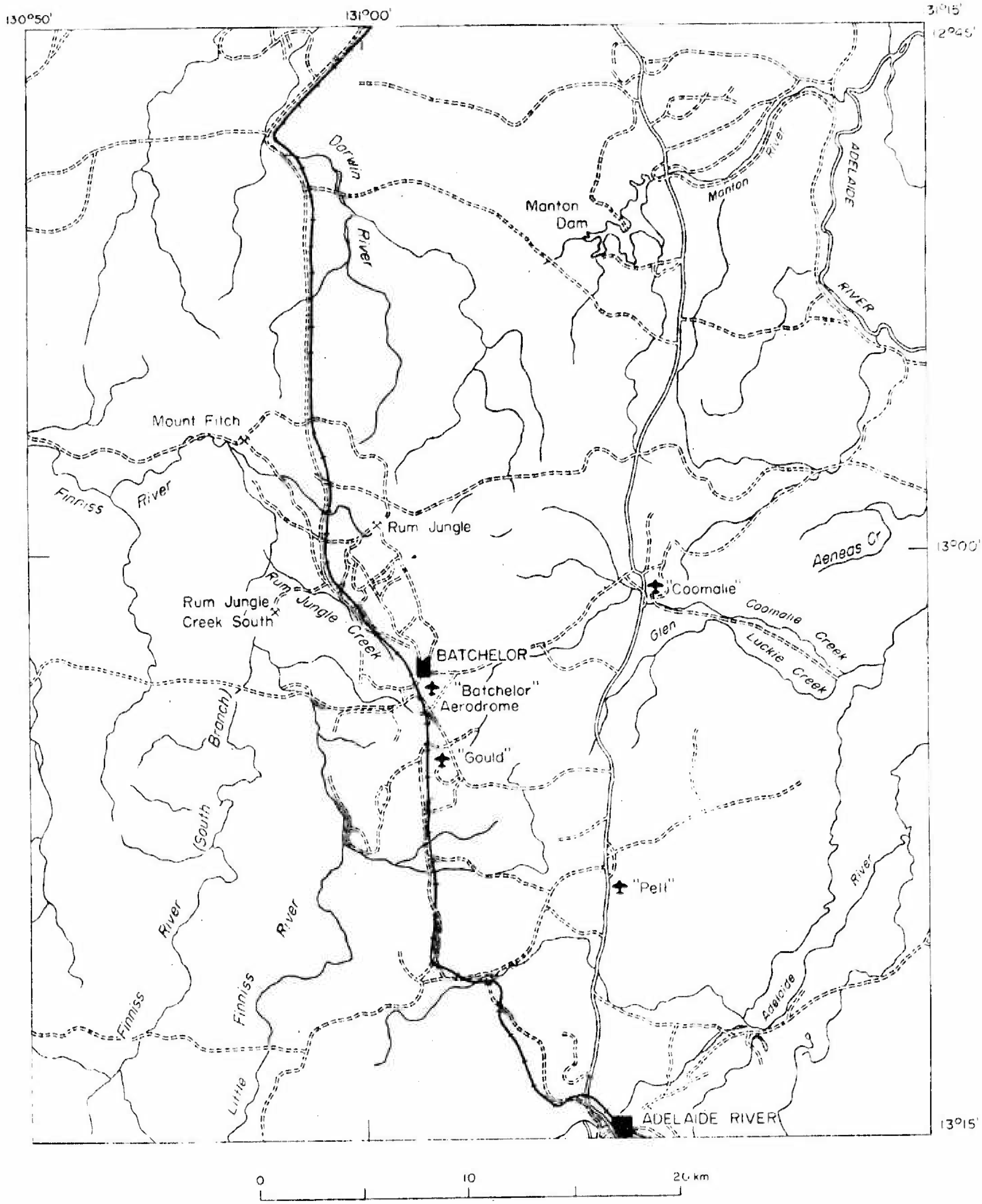
(93) Quartz pebble conglomerate on both sides of the quartz vein.

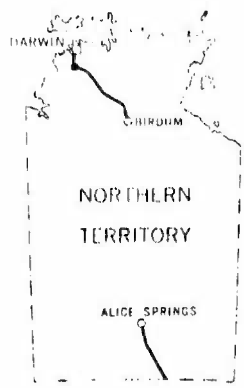
(94), (95), (96) Unconformities are exposed here between the Rum Jungle Complex and the Crater Formation.

