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THE GEOLOGICAL RELATIONSHIPS OF THE RUM JUNGLE COMPLEX

by

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SUMMARY

The Rum Jungle Granite Complex occupies the core of domed low-grade metasediments. Six major units have been distinguished within the Complex; these are, in order of decreasing age, schists and gneisses, granite gneiss, meta-diorite, coarse granite, large feldspar granite, and leucocratic granite. Veins and dykes of pegmatite, amphibolite, and quartz-tourmaline are also present.

The surrounding metasediments have not been intruded by any of the rocks of the Complex, as was previously maintained, but rest unconformably upon them. Later folding and metamorphism have caused the basement to occupy the centre of a dome of metasediments, similar to some of the mantled gneiss domes of Finland.

INTRODUCTION

The Rum Jungle Complex, previously referred to as the "Rum Jungle Granite", lies within a core of domed, low-grade, Lower Proterozoic metasediments of the Pine Creek geosyncline (Malone, 1962 a & b). It is situated in the Katherine-Darwin region of the Northern Territory about 50 miles south of Darwin. Interest in the region has been continuous since 1949, when uranium-copper mineralization was discovered at Rum Jungle in the metasediments immediately adjacent to the Complex. Previous workers believed that the metasediments were domed and intruded by the granite (Sullivan & Matheson, 1952; Malone 1962). Sullivan & Matheson, and Roberts (1960) have suggested that the granite intrusion was responsible for the mineralization. An opposing viewpoint was presented by Condon & Walpole (1955), who suggested that the uranium mineralization was controlled by the sedimontry environment and was unrelated to the granite.

In 1962 B.P. Ruxton and J. Shields of the Bureau of Mineral Resources (pers. comm.) recognised two main types of granite, an early coarse-grained variety associated with migmatite and a later leucocratic type. They also found, at the margins of the Complex, evidence suggesting that the surrounding metasediments rest unconformably on some if not all of the granitic rocks of the Complex.

The results of a more detailed study of the rocks within the complex and their relationships with the surrounding low-grade metasediments are presented in this paper.

GENERAL RELATIONSHIPS

The Rum Jungle Complex occurs in two adjacent areas surrounded by domed metasedimentary rocks (Fig. 1). The Complex within the larger southern dome has an area of about 80 square miles; and in the smaller northern dome 8 square miles. Exposures in the southern, central and north-eastern parts of the complex are scattered but fairly abundant; those in the north and north-western parts are sparse, so that boundaries here are ill defined.

The Giants Reef Fault, a dextral wrench fault with a north-easterly strike, cuts both the Complex and the surrounding metasediments. It has a horizontal displacement of 3.6 miles.

Except where the metasediments are faulted against the rocks of the Complex, or intensely contorted, it is notable that they dip away from the Complex at angles ranging from 30° to 70°. Malone (1962 a & b) also made similar observations, but he maintained that the 'granite' was a concordant intrusion, transgressing the metasediments locally. However he also states that the Beestons Formation, which is the oldest exposed unit of the surrounding metasediments,'may have been deposited directly on basement'.

Fig. 1 shows that the trend of the rock units within the Complex is truncated by the encircling metasediments. Also the foliation within the various units of the Complex appears to be independent of the contact with the metasedimentary envelope.

THE METASEDIMENTS

The metasediments surrounding the complex have been divided into the Batchelor Group and the overlying Goodparla Group, the later including the Golden Dyke and Masson Formations (Malone, 1962 a & b). They are considered to be of Lower Proterozoic age (Walpole & Smith, 1962).

The Batchelor Group consists mainly of arkose, grit, conglomerate, quartz greywacke, quartz-hematite breccia, and phyllite, interlayered with dolomite, tremolite-quartz-calcite schist, tremolite-talc schist and talc schist. Malone (1962 a) also records andalusite-muscovite schist, but the author failed to find andalusite in a close examination of the phyllites near the contact with the complex. Roberts (1960) records the presence of two generations of andalusite in mineralized shear zones of White's mine. He states, however, that the andalusite is confined to the shear zones and is not found in rocks of the same lithology on either side of it. Malone interprets the assemblages listed above as products of contact metamorphism, although they may equally well be low greenschist facies assemblages.

The Golden Dyke Formation overlies the Batchelor Group and is nowhere in contact with the Complex. It consists predominantly of pelites and semi-pelites. Both the Golden Dyke Formation and the Batchelor Group are locally silicified and in places silicification is accompanied by quartz-tourmaline veins.

The Acacia Gap tongue of the Masson Formation is a tongue of predominantly arenaceous rocks which lenses into the lower part of the Golden Dyke Formation.