TABLE 1: Principal Features of Orebodies and Prospects in the Rum Jungle Area

Mine or Prospect	Reference	Minerals	Host Rock	Major Structural Control	Stratigraphic Control
Area 55 Pospect	Pritchard (1964)	U, Cu, Pb, Co Ni	Carbonaceous schist, chert, and chlorite schist (Pld)	Within nose closures of two anticlines, on western margin of inter-basement syncline	Pld-Plo contact
	Berkman (1968)	Cu, Co, Ni	Dolomite and tremolite Schist (Plo)		
Browns Prospect	Daly et al. (1962) Thomas & Whitcher (1965) Fraser (in press)	Pb, Cu, Zn, Ni	Graphitic shale (Pld)	Within inflexion in northern limb of Embayment Syncline	Pld-Plo contact
Intermediate Mine	Fraser (in press)	Cu	Brecciated pyritic graphitic shale (Pld)		
Whites Mine	Roberts (1960) Spratt (1965) Berkman (1968)	U, Cu, Co, Ni, Pb	Pyritic graphitic shale (Pld)	Within northern limb of Embayment syncline	Pld-Plo contact
Dysons Mine	Spratt (1965) Berkman (1968)	U	Graphitic shale (Pld), with interbedded quartzite (Pla)	Within faulted steep isoclinal syncline of Embayment syncline	Pld-Plo contact
Rum Jungle Creek South Mine	Berkman (1964)	U	Pyritic chloritic schist (Pld)	Within core of complex isoclinal fold, in deepest part of inter-basement syncline	Within Pld
Mt Burton Mine	Spratt (1965) Pritchard et al. (1965) Berkman (1968)	U, Cu	Pyritic black shale (Pld) and quartzite (Pla)	Within crest of anticlinal fold	Close to Pld-Plo contact
Mt Fitch Prospect	Ward (1953) Berkman (1968)	U, Cu	Black shale (Pld) and dolmite (Plo)	Within eastern limb of shallow syncline	Pld-Plo contact
Woodcutters L5 Pospect	Crohn et al. (1967) Ivanac et al. (1968) Roberts (1973)	Pb, Zn	Dolomitic shale (Pld)	Vertical fissure fillings within nose of tightly folded anticline	Pld-Plo contact
Waterhouse No. 2 Prospect	Daly et al. (1960) Ruxton et al. (1961) Semple (1967)	Cu, U	Black shale (Pld), associated with hematite-quartzite breccia	Western flank of south-plunging anticline	Within Pld

Plo - Coomalie Dolomite　　Pld - Golden Dyke Formation　　Pla - Acacia Gap Tongue





Road or track
Highway
Township
Mine

Fig I. LOCALITY MAP

To accompany Record 1974/41

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D 52/A/140

Fig 2 Nonconformity between sheared granite of the Rum Jungle Complex (A) and arkosic sediments of the Beestons Formation (B); contact marked by a chloritic shear zone (C). 2 Km northeast of Batchelor. (Neg. GA/8940)

Fig 3 Basal vein quartz boulder conglomerate of the Crater Formation nonconformably overlying sheared granite of the Rum Jungle Complex. 3.5 Km northwest of Batchelor. (Neg. M1574)

Fig 4 Nonconformity between angular vein quartz conglomerate of the Beestons Formation and granitic bedrock of the Rum Jungle Complex. 3.2 Km north-northwest of Batchelor. (Neg. GA/8945)

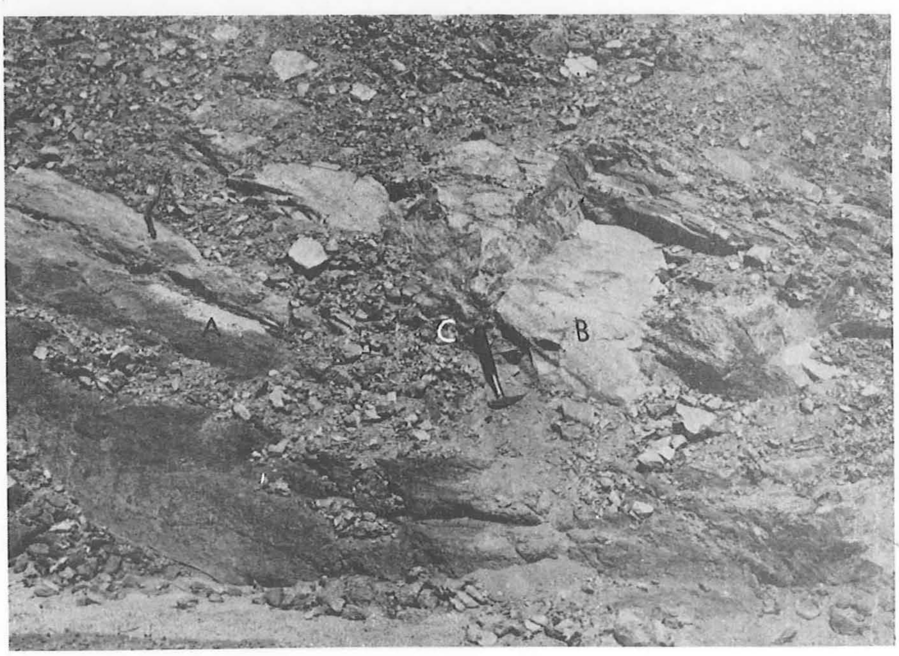


Fig 5 Nonconformity between cross bedded arkosic sediment of the Crater Formation (B) and sheared porphyritic granite of the Rum Jungle Complex (A); contact (C) is marked by a shear zone. 16 Km northwest of Batchelor. (Neg. GA/8941)

Fig 6 Stromatolite structures in Celia Dolomite. 5 Km west of Coomalie Airfield (Neg. M1574)

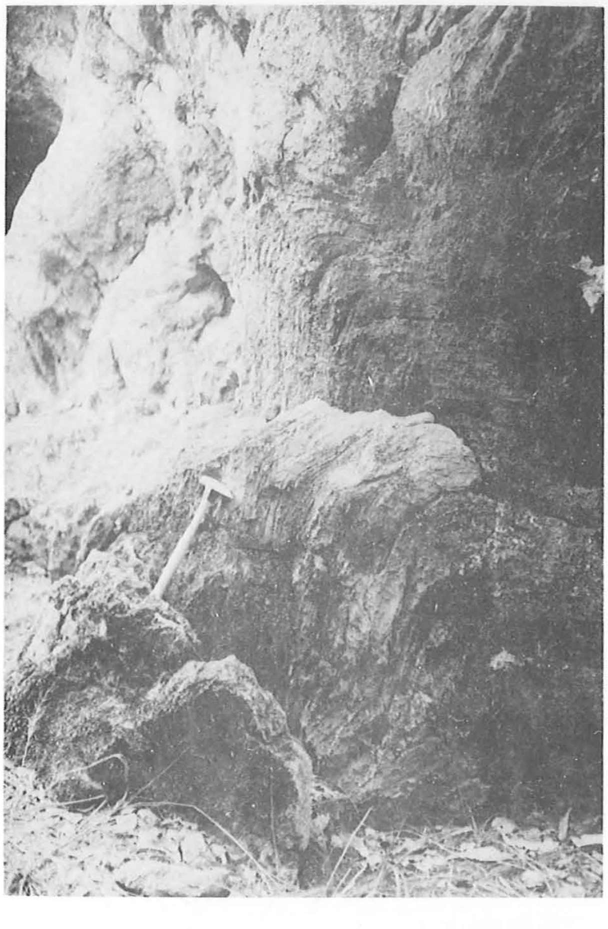


Fig 7 Algal mound structures in Celia Dolomite. Locality as for fig. 6. (Neg. M1574)