Amphibolites containing hornblende or actinolite and plagioclase occur within the Golden Dyke Formation on the western side of the Complex. These are thought to be tholeiitic dolerite sills (see Table 1) emplaced in the sediments before folding and metamorphism. Similar amphibolite bodies occur in other parts of the Pine Creek Geosyncline (Bryan, 1962).

Although in general the metasediments form a broad dome dipping away from the Complex, in detail the structure is complicated. P. Williams of Consolidated Zinc (pers. comm.) identified three major periods of folding, in a structural study of the area, an early east-west folding, a period of north-west folding, and a subsequent folding sub-parallel to the Giants Reef Fault. The north-west folding is the most pronounced of the three and coincides closely with the dominant fold direction of the Pine Creek Geosyncline.

ROCKS OF THE COMPLEX

Six major rock units have been distinguished within the Complex (Fig. 1). In order of decreasing age these are : schists and gneisses, granite gneiss, meta-diorite, coarse granite, large feldspar granite, and leucocratic granite. Veins and dykes of pegmatite and amphibolite are also present, the latter being similar in mineralogy and composition to those found within the surrounding metasediments. Quartz-tourmaline veins are fairly common at the margins of the Complex as well as in the metasedimentary envelope.

The schists, gneisses, and granite gneiss are strongly contorted, although the overall direction of strike is easterly. Other rocks are mostly massive, except that a locally developed conspicous foliation with a constant strike of about 140° can be found throughout the complex irrespective of the distribution of the major rock types or the boundaries between them. This secondary foliation is sub-parallel to the axes of the north-westerly folds of the surrounding metasediments. In places the shearing producing the secondary foliation has been so intense that otherwise massive rock develops a segregation banding consisting of alternating light and dark bands. Thus all rocks of the Complex show varying degrees of post-crystalline fracturing and retrogressive metamorphism. Along many parts of the contact between the Complex and the metasediments there has been intense shearing and mylonitization, making it difficult to distinguish between sheared granite and sheared arkose of the Batchelor Group.

Schists and Gneisses

The schists and gneisses, which are believed to have originated from sedimentary rocks, include biotite gneiss, biotite-muscovite gneiss, biotite granofels, thinly banded feldspathic gneiss, quartz-muscovite schist and possibly phyllite, chlorite schist, and actinolite schist. They are found in a small, poorly exposed area on the eastern side of the Complex or as inclusions and remnants within the younger rocks of the Complex.

The phyllites and chlorite and actinolite schists occur along the immediate margin of the Complex. Because of the paucity of outcrop it is not clear whether they are locally retrogressively metamorphosed schists and gneisses or low-grade metamorphic rocks of the surrounding Batchelor Group.

The schists and gneisses contain quartz, microcline, plagioclase, biotite, and muscovite in varying proportions, with sphene, magnetite, and fluorite as common accessory minerals. In some localities biotite forms small ovoid clusters that may be relicts of original garnet. Pinnite pseudomorphing cordierite is found in large granofels inclusions within the coarse granite near the North Australian railway, east of Mount Fitch. Fine microscopic veinlets of microcline and quartz are invariably present along grain boundaries and cutting fractured minerals.

The presence of oligoclase, or oligoclase and minor epidote, suggests that they have formed under conditions of the almandine-amphibolite facies (Turner & Verhoogen, 1960).

Granite Gneiss

The granite gneiss occurs in an arcuate belt in the centre of the Complex (Fig. 1). The relationship between the granite gneiss, metadiorite, and coarse granite is not certain since there are no mutual contacts. However it contains inclusions of the schists and gneisses and is itself cut by the leucocratic granite (Plate 2, Fig. 1) and by pegmatite veins. It appears to grade into the large feldspar granite by increase in number of large microcline crystals.

It is medium and even-grained and ranges from well-banded granite gneiss (Plate 1, Fig. 1) through streaky and nebulitic granite gneiss to homogeneous granite gneiss (Berthelson, 1961). In places it is agmatitic and contains both rounded and angular inclusions of contorted schists whose folding bears no relationship to the foliation of the enclosing granite gneiss, thus indicating that the inclusions have been rolled (Plate 1, Fig. 2).

The granite gneiss is extensively contorted. The overall trend of the foliation or banding ranges from 90 to 180°, the most prominant direction being about 110°; it is generally vertical or steeply inclined. Because of the extensive folding, and intimate association with the schists and gneisses, the granite gneiss is believed to be older than both the metadiorite and the coarse granite.

The granite gneiss consists of microcline, quartz, oligoclase, and biotite, with muscovite in places, and accessory apatite, fluorite, and zircon. Epidote may also be present as small secondary grains enclosed by oligoclase, indicating that the rock has undergone slight retrogressive metamorphism.