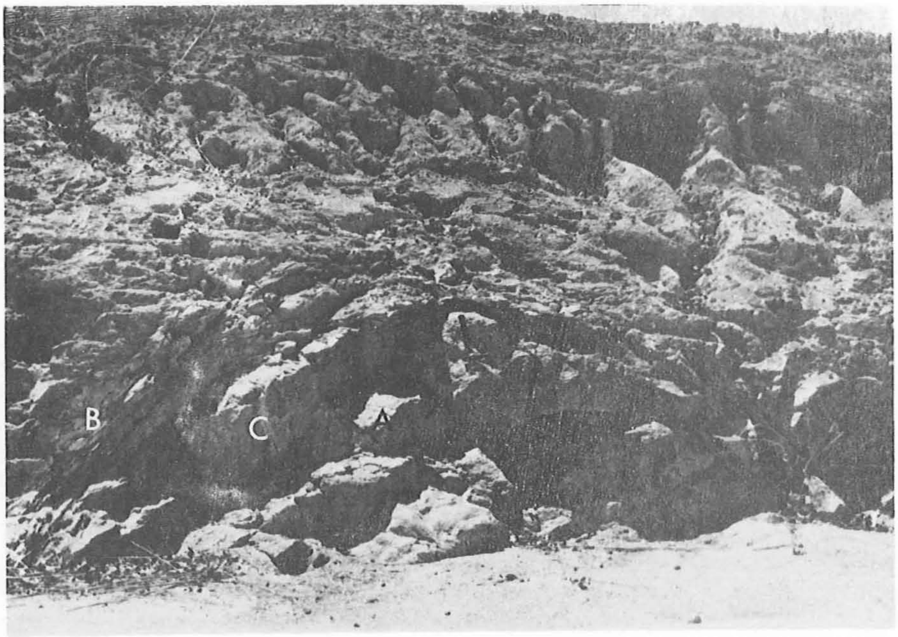


Fig 8 Biotite granite (A) intruding schist and granite of the Rum Jungle Complex (B) with associated quartz-tourmaline veins (C). Locality as for fig. 5. (Neg. GA/8944)

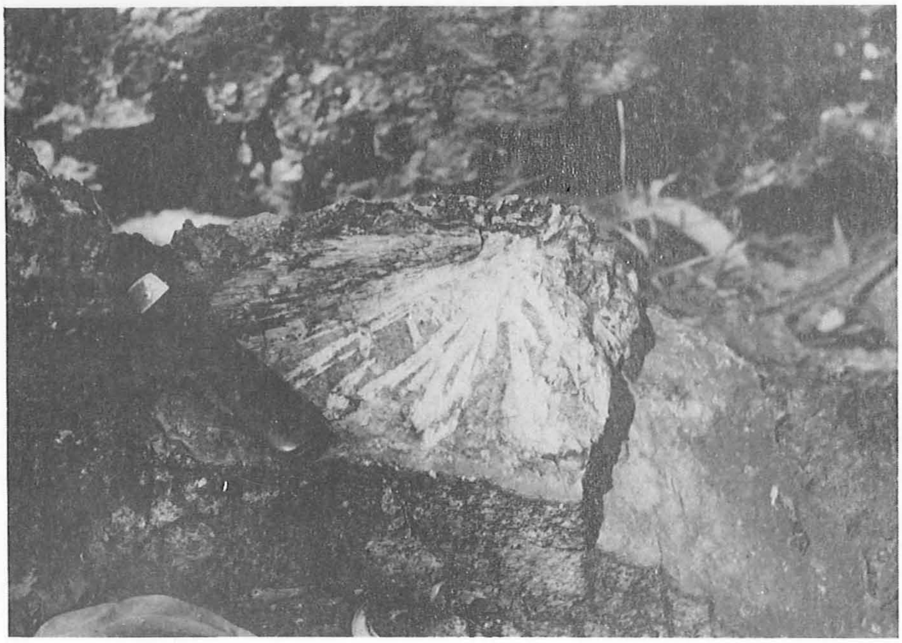


Fig 9 Scapolite crystals developed within granite on the margin of the Waterhouse Granite. 2.4 Km south-southwest of Eva Valley homestead. (Neg. GA/8934)