Meta-Diorite

The meta-diorite is of small areal extent and occurs in two localities, one south of Manton Dam and the other on the eastern side of the Complex, south of the Giants Reef fault. It also occurs as small inclusions or remnants within the large feldspar granite.

The rock is dark, fine-grained, and massive (except where sheared). It cuts sharply across the metamorphic banding (Plate 1, Fig. 3) and is itself cut and veined by the leucocratic granite (Plate 1, Fig. 6). Its relationship to the coarse granite is not known, but it appears to grade laterally into the large feldspar granite. It is clearly of magnatic origin and was emplaced after a period of metamorphism and migmatization, and before the leucocratic granite was emplaced.

The mineral assemblage is oligoclase (An_{26}), biotite, and quartz, with minor epidote, sphene and magnetite. Also present are thin intergranular microscopic patches and veins of aplite microcline and quartz as in the schists and gneisses. Many plagioclase crystals are bent or fractured, indicating that the rock has undergone post-crystalline deformation which is probably related to the strong 140° shearing found locally throughout the Complex. Epidote occurs as inclusions within the oligoclase, indicating partial retrogressive metamorphism, and also in clusters with biotite. Retrogressive metamorphism of meta-diorite inclusions within the large feldspar granite has been complete, and here secondary albite coexists with epidote. There is also an increase in the amount of intergranular aplitic material present.

Coarse Granite

This is a pink, leucocratic, massive, coarse and fairly even-grained adamellite occurring in the south-western part of the complex. It contains xenoliths of schistose material and is cut by veins of the leucocratic granite (Plate 2, Fig. 2). It appears to have gradational contacts with the large feldspar granite, and is thought to be the older since the large feldspar granite is found as inclusions within the leucocratic granite, but not in the coarse granite.

It consists of microcline, quartz, plagioclase, biotite or chloritised biotite and sericite. Fluorite is a common accessory mineral, as in both the leucocratic and large feldspar granites. Pale blue opalescent quartz is characteristic. The plagioclase ranges from albite (An_5) to oligoclase (An_{12}) and appears to be primary; however, in some crystals small amounts of secondary carbonate are present. Along the southern margin of the complex, where the shearing has been most intense, the plagioclase has been almost completely sericitized and quartz veinlets cut fractured mineral grains.

Large Feldspar Granite

The large feldspar granite is the most extensive member and crops out over most of the Complex. It contains inclusions or remnants of schists, gneisses, and diorite. Contacts with these inclusions and with the older members of the Complex are gradational as a result of the gradual increase in the number of large feldspar crystals (Plate 1, Fig. 5), and nowhere is the large feldspar granite clearly intrusive into the older members of the Complex. It is itself intruded and veined by pegmatites and by the leucocratic granite (Plate 2, Fig. 3). Where some veins of leucocratic granite cut across the large feldspar granite, accretions of large feldspar crystals occur at the contact within the large feldspar granite.

The large feldspar granite is of adamellite composition, with variable amounts of felsic and femic minerals. It is characterized by large tabular or ovoid feldspar crystals which attain a length of up to 2.5 inches (Plate 1, Fig. 4; Plate 2, Fig. 3). Generally the feldspar is microcline, but albite is found at the contact with the meta-diorite to the south of the Giants Reef Fault; megascopically this rock is indistinguishable from the normal microcline-bearing large feldspar granite. The minerals present are microcline, quartz, plagioclase, biotite or chloritized biotite, with secondary muscovite, epidote, and carbonate, and accessory magnetite, sphene, apatite, zircon, and fluorite. Sphene is particularly abundant. Intergranular aplitic veins and patches of microcline and quartz, similar to those mentioned in other members of the complex, are abundant and many crystals are veined or entirely enclosed by this material. Many plagioclase crystals are partially digested by it, and in some rocks where it cuts across plagioclase crystals, patches of microcline can be seen to be replacing the plagioclase. Replacement of plagioclase by microcline is widespread throughout the large feldspar granite.

The plagioclase ranges in composition from albite to oligoclase. The albite is secondary and is intergrown with secondary calcium-bearing minerals such as epidote and calcite. Many plagioclase crystals have also been extensively replaced by secondary sericite. This retrogressive metamorphism to an assemblage of the greenschist facies appears to be closely associated with the quartz-microcline veining. Where this is slightly developed as in the diorite and granite gneiss the retrogressive metamorphism is incipient, but where the veining is more intense, as in the large feldspar granite or in inclusions of diorite within it, the retrogressive metamorphism has been more extreme.

Leucocratic Granite and Pegmatites

The main areas of leucocratic granite are a north-west trending belt in the southern part of the Complex, an easterly trending lobe on the west of the Complex, and smaller areas in the north and centre of the Complex. It also occurs in abundant dykes and veins throughout the large feldspar granite, and to a lesser extent in the other rocks of the Complex. The small and poorly exposed dome at the northern end of the Complex appears to consist mainly of leucocratic granite with abundant gneiss and granite gneiss inclusions. The leucocratic granite south of the Manton Dame also contains many gneissic inclusions. It is the youngest member of the Complex, and is cut only by veins of quartz-tourmaline and veins and dykes of pegmatite (Plate 2, Fig. 4) and amphibolite.

The leucocratic granite is a fine to medium, even-grained, pink or grey adamellite, aplitic and pegmatite in places, and containing microcline, quartz, albite, chloritized biotite, minor muscovite, and accessory apatite, magnetite, fluorite, zircon, and occasionally epidote. From textural relationships, both microcline and albite appear to have crystallized simultaneously. The albite is considered to be of primary origin, since secondary calcium-bearing minerals are absent (Marmo, 1961). Thus from a textural and mineralogical viewpoint the leucocratic granite is very similar to the late kinematic granites of Finland (Marmo, 1955). In some samples, traces of fine microcline-quartz aplitic material are found in small amounts along intergranular boundaries. This is similar to the aplitic material found in the older rock, particularly the large feldspar granite. It is probably a late magmatic phase of the leucocratic granite, related to the megascopic aplite and pegmatite veins that can be seen cutting it.

East of Mount Fitch is a grey granite, rather coarser than the leucocratic granite, but mineralogically similar to it and also containing primary albite. It appears to grade south-eastwards into the leucocratic granite and is believed to be a variety of it. The Mount Fitch granite contains radial growths of tourmaline and veins of tourmaline and quartz mostly along joint planes, and especially at the margins of the Complex.

Within the Complex are sporadic veins and dykes of pegmatites, which appear to be mostly associated with the leucocratic and large feldspar granites. They consist mainly of microcline and quartz, with small but varying amounts of muscovite. Although they can be found cutting the leucocratic granite (Plate 2, Fig. 4), they are believed to be a late-stage differentiate of it, since some veins of leucocratic granite grade into pegmatite-like veins through accumulation of large feldspar crystals at the margins or along the centre, where there may also be quartz and occasionally muscovite.

Amphibolite and Quartz-Tourmaline Veins

These are the youngest units within the complex. Thin amphibolite veins intrude both the coarse and leucocratic granites. They consist of plagioclase (An_{54}) and hornblende and are mineralogically and chemically similar to the amphibolite bodies intruding the surrounding low-grade metasediments.

Table 1.

	(1)	(2)	(3)
SiO_2	51.5	52.5	50.83
TiO_2	0.72	1.01	2.03
Al_2O_3	13.8	12.8	14.07
Fe_2O_3	2.40	1.78	2.88
FeO	8.7	11.90	9.00
MnO	0.18	0.21	0.18
MgO	7.65	5.35	6.34
CaO	11.40	9.40	10.42
Na_2O	1.37	2.70	2.23
K_2O	0.18	0.17	0.82
H_2O+	1.71	1.71	0.91
H_2O-	0.16	0.14	-
CO_2	0.08	0.09	-
P_2O_5	0.08	0.31	0.23
Total	99.93	100.07	99.94

(1) Amphibolite, intrusive into Golden Dyke formation, Dolerite Ridge.
Analyst : C.R. Edmund, Australian Mineral Development Laboratory.

(2) Amphibolite, intrusive into the Rum Jungle Complex.
Analyst : C.R. Edmund, Australian Mineral Development Laboratory.

(3) Average tholeiitic basalt (Nockolds, 1954).

Both appear to be tholeiitic dolerites which have undergone low-grade regional metamorphism. The quartz-tourmaline veins cut both the surrounding metasediments and the rocks of the Complex. However, they are only found at the margins of the Complex, along joint planes and veins extending into the metasediments. The veins within the Complex both cut and displace pegmatite veinlets in the Mount Fitch variety of the leucocratic granite, thus indicating a later origin. The age relationship between the amphibolite and the quartz-tourmaline veins is not known.

RELATIONSHIP BETWEEN THE RUM JUNGLE COMPLEX AND THE SURROUNDING ROCKS

It is clear that the Batchelor Group must be younger than the schists and gneisses and that it must rest unconformably upon them.