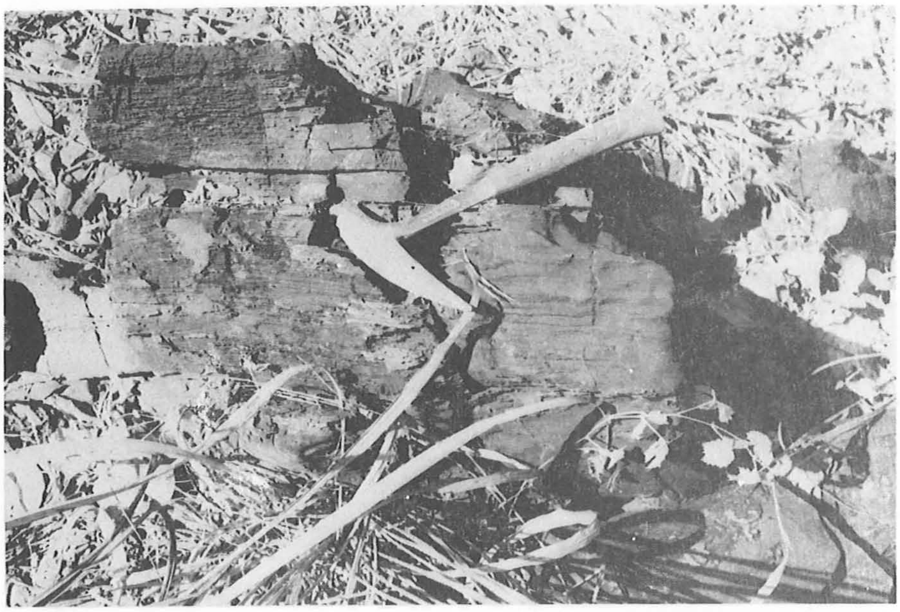


Fig 10 Carbonaceous, calcareous pyritic shale of the "transition zone" beds belonging to the Golden Dyke Formation. ·8 Km west of Crater Lake. (Neg. M1574)

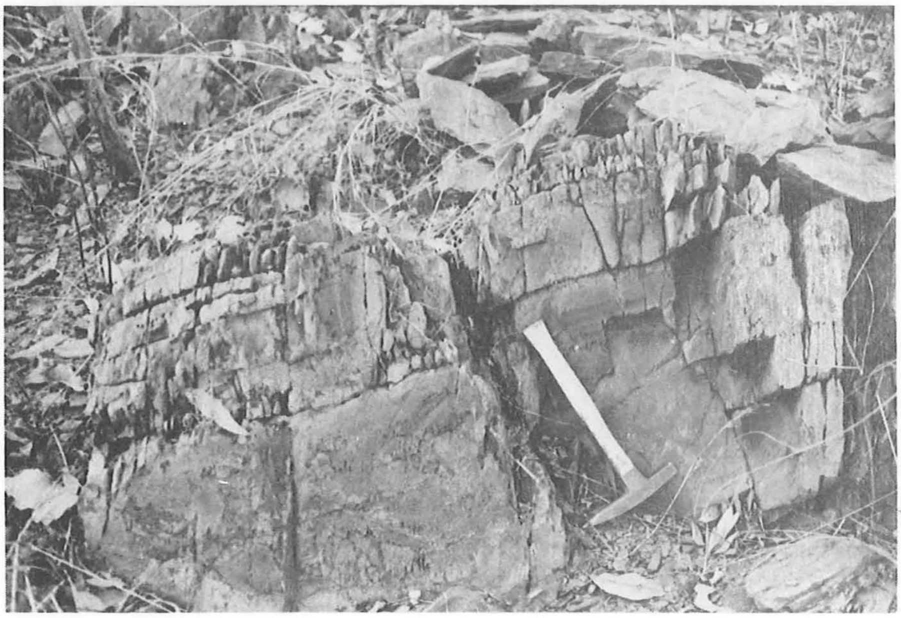
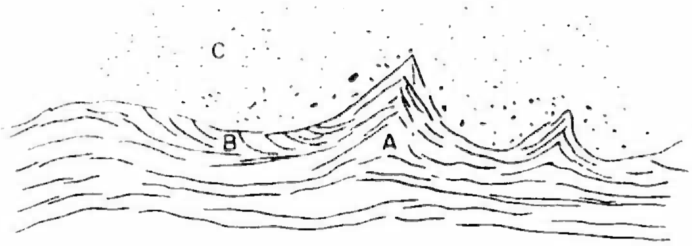


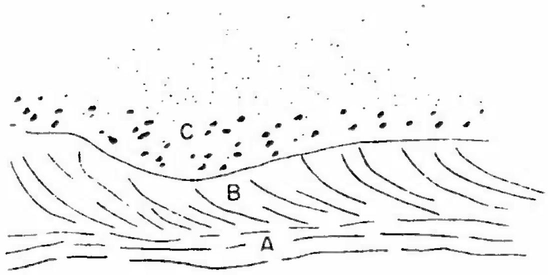
Fig 11 Axial plane cleavage in siltstone beds of the Burrell Creek Formation, with fracture cleavage developed in the more massive sandstone beds. 8 Km north of Adelaide River township. (Neg. M1574)

Fig 12. Sedimentary structures from the Burrell Creek and Noltenius Formations.