There are three possible relationships for the granitic rocks of the Complex :

(1) they are all intrusive into the metasediments, or
(2) only some of them intrude, and the others are older than the metasediments, as are the schists and gneisses, or
(3) all the rocks of the Complex are unconformably overlain by the younger metasediments.

Nowhere has a clearly intrusive contact been observed. Any argument for intrusion depends upon the doming of the metasediments around the Complex, and upon the presence of silicification, metamorphism, and quartz-tourmaline veining within the metasediments along the margin of the Complex.

It was pointed out earlier that the mineral assemblages previously taken as indicative of contact metamorphism (Malone, 1962) can also be interpreted as being the result of low-grade regional metamorphism of the greenschist facies. The presence of andalusite cyrstals is the main obstacle to the latter interpretation, but they are confined to mineralized shear zones and appear to be of hydrothermal rather than contact metamorphic origin.

Silicification and accompanying quartz-tourmaline veining are quite common in the metasediments along the margins of the Complex. The quartz-tourmaline veins have been shown to be younger than the leucocratic granite and the pegmatites. If they were related to the leucocratic granite one would expect them to occur in the centre of the Complex at the edges of that granite, but this is not so. They are mostly confined to the metasediments and along fractures and joint planes in the marginal rocks of the complex. Furthermore, silicification of low grade metasediments is quite common elsewhere in the Katherine-Darwin region, and quartz-tourmaline veins can be found far from any known granite contacts. All that can be confidently stated is that the quartz-tourmaline veining is younger than both the metasediments and the leucocratic granite. It is more probably related to the low-grade metamorphism of the region than to any granitic intrusion.

The conspicuous dome of metasediments surrounding the Rum Jungle Complex was previously thought to have been formed by intrusion of granite (Sullivan & Matheson, 1952; Roberts, 1960; Malone, 1962). If this is the case one would suspect that the doming occurred either after the major folding in the region or synchronously with it; otherwise the domed structure would have been markedly affected by later folding. However, it has been shown that all the members of the Complex have been foliated by a pronounced north-westerly shearing which coincides in direction with the fold axes of the middle period of folding in the area. Consequently all the rocks of the Complex must have been present before this major folding. Furthermore, within the Complex, cutting the leucocratic and coarse granites are amphibolites mineralogically and chemically similar to those in the surrounding metasediments. As these amphibolites appear to have been domed together with the metasediments it is impossible for the leucocratic granite, or any earlier member of the Complex, to have been responsible for the doming, since they are older than the amphibolites.

Both the coarse and leucocratic granites contain xenoliths of older rocks of the Complex. If either of these granites had intruded the metasediments it would be reasonable to expect some assimilation zones containing many xenoliths, particularly at the immediate margins of the Complex where granite is in contact with banded ironstones or quartz-hematite breccia. Such zones have not been found. In a few places, within the Complex are small outcrops of banded ironstone. These could be interpreted as roof pendants, but the surrounding granite is free from xenoliths or any sign of contamination and therefore it is believed they are downfolded or faulted blocks. Further evidence against any intrusion is that although the leucocratic granite veins all the older rocks of the Complex, it has not been found veining the metasediments even where large feldspar granite, containing leucocratic granite veins, is in contact with them.

The previous sections have shown that there is little, if any, reliable evidence that any of the rocks of the Complex have intruded the metasediments. Therefore it appears probable that the metasediments rest unconformably upon them. This is supported by the distribution of rock types within the Complex, as seen in Fig. 1, which is more suggestive of an inlier of granitic basement unconformably overlain by metasediments than of a Complex of successive granitic intrusions.

The Batchelor Group contains abundant arkose and conglomerates. The arkose is composed of grains of microcline and quartz in a sericitic and chloritic groundmass, indicating derivation from a granitic source. Furthermore some arkose contains blue opaline quartz grains which are remarkably similar to the opaline quartz of the coarse granite. Within the conglomerates can be found sporadic pebbles of the Coarse and Leucocratic granites as well as the older rocks of the complex. The Leucocratic granite pebbles are texturally and mineralogically identical with the Leucocratic granite of the Complex, and contain primary albite, a diagnostic feature of this granite.

From the above evidence it is clear that the surrounding metasediments have not been intruded by any of the granites of the Rum Jungle Complex, and that they have been partially derived from the rocks of the Complex, upon which they rest unconformably. Later multiple folding and low-grade regional metamorphism of the sediments of the Pine Creek geosyncline has resulted in the underlying granitic rocks becoming a basement inlier in the centre of a dome, similar to some of the mantled gneiss domes of Finland (Eskola, 1948). Indeed the lithology of the surrounding Batchelor Group and Golden Dyke Formation is remarkably similar to their Finnish counterparts.

The Finnish domes described by Eskola range from those in which the gneissic or granitic material occurs as a basement inlier, through concentrically foliated gneiss domes that have been partially granitized and remobilized and intrude the overlying metasediments, to domes in which remobilization has been complete and the granite is fully intrusive into the metasediments. The Rum Jungle complex corresponds to the earlier type, where granitization or remobilization has not accompanied doming, and the leucocratic, or late kinematic, granite was emplaced before the metasediments were laid down.

Within the Katherine-Darwin region, there are several apparently intrusive granites surrounded by domed metasediments. These granites may correspond to the final intrusive stage of Eskola's mantled gneiss dome series, and further investigations of granites in the area may show the presence of other members of the series.

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Plate I

Fig. 1 : Well-banded and contorted granite gneiss.

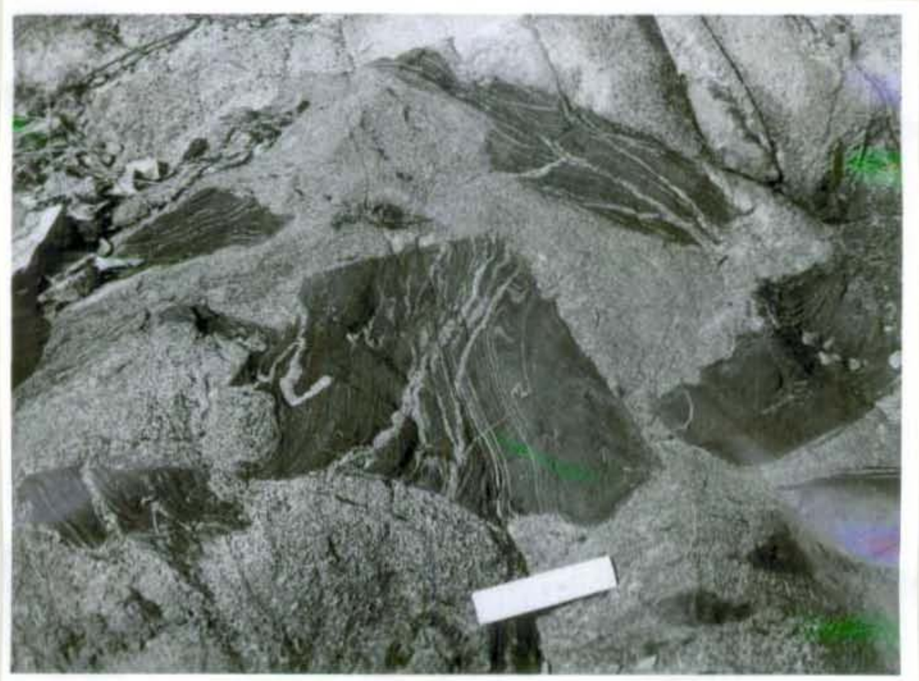


Fig. 2 : Agmatitic granite gneiss, containing abundant schistose inclusions. (This photograph was taken within a few yards of Fig. 1).

Plate I (continued)

Fig. 3 : Metadiorite cutting across the foliation of thinly banded gneisses.

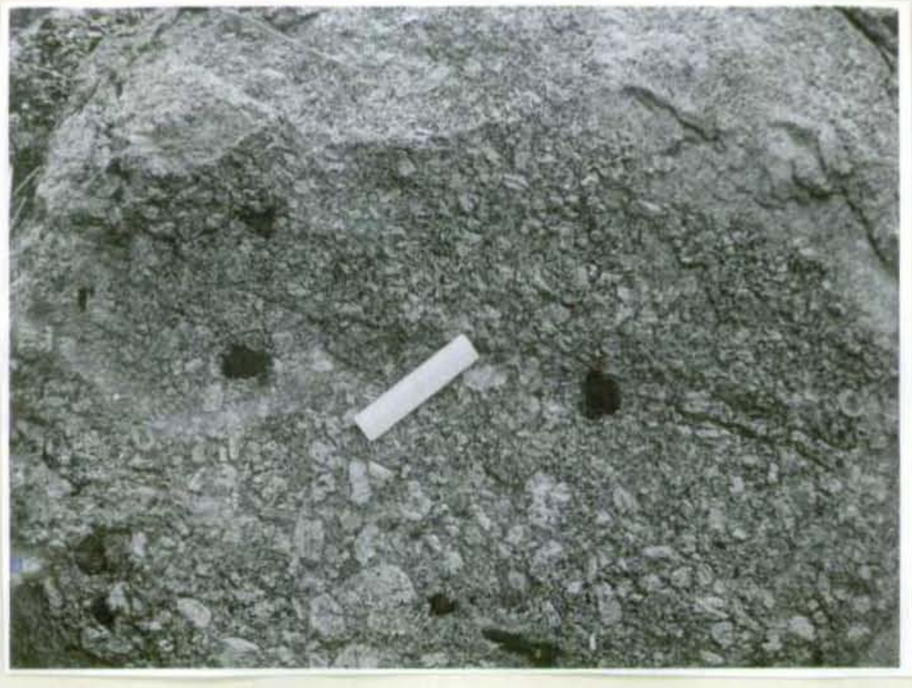


Fig. 4 : Typical large feldspar granite.