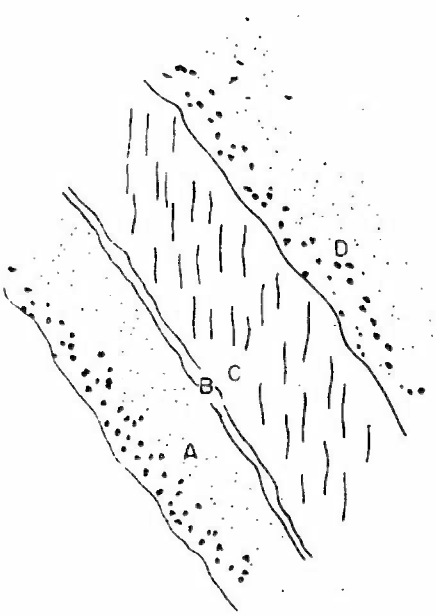
3 cm

A. A Flame structure
B. Small scale cross bedding
C. Graded bed



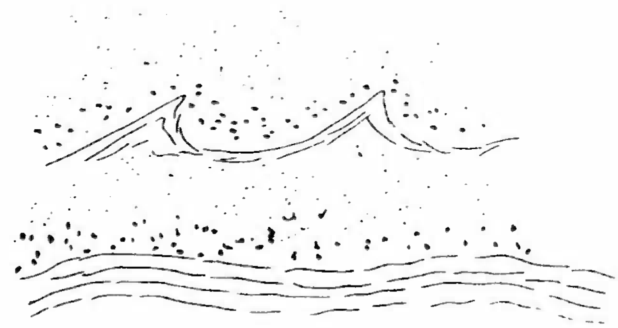
3 cm

C. A. Finely laminated siltstone
B. Cross bedding
C. Scour and fill structure



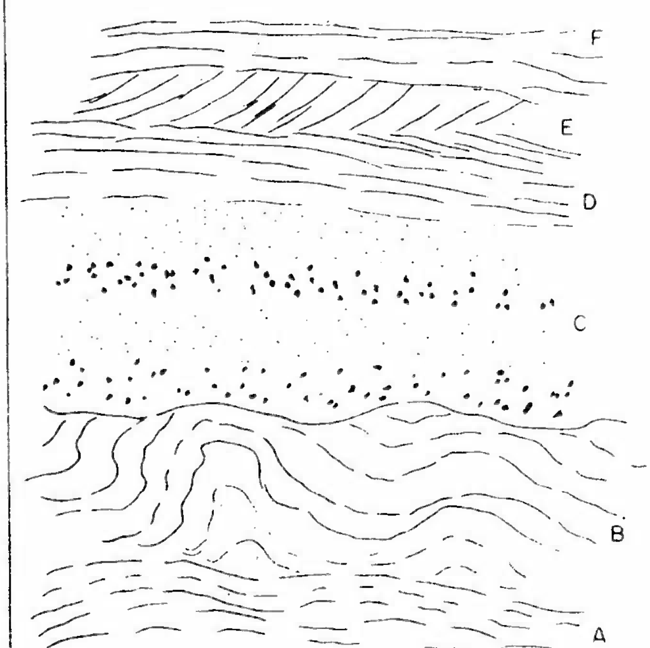
10 cm

E. A,D. Graded beds
B. Chert bed
C. Cleavage developed in siltstone interbeds



3 cm

B. Flame structures separating two graded beds



10 cm

D. A,D,F. Finely laminated siltstone beds
B. Intraformational slumping within mudstone beds
C. Two cycles of graded bedding
E. Cross bedding