Plate I (continued)

Fig. 5 : A boulder showing gradual transition from metadiorite to large feldspar granite by accumulation of feldspar crystals.

Fig. 6 : Metadiorite cut by thin veins of leucocratic granite.

Plate II

Fig. 1 : Well-banded granite gneiss cut by the leucocratic granite.

Fig. 2 : Coarse granite cut by a dyke of leucocratic granite.

Plate II (continued)

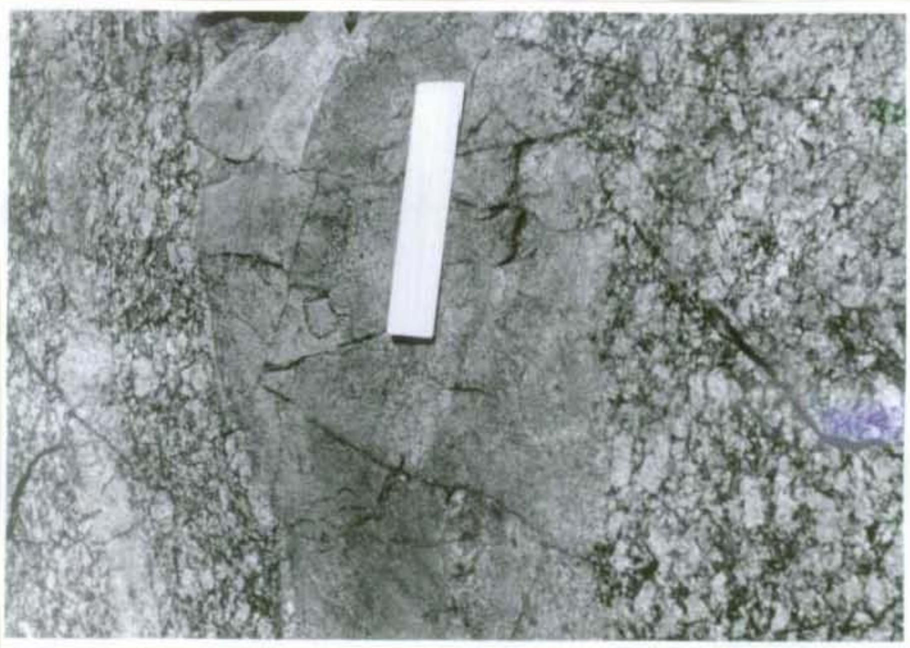


Fig. 3 : Large feldspar granite cut by a vein of leucocratic granite.