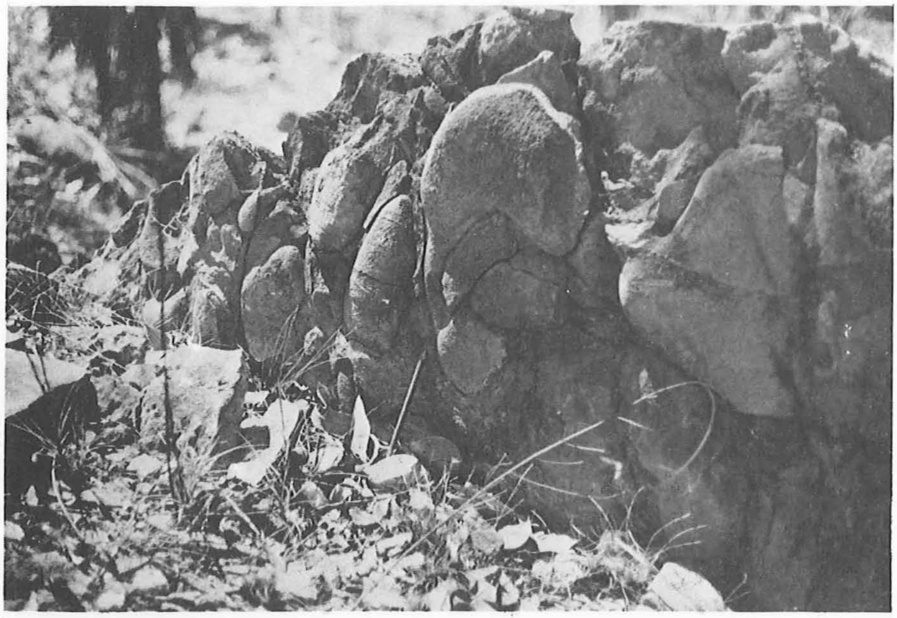


Fig 13 Flute casts on the base of a quartz greywacke bed of the Noltenius Formation. 14 Km west of the Darwin River Siding. (Neg. M1574)

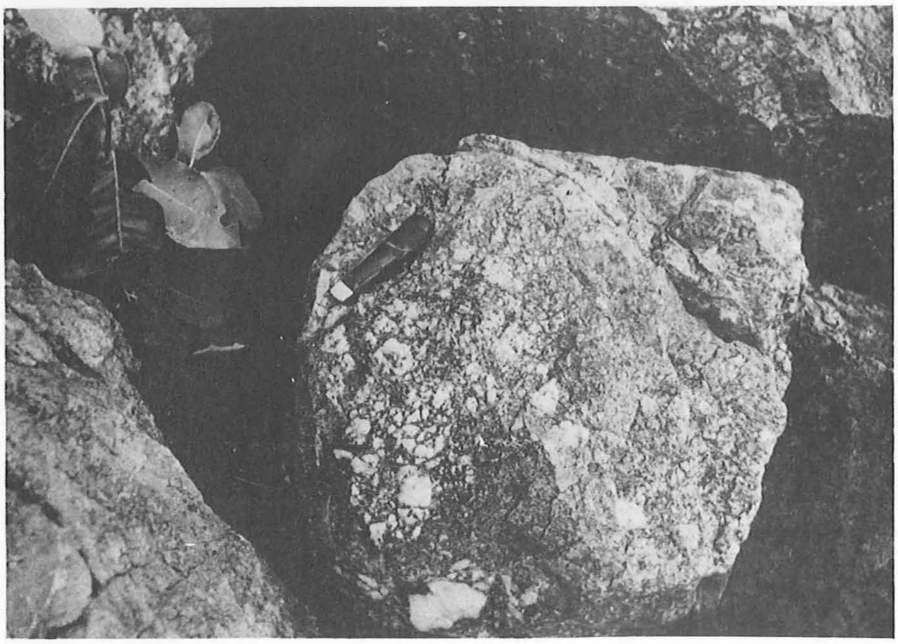


Fig 14 Hematite-quartzite-breccia, the basal unit of the Depot Creek Sandstone Member. 2 Km north of Milton Springs homestead. (Neg. GA/8938)