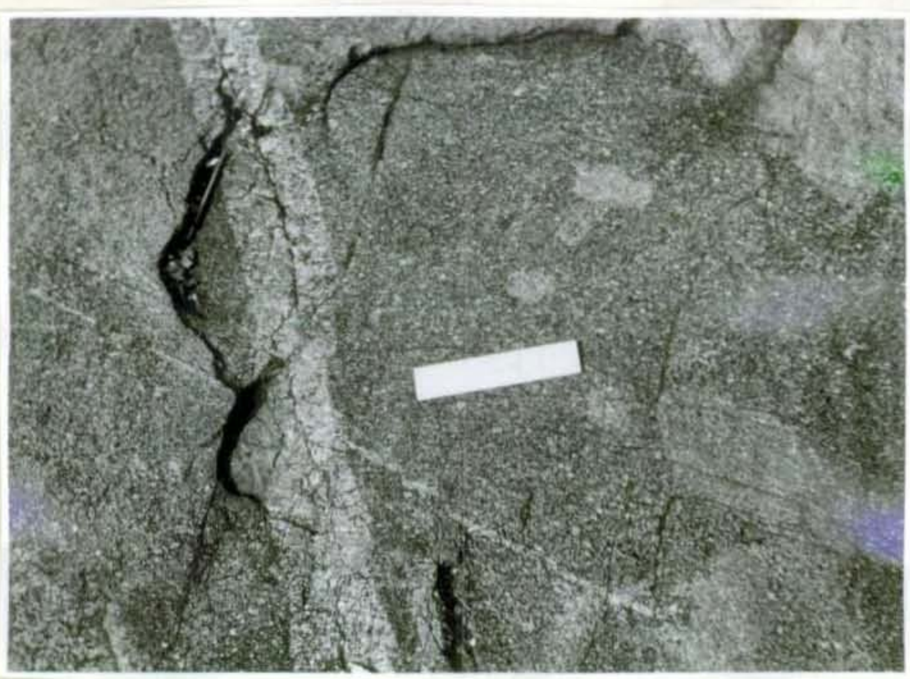
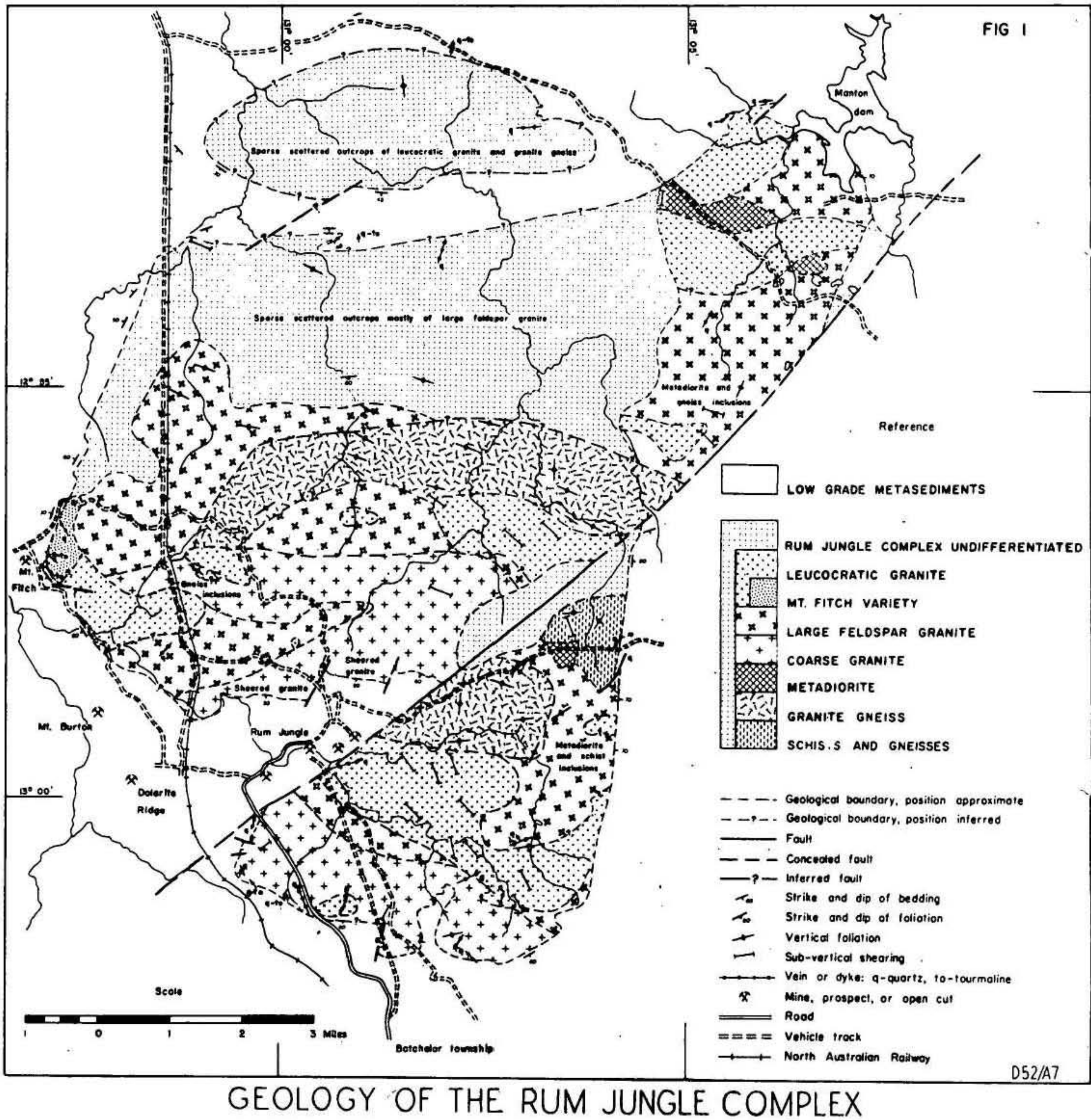


Fig. 4 : Leucocratic granite cut by a thin vein of pegmatite.



GEOLOGY OF THE RUM JUNGLE COMPLEX