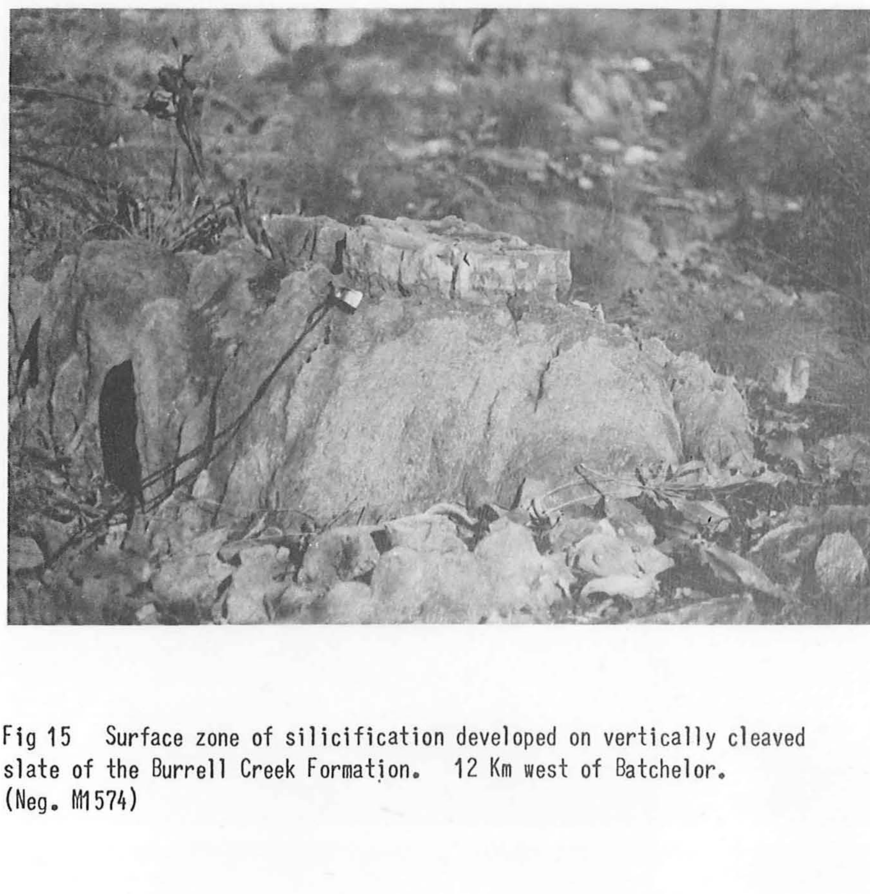


Fig 15 Surface zone of silicification developed on vertically cleaved slate of the Burrell Creek Formation. 12 Km west of Batchelor. (Neg. M1574)

Fig 16.


B.M.R.
GEOLOGICAL AND
GEOPHYSICAL SURVEY
AREAS
RUM JUNGLE
0
5 km
131°00'
131°10'
12°50'
13°00'
DARWIN
ACACIA AREA
Acacia Creek
Darwin River
Manton River
ADELAIDE RIVER
MANTON AREA
Manton Dam
RUM JUNGLE
COMPLEX
Australian
North
Railway
MOUNT FITCH NORTH
MOUNT FITCH
MOUNT BURTON AREA
MOUNT BURTON
River
Finniss
GIANTS REEF FAULT
RUM JUNGLE
BROWNS S-W
AREA 55B
AREA 55
RUM JUNGLE TRIANGLE (NORTH)
RUM JUNGLE TRIANGLE (SOUTH)
RUM JUNGLE CREEK SOUTH
BATCHELOR
POWER LINE
Airfield
BATCHELOR LATERITES EXTENDED
WOODCUTTERS AREA
AREA 44 EXTENDED
HUANDOT
HUANDOT MAGNESITE PROSPECT
CELIA MAGNESITE PROSPECT
COOMALIE GAP WEST (NORTHERN SECTION)
COOMALIE GAP WEST (SOUTHERN SECTION)
STUART HIGHWAY
COOMALIE CREEK
Gould Airfield
GOULD
AREA
MOUNT MINZA AREA
WATERHOUSE
GRANITE
WATERHOUSE NO 2 PROSPECT
ADELAIDE RIVER
PINE CREEK
To accompany Record 1974/41
D52/A/136

RUM JUNGLE DISTRICT
NORTHERN TERRITORY

PLATE I

To accompany Record 1974/41

D52/A/139